ERGONOMÍA OCUPACIONAL

INVESTIGACIONES Y APLICACIONES

VOL. 18

ERGONOMÍA OCUPACIONAL

INVESTIGACIONES Y APLICACIONES

VOL. 18

Datos de catalogación bibliográfica

ENRIQUE DE LA VEGA BUSTILLOS,
CARLOS ESPEJO GUASCO, ELISA CHACÓN MARTÍNEZ, CARLOS RAUL NAVARRO.

ERGONOMÍA OCUPACIONAL, INVESTIGACIONES Y SOLUCIONES VOL. 18

Sociedad de Ergonomistas de México, A.C. (SEMAC) 2025

ISBN: 978-8-218-62506-1

Formato; Carta Paginas 679

Primera edición en español, 2025

ISBN: 978-8-218-62506-1

Las denominaciones empleadas, en concordancia con la práctica seguida en las Naciones Unidas, y la forma en que aparecen presentados los datos en las publicaciones de la SEMAC no implican juicio alguno sobre la condición jurídica de ningún país, zona o territorio citado o de sus autoridades, nio respecto de la delimitación de sus fronteras.

La responsabilidad de las opiniones expresadas en los trabajos, estudios o colaboraciones aquí presentados incumbe exclusivamente a sus autores y su publicación no significa que SEMAC las sancione.

Las referencias a firmas o a procesos o productos comerciales no implica aprobación alguna por parte de SEMAC, y el hecho de que no se mencionen firmas o procesos o productos comerciales no implica desaprobación alguna.

Las publicaciones de SEMAC pueden obtenerse a través de la página Web www.semac.org.mx sin costo alguno

Todos los trabajos aquí presentados se sometieron a una evaluación doble ciego por parte del Comité Académico.

Editado en México

SOCIEDAD DE ERGONOMISTAS DE MÉXICO A.C. (SEMAC)

2025

ERGONOMÍA OCUPACIONAL

INVESTIGACIONES Y SOLUCIONES

VOL. 18

EDITADO POR:

CARLOS ESPEJO GUASCO
Presidente Fundador SEMAC

ELISA CHACÓN MARTÍNEZ
Presidente SEMAC 2012-2014

CARLOS RAUL NAVARRO
Presidente SEMAC 2024-2026

ENRIQUE DE LA VEGA BUSTILLOS
Presidente SEMAC 2002-2004

ISBN: 978-8-218-62506-1

Prefacio

Este año esperamos grandes noticias de la Secretaria del Trabajo y Prevision Social, específicamente, estamos convencidos que esteaño se publicara en el Diario Oficial de la Federación ña Norma Oficial Mexicana 036-2, referente a trabajo repetitivo, con lo cual daremos un paso mas en la protección de los trabajadores que crean la riqueza de este país.

Mientras eso sucede, les presentamos rl volumen 18 de nuestra serie "Ergonomia Ocupacional, Investigaciones y Soluciones" que, como todos los años, nos hemos esforzado en presentar los mejor de los investigadores nacionales y algunos extranjeros.

Aquí podemos encontrar documentos de antropometría, ergonomía cognitiva, ergonomía participativa, MicroErgonomia, MacroErgonomia, entre otros trabajos,

Esperamos sinceramente que lo disfruten tanto como lo hemos disfrutado nosotros en la elaboración de este libro. No es un trabajo sencillo pero afortunadamente tenemos amigos que forman el cuerpo académico que nos acompañan cada año en esta labor. Muchas gracias a los autores, cuerpo académicos y todos los colaboradores que hace posible la edición de este libro.

Enrique de la Vega Bustillos
Marzo de 2025

CONTENT

ENVIRONMENTAL CONDITIONS

ERGONOMICS AND GENDER

LEGAL ERGONOMICS

INDUSTRIAL ERGONOMICS

MICROERGONOMICS

MANUAL MATERIAL HANDING

OCCUPATIONAL HEALTH

ORGANIZATIONAL ERGONOMICS

PARTICIPATORY ERGONOMICS

WORK ASSESSMENT

COMITÉ ACADÉMICO

JOAQUÍN VÁSQUEZ QUIROGA
Universidad de Sonora

JOSÉ ADOLFO VALERA GONZÁLEZ
Universidad Autónoma de Baja California

KARLA PATRICIA LUCERO DUARTE
TECNM/Instituto Tecnológico de Hermosillo

LAMBERTO VÁZQUEZ VELOZ
TECNM/Instituto Tecnológico de Agua Prieta

NANCY IVETTE ARANA DE LAS CASAS
TECNM/Instituto Tecnológico de Ciudad Cuauhtémoc

PATRICIA EUGENIA SORTILLÓN GONZÁLES
Universidad de Sonora

PEDRO WRIU VALENZUELA
Universidad del Noroeste

ROSALIO AVILA CAHURET
Universidad de Guadalajara

VICTORIO MARTINEZ CASTRO
Corporación Regional de Enseñanza Superior
en Ergonomía S.C.

YANET VILLARREAL GONZALEZ
Universidad Autónoma de Baja California

ENRIQUE JAVIER DE LA VEGA BUSTILLOS
TECNM/Instituto Tecnológico de Hermosillo

ANTHROPOMETRY OF WORKERS IN A SALT INDUSTRY COMPANY IN SOUTHERN SONORA

Gabriela Soto Robles[1], ORCID: 0009-0008-4571-0010, María del Socorro Félix Lopez[1], ORCID: 0009-0006-1895-0022, Iván Francisco Rodríguez-Gámez[1], ORCID: 0000-0002-7713-4440, Arnulfo A. Naranjo Flores[1], ORCID: 0000-0002-5654-6091, and Aidé Aracely Maldonado-Macías2, ORCID: 0000-0002-4959-161X

[1]Department of Industrial Engineering
Technological Institute of Sonora
818 S 5 de febrero St
Ciudad Obregon, Sonora 85000

[2]Department of Industrial Engineering and Manufacturing
University Autonomous of Ciudad Juarez
450 N Del Charro Avenue
Ciudad Juarez, Chihuahua 32310

Corresponding author's e-mail: ifrodriguez@itson.edu.mx

Resumen: La antropometría es la disciplina encargada de la recopilación y medición sistemática de las características físicas del cuerpo humano, principalmente el peso, el tamaño y la forma del cuerpo. Esta disciplina, como herramienta de la Ergonomía, permite adaptar el entorno a las personas mediante el diseño o rediseño de estaciones de trabajo, teniendo en cuenta las cartas antropométricas. En el 2023, la empresa bajo estudio de la industria de la sal registró que el 38% de las enfermedades profesionales presentes en los empleados del área operativa están relacionadas con trastornos musculoesqueléticos (TME). A raíz de la incidencia de las enfermedades profesionales, se llevó a cabo una evaluación de riesgos ergonómicos identificando la presencia de éstos en los diferentes procesos, como posturas inadecuadas, manipulación de cargas y repetitividad de tareas, lo que ha provocado problemas de salud en la espalda, hombros y manos. Los TME se deben a los diseños disergonómicos presentes en los procesos productivos y a la carencia de datos antropométricos de los trabajadores para el diseño y rediseño de puestos de trabajo, así como a la escasez y vigencia de datos antropométricos de la región. Se planteó como objetivo diseñar cartas antropométricas de los trabajadores del área operativa de la empresa salinera para obtener una base de datos precisa que apoye a la empresa en el diseño o rediseño de herramientas, equipos y estaciones de trabajo. La metodología propuesta consta de 5 pasos: 1) Definir las dimensiones a medir, 2) informar a los trabajadores, 3) realizar la medición de los trabajadores, 4) analizar los datos y 5) diseñar las cartas antropométricas. Como resultado, se establecieron 51 medidas antropométricas, se midió a 63 trabajadores y se elaboró una carta antropométrica del personal del área operativa que incluye el 5%, 50% y 95% percentil. Se logró el objetivo planteado de la investigación, ya que se obtuvo la carta antropométrica de los trabajadores del área operativa. La carta antropométrica no sólo contribuye a la mejora de las condiciones de trabajo dentro de la empresa, sino que sienta las bases para futuras investigaciones en el campo de la ergonomía, beneficiando a los usuarios interesados en diseñar espacios de trabajo más inclusivos, seguros y eficientes. Además, estos datos contribuyen a la caracterización de la población laboral del sur de Sonora.

Palabras clave: Antropometría, Diseño, Carta antropométrica, Percentiles.

Relevancia para la ergonomía: Esta investigación contribuye con datos de una región en particular del país para el campo de diseño ergonómico de equipos, maquinaria, herramientas y estaciones de trabajo. Los resultados pueden utilizarse para desarrollar mejores estándares ergonómicos, además de mejorar la comodidad, bienestar y eficiencia laboral.

Abstract: Anthropometry is the discipline in charge of systematically collecting and measuring the human body's physical characteristics, mainly the body's weight, size, and shape. As a tool of Ergonomics, this discipline allows to adapt the environment to people through the design or redesign of workstations, considering the anthropometric charts. In 2023, the company under study in the salt industry recorded that 38% of occupational diseases present in employees in the operational area are related to musculoskeletal disorders (MSDs). As a result of the incidence of occupational diseases, an ergonomic risk assessment was carried out, identifying ergonomic risks in the different processes, such as inadequate postures, load handling, and task repetitiveness, which have caused health problems in the back, shoulders, and hands. MSDs are due to the dysergonomic designs present in the production processes, the lack of workers' anthropometric data for the design and redesign of workstations, and the scarcity and validity of anthropometric data in the region. The objective was to design anthropometric charts of the workers in the operational area of the salt company to obtain an accurate database to support the company in the design or redesign of tools, equipment, and workstations. The proposed methodology consists of 5 steps: 1) define the dimensions to be measured, 2) inform the workers, 3) perform the measurement of the workers, 4) analyze the data, and 5) design the anthropometric charts. As a result, 51 anthropometric measurements were established, 63 workers were measured, and an anthropometric chart of the personnel in the operational area was prepared, including the 5%, 50%, and 95% percentile. The objective of the research was achieved since the anthropometric chart of the workers in the operative area was obtained. The anthropometric chart not only contributes to the improvement of working conditions within the company but also lays the groundwork for future research in the field of ergonomics, benefiting users interested in designing more

inclusive, safe, and efficient workspaces. In addition, these data contribute to the characterization of the working population in southern Sonora.

Keywords. Anthropometry, Design, Anthropometric chart, Percentiles.

Relevance to Ergonomics: This research contributes data from a particular country region to the ergonomic design of equipment, machinery, tools, and workstations. The results can be used to develop better ergonomic standards and improve comfort, well-being, and work efficiency.

1. INTRODUCTION

Anthropometry (derived from the Greek Anthropos: human and, Metron: measure) refers to the systematic measurement of the physical characteristics of the human body, primarily body weight, body size, and shape (Tur & Bibiloni, 2019). This discipline serves as a tool for Ergonomics in order to adapt the environment to people (Mondelo et al., 1999) In addition, it allows the creation of an adequate work environment through the design or redesign of tools, furniture, equipment, and workstations under the consideration of anthropometric charts since these provide information on the dimensions of a given population and are widely used by designers. So far, in Sonora, there are only two previous studies related to the industrial sector: one was conducted in 2002 in the maquila of Cd. Obregón (Mungarro, 2002) and another in 2010, focused on workers in the automotive sector in Hermosillo (De la Vega, 2010; López Acosta et al., 2019). Both studies are at least 15 years old, so their validity is questionable since the periodic updating of anthropometric charts is crucial to reflect changes in body dimensions; some authors recommend doing it every 5 to 10 years in populations with significant variations (Kim et al., 2018) and every 15 to 20 years in more stable populations (Karlberg et al., 1999); however, there is no time standard that guarantees the validity in the use of these data in the design of workstations. In addition, if the data are specific to a group of workers within an organization, the validity will depend on the stability of the workforce.

On the other hand, in 2023, the company under study in the salt industry recorded that 38% of occupational diseases present in employees in the operational area are related to musculoskeletal disorders (MSDs). In addition, it carried out an ergonomic risk assessment identifying the presence of these in the different processes, such as inadequate postures, load handling, and repetitiveness of tasks, so that workers have experienced health problems in the back, shoulders, and hands, among other areas. Considering these considerations, the need to design and/or redesign ergonomic approach tools, equipment, and workstations was determined. However, this organization lacks anthropometric charts of workers in the operational area that allow for the physical dimensions of their workers to be characterized, and the scarcity of anthropometric data in the region is taken into account. The validity of the same reinforces the need for this research to have an anthropometric chart of this particular population to design and/or redesign workstations to eliminate or reduce the incidence of this type of disease.

2. OBJETIVE

Design anthropometric charts of the workers in the operational area of the salt company to obtain an accurate database to support the company in the design or redesign of tools, equipment, and workstations.

3. METHODOLOGY

3.1 Subjects of study

In this study, 63 employees were considered from the operating area of the salt company; it was all male. Of these, 28 are between 31 and 40 years old, 16 are between 41 and 50, nine are between 21 and 30, seven are between 51 and 60, and only three are between 15 and 20 years old. His place of birth: 96.8% (61) of the employees were born in Sonora. Meanwhile, 3.2% (2) of the personnel were born in Baja California Sur and Michoacán. As for the place of birth of the father and mother, 84.1% belong to the states of Sonora and Sinaloa.

3.2 Instruments, Software, and measuring equipment

3.2.1. Measuring equipment

The following measuring equipment was used to measure the body measurements of the workers:

a) Digital scale. Capacity 180 Kg. For weighing of workers

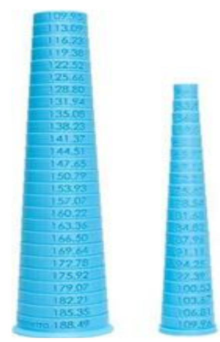
b) Cajón antropométrico, para tomar las medidas del sujeto en posición sentado.

c) Antropómetro, se utilizó para la toma de medidas del pie, como el largo y el ancho.

d) Stadiometer, used to measure heights in standing and sitting positions.

e) Anthropometric tape, used to measure the circumferences of the head, neck, chest, waist, hip, and ear-to-ear distance.

f) Graduated cone, used to measure the grip of the subject's hand.



g) Vernier-type anthropometer is used to measure the lengths of the subject's body, including shoulder width, chest length, and hip width.

h) Digital tape measure was used to measure leg lengths, instep height of the foot, and arm length.

Figure 1. Measuring equipment used

3.2.2. Instrument

The format proposed by De la Vega B. and Pedro López H. was used to record the dimensions. Figure 2 shows the format used

3.2.3. Software

- The Excel package for Windows was used to capture the data collected, in which the subject's personal information was entered, such as name, area in which he/she works in the company, age range, place of birth (state), as well as that of his/her parents, and the dimensions of each of the 51 anthropometric measurements.

- Minitab 2021 statistical software was used to analyze the data, and graphs were made to verify the outliers (box and whisker) and the frequency (histogram). In addition, the mean, variance, standard deviation, kurtosis, skewness, and percentiles were obtained for the different anthropometric dimensions.

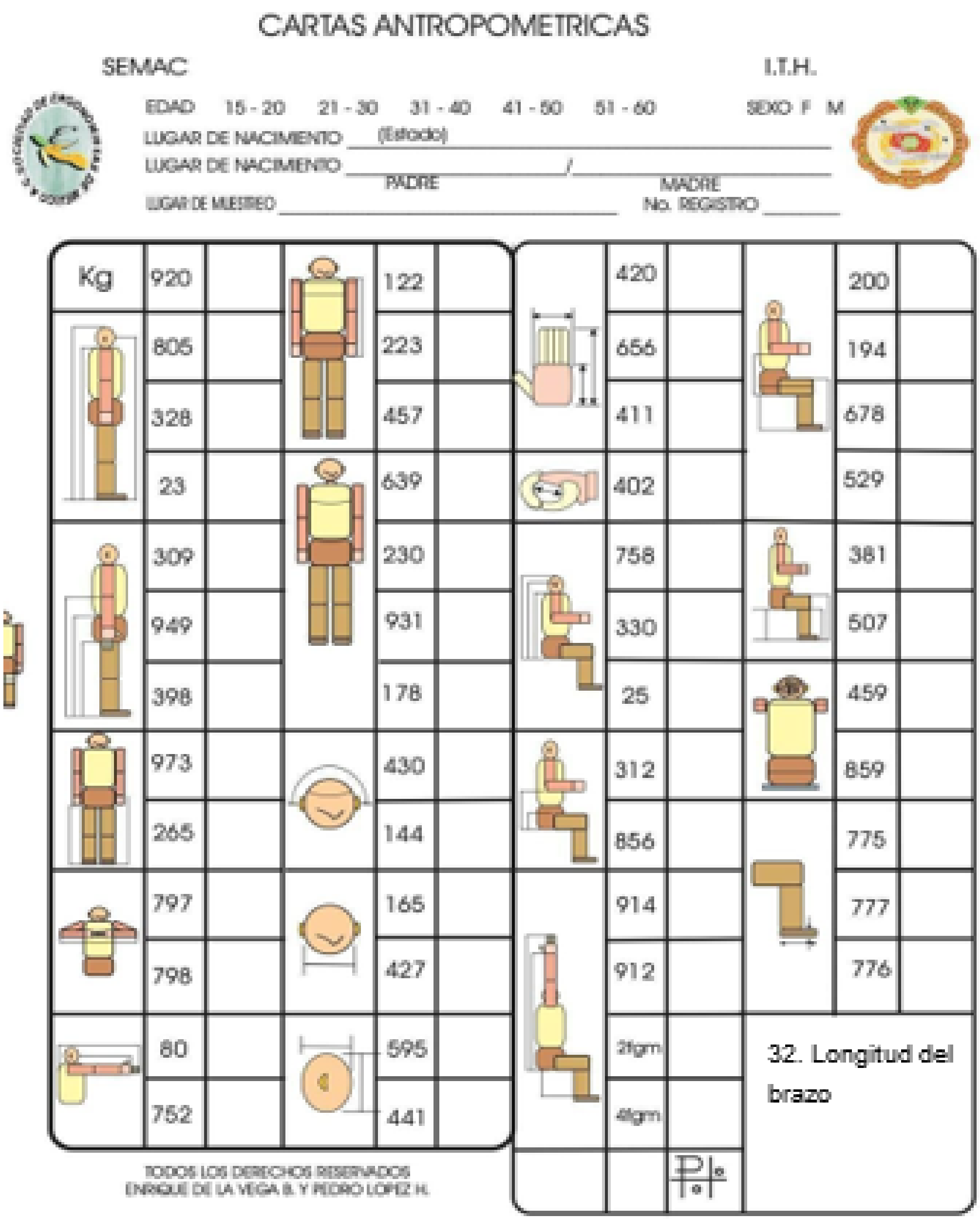


Figure 2. Anthropometric chart format.
Source: Enrique De la Vega B. y Pedro López H.

3.3 Method

A five-step method is proposed:

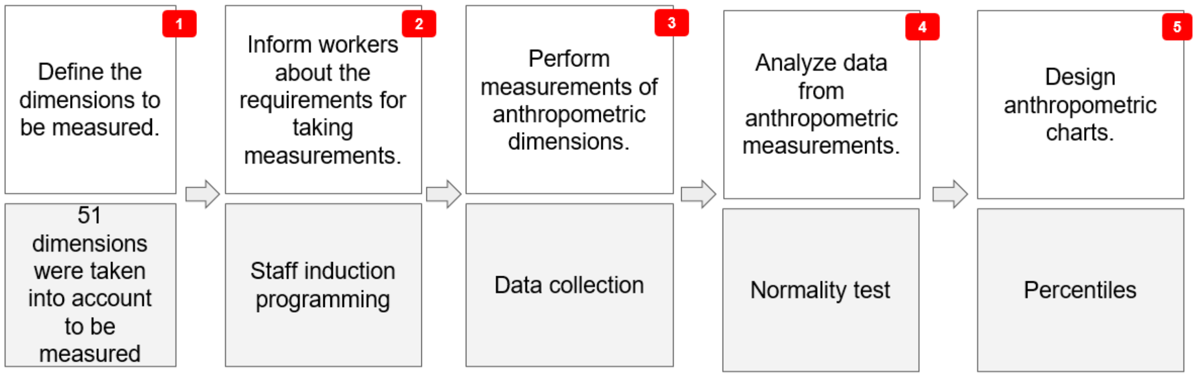


Figure 3. Method proposed

3.3.1. Step 1: Define the dimensions to be measured

In step I, the anthropometric dimensions to be measured were defined based on similar studies, considering the dimensions of the anthropometric chart proposed by Enrique de la Vega and Pedro López. These measurements cover various areas of the body, such as heights, circumferences, widths, and specific lengths, and aim to obtain detailed data.

3.3.2. Step 2: Inform workers about the requirements for taking measurements

In step II, workers were informed about the objective of the project, its benefits, and the requirements for taking the dimensions through a dissemination campaign. In addition, the measurement schedule should be established in this step, where the workers' participation is scheduled to reduce the impact of the absence of personnel in the production process.

3.3.3. Step 3: Perform measurements of anthropometric dimensions

In step III, the anthropometric dimensions were taken using a guide to describe the different dimensions suggested by López Acosta et al. (2019), as well as the measuring equipment and the recording form (anthropometric measurement table) to capture the selected body dimensions. Two postures were prepared for the measurement: 1) standing and 2) with the subject sitting.

- Standing: where the subject remains standing, facing forward (maintaining the Frankfurt plane position), with ankles together, toes apart, and arms hanging at their sides, which is known as the anthropometric attention position.

- Subject sitting: where the subject remains seated, facing forward (maintaining the Frankfurt plane position), with arms hanging relaxed at their sides and with their feet resting so that the flexed knees are at a 90° angle.

3.3.4. Step 4: Analyze data from anthropometric measurements

In step IV, the measurement data were analyzed, where they were cleaned, and once possible errors were ruled out, the normality for each dimension was verified.

3.3.5. Step 5: Design anthropometric charts

In step V, the anthropometric chart was designed, which includes the body dimensions, the mean, median, variance, and percentiles (5, 50, and 95). The following equation (1) and the Z-values (see Table 1) were used to calculate the percentiles.

$$\boldsymbol{Ptile = \bar{X} \pm Z * S} \quad \textbf{(1)}$$

Where:

Ptile = Value of the desired percentile.

$\boldsymbol{\bar{X}}$ = Mean or average of the anthropometric dimension.

Z = Constant that depends on the selected percentile, obtained from the Z table.

S = Standard deviation.

Table 1. Standardized values (Z)

Percentile	Z-Value
5	1.654
50	0
95	1.646

4. RESULTS

The main results of this research are listed below:

4.1 Step 1: Define the dimensions to be measured

Based on similar studies conducted in other countries and on the recommendations of the Society of Ergonomists of Mexico A.C. (SEMAC), it was agreed to record a total of 50 body dimensions using the anthropometric chart format (see Figure 2), to which the arm length (32) was integrated, resulting in a total of 51 measurements.

These body measurements cover different body parts, including heights, circumferences, widths, and specific lengths, to collect detailed data to improve the design of tools, furniture, and working conditions in the salt company. The list of dimensions and their coding is presented below.

Table 2. Anthropometric measurements

Anthropometric Measure	
1. Body weight (920)	27. Hand length (420)
2. Height (805)	28. Palm length (656)
3. Height at eye (328)	29. Palm width (411)
4. Height at shoulder (23)	30. Grip diameter (inside) (402)
5. Height at elbow (309)	31. Seat to head height (758)
6. Height at waist (949)	32. Seat to eye height (330)
7. Height at buttock (398)	33. Seat to shoulder height (25)
8. Wrist height (973)	34. Seat to elbow height at 90° (312)
9. Height to the middle finger in normal position (265)	35. Thigh height (856)
10. Width of the arms extended laterally (797)	36. Height from seat to middle finger with arms extended upwards (914)
11. Width of elbows with hands at the center of the chest (798)	37. Height from center of fist with arms extended upward (912)
12. Arm length to wall (80)	38. Height of head to the floor in a sitting position (2fgm)
13. Distance from the wall to the center of the fist (752)	39. Height from floor to seat (4fgm)
14. Shoulder width (122)	40. Back of knee to wall length (200)
15. Chest width (223)	41. Length of knee to wall (194)
16. Hip width (457)	42. Height of the floor to the back of the knee (678)
17. Neck circumference (639)	43. Floor to knee height (529)
18. Chest circumference (230)	44. Length from elbow to middle finger (381)
19. Waist circumference (931)	45. Back width with arms extended out in front (507)
20. Hip Circumference (178)	46. Seated hip width (459)
21. Head circumference (230)	47. Thigh width with knees together (859)
22. Distance from ear to ear above head (144)	48. Foot length (775)
23. Face width at sideburns (165)	49. Foot width (777)
24. Head width (427)	50. Instep height (776)
25. Height of the chin to the top of the head (595)	51. Arm length (32)
26. Head length (441)	

The origin of this coding and its description are based on the measurements used by the National Aeronautics and Space Administration (NASA) (Churchill et al., 1978).

4.2 Step 2: inform workers about the requirements for taking measurements

To inform the workers about the purpose of the study and the requirements for taking the anthropometric measurements, induction sessions were organized, where the information necessary to participate in the measurements was explained to the workers. Evidence of the induction session is shown in Figure 4 below.

Figure 4. Induction presentation.

In addition, they were given a brochure with the most relevant information and the requirements to participate in the study. At this stage, any doubts of the operators were resolved to ensure their informed participation, and the tentative date for their measurement was established.

4.3 Step 3: Perform measurements of anthropometric dimensions

First, a space or place was set up that allowed some privacy and comfort for the worker, as well as facilitating the measurement for the evaluators to continue with the measurement of each anthropometric measurement and the recording of the dimensions in the format of the 63 workers in the operational area. The following Figure 5 shows some evidence of the operators' measurement.

Figure 5. Evidence of the measurement of the operators in the operational area

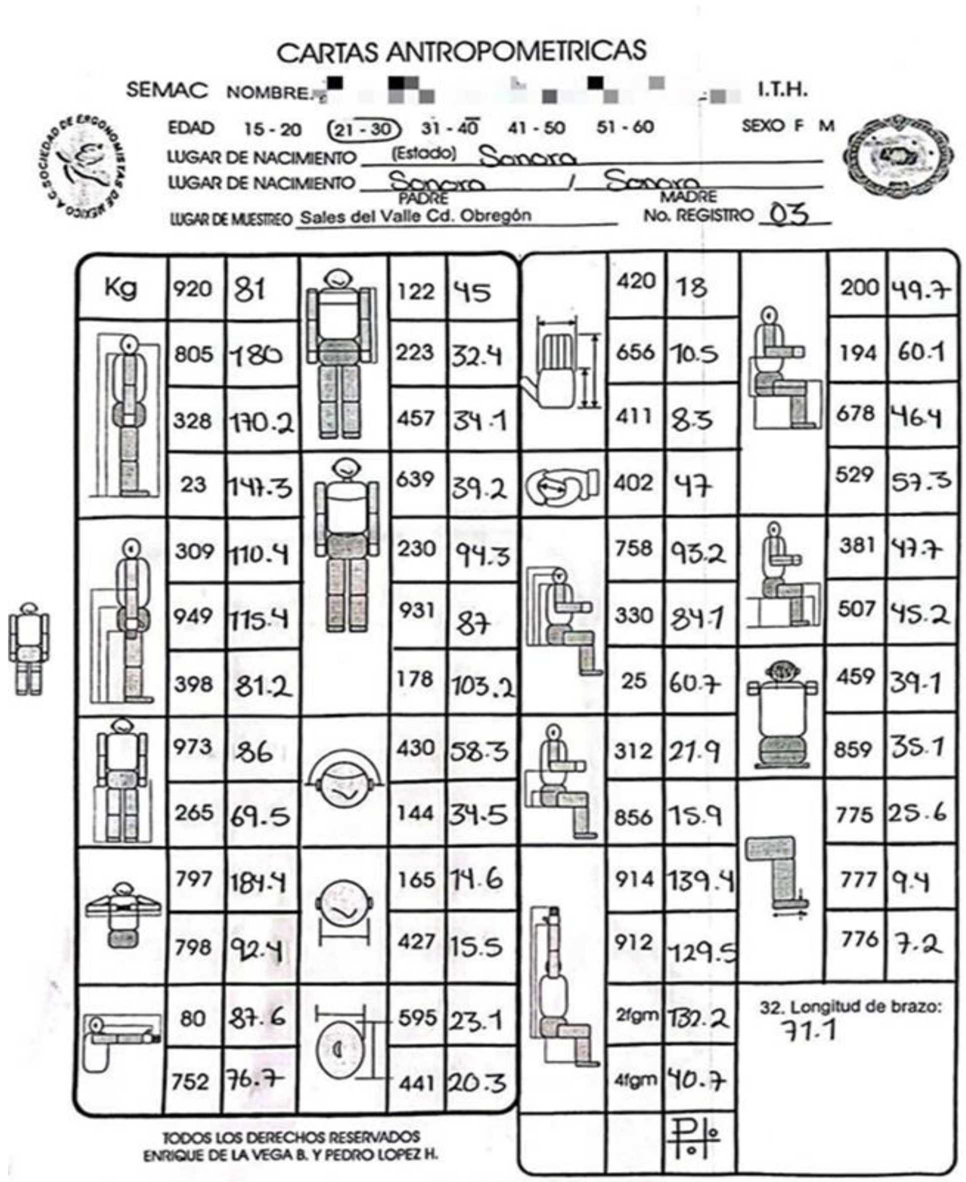
For each operator, each dimension was recorded, as shown in Figure 6:

4.4 Step 4: analyze data from anthropometric measurements

Before the analysis, a database was prepared with all the records of the 63 workers; the data were cleaned to detect any capture errors, extreme values by means of whisker box plots, inadequate behavior, missing data, and unexpected variability.

With the help of the box-whisker plot, outliers in some measurements were eliminated to ensure the study's validity and accuracy. Frequency histograms were also made to visualize the data's behavior, where the data's concentration, possible anomalies, and dispersion could be observed; these graphs were applied to the 51 measures analyzed. The box plot of the worker's weight measurement (920) is shown below:

In addition, a data analysis was carried out, where the normality of the 51 measurements was verified using Minitab software. The test performed was the Kolmogorov-Smirnov test, considering a confidence level of 95%. Figure 9 shows the goodness of fit test for the worker's weight.



CARTAS ANTROPOMETRICAS

SEMAC NOMBRE [redacted] I.T.H.

EDAD 15 - 20 (21 - 30) 31 - 40 41 - 50 51 - 60 SEXO F M

LUGAR DE NACIMIENTO (Estado) Sonora

LUGAR DE NACIMIENTO Sonora / Sonora

PADRE MADRE

LUGAR DE MUESTREO Sales del Valle Cd. Obregón No. REGISTRO 03

Kg 920	81	122	45	420	18	200	49.7
805	180	223	32.4	656	10.5	194	60.1
328	170.2	457	34.1	411	8.3	678	46.4
23	147.3	639	39.2	402	47	529	57.3
309	110.4	230	94.3	758	93.2	381	47.7
949	115.4	931	87	330	84.1	507	45.2
398	81.2	178	103.2	25	60.7	459	39.1
973	86	430	58.3	312	27.9	859	35.1
265	69.5	144	34.5	856	15.9	775	25.6
797	184.4	165	14.6	914	139.4	777	9.4
798	92.4	427	15.5	912	129.5	776	7.2
80	87.6	595	23.1	2fgm	132.2	32. Longitud de brazo: 71.1	
752	76.7	441	20.3	4fgm	40.7		

TODOS LOS DERECHOS RESERVADOS
ENRIQUE DE LA VEGA B. Y PEDRO LOPEZ H.

Figure 6. Recording of anthropometric dimensions

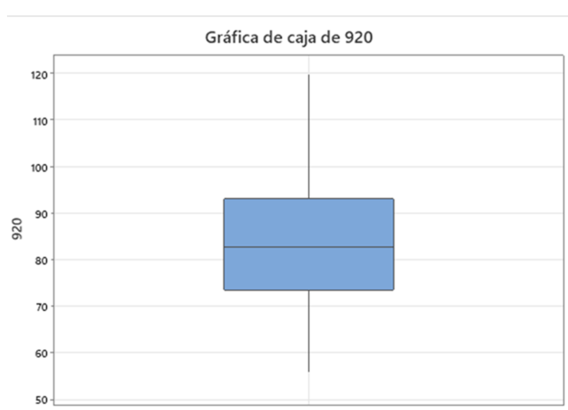


Figure 7. Box-whisker plot of workers' weight (920).

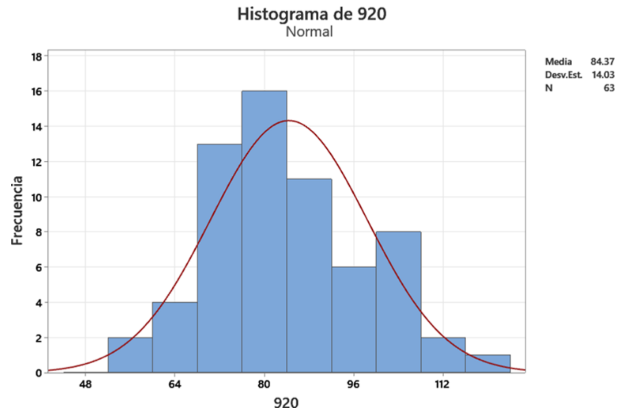


Figure 8. Histogram of worker's weight (920)

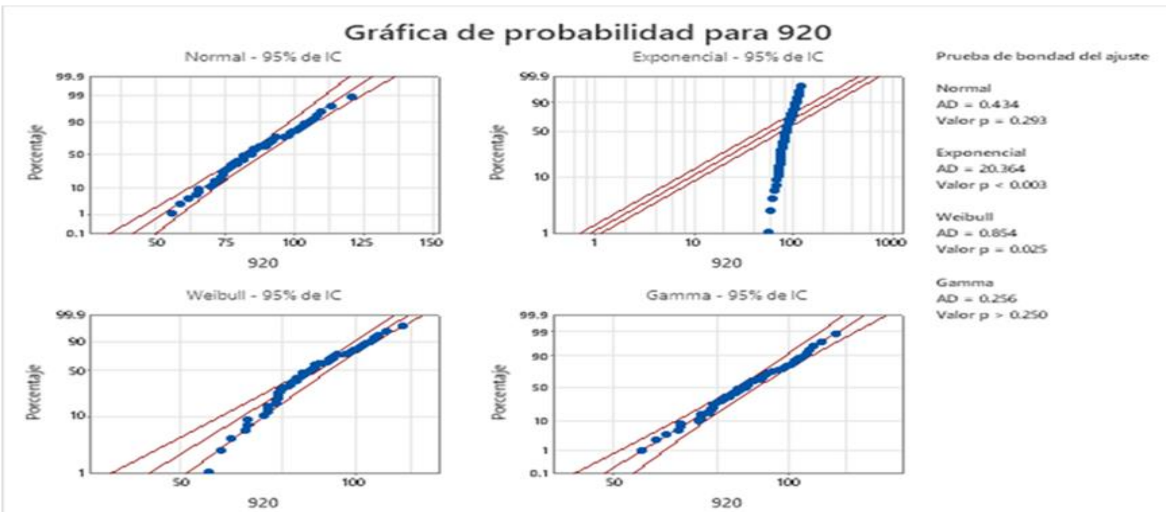


Figure 9. Goodness-of-fit test for the weight of workers (920).

The above tests resulted in the identification of the type of distribution; Table 3 shows the type of distribution for the 51 anthropometric measures considered in the study.

Table 3. Type of distribution for each anthropometric dimension.

Dimensions	Types of distributions	Dimensions	Types of distributions	Dimensions	Types of distributions
920	Normal	230	**Lognormal**	856	Normal
805	Normal	931	**Weibull**	914	Normal
328	Normal	178	Normal	912	Normal
23	Normal	430	Normal	2fgm	Normal
309	Normal	144	Normal	4fgm	Normal
949	Normal	165	Normal	200	Normal

398	Normal	427	Normal	194	Normal
973	Normal	595	Normal	678	Normal
265	Normal	441	Normal	529	Normal
797	Normal	420	Normal	381	Normal
798	Normal	656	Normal	507	Normal
80	Normal	411	Normal	459	Normal
752	Normal	402	Normal	859	Normal
122	Normal	758	Normal	775	Normal
223	**Lognormal**	330	Normal	777	Normal
457	Normal	25	Normal	776	Normal
639	Normal	312	Normal	32	Normal

Only three measurements that did not have a normal distribution were identified, for which the percentile was determined using the median as the measure of central tendency.

The database of anthropometric dimensions is available upon request by e-mail to the corresponding author's email address.

4.5 Step 5: Design anthropometric charts

Once the normality of the data was verified, with the statistics corresponding to the study, such as mean, variance, and percentiles, we proceeded to prepare the anthropometric charts for each dimension. More data can be found in the charts, in addition to the percentiles, the standard deviation, kurtosis, skewness, summation, minimum, maximum, and total of the measured individuals.

Below is one of the 51 anthropometric charts made, corresponding to the worker's weight (920).

Table 4. Anthropometric chart of workers' weight

ANTHROPOMETRIC CHART						
WORKER'S WEIGHT						
Code: #920						
Lbs.	Indicator	Kg.				
186.00	Mean	84.37				
434.20	Variance	196.95				
30.93	Std. Dev.	14.03		Lbs.	Percentile	Kg.
123.02	Minimum	55.8		24.13	5%	61.28
264.55	Maximum	120		33.22	50%	84.37

Skewness=	0.35	42.30	95%	107.45
Kurtosis=	-0.31			
Sum =	5315.10			
Number of subjects=	63			

In addition to the individual anthropometric charts, a concentrated chart was prepared with the data of all the participants in the operative area. This chart, which includes the total measurements, mean, median, standard deviation, variance, and percentiles of the 5th, 50th, and 95th percentile, is a crucial tool for understanding the anthropometric characteristics of the operative area. For normally distributed dimensions, the mean was used as a measure of central tendency to calculate the percentiles, and for dimensions without normal distribution, the median was used. The concentrated anthropometric chart of the operative area is shown below in the Table 5.

5. CONCLUSIONS

It is important to point out that the objective of the research was achieved since the anthropometric chart of the workers in the operative area of the company under study in the salt industry was obtained. The anthropometric chart will allow the ergonomic design or redesign of tools, equipment, and workstations in the organization, improving the designs' adaptability to the personnel's physical limitations and thus reducing the discomfort and diseases related to MSDs afflicting this organization. This work not only contributes to the improvement of working conditions within the company but also lays the groundwork for future research in the field of ergonomics, benefiting users interested in designing more inclusive, safe, and efficient workspaces.

On the other hand, these data contribute to the characterization of the population of southern Sonora, specifically the municipality of Cajeme. Therefore, they interest researchers, teachers, students, and other professionals who wish to delve deeper into anthropometric analysis.

Table 5. Anthropometric chart of the operative area

No.	Body dimension	Mean	Median	Std. Dev.	Variance	Percentiles		
						5%	50%	95%
1	Body weight (920)	84.37	82.80	14.03	196.95	61.28	84.37	107.45
2	Height (805)	170.21	170.00	5.44	29.64	161.26	170.21	179.17
3	Height at eye (328)	159.84	160.20	5.58	31.16	150.66	159.84	169.02
4	Height at shoulder (23)	141.08	141.50	5.38	28.95	132.23	141.08	149.93
5	Height at elbow (309)	107.54	107.60	3.99	15.92	100.97	107.54	114.10
6	Height at waist (949)	107.10	107.40	4.53	20.51	99.65	107.10	114.55
7	Height at buttock (398)	75.63	75.70	3.57	12.72	69.76	75.63	81.50
8	Wrist height (973)	82.76	82.50	3.18	10.12	77.53	82.76	87.99
9	Height to the middle finger in normal position (265)	65.22	65.00	2.81	7.92	60.60	65.22	69.85
10	Width of the arms extended laterally (797)	175.57	174.60	7.36	54.16	163.46	175.57	187.68
11	Width of elbows with hands at the center of the chest (798)	89.09	89.20	3.86	14.90	82.74	89.09	95.44
12	Arm length to wall (80)	85.21	84.50	3.77	14.20	79.01	85.21	91.41
13	Distance from the wall to the center of the fist (752)	73.25	72.50	3.13	9.79	68.11	73.25	78.40
14	Shoulder width (122)	43.88	44.00	2.36	5.57	40.00	43.88	47.77
15	Chest width (223)	33.95	33.30	3.17	10.06	28.08	33.30	38.52
16	Hip width (457)	35.57	35.40	2.31	5.36	31.76	35.57	39.38
17	Neck circumference (639)	40.54	40.00	3.03	9.19	35.56	40.54	45.53
18	Chest circumference (230)	102.14	101.20	9.08	82.46	86.26	101.20	116.14
19	Waist circumference (931)	96.75	92.60	13.08	171.06	71.08	92.60	114.12
20	Hip Circumference (178)	103.69	103.50	7.73	59.69	90.98	103.69	116.40
21	Head circumference (230)	56.88	56.70	1.74	3.04	54.01	56.88	59.75
22	Distance from ear to ear above head (144)	36.36	36.40	1.38	1.89	34.10	36.36	38.63
23	Face width at sideburns (165)	15.19	15.20	0.71	0.50	14.03	15.19	16.36
24	Head width (427)	16.05	16.00	0.69	0.48	14.92	16.05	17.19
25	Height of the chin to the top of the head (595)	21.82	21.80	1.04	1.08	20.11	21.82	23.53
26	Head length (441)	19.07	19.00	0.83	0.68	17.70	19.07	20.43
27	Hand length (420)	18.44	18.40	0.85	0.73	17.04	18.44	19.84
28	Palm length (656)	10.58	10.50	0.33	0.57	9.64	10.58	11.52
29	Palm width (411)	8.51	8.50	0.36	0.13	7.92	8.51	9.10
30	Grip diameter (inside) (402)	46.75	47.00	3.32	11.03	41.28	46.75	52.21
31	Seat to head height (758)	90.08	90.00	3.07	9.44	85.03	90.08	95.14
32	Seat to eye height (330)	80.38	80.40	3.48	12.12	74.65	80.37	86.10
33	Seat to shoulder height (25)	60.59	60.70	2.95	8.73	55.73	60.59	65.45
34	Seat to elbow height at 90° (312)	26.43	26.70	2.95	8.70	21.57	26.43	31.28
35	Thigh height (856)	15.33	15.00	1.48	2.20	12.89	15.33	17.77

36	Height from seat to middle finger with arms extended upwards (914)	133.94	134.30	5.72	32.72	124.53	133.94	143.35
37	Height from center of fist with arms extended upward (912)	122.45	122.30	5.66	32.01	113.14	122.45	131.76
38	Height of head to the floor in a sitting position (2fgm)	131.05	131.10	3.30	10.91	125.62	131.05	136.48
39	Height from floor to seat (4fgm)	40.70	40.70	0.00	0.00	40.70	40.70	40.70
40	Back of knee to wall length (200)	50.78	50.50	2.89	8.33	46.03	50.78	55.53
41	Length of knee to wall (194)	60.52	60.30	2.83	8.00	55.86	60.52	65.17
42	Height of the floor to the back of the knee (678)	43.12	43.00	1.90	3.62	39.98	43.12	46.25
43	Floor to knee height (529)	52.78	52.70	2.17	4.71	49.21	52.78	56.36
44	Length from elbow to middle finger (381)	46.96	47.10	1.97	3.87	43.72	46.96	50.19
45	Back width with arms extended out in front (507)	44.39	44.10	2.79	7.81	39.79	44.39	48.98
46	Seated hip width (459)	40.53	40.50	3.32	11.04	35.07	40.53	46.00
47	Thigh width with knees together (859)	36.25	35.90	3.06	9.37	31.21	36.25	41.29
48	Foot length (775)	26.01	26.10	0.95	0.90	24.44	26.00	27.57
49	Foot width (777)	9.97	10.00	0.55	0.30	9.06	9.97	10.87
50	Instep height (776)	7.13	7.10	0.45	0.20	6.39	7.13	7.86
51	Arm length (32)	67.18	67.40	3.33	11.08	61.70	67.18	72.65

6. REFERENCES

Churchill, E., Laubach, L. L., Mcconville, J. T., & Tebbetts, I. (1978). *Anthropometric source book. Volume 1: Anthropometry for designers*. NASA.

Karlberg, J., Cheung, Y. B., & Luo, Z. C. (1999). *An update on the update of growth charts*. 797–800.

Kim, J. H., Yun, S., Hwang, S., Shim, J. O., Chae, H. W., & Joo, Y. (2018). *The 2017 Korean National Growth Charts for children and adolescents: development, improvement, and prospects*. *61*(5), 135–149.

López Acosta, M., De la Vega Bustillos, E., Ramírez Cárdenas, E., Chacara Montes, A., Velarde Cantú, J. M., & Báez Hernández, G. E. (2019). *Antropometría para el diseño de puestos de trabajo* (1 ft. Edition). ITSON. https://www.itson.mx/publicaciones/Documents/ingytec/libro%20antropometri%CC%81a.pdf

Mondelo, P. R., Gregori, E., & Barrau Pedro. (1999). *Ergonomía 1 Fundamentos* (3ra Edición). Mutua Universal.

Mungarro, C. E. (2002). *Cartas Antropométricas para la población laboral de la maquila de Cd. Obregón.* Instituto Tecnológico de Sonora.

Tur, J. A., & Bibiloni, M. D. M. (2019). Anthropometry, body composition and resting energy expenditure in human. In *Nutrients* (Vol. 11, Issue 8). MDPI AG. https://doi.org/10.3390/nu11081891

ANTHROPOMETRY AS A TOOL FOR JOB ANALYSIS IN A TEXTILE COMPANY.

Joaquín Vásquez Tachiquín[1], https://orcid.org/0009-0003-6346-4689 [1], Joaquín Vásquez Quiroga *[1], https://orcid.org/0009-0002-3533-9330 [1], Enrique de la Vega Bustillos [2], https://orcid.org/0000-0002-0761-6858 [2], Jesús Martin Cadena Badilla [1], https://orcid.org/0000-0002-2644-1424 [1], and Francisco J. León Moreno [1] https://orcid.org/0000-0002-2245-384X [1]

[1] Department of Physical, mathematics and Engineering
University of Sonora
Caborca, Sonora, México 83600

[2]Department of Industrial Engineering
Tecnológico Nacional de México/Instituto Tecnológico de Hermosillo
Hermosillo, Sonora, México

Corresponding author's e-mail: joaquin.vasquez@unison.mx

RESUMEN: El desarrollo de este trabajo es la primera parte de un macro estudio en la zona Industrial de Caborca, Sonora, México, con la finalidad de conocer la existencia de posibles oportunidades de aplicación en el campo de ergonomía, en el caso específico en trabajadores de la industria textil. Como primer paso sería generar una base de datos antropométricos confiable en los puestos de trabajo de esta industria, buscando con ello dar inicio con una serie de investigaciones en esta área productiva de nuestro Estado de Sonora y en la Región de Caborca, Sonora.

La industria textil es una parte importante de la economía de todos los países, según la publicación del sitio Morder Intelligence en el Informe de la Industria Textil: Análisis global, tamaño del mercado y Pronósticos (2025-2030), estima que a nivel mundial el mercado textil será de 774.33 mil millones de dólares en el año 2025 y que alcanzará los 920.55 mil millones de dólares para el año 2030, también menciona que según la Organización Internacional de Trabajo el sector textil fue altamente afectado durante la primera mitad del año 2020 por la pandemia de COVID-19 teniendo una reducción del 70% en las exportaciones de los principales compradores de la Unión Europea, Estados Unidos y Japón. Sin embargo, hace saber que este mercado está en crecimiento constante y en recuperación.

El número de personas registradas que participan en este sector productivo según la Cámara Nacional de la Industria Textil (CANAINTEX) en el mes de noviembre de 2024 se registraron cerca de 1.2 millones de empleos en la Industria Textil en nuestro país.

Buscando oportunidades de apoyo para las personas que están inmersas en el sector de la industria textil, se dio inicio con el registro de algunas dimensiones antropométricas de los trabajadores de esta industria en Caborca, Sonora. Se pretende generar base de datos antropométricas importantes que sirvan para dimensionar herramientas y estaciones de trabajo que se adapten a las verdaderas necesidades de los trabajadores en la elaboración de los productos de esa empresa. Al considerar las medidas antropométricas, se permite adecuar el entorno laboral y las herramientas a las características y alcance físico de los trabajadores, evitando así, que el trabajador se vea en la necesidad de adaptarse a las condiciones de la estación o área de trabajo y pueda realizar su trabajo de manera eficiente y segura.

Palabras clave: Antropometría, ergonomía, puesto de trabajo, industria textil.

Aportaciones a la Ergonomía: Generar una base de datos antropométrica que contenga las dimensiones de la población que participa en la industria textil en Caborca, Sonora, México y que pueda ser un aporte para el resto del Estado y el País.

Abstrac: The work developed here is the first part of a macro study in the Industrial zone of Caborca, Sonora, Mexico, with the purpose of knowing the possible existing opportunities of the application of the ergonomics field, in the specific case of workers in the textile industry. The first step would be to generate a reliable anthropometric database in the workplaces of this industry, thus seeking to start a series of investigations in this productive area of our State of Sonora and in the Region of Caborca, Sonora.

The textile industry is an important part of the economy of all countries, according to the publication of the site Morder Intelligence in the Textile Industry Report: Global Analysis, Market Size and Forecasts (2025-2030), estimates that worldwide the textile market will be of 774.33 billion dollars in the year 2025 and will reach 920. 55 billion dollars by the year 2030, it also mentions that according to the International Labor Organization the textile sector was highly affected during the first half of the year 2020 by the COVID-19 pandemic having a 70% reduction in exports from the main buyers of the European Union, United States and Japan. However, it makes known that this market is steadily growing and recovering.

The number of registered people involved in this productive sector according to the National Chamber of the Textile Industry (CANAINTEX) in the month of November 2024 there were about 1.2 million jobs in the Textile Industry in our country.

Looking for support opportunities for people who are immersed in the textile industry sector, we started with the registration of some anthropometric dimensions of workers in this industry in Caborca, Sonora. The aim is to generate important anthropometric data bases that serve to dimension tools and workstations that adapt to the real needs of the workers in the elaboration of the products of this company.

By considering the anthropometric measurements, it is possible to adapt the work environment and tools to the characteristics and physical reach of the workers, thus avoiding the need for the worker to adapt to the conditions of the workstation or work area and to be able to perform his work efficiently and safely.

Key words: anthropometry, ergonomics, workstation, textile industry.

Contributions to Ergonomics: To generate an anthropometric database containing the dimensions of the population that participates in the textile industry in Caborca, Sonora, Mexico and that can be a contribution for the rest of the State and Country.

1. INTRODUCTION

The textile industry is an important part of the economy in the region of Caborca, Sonora, Mexico, since it has a good positioning of the products that are produced here for the national and international market. In addition, the production and export of the products that are produced in this branch causes a considerable economic spill and generation of jobs for the region throughout the year.

According to INEGI 2019, the Textile and Apparel Industry generated a Gross Domestic Product (GDP) value of 133,028 million current pesos during January-September 2019, contributing 40.3% to the Textile Industry and 59.7% to the Apparel Industry.

According to Zavala- Villagómez, Aguilasocho-Montoya & Galeana-Figueroa, (2021) workplaces should be a combination between the necessary work spaces and the equipment used, where the workers' capabilities and work demands should be precisely identified, seeking an ergonomic balance in both. It also refers to the importance of identifying not only physical but also ergonomic and psychosocial risk factors.

With the recording of anthropometric measurements, the aim is to avoid the suffering of musculoskeletal disorders due to non-ergonomic postures adopted during the necessary work in each workstation of the industry under study; in addition, the measurement of anthropometric data of the users will allow identifying the importance of their capabilities and physical scope when performing their work.

According to the study recorded by Ortiz Porras et. al (2022), the overexertion performed by textile sector workers in the development of their work causes multiple musculoskeletal disorders in some parts of the body such as the back, neck, shoulders, upper and lower extremities, as well as joints.

According to Miranda Rodríguez, B. X., & Sáenz Julcamoro, L. A. (2020) seeking to evaluate the possibilities for improvement of a workstation in the textile industry, developed a model of a workstation using observational ergonomic techniques such as REBA, RULA and NIOSH, as well as engineering tools such as the Material Handling System, Study of Methods among others, contributing with their study a reduction of 44.42% of Musculoskeletal Disorders.

Intriago Mejía, A. C. (2021) mentions the importance of identifying ergonomic risks in the industry, with this it is possible to train and inform workers about the control and preventive behaviors that help them to take actions that can benefit their health.

This is why the study conducted here is important, since it may be possible that there is a need to adjust anthropometric measurements of the users of tools and equipment in the product assembly process, which can significantly affect work efficiency.

2. OBJETIVE

To develop a research with the necessary ergonomic elements in the field of anthropometry, seeking to build a database of workers in the textile industry in the Industrial Park of Caborca, Sonora, Mexico.

3. DELIMITATION

The study has certain limitations, since only the textile companies of H. Caborca, Sonora, Mexico will be considered.

4. METHODOLOGY

4.1 Introduction.

For the recording of anthropometric data of workers in the textile industry in Caborca, Sonora, Mexico, the procedures defined and classified in the book published by NASA (National Aeronautics and Space Administration), 1978 will be considered. Anthropology Research Project 1978 Anthropometric Source Book, Vol. I: Anthropometry for Designers.

4.2 Description of the method.

The data recorded were collected in a cross-sectional observational manner from a convenience sample of 100 workers in the textile industry of Caborca, Sonora, Mexico.

4.3 Materials.

The following equipment was used for the development of the research:

- Two anthropometers model 01140, 01290 and 01291 Lafayette brand.
- Two Clarita model anthropometric kits.
- One Seca stadiometer.
- One Seca analog scale.
- Two Stanley Powerlock flexometers.
- Two flexible tape measures.
- A computer for recording information.

The methodology for taking the measurements was as follows:

For the collection of the study data and the recording of information, the precautions and freedoms of the company were adjusted to the workers' rest time.

The recording of information in the formats was carried out by two teams composed of two people each, while one took the measurements, the other wrote down the data on the anthropometric chart.

During the data collection, the workers were passing by once they had finished their food intake and their half-day break see figure 1.

.

Figure 1. Recording of anthropometric measurements by the two teams

The 24 measurements shown in Table 1 are those recorded for the case study of this work, where the worker remained standing and for each of the measurements the procedure shown in the book published by NASA (National Aeronautics and Space Administration), 1978, was followed. Anthropology Research Project 1978 Anthropometric Source Book, Vol. I: Anthropometry for Designers..

Table 1. Measurements recorded in the study.

Code	Size name
N920	Weight
N805	Height
N328	Height at standing eye
N23	Height at shoulder standing
N309	Height at elbow standing
N949	Height at waist standing
N398	Height at buttock standing
N973	Height at wrist stationary
N265	Height at middle finger standing
N797	Width of outstretched arms
N798	Width of elbows to center of chest
N80	Arm length to wall
N122	Width of shoulders standing
N223	Standing chest width

N457	Standing hip width
N144	Distance from ear to ear above the head
N427	Head width
N441	Length of head
N420	Length of hand
N656	Length of palm of hand
N411	Width of palm of hand
N402	Grip diameter(inside)
N529	Height from ground to knee
N381	Length elbow to middle finger

5. ANALYSIS OF RESULTS

The results obtained in the investigation of the anthropometric measurements of the textile industry workers in Caborca, Sonora, were statistically processed showing the calculations of the 5th, 50th, and 95% percentiles, as well as the maximum and minimum of the measurements. Table 2 shows the results described above for the anthropometric dimensions corresponding to the data for men and Table 3 for women. The calculation of weight is recorded in kilograms and the rest of the measurements shown in Table 2 and 3 are in centimeters.

Table 2. Results obtained from the 66 men registered in the study of female textile workers in Caborca, Sonora, Mexico.

		Percentiles				
Code	**Size name**	**5%**	**50%**	**95%**	**Mínimo**	**Máximo**
N920	Weight	55	82	122	52	128
N805	Height	165	176	185	164	193
N328	Height at standing eye	157	167	174	153	180
N23	Height at shoulder standing	128	149	162	53	167
N309	Height at elbow standing	104	116	124	103	152
N949	Height at waist standing	93	101	125	91	128
N398	Height at buttock standing	74	88	103	70	112
N973	Height at wrist stationary	80	88	95	78	97
N265	Height at middle finger standing	63	70	75	61	80
N797	Width of outstretched arms	82	93	102	79	103

N798	Width of elbows to center of chest	42	49	54	34	85
N80	Arm length to wall	73	80	87	71	90
N122	Width of shoulders standing	45	49	54	41	55
N223	Standing chest width	24	34	40	19	42
N457	Standing hip width	31	36	41	29	41
N144	Distance from ear to ear above the head	17	19	20	15	21
N427	Head width	14	16	17	13	18
N441	Length of head	20	22	24	19	25
N420	Length of hand	17	18	19	16	20
N656	Length of palm of hand	9	10	11	9	11
N411	Width of palm of hand	8	8	9	7	9
N402	Grip diameter(inside)	3	4	6	3	6
N529	Height from ground to knee	45	49	57	39	58
N381	Length elbow to middle finger	45	48	51	44	56

Table 3. Results obtained from the 34 women registered in the study of textile industry workers in Caborca, Sonora, Mexico.

		Percentiles				
Code	**Size name**	**5%**	**50%**	**95%**	**Mínimo**	**Máximo**
N920	Weight	52	62	87	52	100
N805	Height	153	164	169	150	169
N328	Height at standing eye	145	154	157	144	160
N23	Height at shoulder standing	129	137	142	128	144
N309	Height at elbow standing	99	105	109	96	110
N949	Height at waist standing	92	96	111	89	115
N398	Height at buttock standing	65	91	97	55	98
N973	Height at wrist stationary	77	80	87	76	87
N265	Height at middle finger standing	59	65	72	58	74
N797	Width of outstretched arms	78	82	102	77	150

N798	Width of elbows to center of chest	41	44	58	41	82
N80	Arm length to wall	66	75	80	62	81
N122	Width of shoulders standing	40	44	48	39	54
N223	Standing chest width	29	32	37	27	40
N457	Standing hip width	31	36	41	30	45
N144	Distance from ear to ear above the head	15	17	19	14	19
N427	Head width	13	15	16	12	16
N441	Length of head	17	20	22	17	23
N420	Length of hand	16	17	21	14	29
N656	Length of palm of hand	8	9	10	8	10
N411	Width of palm of hand	7	8	9	6	9
N402	Grip diameter(inside)	4	5	6	3	7
N529	Height from ground to knee	44	50	55	41	55
N381	Length elbow to middle finger	42	43	47	40	50

Of the 100 workers randomly and voluntarily participating in the sample, 66% were men and 34% were women see Figure 2.

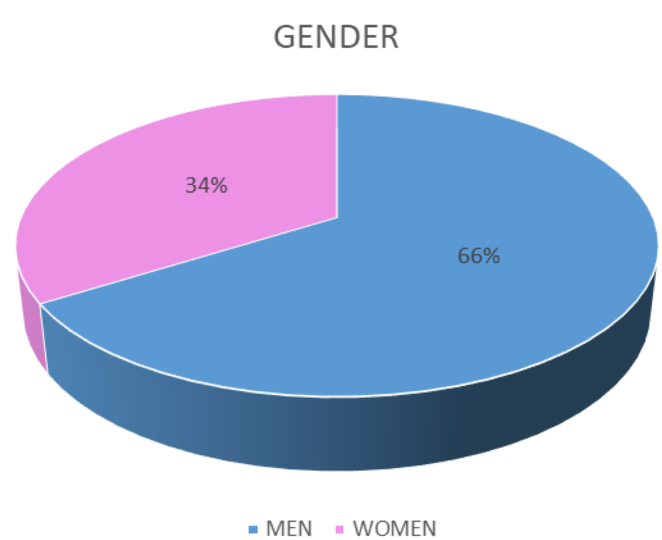


Figure 2. Gender of the 100 registered workers in the textile industry in Caborca, Sonora, Mexico

The place of origin of the participants was also considered in the registry, where 100% of the records belong to the Caborca region.

6. CONCLUSIONS.

Undoubtedly, recording anthropometric data and the information gathered in this initial study will allow us to have a certainty in the creation of profiles with anthropometric features functional with the population of users in each of the workstations.

In order to have a greater certainty of data and a greater number of dimensions, it is advisable to do the study again with the participation of more workers from the different areas and a greater number of measurements, with the purpose of reducing the possibilities of error in the design proposals of the workstations and the tools used, thus seeking to reduce the possibilities of musculoskeletal disorders, errors in production and by conclusion an increase in the productivity of the company and greater employee satisfaction when developing their own activities in the textile industry.

REFERENCES

https://www.mordorintelligence.ar/industry-reports/global-textile-industry---growth-trends-and-forecast-2019---2024

https://canaintex.org.mx/informacion-estadistica-enero-2025/#elementor-toc__heading-anchor-11

Intriago Mejía, A. C. (2021). Riesgos ergonómicos en salud y seguridad ocupacional y el desempeño laboral en las empresas textiles.

Miranda Rodríguez, B. X., & Sáenz Julcamoro, L. A. (2020). Método Ergonómico para el Rediseño de Estaciones de Trabajo para Reducir los TME en las empresas PyME del Sector Textil.

NASA (National Aeronautics and Space Administration), 1978. Anthropology Research Project 1978 Anthropometric Source Book, Vol. I: Anthropometry for Designers, NASA Reference Publication 1024' Webb Associates (Ed.). National Aeronautics and Space Administration Scientific and Technical Information Office, Houston, Texas, USA

Ortiz Porras, Jorge, Bancovich Erquínigo, Andrei, Candia Chávez, Taddy, Huayanay Palma, Lisseth, & Raez Guevara, Luis. (2022). Método ergonómico para reducir el nivel de riesgo de trastornos musculoesqueléticos en una pyme de confección textil de Lima - Perú. Industrial Data, 25(2), 143-169. Epub 00 de diciembre de 2022.https://doi.org/10.15381/idata.v25i2.22769

Vergara Lope D. Memoria reglamentaria presentada ante la Academia de Medicina por el socio titular doctor Daniel Vergara-Lope, en la sesión ordinaria del 6 de octubre de 1909. Gac Med Mex 1910;5(1):8-14.

Zavala Villagómez, P., Aguilasocho Montoya, D., & Galeana Figueroa, E. (2021). Análisis de la tendencia en la investigación de la competitividad de la industria de la confección del vestido en México (1996-2018). Repositorio De La Red Internacional De Investigadores En Competitividad, 14(14). Recuperado a partir de https://www.riico.net/index.php/riico/article/view/1904

ANTHROPOMETRIC CHARTS OF THE STUDENT POPULATION OF UNIVERSIDAD DE LA SIERRA, MOCTEZUMA, SONORA

Cristian Vinicio López Del Castillo, Francisco Javier German Vázquez, Flor Jackeline German Reyes, Dinora Monroy Meléndez, Penélope Guadalupe Álvarez Vega

Ingeniería Industrial en Productividad y Calidad
Universidad de la Sierra
Carretera Moctezuma-Cumpas
Moctezuma, Sonora

Corresponding author's e-mail: clopez@unisierra.edu.mx

Resumen. El presente trabajo se llevó acabo en las instalaciones de la Universidad de la Sierra en Moctezuma, Sonora, donde se trabajó en un proyecto que fue diseñar cartas antropométricas para la población activa de la zona serrana esto se realizó con el objetivo de mejorar y adaptar los entornos laborales para todos los trabajadores, se tomaron medidas a 236 personas desde la altura, el peso, la altura al hombro, hasta el ancho y alto del pie, se profundizo en las 50 medidas más importantes del cuerpo humano, se obtuvieron tres cartas antropométricas una para la población activa mixta, otra para hombres y una de mujeres. La muestra se obtuvo por medio de la ecuación de Murray y Larry. Se utilizaron instrumentos de medición como un antropómetro, bascula, cinta métrica. Se trabajo en este diseño de cartas ya que sabemos la problemática que existe en las empresas por falta de ergonomía ya que hay un sin fin de enfermedades ergonómicas desde el síndrome del túnel carpiano, tendinitis, codo de tenista, hasta estrés laboral, al obtener las cartas antropométricas se puede rediseñar las estaciones de trabajo en base a estas medidas ya que son de la población que está laborando, tomando en cuenta la normativa vigente.

Palabras claves: Cartas antropométricas, diseño, enfermedades ergonómicas

Relevancia para la ergonomía: Este proyecto proporciona cartas antropométricas específicas para la población activa de la región serrana, permitiendo el rediseño de estaciones de trabajo y herramientas adaptadas a las dimensiones corporales reales de los trabajadores. Al integrar datos antropométricos actualizados, se mejora la seguridad, la comodidad y la eficiencia en los entornos laborales.

Abstract. The present study was conducted at the facilities of the Universidad de la Sierra in Moctezuma, Sonora, where a project was carried out to design anthropometric charts for the working population of the mountainous region. The objective was to improve and adapt work environments for all workers. Measurements were taken from 236 individuals, including height, weight, shoulder height, as well as foot width and height. A total of 50 key body measurements were analyzed in depth. Two anthropometric charts were created: one working population, for men, and one for women. The sample was obtained using the Murray and Larry equation. Measuring instruments such as an anthropometer, scale, and measuring tape were used. The development of these charts was undertaken due to the well-known issues in workplaces caused by a lack of ergonomics, which lead to various ergonomic disorders, including carpal tunnel syndrome, tendinitis, tennis elbow, and work-related stress. By obtaining these anthropometric charts, workstations can be redesigned based on the actual measurements of the working population, considering current regulations.

Keywords: Anthropometric charts, design, ergonomic disorders

Relevance to Ergonomics: Design of anthropometric charts based on 50 measurements to improve the work environment.

1. INTRODUCTION

The design of workstations and tools in work environments must consider the body dimensions of workers to optimize ergonomics and reduce the risk of injury. This research focuses on the creation of anthropometric charts based on the active population of the mountain region of the State of Sonora, with the purpose of improving the adaptability of work spaces to the physical characteristics of employees. To this end, 50 anthropometric measurements were collected from 236 people, allowing the preparation of reference tables for the ergonomic redesign of tools and workstations. Collecting this data is crucial to ensure that workstations are suitable for employees' body diversity and optimize their performance and well-being.

2. OBJECTIVES

Prepare anthropometric charts of the working population of the mountain region to optimize the design of workstations and tools, to improve ergonomics, reduce the risk of injuries and increase efficiency in work environments.

3. DELIMITATIONS

This study is limited to the working population of the mountain region of the State of Sonora, using data from 236 people, mainly students from the Universidad de la Sierra. 50 anthropometric measurements were taken with specific tools such as anthropometer, tape measure, scale and chair. Its application focuses on improving workstations and tools in companies in the region. Furthermore, the study was carried out in a single data collection period, without long-term follow-up, and its results are applicable only to this geographical area.

4. JUSTIFICATION

This project is based on the need to have updated and specific anthropometric data on the working population of the mountain region of the State of Sonora. Currently, many work environments do not consider workers' body dimensions in the design of their workstations and tools, leading to discomfort, decreased efficiency, and increased risk of injury. The creation of anthropometric charts will allow these spaces to be optimized, improving ergonomics and safety at work. Furthermore, this information will benefit both companies and employees, promoting a more accessible work environment adapted to the real needs of users.

A study carried out in 2023 in university administrative workers identified a relationship between ergonomic risk factors and the appearance of musculoskeletal disorders. The results suggest that inadequate postures and poorly designed workstations contribute significantly to the prevalence of these disorders among administrative staff.

In 2024, the IMSS (Mexican Social Security Institute), estimated that 5.16% of work-related illnesses are related to musculoskeletal damage, which causes illness and pain.

5. METHODOLOGY

5.1 Murray and Larry equation

The Murray and Larry (2005) equation was used to determine the appropriate sample size, using a confidence Interval of 95% and a margin error of 5%, from a population of 608 students.

$$n = \frac{Z^2 \sigma^2 N}{e^2 (N-1) + Z^2 \sigma^2}$$

Figure 1. Equation for sample

With these data, the population sample was obtained.

$$n = \frac{(1.96)^2 (0.5)(0.5)(608)}{(0.5)\ (608-1)+(1.96)^2(0.5)(0.5)} \; 235.65 \qquad (1)$$

The sample result was 235.65 rounded to 236 samples to ensure the confidence level.

5.2 Measuring instruments

To carry out this project, the following measuring instruments were used: A scale, an anthropometer, vernier, 200 cm tape measure, circumference meter.

5.3 Conducting the experiment

Before starting the Measurement procedure, a sample number is calculated in order to obtain the data that had to be recorded, obtaining a sample of 236 measurements, these 236 people from men and women with an age range of 18 to 23 years were taken from the different educational programs of the Universidad de la Sierra, these students are inhabitants of the different municipalities of the mountain region of the State of Sonora, since they can be part of the working population of our region and the state.

Firstly, it was decided to work in three stations, in which these measurements were taken, in the first station the data of the first 16 measurements related to weight and height measurements were taken; in the second station, 17 more measurements were collected, which are the circumferences of the body; then, at the third station, the 17 missing measurements were taken, which were taken while sitting in an ergonomic chair, obtaining a total of 50 anthropometric measurements from weight and height to foot width and height. Most of these were measured on the right side, also taking into account a range of 3 to 5 millimeters due to the thickness of the clothing when they were measured on the body, in the foot measurements if they were taken without shoes and without socks, as well as weight and height, the dominant hand was the right, last but not least an ergonomic chair was used to take measurements with the body sitting well.

Figure 2. Taking measurements

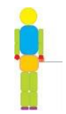
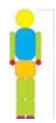
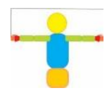
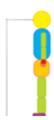
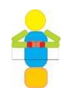
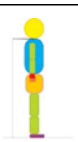
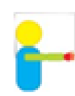
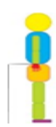
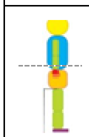
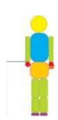
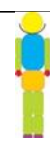
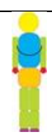
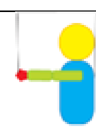
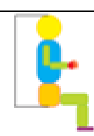
6. RESULTS

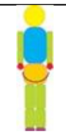
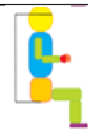
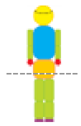
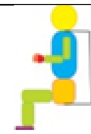
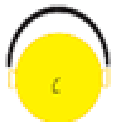
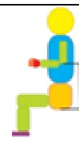
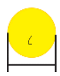
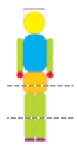
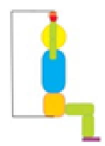
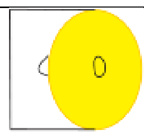
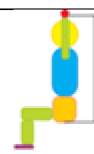
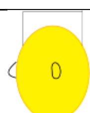
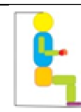
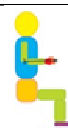
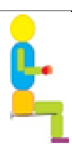
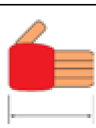
The 236 cards were obtained for each person, three anthropometric cards were made, one for men, one for women and one mixed. From each of the 50 measurements, the standard deviation, maximum, minimum, mean, and the corresponding percentiles 0.5, 0.50, and 0.95 were taken.

The main reason that led to carrying out this project is the need to have accurate and updated data on the body dimensions of the population adapted to regional characteristics. Anthropometric charts are fundamental tools in the design of products, spaces and services. However, in many regions, the available data is outdated or does not reflect the specific characteristics of the local population. This generates unergonomic designs, discomfort and even health risks. The aim is to provide precise information that allows improving the well-being and safety of people.

The main beneficiary is the working people who depend on anthropometric information for the design of ergonomic and safe products and spaces indirectly. The entire population also benefits, since the objective is to improve the quality of life through more comfortable, safe and adapted products to the real dimensions of the users.

Table 1. Anthropometric Charts of the Active Population of Men

	(920) Weight	**x̄:** 79.72 **Min:** 48.00 **Max:** 144.80 **σ** :20.14 **Pk 0.50:** 75.50 **Pk 0.95** :120.21 **Pk 0.05:** 55.49		(265) Height to the third (middle) finger	**x̄:** 64.44 **Max:** 87.70 **Min:** 53.50 **σ:** 4.71 **Pk 0.50:** 64.00 **Pk 0.95:** 71.00 **Pk 0.05:** 58.00
	(805) Stature	**x̄:** 172.12 **Min:** 157.20 **Max:** 191.00 **σ:** 6.70 **Pk 0.50:** 172.20 **Pk 0.95:** 183.40 **Pk 0.05:** 160.26		(797) Lateral width of the arms	**x̄:** 165.85 **Max:** 193.00 **Min:** 64.00 **σ:** 27.82 **Pk 0.50:** 174.00 **Pk 0.95:**185.58 **Pk 0.05:** 81.40
	(328) Eye height	**x̄:** 160.95 **Max:** 181.00 **Min:** 147.20 **σ:** 6.79 **Pk 0.50:** 161.00 **Pk 0.95:** 171.53 **Pk 0.05:** 149.63		(798) Width of elbows	**x̄:** 90.44 **Max:** 101.00 **Min:** 77.00 **σ:** 4.70 **Pk 0.50:** 90.50 **Pk 0.95:** 97.80 **Pk 0.05:** 83.00
	(23) Shoulder height	**x̄:** 142.50 **Max:** 158.00 **Min:** 109.00 **σ:** 7.30 **Pk 0.50:** 144.15 **Pk 0.95:** 154.01 **Pk 0.05:** 132.70		(80) Length of the arm relative to the wall	**x̄:** 87.12 **Max:** 101.00 **Min:** 73.00 **σ:** 5.50 **Pk 0.50:** 87.00 **Pk 0.95:** 96.70 **Pk 0.05:** 78.48
	(309) Elbow height	**x̄:** 108.51 **Max:** 144.50 **Min:** 85.00 **σ:** 8.18 **Pk 0.50:** 108.40 **Pk 0.95:** 119.92 **Pk 0.05:** 98.84		(122) Shoulder width	**x̄:** 45.84 **Max:** 56.00 **Min:** 39.50 **σ:** 3.09 **Pk 0.50:** 45.65 **Pk 0.95:** 51.55 **Pk 0.05:** 40.76
	(949) Hip height	**x̄:** 95.45 **Max:** 125.70 **Min:** 83.00 **σ:** 7.70 **Pk 0.50:** 95.10 **Pk 0.95:** 108.73 **Pk 0.05:** 83.85		(223) Chest width	**x̄:** 31.77 **Max:** 42.00 **Min:** 22.30 **σ:** 3.94 **Pk 0.50:** 31.50 **Pk 0.95:** 38.93 **Pk 0.05:** 26.35
	(398) Buttock height	**x̄:** 75.67 **Max:** 86.10 **Min:** 62.00 **σ:** 4.88 **Pk 0.50:** 75.60 **Pk 0.95:** 84.50 **Pk 0.05:** 68.46		(457) Hip width	**x̄:** 35.36 **Max:** 45.70 **Min:** 28.80 **σ:** 3.39 **Pk 0.50:** 34.90 **Pk 0.95:** 42.30 **Pk 0.05:** 30.90
	(973) Wrist height	**x̄:** 82.20 **Max:** 90.00 **Min:** 64.50 **σ:** 4.60 **Pk 0.50:** 82.00 **Pk 0.95:** 89.15 **Pk 0.05:** 74.28		(639) Neck circumference	**x̄:** 37.08 **Max:** 47.00 **Min:** 30.00 **σ:** 3.43 **Pk 0.50:** 37.00 **Pk 0.95:** 44.00 **Pk 0.05:** 32.00
	(230) Chest circumference	**x̄:** 95.73 **Max:** 134.50 **Min:** 77.00 **σ:** 11.87 **Pk 0.50:** 95.50 **Pk 0.95:** 120.00 **Pk 0.05:** 79.70		(752) Distance from wall to center of grip	**x̄:** 76.71 **Max:** 93.50 **Min:** 64.50 **σ:** 5.13 **Pk 0.50:** 76.00 **Pk 0.95:** 87.00 **Pk 0.05:** 69.25
	(931) Waist circumference	**x̄:** 88.87 **Max:** 129.00 **Min:** 67.00 **σ:** 14.26 **Pk 0.50:** 87.00 **Pk 0.95:** 114.60 **Pk 0.05:** 70.00		(758) Seat to head height	**x̄:** 89.19 **Max:** 101.00 **Min:** 78.60 **σ:** 4.01 **Pk 0.50:** 89.00 **Pk 0.95:** 95.24 **Pk 0.05:** 82.89

	(178) Hip circumference	**x̄:** 102.93 **Max:** 133.00 **Min:** 80.10 **σ:** 10.15 **Pk 0.50:** 100.00 **Pk 0.95:** 123.00 **Pk 0.05:** 90.00		(330) Seat to eye height	**x̄:** 78.84 **Max:** 88.00 **Min:** 68.70 **σ:** 4.04 **Pk 0.50:** 78.65 **Pk 0.95:** 85.30 **Pk 0.05:** 72.11
	(430) Head circumference	**x̄:** 55.62 **Max:** 62.00 **Min:** 35.00 **σ:** 3.46 **Pk 0.50:** 56.00 **Pk 0.95:** 60.00 **Pk 0.05:** 52.00		(25) Seat to shoulder height	**x̄:** 62.00 **Max:** 72.60 **Min:** 52.70 **σ:** 3.58 **Pk 0.50:** 62.10 **Pk 0.95:** 68.68 **Pk 0.05:** 55.84
	(144) Ear width	**x̄:** 36.51 **Max:** 54.00 **Min:** 31.50 **σ:** 2.34 **Pk 0.50:** 36.50 **Pk 0.95:** 39.00 **Pk 0.05:** 33.00		(312) Elbow height at 90°, sitting	**x̄:** 25.18 **Max:** 35.00 **Min:** 16.50 **σ:** 3.12 **Pk 0.50:** 25.00 **Pk 0.95:** 30.92 **Pk 0.05:** 19.91
	(165) Face Width	**x̄:** 14.69 **Max:** 19.30 **Min:** 12.90 **σ:** 0.98 **Pk 0.50:** 14.60 **Pk 0.95:** 16.23 **Pk 0.05:** 13.30		(856) Thigh-high, sitting	**x̄:** 15.52 **Max:** 21.60 **Min:** 11.40 **σ:** 2.43 **Pk 0.50:** 15.10 **Pk 0.95:** 20.46 **Pk 0.05:** 11.97
	(427) Head width	**x̄:**15.87 **Max:** 24.50 **Min:** 13.50 **σ:** 1.10 **Pk 0.50:** 15.90 **Pk 0.95:** 17.00 **Pk 0.05:** 14.44		(914) Seat height to middle finger with arms up	**x̄:** 133.18 **Max:** 152.00 **Min:** 119.00 **σ:** 6.49 **Pk 0.50:** 133.30 **Pk 0.95:** 145.34 **Pk 0.05:** 122.70
	(595) Height from chin to top of head	**x̄:**24.89 **Max:** 35.50 **Min:** 15.50 **σ:** 2.05 **Pk 0.50:** 25.00 **Pk 0.95:** 27.00 **Pk 0.05:** 21.76		(912) Height of the center of the fist with the arms up	**x̄:** 121.23 **Max:** 143.00 **Min:** 109.50 **σ:** 5.93 **Pk 0.50:** 121.05 **Pk 0.95:** 131.08 **Pk 0.05:** 111.85
	(441) Head length	**x̄:** 18.98 **Max:** 24.50 **Min:** 10.70 **σ:** 1.36 **Pk 0.50:** 19.10 **Pk 0.95:** 20.59 **Pk 0.05:** 17.14		(2FGM) Height from head to floor, sitting	**x̄:**130.73 **Max:** 140.70 **Min:** 118.30 **σ:** 5.20 **Pk 0.50:** 130.85 **Pk 0.95:** 138.15 **Pk 0.05:** 122.33
	(4FGM) Floor to seat height	**x̄:** 41.41 **Max:** 48.20 **Min:** 31.50 **σ:** 3.15 **Pk 0.50:** 41.50 **Pk 0.95:** 46.37 **Pk 0.05:** 36.90		(381) Length from elbow to middle finger	**x̄:** 46.53 **Max:** 52.90 **Min:** 36.80 **σ:** 2.77 **Pk 0.50:** 46.60 **Pk 0.95:** 50.59 **Pk 0.05:** 42.20
	(200) Length of the back of the knee, at chair back	**x̄:** 49.90 **Max:** 61.10 **Min:** 34.20 **σ:** 4.49 **Pk 0.50:** 50.35 **Pk 0.95:** 56.68 **Pk 0.05:** 41.63		(507) Width of the back with arms extended in front	**x̄:** 44.00 **Max:** 51.60 **Min:** 31.00 **σ:** 3.69 **Pk 0.50:** 43.60 **Pk 0.95:** 50.47 **Pk 0.05:** 38.04
	(194) Length from knee to back of chair	**x̄:** 63.07 **Max:** 73.20 **Min:** 45.50 **σ:** 4.73 **Pk 0.50:** 63.70 **Pk 0.95:** 70.13 **Pk 0.05:** 54.66		(459) Hip width, sitting	**x̄:** 37.11 **Max:** 48.80 **Min:** 26.30 **σ:** 4.47 **Pk 0.50:** 36.80 **Pk 0.95:** 45.87 **Pk 0.05:** 30.41
	(420) Hand length	**x̄:** 18.53 **Max:** 20.80 **Min:** 15.50 **σ:** 0.59 **Pk 0.50:** 18.50 **Pk 0.95:** 20.10 **Pk 0.05:** 17.07		(859) Width of thighs with knees together	**x̄:** 33.45 **Max:** 44.40 **Min:** 24.20 **σ:** 3.94 **Pk 0.50:** 33.40 **Pk 0.95:** 40.44 **Pk 0.05:** 27.85

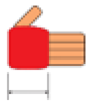
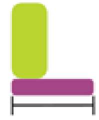
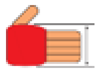
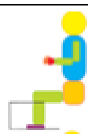
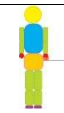
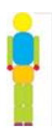
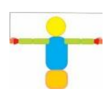
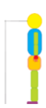
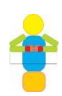
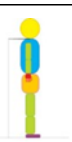
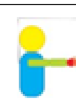
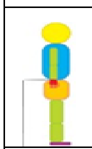
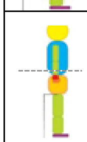
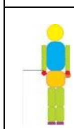
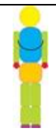
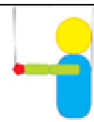
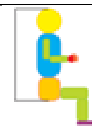
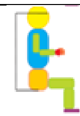
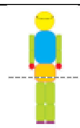
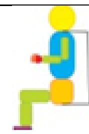
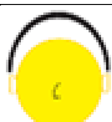
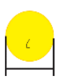
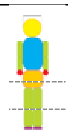
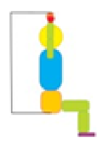
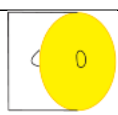
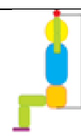
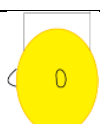
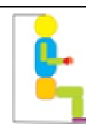
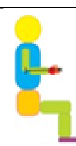
	(656) Palm length	**x̄:** 10.52 **Max:** 14.50 **Min:** 8.00 **σ:** 0.84 **Pk 0.50:** 10.50 **Pk 0.95:** 11.62 **Pk 0.05:** 9.10		(775) Foot length	**x̄:** 25.33 **Max:** 28.50 **Min:** 21.60 **σ:** 1.38 **Pk 0.50:** 25.50 **Pk 0.95:** 27.50 **Pk 0.05:** 22.94
	(411) Palm width	**x̄:** 8.32 **Max: 10.00** **Min:** 5.50 **σ:** 0.64 **Pk 0.50:** 8.40 **Pk 0.95:** 9.30 **Pk 0.05:** 7.40		(777) Foot width	**x̄:** 8.80 **Max:** 11.20 **Min:** 5.40 **σ:** 1.07 **Pk 0.50:** 9.00 **Pk 0.95:** 10.33 **Pk 0.05:** 7.00
	(402) Inside Grip Diameter	**x̄:** 46.24 **Max:** 57.00 **Min:** 36.00 **σ:** 3.82 **Pk 0.50:** 46.00 **Pk 0.95:** 52.00 **Pk 0.05:** 40.00		(776) Instep height	**x̄:** 6.45 **Max:** 9.50 **Min:** 3.40 **σ:** 1.35 **Pk 0.50:**6.40 **Pk 0.95:** 9.00 **Pk 0.05:** 4.34
	(678) Height from floor to back of knee	**x̄:** 43.42 **Max:** 55.40 **Min:** 32.00 **σ:** 4.08 **Pk 0.50:** 43.35 **Pk 0.95:** 49.41 **Pk 0.05:** 37.21		(529) Floor to knee height	**x̄:** 52.81 **Max:** 64.00 **Min:** 40.30 **σ:** 3.26 **Pk 0.50:** 52.70 **Pk 0.95:** 58.60 **Pk 0.05:** 48.50

Table 2. Anthropometric Charts of the Active Population of Woman

	(920) Weight	**x̄:** 68.46 **Min:** 44.30 **Max:** 109.50 **σ** :14.80 **Pk 0.50:** 64.70 **Pk 0.95** :99.34 **Pk 0.05:** 47.99		(265) Height to the third (middle) finger	**x̄:** 61.32 **Max:** 83.60 **Min:** 54.80 **σ:** 4.07 **Pk 0.50:** 61.00 **Pk 0.95:** 68.04 **Pk 0.05:** 56.05
	(805) Stature	**x̄:** 161.04 **Min:** 146.30 **Max:** 175.00 **σ:** 6.30 **Pk 0.50:** 161.815 **Pk 0.95:** 172.44 **Pk 0.05:** 150.82		(797) Lateral width of the arms	**x̄:** 161.38 **Max:** 178.00 **Min:** 145.00 **σ:** 7.50 **Pk 0.50:** 161.00 **Pk 0.95:**175.18 **Pk 0.05:** 150.00
	(328) Eye height	**x̄:** 149.68 **Max:** 163.30 **Min:** 134.00 **σ:** 6.28 **Pk 0.50:** 149.55 **Pk 0.95:** 161.61 **Pk 0.05:** 139.15		(798) Width of elbows	**x̄:** 82.08 **Max:** 91.00 **Min:** 71.00 **σ:** 4.41 **Pk 0.50:** 82.00 **Pk 0.95:** 89.00 **Pk 0.05:** 74.50
	(23) Shoulder height	**x̄:** 133.91 **Max:** 146.40 **Min:** 120.00 **σ:** 5.50 **Pk 0.50:** 133.30 **Pk 0.95:** 144.34 **Pk 0.05:** 123.71		(80) Length of the arm relative to the wall	**x̄:** 80.22 **Max:** 92.00 **Min:** 62.50 **σ:** 5.29 **Pk 0.50:** 80.00 **Pk 0.95:** 89.35 **Pk 0.05:** 71.00
	(309) Elbow height	**x̄:** 101.68 **Max:** 111.50 **Min:** 89.10 **σ:** 4.43 **Pk 0.50:** 101.00 **Pk 0.95:** 110.08 **Pk 0.05:** 95.30		(122) Shoulder width	**x̄:** 41.17 **Max:** 49.80 **Min:** 30.00 **σ:** 3.38 **Pk 0.50:** 40.55 **Pk 0.95:** 47.84 **Pk 0.05:** 36.22
	(949) Hip height	**x̄:** 92.91 **Max:** 115.00 **Min:** 76.50 **σ:** 8.71 **Pk 0.50:** 92.50 **Pk 0.95:** 108.58 **Pk 0.05:** 78.88		(223) Chest width	**x̄:** 28.76 **Max:** 37.70 **Min:** 22.00 **σ:** 3.09 **Pk 0.50:** 28.45 **Pk 0.95:** 34.90 **Pk 0.05:** 24.50
	(398) Buttock height	**x̄:** 71.64 **Max:** 84.30 **Min:** 61.10 **σ:** 4.38 **Pk 0.50:** 71.50 **Pk 0.95:** 79.54 **Pk 0.05:** 63.28		(457) Hip width	**x̄:** 36.19 **Max:** 47.00 **Min:** 24.50 **σ:** 3.62 **Pk 0.50:** 36.00 **Pk 0.95:** 43.00 **Pk 0.05:** 31.18
	(973) Wrist height	**x̄:** 78.22 **Max:** 104.00 **Min:** 61.00 **σ:** 5.13 **Pk 0.50:** 78.25 **Pk 0.95:** 86.00		(639) Neck circumference	**x̄:** 32.62 **Max:** 42.00 **Min:** 26.50 **σ:** 3.28 **Pk 0.50:** 33.00 **Pk 0.95:** 39.00

		Pk 0.05: 71.95			**Pk 0.05:** 28.00
	(230) Chest circumference	**x̄:** 95.52 **Max:** 124.00 **Min:** 76.00 **σ:** 10.35 **Pk 0.50:** 94.00 **Pk 0.95:** 120.00 **Pk 0.05:** 81.55		(752) Distance from wall to center of grip	**x̄:** 71.20 **Max:** 83.00 **Min:** 61.00 **σ:** 4.35 **Pk 0.50:** 71.00 **Pk 0.95:** 78.10 **Pk 0.05:** 64.50
	(931) Waist circumference	**x̄:** 80.52 **Max:** 115.00 **Min:** 60.00 **σ:** 12.27 **Pk 0.50:** 78.00 **Pk 0.95:** 106.45 **Pk 0.05:** 64.00		(758) Seat to head height	**x̄:** 85.29 **Max:** 94.30 **Min:** 79.00 **σ:** 2.92 **Pk 0.50:** 85.00 **Pk 0.95:** 91.08 **Pk 0.05:** 80.66
	(178) Hip circumference	**x̄:** 101.79 **Max:** 131.00 **Min:** 85.00 **σ:** 10.71 **Pk 0.50:** 99.50 **Pk 0.95:** 124.35 **Pk 0.05:** 86.28		(330) Seat to eye height	**x̄:** 74.98 **Max:** 84.00 **Min:** 69.50 **σ:** 3.00 **Pk 0.50:** 74.80 **Pk 0.95:** 80.05 **Pk 0.05:** 69.91
	(430) Head circumference	**x̄:** 53.74 **Max:** 60.00 **Min:** 34.00 **σ:** 3.56 **Pk 0.50:** 54.00 **Pk 0.95:** 58.00 **Pk 0.05:** 51.13		(25) Seat to shoulder height	**x̄:** 58.68 **Max:** 72.60 **Min:** 51.00 **σ:** 3.08 **Pk 0.50:** 58.25 **Pk 0.95:** 63.75 **Pk 0.05:** 53.80
	(144) Ear width	**x̄:** 34.56 **Max:** 40.00 **Min:** 34.00 **σ:** 2.03 **Pk 0.50:** 35.00 **Pk 0.95:** 38.00 **Pk 0.05:** 31.28		(312) Elbow height at 90°, sitting	**x̄:** 25.22 **Max:** 31.60 **Min:** 18.60 **σ:** 2.31 **Pk 0.50:** 25.10 **Pk 0.95:** 29.14 **Pk 0.05:** 21.78
	(165) Face Width	**x̄:** 13.52 **Max:** 15.50 **Min:** 11.50 **σ:** 0.76 **Pk 0.50:** 13.50 **Pk 0.95:** 15.00 **Pk 0.05:** 12.30		(856) Thigh-high, sitting	**x̄:** 14.92 **Max:** 21.00 **Min:** 10.00 **σ:** 2.15 **Pk 0.50:** 15.00 **Pk 0.95:** 18.73 **Pk 0.05:** 11.53
	(427) Head width	**x̄:**15.45 **Max:** 22.50 **Min:** 14.00 **σ:** 0.94 **Pk 0.50:** 15.40 **Pk 0.95:** 16.50 **Pk 0.05:** 14.40		(914) Seat height to middle finger with arms up	**x̄:** 123.25 **Max:** 136.50 **Min:** 107.60 **σ:** 5.51 **Pk 0.50:** 123.40 **Pk 0.95:** 133.40 **Pk 0.05:** 114.68
	(595) Height from chin to top of head	**x̄:**23.55 **Max:** 27.50 **Min:** 21.40 **σ:** 1.08 **Pk 0.50:** 23.50 **Pk 0.95:** 25.45 **Pk 0.05:** 21.96		(912) Height of the center of the fist with the arms up	**x̄:** 112.06 **Max:** 125.00 **Min:** 198.00 **σ:** 5.51 **Pk 0.50:** 112.40 **Pk 0.95:** 123.53 **Pk 0.05:** 102.34
	(441) Head length	**x̄:** 18.26 **Max:** 20.50 **Min:** 14.40 **σ:** 0.87 **Pk 0.50:** 18.35 **Pk 0.95:** 19.64 **Pk 0.05:** 17.00		(2FGM) Height from head to floor, sitting	**x̄:**124.94 **Max:** 138.00 **Min:** 113.50 **σ:** 5.12 **Pk 0.50:** 125.00 **Pk 0.95:** 135.58 **Pk 0.05:** 116.86
	(4FGM) Floor to seat height	**x̄:** 39.59 **Max:** 46.50 **Min:** 35.40 **σ:** 2.88 **Pk 0.50:** 38.05 **Pk 0.95:** 45.25 **Pk 0.05:** 36.45		(381) Length from elbow to middle finger	**x̄:** 42.28 **Max:** 47.80 **Min:** 32.00 **σ:** 2.84 **Pk 0.50:** 42.50 **Pk 0.95:** 46.55 **Pk 0.05:** 38.00

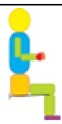
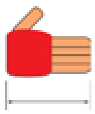
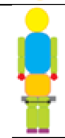
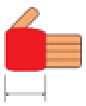
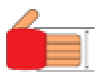
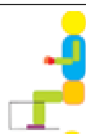
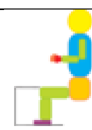
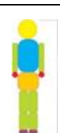
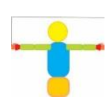
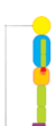
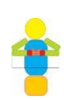
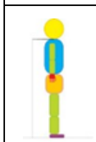
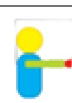
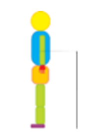
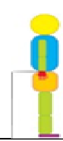
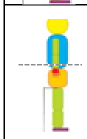
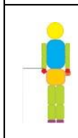
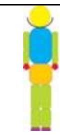
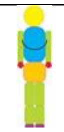
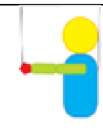
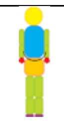
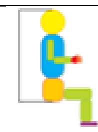
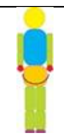
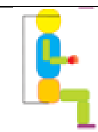
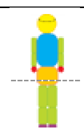
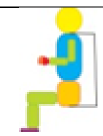
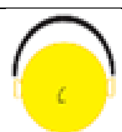
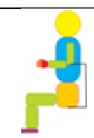
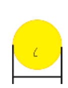
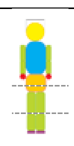
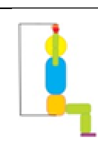
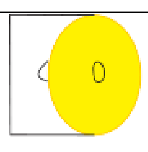
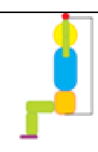
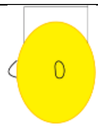
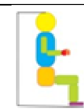
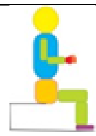
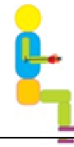
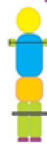
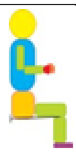
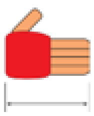
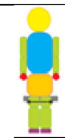
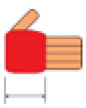
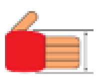
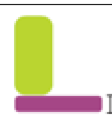
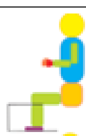
	(200) Length of the back of the knee, at chair back	**$\bar{x}$:** 46.76 **Max:** 57.00 **Min:** 37.60 **σ:** 3.75 **Pk 0.50:** 46.80 **Pk 0.95:** 53.93 **Pk 0.05:** 40.15		(507) Width of the back with arms extended in front	**$\bar{x}$:** 39.43 **Max:** 49.50 **Min:** 30.20 **σ:** 3.37 **Pk 0.50:** 39.10 **Pk 0.95:** 45.39 **Pk 0.05:** 33.63
	(194) Length from knee to back of chair	**$\bar{x}$:** 57.59 **Max:** 69.00 **Min:** 48.00 **σ:** 4.25 **Pk 0.50:** 57.15 **Pk 0.95:** 64.53 **Pk 0.05:** 50.46		(459) Hip width, sitting	**$\bar{x}$:** 38.37 **Max:** 53.20 **Min:** 29.50 **σ:** 4.29 **Pk 0.50:** 37.80 **Pk 0.95:** 46.84 **Pk 0.05:** 31.67
	(420) Hand length	**$\bar{x}$:** 16.95 **Max:** 19.20 **Min:** 14.60 **σ:** 1.00 **Pk 0.50:** 17.00 **Pk 0.95:** 18.85 **Pk 0.05:** 15.50		(859) Width of thighs with knees together	**$\bar{x}$:** 35.01 **Max:** 52.70 **Min:** 20.20 **σ:** 4.93 **Pk 0.50:** 34.70 **Pk 0.95:** 43.35 **Pk 0.05:** 28.20
	(656) Palm length	**$\bar{x}$:** 9.67 **Max:** 11.50 **Min:** 7.60 **σ:** 0.72 **Pk 0.50:** 9.60 **Pk 0.95:** 10.95 **Pk 0.05:** 8.50		(775) Foot length	**$\bar{x}$:** 22.78 **Max:** 26.00 **Min:** 19.00 **σ:** 1.27 **Pk 0.50:** 22.70 **Pk 0.95:** 24.94 **Pk 0.05:** 21.90
	(411) Palm width	**$\bar{x}$:** 7.43 **Max:** 8.70 **Min:** 6.10 **σ:** 0.46 **Pk 0.50:** 7.40 **Pk 0.95:** 8.39 **Pk 0.05:** 6.70		(777) Foot width	**$\bar{x}$:** 7.85 **Max:** 10.90 **Min:** 5.80 **σ:** 1.10 **Pk 0.50:** 7.85 **Pk 0.95:** 9.75 **Pk 0.05:** 6.21
	(402) Inside Grip Diameter	**$\bar{x}$:** 43.40 **Max:** 52.00 **Min:** 33.00 **σ:** 4.39 **Pk 0.50:** 43.00 **Pk 0.95:** 51.55 **Pk 0.05:** 36.00		(776) Instep height	**$\bar{x}$:** 5.80 **Max:** 9.20 **Min:** 3.50 **σ:** 1.23 **Pk 0.50:**5.70 **Pk 0.95:** 7.84 **Pk 0.05:** 3.90
	(678) Height from floor to back of knee	**$\bar{x}$:** 40.52 **Max:** 48.00 **Min:** 32.00 **σ:** 3.44 **Pk 0.50:** 40.10 **Pk 0.95:** 46.58 **Pk 0.05:** 34.78		(529) Floor to knee height	**$\bar{x}$:** 50.20 **Max:** 84.00 **Min:** 40.00 **σ:** 4.83 **Pk 0.50:** 49.85 **Pk 0.95:** 57.07 **Pk 0.05:** 44.60

Table 3. Anthropometric Charts of the Active Population of Mixed

	(920) Weight		**$\bar{x}$:** 75.23 **Min:** 43.00 **Max:** 144.80 **σ :** 18.97 **Pk 0.50:** 71.00 **Pk 0.95 :** 115.86 **Pk 0.05:** 52.39		(265) Height to the third (middle) finger	**$\bar{x}$:** 63.17 **Max:** 87.70 **Min:** 53.50 **σ:** 4.71 **Pk 0.50:** 62.80 **Pk 0.95:** 69.85 **Pk 0.05:** 57.00
	(805) Stature		**$\bar{x}$:** 167.89 **Min:** 146.30 **Max:** 191.00 **σ:** 8.47 **Pk 0.50:** 168.00 **Pk 0.95:** 182.00 **Pk 0.05:** 153.50		(797) Lateral width of the arms	**$\bar{x}$:** 168.34 **Max:** 193.00 **Min:** 131.50 **σ:** 10.37 **Pk 0.50:** 168.00 **Pk 0.95:**184.50 **Pk 0.05:** 151.00
	(328) Eye height		**$\bar{x}$:** 156.27 **Max:** 181.00 **Min:** 134.00 **σ:** 8.61 **Pk 0.50:** 155.75 **Pk 0.95:** 170.50 **Pk 0.05:** 142.26		(798) Width of elbows	**$\bar{x}$:** 86.78 **Max:** 99.00 **Min:** 71.00 **σ:** 6.17 **Pk 0.50:** 87.00 **Pk 0.95:** 97.00 **Pk 0.05:** 76.00
	(23) Shoulder height		**$\bar{x}$:** 139.57 **Max:** 158.00 **Min:** 109.00 **σ:** 8.13 **Pk 0.50:** 138.65 **Pk 0.95:** 153.10 **Pk 0.05:** 126.72		(80) Length of the arm relative to the wall	**$\bar{x}$:** 84.22 **Max:** 99.00 **Min:** 62.50 **σ:** 6.24 **Pk 0.50:** 84.00 **Pk 0.95:** 94.92 **Pk 0.05:** 74.00

	(309) Elbow height		**x̄:** 105.61 **Max:** 144.00 **Min:** 85.00 **σ:** 7.62 **Pk 0.50:** 104.50 **Pk 0.95:** 116.10 **Pk 0.05:** 96.50		(122) Shoulder width	**x̄:** 43.57 **Max:** 56.00 **Min:** 30.00 **σ:** 3.99 **Pk 0.50:** 43.55 **Pk 0.95:** 50.07 **Pk 0.05:** 37.68
	(949) Hip height		**x̄:** 94.31 **Max:** 125.75 **Min:** 76.50 **σ:** 8.25 **Pk 0.50:** 94.00 **Pk 0.95:** 107.92 **Pk 0.05:** 82.00		(223) Chest width	**x̄:** 30.40 **Max:** 42.00 **Min:** 22.00 **σ:** 3.88 **Pk 0.50:** 29.70 **Pk 0.95:** 37.38 **Pk 0.05:** 25.10
	(398) Buttock height		**x̄:** 73.97 **Max:** 86.10 **Min:** 61.10 **σ:** 5.07 **Pk 0.50:** 73.80 **Pk 0.95:** 83.29 **Pk 0.05:** 65.50		(457) Hip width	**x̄:** 35.74 **Max:** 47.00 **Min:** 24.50 **σ:** 3.52 **Pk 0.50:** 35.20 **Pk 0.95:** 42.62 **Pk 0.05:** 30.92
	(973) Wrist height		**x̄:** 80.46 **Max:** 104.00 **Min:** 61.00 **σ:** 5.22 **Pk 0.50:** 80.00 **Pk 0.95:** 88.50 **Pk 0.05:** 72.60		(639) Neck circumference	**x̄:** 35.07 **Max:** 47.00 **Min:** 26.50 **σ:** 4.02 **Pk 0.50:** 35.00 **Pk 0.95:** 42.00 **Pk 0.05:** 29.00
	(230) Chest circumference		**x̄:** 95.97 **Max:** 134.50 **Min:** 74.00 **σ:** 11.22 **Pk 0.50:** 94.50 **Pk 0.95:** 120.00 **Pk 0.05:** 80.60		(752) Distance from wall to center of grip	**x̄:** 74.35 **Max:** 93.50 **Min:** 61.00 **σ:** 5.52 **Pk 0.50:** 74.50 **Pk 0.95:** 85.00 **Pk 0.05:** 65.50
	(931) Waist circumference		**x̄:** 85.09 **Max:** 129.00 **Min:** 60.00 **σ:** 14.01 **Pk 0.50:** 81.00 **Pk 0.95:** 112.00 **Pk 0.05:** 67.00		(758) Seat to head height	**x̄:** 87.55 **Max:** 101.00 **Min:** 78.60 **σ:** 4.07 **Pk 0.50:** 87.50 **Pk 0.95:** 94.80 **Pk 0.05:** 81.85
	(178) Hip circumference		**x̄:** 102.12 **Max:** 133.00 **Min:** 80.10 **σ:** 10.39 **Pk 0.50:** 100.00 **Pk 0.95:** 123.00 **Pk 0.05:** 88.00		(330) Seat to eye height	**x̄:** 77.25 **Max:** 88.00 **Min:** 68.70 **σ:** 4.11 **Pk 0.50:** 76.95 **Pk 0.95:** 84.65 **Pk 0.05:** 70.81
	(430) Head circumference		**x̄:** 54.80 **Max:** 62.00 **Min:** 34.00 **σ:** 3.62 **Pk 0.50:** 55.00 **Pk 0.95:** 59.00 **Pk 0.05:** 51.00		(25) Seat to shoulder height	**x̄:** 60.50 **Max:** 72.60 **Min:** 50.70 **σ:** 3.75 **Pk 0.50:** 60.30 **Pk 0.95:** 67.33 **Pk 0.05:** 55.08
	(144) Ear width		**x̄:** 35.63 **Max:** 54.00 **Min:** 26.00 **σ:** 2.41 **Pk 0.50:** 36.00 **Pk 0.95:** 39.00 **Pk 0.05:** 32.00		(312) Elbow height at 90°, sitting	**x̄:** 25.20 **Max:** 35.00 **Min:** 16.50 **σ:** 2.78 **Pk 0.50:** 25.00 **Pk 0.95:** 29.54 **Pk 0.05:** 20.60
	(165) Face Width		**x̄:** 14.16 **Max:** 19.30 **Min:** 11.50 **σ:** 1.06 **Pk 0.50:** 14.00 **Pk 0.95:** 16.00 **Pk 0.05:** 12.50		(856) Thigh-high, sitting	**x̄:** 15.25 **Max:** 21.60 **Min:** 10.00 **σ:** 2.33 **Pk 0.50:** 15.10 **Pk 0.95:** 19.92 **Pk 0.05:** 11.82
	(427) Head width		**x̄:**15.68 **Max:** 24.50 **Min:** 13.50 **σ:** 1.05 **Pk 0.50:** 15.60 **Pk 0.95:** 16.98 **Pk 0.05:** 14.40		(914) Seat height to middle finger with arms up	**x̄:** 129.01 **Max:** 152.00 **Min:** 107.60 **σ:** 7.82 **Pk 0.50:** 128.85 **Pk 0.95:** 142.58 **Pk 0.05:** 116.54
	(595) Height from chin to top of head		**x̄:**24.28 **Max:** 35.50 **Min:** 15.50 **σ:** 1.80 **Pk 0.50:** 24.30 **Pk 0.95:** 26.70 **Pk 0.05:** 22.00		(912) Height of the center of the fist with the arms up	**x̄:** 117.30 **Max:** 143.00 **Min:** 98.00 **σ:** 7.32 **Pk 0.50:** 117.00 **Pk 0.95:** 129.67 **Pk 0.05:** 104.39

	(441) Head length		$\bar{x}$: 18.66 **Max:** 24.50 **Min:** 10.70 **σ:** 1.22 **Pk 0.5:** 18.60 **Pk 0.95:** 20.20 **Pk 0.05:** 17.02		(2FGM) Height from head to floor, sitting	$\bar{x}$:128.21 **Max:** 140.70 **Min:** 113.50 **σ:** 5.90 **Pk 0.50:** 128.00 **Pk 0.95:** 137.88 **Pk 0.05:** 119.00
	(4FGM) Floor to seat height		$\bar{x}$: 40.65 **Max:** 48.20 **Min:** 31.50 **σ:** 3.16 **Pk 0.50:** 40.50 **Pk 0.95:** 46.01 **Pk 0.05:** 36.80		(381) Length from elbow to middle finger	$\bar{x}$: 45.08 **Max:** 52.90 **Min:** 32.00 **σ:** 3.44 **Pk 0.50:** 51.30 **Pk 0.95:** 57.45 **Pk 0.05:** 45.40
	(200) Length of the back of the knee, at chair back		$\bar{x}$: 48.56 **Max: 61.50** **Min:** 34.20 **σ:** 4.46 **Pk 0.50:** 48.75 **Pk 0.95:** 56.05 **Pk 0.05:** 41.23		(507) Width of the back with arms extended in front	$\bar{x}$: 42.14 **Max:** 51.60 **Min:** 30.20 **σ:** 4.21 **Pk 0.50:** 42.00 **Pk 0.95:** 49.60 **Pk 0.05:** 35.00
	(194) Length from knee to back of chair		$\bar{x}$: 60.23 **Max:** 73.20 **Min:** 45.50 **σ:** 5.25 **Pk 0.50:** 60.05 **Pk 0.95:** 68.81 **Pk 0.05:** 51.33		(459) Hip width, sitting	$\bar{x}$: 37.68 **Max:** 53.20 **Min:** 26.30 **σ:** 4.43 **Pk 0.50:** 37.40 **Pk 0.95:** 46.50 **Pk 0.05:** 31.02
	(420) Hand length		$\bar{x}$: 17.82 **Max:** 20.80 **Min:** 14.60 **σ:** 1.25 **Pk 0.50:** 18.00 **Pk 0.95:** 19.78 **Pk 0.05:** 15.70		(859) Width of thighs with knees together	$\bar{x}$: 34.15 **Max:** 52.70 **Min:** 20.20 **σ:** 4.47 **Pk 0.50:** 34.05 **Pk 0.95:** 42.40 **Pk 0.05:** 28.03
	(656) Palm length		$\bar{x}$: 10.14 **Max:** 14.50 **Min:** 7.60 **σ:** 0.89 **Pk 0.50:** 10.20 **Pk 0.95:** 11.50 **Pk 0.05:** 8.52		(775) Foot length	$\bar{x}$: 24.20 **Max:** 30.50 **Min:** 19.00 **σ:** 1.88 **Pk 0.50:** 24.00 **Pk 0.95:** 27.16 **Pk 0.05:** 21.24
	(411) Palm width		$\bar{x}$: 7.92 **Max:** 10.00 **Min:** 5.50 **σ:** 0.72 **Pk 0.50:** 7.90 **Pk 0.95:** 9.10 **Pk 0.05:** 6.90		(777) Foot width	$\bar{x}$: 8.37 **Max:** 11.20 **Min:** 5.40 **σ:** 1.18 **Pk 0.50:** 8.50 **Pk 0.95:** 10.10 **Pk 0.05:** 6.40
	(402) Inside Grip Diameter		$\bar{x}$: 44.97 **Max:** 57.00 **Min:** 33.00 **σ:** 4.31 **Pk 0.50:** 45.00 **Pk 0.95:** 52.00 **Pk 0.05:** 38.00		(776) Instep height	$\bar{x}$: 6.16 **Max:** 9.50 **Min:** 3.40 **σ:** 1.33 **Pk 0.5:**6.00 **Pk 0.95:** 8.50 **Pk 0.05:** 4.02
	(678) Height from floor to back of knee		$\bar{x}$: 42.20 **Max:** 55.40 **Min:** 32.00 **σ:** 4.08 **Pk 0.50:** 42.40 **Pk 0.95:** 48.50 **Pk 0.05:** 35.70		(529) Floor to knee height	$\bar{x}$: 51.44 **Max:** 84.00 **Min:** 40.00 **σ:** 4.35 **Pk 0.50:** 51.30 **Pk 0.95:** 57.45 **Pk 0.05:** 45.40

7. CONCLUSIONS

This project focused on the creation of anthropometric charts for the working population of the mountain region, in order to improve the design of workstations and tools. By collecting 50 measurements from 236 people, precise data was obtained that allowed ergonomics to be optimized, reducing the risk of injury and increasing work efficiency. The results of this study will contribute to a work environment more appropriate to local physical characteristics, promoting the safety and well-being of employees, and offering benefits to both companies and workers.

8. REFERENCES

Ergonomics: How to Design for Ease and Efficiency" de Kroemer, K. H. E. (2006). Prentice Hall.

Pheasant, Stephen. Bodyspace: Anthropometry, Ergonomics and the Design of Work. CRC Press, 1996.

Universidad de la sierra. (2008). Ergonomia y seguridad industrial (1.a ed.).

Llanos Yarlaque, M., & Zuñe Villalobos, G. A. (2023). Factores asociados a trastornos musculoesqueléticos en docentes y personal administrativo de la Universidad.

EFFECT OF BINAURAL BEATS ON COGNITIVE ERGONOMICS: LITERATURE REVIEW

Lindsay Fernanda Nava Ornelas, Ana Isela García Acosta, Manuel Alejandro Barajas Bustillos

Department of Graduate and Research
Tecnológico Nacional de México/Instituto Tecnológico de Cd. Juárez
Technological Ave.1340, 32500
Cd. Juárez, Chih., México

Corresponding author's e-mail: agarcia@itcj.edu.mx

Resumen: Los ritmos binaurales se presentan como una técnica de estimulación cerebral basada en sonidos de baja frecuencia generados al escuchar tonos ligeramente diferentes en cada oído a través de auriculares estéreo. Estos ritmos promueven estados de concentración, creatividad y relajación. Se proponen como herramientas útiles en contextos como el trabajo, la gestión del estrés. Estudios previos sugieren su impacto en la fatiga, la ansiedad y el dolor, lo que refuerza su relevancia en la neuroergonomía (Opartpunyasarn, 2022).

Este artículo tiene como objetivo realizar una revisión de la literatura sobre los ritmos binaurales, evaluando su capacidad para mejorar el enfoque mental, reducir la fatiga, aliviar el estrés y explorar sus efectos en la salud mental, física y cognitiva, destacando aplicaciones en ámbitos laborales.

Esta revisión bibliográfica se centra en el estudio de los pulsos binaurales y su impacto en la productividad durante actividades de ensamble manual.
Se analizaron investigaciones que estudian específicamente los efectos de los pulsos binaurales sobre variables como la concentración, la reducción de estrés, y la mejora del rendimiento en tareas repetitivas o de precisión.

Se incluyeron artículos científicos revisados por pares, estudios experimentales, y revisiones, aunque el análisis no está limitado a una región específica, se dio prioridad a estudios realizados en contextos industriales relevantes para países de América y Europa, donde estas tecnologías tienen aplicaciones prácticas.

Se seleccionaron publicaciones en inglés y español para abarcar un panorama más amplio de la literatura disponible. Las investigaciones revisadas se centran en sujetos adultos que realizan actividades de ensamble manual. La metodología se lleva a cabo mediante la búsqueda de información a través de bases de datos.

A modo de conclusión se analiza que estos hallazgos subrayan el potencial de los ritmos binaurales como herramienta de apoyo para la mejora del bienestar mental, físico y cognitivo, aunque es necesario continuar investigando para comprender plenamente sus efectos. Este enfoque reafirma la utilidad de los ritmos

binaurales como estrategias innovadoras para apoyar la ergonomía cognitiva y fisiológica en diversos contextos.

Palabras clave: Ritmos Binaurales, Estimulación Cerebral, Auriculares Estéreo, Ergonomía Cognitiva.

Relevancia para la ergonomía: Dentro de las aportaciones a la ergonomía se encuentra la optimización del rendimiento cognitivo, ya que los ritmos binaurales pueden emplearse para mejorar la concentración y reducir la fatiga en contextos laborales de alta demanda cognitiva. Además, la reducción de la carga mental, ya que, las aplicaciones en neuroergonomía facilitan el manejo del estrés, el tiempo de reacción y la vigilancia, apoyando la relación máquina-humano. Asimismo, diseño de entornos de trabajo dentro de la integración de estímulos auditivos rítmicos para optimizar el bienestar físico y mental en el trabajo. Finalmente, en la investigación aplicada con el uso de herramientas para evaluar cambios fisiológicos y su relación con ritmos binaurales. **Abstract:** Binaural beats are introduced as a brain stimulation technique based on low frequency sounds generated by listening to slightly different tones in each ear through stereo headphones. These rhythms promote states of concentration, creativity, and relaxation. They are proposed as useful tools in contexts such as work, stress management. Previous studies suggest their impact on fatigue, anxiety and pain, reinforcing their relevance in neuroergonomics (Opartpunyasarn, 2022).

This article aims to conduct a literature review on binaural beats, assessing their ability to improve mental focus, reduce fatigue, relieve stress and explore their effects on mental, physical and cognitive health, highlighting applications in occupational settings.

This literature review focuses on the study of binaural beats and their impact on productivity during manual assembly activities.

Research specifically studying the effects of binaural pulses on variables such as concentration, stress reduction, and improved performance in repetitive or precision tasks was analyzed.

Peer-reviewed scientific articles, experimental studies, and reviews were included, although the analysis is not limited to a specific region, priority was given to studies conducted in industrial contexts relevant to countries in the Americas and Europe, where these technologies have been used in the past.

English and Spanish publications were selected to cover a broader panorama of the available literature. The research reviewed focuses on adult subjects who perform manual assembly activities and the methodology is carried out by searching for information through databases.

By way of conclusion, it is discussed that these findings highlight the potential of binaural beats as a supportive tool for the improvement of mental, physical and cognitive well-being, although further research is needed to fully understand their effects. This approach reaffirms the utility of binaural beats as innovative strategies to support cognitive and physiological ergonomics in diverse contexts.

Key Words: Binaural Beats, Brain Stimulation, Stereo Headphones, Cognitive Ergonomics.

Relevance to Ergonomics: Among the contributions to ergonomics is the optimization of cognitive performance, as binaural beats can be used to improve concentration and reduce fatigue in cognitively demanding work contexts. In addition, the reduction of mental workload, since neuroergonomics applications facilitate stress management, reaction time and vigilance, supporting the machine-human relationship. Also, design of work environments within the integration of rhythmic auditory stimuli to optimize physical and mental well-being at work. Finally, in applied research with the use of tools to evaluate physiological changes and their relationship with binaural rhythms.

1. INTRODUCTION

Human beings are surrounded by sounds in our daily activities, those sounds that our ears hear are called acoustic stimuli that affect us in our emotions, moods and feelings consciously and unconsciously, one of the most common acoustic stimuli is music. Currently binaural beats are being used to relax, improve sleep and aid meditation. Binaural beats are produced when a different frequency tone is heard in each ear. In our brain the alpha waves are activated more when listening to binaural beats. Alpha waves are linked to the state of relaxation. It has been found that 10 Hz alpha binaural beats increased interhemispheric coherence at alpha frequencies (Omeroglu & Li, 2022).

Studies have shown that binaural theta rhythms increased depression and negative mood subscale scores (Wahbeh, et al., 2007). Theta binaural beats showed that people had more fear-induced mood states (Pluck & Lopez-Eagle, 2019). However, other studies claim that binaural theta rhythms increase meditative states (Jirakittayakorn & Wongsawat, 2017). Beta waves are related to attention, wakefulness and concentration. However, less research has been conducted on the effect of beta binaural beats with respect to mood states (Omeroglu & Li, 2022).

Research was conducted to see the effects of binaural pulses on anxiety and stress. Military service members after deployment were played music with masked binaural pulses and without binaural pulses, showing less stress when listening to music with binaural pulses (Gantt et al., 2017).

Another study showed that binaural gamma beats showed improved visual attention, as well as increased concentration on both local and global tasks (Colzato et al., 2017).

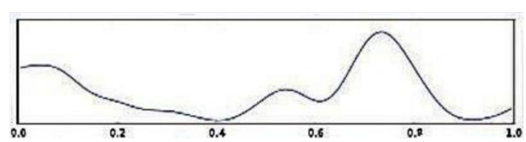
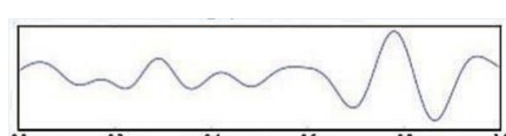
Labor productivity has been the subject of much research, since it is directly associated with individual and collective performance in the workplace. Several factors influence the increase or decrease of productivity, among which environmental stimuli and psychological conditions stand out. In this context, binaural waves have gained relevance in the field of psychology and neuroscience due to their ability to induce effects in the brain that affect cognitive processes such as attention, concentration and stress (Hirsh, 2019; Lee et al., 2021).

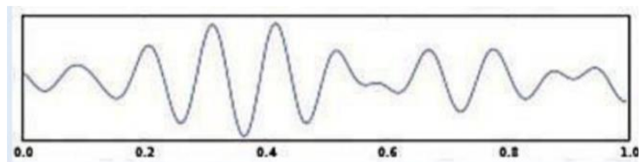
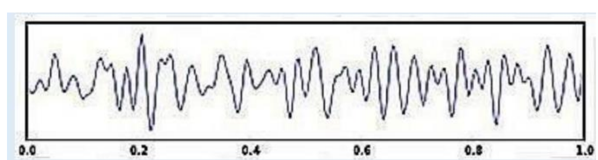
1.1. Binaural waves

Binaural waves are an auditory phenomenon that occurs when two tones of slightly different frequencies are presented separately in each ear, generating a perception of an additional tone. This phenomenon has been the subject of study for its potential benefits in improving cognition, well-being and, particularly, work productivity.

In the central nervous system (CNS), neurons communicate through a synchronization of electrochemical signals, triggering ionic currents that flow between synaptic contacts (Schaul, 1998). This intricate process gives life to rhythmic voltage fluctuations that course through the various regions of the brain, known as neuronal oscillations or brain waves (Buzaki, 2006). On the other hand, electroencephalogram (EEG) emerges as an essential tool to unravel brain electrical activity. This record shows five types of waves, where the beta waves derive two that are lower and upper beta waves (Table 1), which takes into account certain characteristics, such as; the frequency, measured in Hertz (Hz), indicates the speed with which the wave repeats in a second, while the amplitude expressed in microvolts (µV), reflects the difference between the maximum and minimum voltage (Talamillo, 2011).

Table 1: Brainwave Types and Characteristics (Sciotto & Niripil, 2018).

Delta Waves	They are slow waves of a frequency between 0.5 and 4 cycles (discharges) per second (cps or Hertz). They are present during the deep sleep state and are dominant in the brain of infants. Delta waves with a high and rhythmic amplitude are commonly found in adults with mental disorders or brain lesions..	
Theta Waves	With a frequency of 4Hz to 7 Hz, they are produced during states of deep meditation, autogenic training, yoga; as well as during the intellectual effort associated with academic learning. The characteristics of this state are: plastic	

	memory, greater learning capacity, fantasy, imagination and creative inspiration.	
Alpha Waves	They have a frequency of 7 Hz to 12 Hz and are associated with states of relaxation. They are recorded especially moments before falling asleep. Their characteristic effects are: pleasant relaxation, calm and carefree thoughts, optimism and a feeling of integration of body and mind. Alpha desynchronization is a normal phenomenon observed when an individual opens his eyes and encounters an image or text that catches his attention.	
Beta Waves	They originate an electromagnetic field with a frequency between 13 and 39 Hz. They are registered when the person is awake in full mental activity and logical thinking.	
Low Beta Waves	They are considered to be the waves of high brain activity. Their frequency ranges between 12 and 16 Hz. Whenever you focus, analyze, calculate or think about your external environment, beta waves are at work.	

High Beta waves	They are associated with fears, anxiety, excessive thoughts, rapid thinking, obsessive-compulsive disorder (OCD), addictions and states of extreme mental performance.	
Gamma Waves	These are high frequency brain waves (40 Hz or more). They are associated with the waves generated when solving problems, whether logical or mathematical, in both children and adults. It is said that they can help learning and mental clarity. Gamma rhythms can be found in any part of the brain. Their presence favors the processing of declarative information through the brain pathways.	

Barrera Román (2017) mentions in his study “The human brain is undoubtedly one of the most complex systems in the known universe and the interest in understanding its functioning dates back to antiquity”.

2. OBJECTIVES

General Objective: To gather and evaluate the existing scientific evidence on their impact on the cognitive and emotional performance of employees in order to understand the functioning of binaural waves and evaluate how they can be used to optimize work productivity.

3. METODOLOGY

3.1. Research Design

The type of research conducted is a narrative literature review, since it is a compilation of analysis of existing studies, where the objective is to compare, analyze and synthesize results of previous research on the effects of binaural beats.

3.2. Materials And Methods

This chapter follows a literature review methodology, which involves the collection and analysis of academic articles, empirical studies, and other relevant resources published in scientific journals, academic conferences, and specialized books. An exhaustive search was conducted in databases such as PubMed, Google Scholar, using keywords such as “binaural beats”, “stereo headphones” and “cognitive ergonomics”. The studies selected were those that explicitly addressed the effects of binaural waves on cognition, performance, and stress. In addition, studies of different methodological approaches were considered, including randomized controlled trials, field studies, and laboratory experiments.

4. RESULTS

Among the results is that, in Europe, Lundager, Kirk, and Staiano (2019) conducted a study involving four groups: two mindfulness practice groups (one novice and one expert), a binaural beats group, and a control group. The results showed that mindfulness experts and participants exposed to binaural beats had lower levels of mental fatigue compared to the other groups. Also, a study by Al-Shargie et al. (2022) investigated the effectiveness of binaural beats in work settings, revealing that 16 Hz binaural pulses improved vigilance, reduced stress, and decreased alpha amylase levels by 44%. They also reduced reaction time by 20% and increased target detection accuracy by 25% ($p < 0.001$). Binaural sounds are recognized to positively influence mood, concentration, and creativity (Kirk, 2019; Fessel, 2018). This phenomenon is related to brainwave entrainment (Gruzelier, 1996), where the brain synchronizes its oscillations with sound stimuli of nearby frequencies presented to each ear. Finally, varied physiological effects have been identified: while some studies report improvements in microcirculation and cardiovascular function after exposure to binaural beats, others show inconclusive or even adverse results (Krasnoff & Chevalier, 2023). Neuroergonomics also offers applications in the human-machine relationship, the reduction of mental workload, and the assessment of cognitive performance in work environments (Pires & Matheus, 2021).

4.1 Definition and Functioning of Binaural Waves

Binaural waves are an acoustic phenomenon that occurs when two tones with slightly different frequencies (usually less than 30 Hz) are presented through headphones, one in each ear. The brain perceives a "wave" corresponding to the difference in frequencies between the two tones presented. For example, if a 300 Hz tone is played in one ear and a 310 Hz tone in the other ear, the brain will perceive a frequency of 10 Hz (Oster, 1973).

The principle behind binaural waves lies in the synchronization of brain waves with the frequency of the auditory stimulus. These frequencies are related to different brain states, such as relaxation, concentration, sleep or meditation. The most common frequencies used in productivity studies are alpha (8-12 Hz) and beta (13-30 Hz), which are associated with mental calmness and concentration, respectively (Smith et al., 2020).

4.2 Cognitive Effects of Binaural Waves

Several studies have investigated how binaural waves can affect brain activity and cognition. Research suggests that stimulation with alpha-frequency binaural wave stimulation can improve concentration, focus, and relaxation, while beta frequencies are related to increased mental activity, alertness, and problem solving (Bishop et al., 2018; Lee et al., 2021).

According to a review of studies, binaural waves can help reduce stress and anxiety, which in turn can increase the ability to concentrate and improve performance in work tasks that require continuous attention or intensive intellectual work (Hirsh, 2019).

4.3 Implications on Labor Productivity

One area of recent interest has been the influence of binaural waves on work productivity. A study by Smith et al. (2020) showed that exposure to beta-frequency binaural waves increased performance on tasks requiring high concentration and problem solving, such as writing and data analysis. Participants who listened to binaural waves during their workday showed greater efficiency in task performance compared to those who did not use these waves.

However, not all studies have shown positive results. Some studies, such as Turner (2018), suggest that binaural waves may not have a significant impact on productivity in distracting or noisy work environments. In addition, some employees experienced adverse effects, such as headaches or mental fatigue when listening to binaural waves for extended periods.

4.4 Ergonomic Implications

Integrating the use of binaural waves into the design of the work environment has the potential to improve cognitive ergonomics. The use of binaural waves can enable employees to maintain an optimal mental state for demanding tasks, reducing fatigue and improving job satisfaction. However, ergonomics should not only consider the effects of binaural waves, but also side effects such as headphone discomfort or auditory fatigue from prolonged use (Sanchez et al., 2019).

4.4.1 Effects on physiology:

- Improved microcirculation: The results of the Menlascan, which measures microcirculation, were less conclusive. Some participants experienced improvements in microcirculation after listening to BBs, while others showed no significant change or even experienced a decrease (Krasnoff & Chevalier, 2023).
- Variable cardiovascular effects: The effects of BB on the cardiovascular system were also variable. Some participants experienced an increase in cardiovascular score, suggesting improved cardiovascular function, while others showed no change or experienced a decrease (Krasnoff & Chevalier, 2023).

5 DISCUSSION

Binaural waves have significant potential to improve work productivity by influencing employees' cognitive abilities, such as concentration, focus, and problem solving. However, the effects of binaural waves are variable and depend on the context and individual conditions of workers. The implementation of binaural waves in work environments should be carefully evaluated to ensure that the benefits outweigh the possible negative effects.

The use of binaural waves in combination with other ergonomic methods, such as environmental noise management and workspace design optimization, could be a promising strategy to improve work productivity. However, more controlled, longitudinal studies are needed to draw definitive conclusions about its long-term impact.

5.1 **Contributions to Ergonomics**

5.2

Binaural waves can be considered as an ergonomic tool to improve psychological well-being and cognitive productivity at work. By integrating binaural waves into the design of the work environment, especially in tasks that require a high level of concentration, it is possible to foster a more efficient and pleasant working atmosphere. In addition, the design of comfortable headphones adapted for long-term use can optimize the benefits of this tool. Future research should explore the practical applications of binaural waves in various work contexts and their integration with other ergonomic practices.

6. REFERENCES

Al-Shargie, F., Katmah, R., Tariq, U., Babiloni, F., Al-Mughairbi, F., & Al-Nashash, H. (2022). Stress management using fNIRS and binaural beats stimulation. *Biomedical Optics*.

Barrera Román, A. (2017). *EvoEEG: un estudio basado en el análisis de ondas cerebrales mediante una interfaz cerebro-computadora* [Tesis de maestría, Centro de Investigación Científica y de Educación Superior de Ensenada, Baja California].

Bishop, D. T., Smith, J. R., & Turner, T. R. (2018). *Effects of binaural beats on cognitive performance and productivity in the workplace*. Journal of Cognitive Neuroscience, 30(4), 195-205. https://doi.org/10.1016/j.jcns.2018.02.008

Buzsaki, G.(2006). Rhythms of the Brain. Oxford University Press. https://books.google.es/books?id=ldz58irprjYC&hl=es&source=gbs_navlinks_s

Colzato, L. S., Barone, H., Sellaro, R., & Hommel, B. (2017).More attentional focusing through binaural beats:Evidence from the global–local task. Psychologicalresearch, 271-277.

Fessel, J. (2018). Amyloid is essential but insufficient for Alzheimer causation: addition of subcellular cofactors is required for dementia. . *International Journal of Geriatric Psychiatry*, 33(1), e14-e21.

Gantt, M. A., Dadds, S., Burns, D. S., Glaser, D., & Moore, A.D. (2017). The effect of binaural beat technology onthe cardiovascular stress response in military servicemembers with postdeployment stress. Journal of Nursing Scholarship, 411-420

Gruzelier, JH. (1996). New advances in EGG and cognition. *Int J Psychophysiol. 24* (1), 1-5. DOI: 10.1016/s0167-8760(96)00069-4

Jirakittayakorn, N., & Wongsawat, Y. (2017). Brain responsesto a 6-Hz binaural beat: effects on general thetarhythm and frontal midline theta activity. Frontiers inneuroscience, 365.

Hirsh, K. A. (2019). *Binaural beats and productivity: A review of the literature*. Journal of Applied Psychology, 104(2), 238-246. https://doi.org/10.1037/apl0000323

Kirk, U. W. (2019). On-the-spot binaural beats and mindfulness reduces behavioral markers of mind wandering. . *Journal of Cognitive Enhancement*, 3, 186-192

Krasnoff, E., & Chevalier, G. (2023). Case report: Binaural beats music assessment experiment. Frontiers in Human Neuroscience, 17, 1138650. https://doi.org/10.3389/fnhum.2023.1138650

Lee, S., Kim, B., & Park, K. (2021). *Cognitive performance and neural synchronization effects of binaural beat stimulation*. Neuroscience and Biobehavioral

Lundager, J; Kirk, J y Staiao, W. (2020). On-the-Spot Binaural Beats and Mindfulness Reduces the Effect of Mental Fatigue. *Journal of Cognitive Enhancement, 4* (3). DOI:10.1007/s41465-019-00162-3

Omeroglu, F., & Li, Y. (2022). Effects of Binaural Beats on Mood and Cognition. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 66(1), 1386-1390. https://doi.org/10.1177/1071181322661517 (Original work published 2022).

Opartpunyasarn, P. (2022). The effect of binaural beat audio on anxiety in patients undergoing fiberoptic bronchoscopy: A prospective randomized controlled trial. *Medicine, 101(24).*

Oster, G. (1973). *Auditory beats in the brain*. Scientific American, 229(4), 94-102.

Pluck, G., & López-Águila, M. A. (2019). Induction of fearbut no effects on cognitive fluency by thetafrequency auditory binaural beat stimulation.Psychology & Neuroscience, 53.

Pires, E., & Matheus, C. (2021). Neuroergonomia: Um diálogo entre as neurociencias e a ergonomia. *Boletim Interfaces da Psicologia da UFRuralRJ*, 147-162.

Sánchez, M., González, R., & Díaz, A. (2019). *Binaural beats in occupational settings: Ergonomic implications and applications*. Ergonomics, 62(7), 994-1003. https://doi.org/10.1080/00140139.2019.1628369

Schaul, N.(1998). The fundamental neural mechanisms of electroencephalography. *Electroencephalogr Clin Neurophysiol,* 106 (2). 101-107. DOI: 10.1016/s0013-4694(97)00111-9

Sciotto, E., & Niripil, E. (2018). Ondas Cerebrales, Conciencia y Cognición. https://www.academia.edu/35611100/ONDAS_CEREBRALES_CONCIENCIA_Y_COGNICI%C3%93N

Smith, J. R., Turner, T., & Lee, S. (2020). *The impact of binaural beats on task performance and concentration in office workers*. Journal of Workplace Productivity, 13(3), 201-215. https://doi.org/10.1016/j.jwp.2020.04.012

Talamillo, T.(2011). Manual básico para enfermeros en electroencefalografía. *Enfermeria docente, 94*, 29-33.

Turner, P. (2018). *Challenges in the application of binaural beats to workplace productivity*. Journal of Occupational Health Psychology, 23(4), 456-465. https://doi.org/10.1037/ocp0000202

Wahbeh, H., Calabrese, C., Zwickey, H., & Zajdel, D. (2007).Binaural beat technology in humans: a pilot study toassess neuropsychologic, physiologic, andelectroencephalographic effects. . The Journal ofAlternative and Complementary Medicine, 199-206.

COMPARISON OF MENTAL WORKLOAD IN PROGRAMMING DEVELOPMENT ACTIVITIES BASED ON THE PROGRAMMING LANGUAGES.

Víctor Hugo Saucedo Díaz[1], Ana Isela García Acosta[2], Manuel Alejandro Barajas Bustillos[2]

[1]Department of Industrial Engineering
Paso del Norte Technological University
Pez Lucio #10526. Col. Puerto Anapra
Cd. Juárez, Chih., México

[2]Department of Graduate and Research
Tecnológico Nacional de México/Instituto Tecnológico de Cd. Juárez
Technological Ave.1340, 32500
Cd. Juárez, Chih., México

Corresponding author's e-mail: agarcia@itcj.edu.mx

Resumen: Las escuelas resultan un lugar propicio para generar estrés y fatiga mental tanto en los alumnos como en el personal que labora, un gran número de estudiantes estudian, trabajan y atienden a su familia. Una tarea titánica para estas personas que buscan cumplir su meta de ser profesionistas. La carga mental describe la carga psicológica que los alumnos consumen en sus actividades diarias, esto les puede causar fatiga, estrés o alguna enfermedad física. Las ingenierías generalmente manejan temas de programación los cuales pueden resultar bastante estresante sobre todo para los principiantes en esta área. En el presente documento se busca determinar si existe una mayor carga mental en el desarrollo de instrucciones en dos de los lenguajes que principalmente se usan en la actualidad como lo son C++ y Python. El primero usado tradicionalmente para el aprendizaje de programación mientras que el segundo, aunque no es un lenguaje nuevo, recientemente ha ido adquiriendo popularidad en la comunidad estudiantil debido a su sencillez de aprendizaje y sus múltiples aplicaciones en diversas áreas de la ingeniería. El estudio se desarrolló en alumnos de ingeniería de la Universidad Paso del Norte, con conocimientos básicos de ambos lenguajes de programación, una vez seleccionados los alumnos se les propuso resolver un problema matemático el cual tenían que hacer en uno de los dos lenguajes, se asignaron 15 alumnos para el lenguaje Python y 15 alumnos en el lenguaje C++, una vez terminada la actividad se aplicó el cuestionario subjetivo NASA TLX, el cual se compone de seis dimensiones que los participantes evalúan en una escala de 0 a 100, estas escalas son demanda mental, demanda física, demanda temporal, rendimiento, esfuerzo y frustración, las cuales arrojan como resultado final una calificación de carga mental. Después de haber obtenido la calificación para cada grupo de alumnos, se procedió a analizarlos en un software estadístico. Los resultados obtenidos no permiten demostrar que haya diferencia entre la carga cognitiva para el uso de ambos lenguajes, lo cual sugiere que el nivel de estrés no depende significativamente de uno de ellos, sino de otros factores como la experiencia en programación y la resolución de problemas de matemáticas.

Palabras Clave: NASA-TLX, Python, C++, Carga mental.

Relevancia para la Ergonomía: La aportación de este trabajo de investigación impacta directamente en la determinación de carga mental en alumnos de ingeniería, aportando a la ergonomía información sobre cómo abordar la fatiga desde una perspectiva académica.

Abstract: Schools can be a breeding ground for stress and mental fatigue for both students and staff. Many students juggle studying, working, and taking care of their families—a Herculean task for those trying to achieve their goal of becoming professionals. The mental load refers to the psychological pressure students face in their daily activities, which can lead to fatigue, stress, or physical illness. Engineering courses often involve programming topics, which can be quite stressful, especially for beginners in this field. This document aims to determine if there is a greater mental load when developing instructions in two of the most commonly used programming languages today: C++ and Python. The former has traditionally been used for learning programming, while the latter, though not a new language, has recently gained popularity among students due to its ease of learning and its multiple applications in various engineering fields. The study was conducted with engineering students at the Universidad Paso del Norte, who had basic knowledge of both programming languages. Once the students were selected, they were asked to solve a math problem in one of the two languages. Fifteen students were assigned to Python and 15 to C++. After completing the activity, the subjective NASA TLX questionnaire was administered, which consists of six dimensions evaluated by the participants on a scale from 0 to 100. These scales assess mental demand, physical demand, temporal demand, performance, effort, and frustration, ultimately producing a mental load score. After obtaining the scores for each group of students, they were analyzed using statistical software. The results obtained do not show a difference in cognitive load when using either programming language, which suggests that the stress level doesn’t significantly depend on one or the other, but rather on other factors like programming experience and solving math problems.

Keywords: NASA-TLX, Python, C++, mental workload.

Relevance to ergonomics: This research contributes directly to understanding mental load in engineering students, providing ergonomic insights on how to tackle fatigue from an academic perspective.

1.INTRODUCTION

The term Mental load is used to describe the psychological or emotional burden associated with the mental or emotional tasks that a person carries out in their daily life (Rubio, 2007). This burden can occur in various contexts, such as work, formal study, family responsibilities, personal relationships, and other aspects of daily life. In the workplace, mental load arises from the development of activities and responsibilities inherent to the job, which can cause stress, fatigue, and adversely affect work performance. Furthermore, it can lead to a higher number of workplace accidents due to the diminished attention of the worker because of the aforementioned consequences (Rolo, 2009).

This concept, although not new, is becoming a focal point for those concerned with working conditions and human performance. The definition of mental workload emerged as a component of the concept of workload, which includes consideration of the physical and mental costs involved in the worker's performance (Cárdenas, 2015). However, the history of this concept has followed specific paths that cross many different disciplinary boundaries. In fact, from the very beginning, the concept of mental load was formed under the influence of a set of theories backed by the development of mathematical models developed after World War II, which originally aimed to describe behavior (Díaz, 2010).

Today, it is a challenge for the field of ergonomics, which, seeking effectiveness, safety, and workplace well-being, aims to prevent the aforementioned consequences for the worker. Finding tools and utilizing existing technology to establish limits within which the employee can perform their work without being overwhelmed by their mental activity and maintain the same level of performance throughout their shift (Vargas, 2020). It is worth noting that the inclusion of technology in productive activities demands a greater amount of cognitive resource consumption; the complexity of jobs has increased as computing has become more prevalent, and the amount of data available for analysis complicates tasks, resulting in people being at risk of experiencing both physical and mental fatigue (Ferrer & Dalmau, 2004).

Mental load does not only appear in productive activities; people who perform certain services also end up being diminished during their workday. In the school environment, whose main objective is to convey concepts, encourage critical thinking, and prepare students for their integration into the labor market. Based on this background, it can be said that both teachers and students require a substantial amount of cognitive skills, even greater than physical ones (González, 2021). The mental requirements that a student faces in acquiring new concepts and skills can generate stress, anxiety, and fatigue, significantly diminishing their well-being and affecting their health (Peralta, 2022).

Remaining in the school context, for most students, areas involving mathematics or requiring reasoning, working memory, attention and concentration, numerical thinking, and abstract thinking are more challenging. According to (Andrade, 2012), mental load arises from the interaction between the characteristics of a task and the characteristics of the individual. Different tasks may be more complex or simpler, depending on the number of necessary steps or the precision they require. At the same time, It can be said that there are students with different skills that make it easier for them to perform tasks where they need to use their logical-mathematical thinking.

Programming is an area that involves developing algorithms and transforming them into instructions that the computer can execute; it may involve the use of logical-mathematical thinking (Aguilar, 2019). As mentioned, it greatly depends on the individual and their prior experience with the task; even so, developing programs can be exhausting for students. While it is true that there are interpreted languages like Python, which have the main benefit of ease in building code, compared to other traditional languages like C++ that are considered less flexible in their syntax (Challenger, 2014). It is unknown if there is a difference in the use of cognitive skills between the implementation of one language or another.

2. THEORETICAL FRAMEWORK

Ergonomics plays a fundamental role in today's industry, aiming to optimize workplace design to improve efficiency and worker health. Commonly, when we talk about health, only the quantification of work accidents is considered, but it should go beyond that; there are injuries that are not immediately identified, but rather a gradual wear occurs that worsens the situation. This study should consider the working conditions and the lifestyle that the worker presents throughout their workday (Luna, 2014). In industrial settings, ergonomics focuses on adjusting environments, tools, and work processes to minimize injuries, fatigue, and stress, while increasing productivity (Torres & Rodríguez, 2021). Proper management of ergonomics in a company improves task performance as it allows employees to work in a comfortable environment that adapts to their work. This not only provides personal benefits but also directly impacts the quality of production and the competitiveness of companies (Castillo, 2018).

Mental load, also known as cognitive load, refers to the level of mental effort or cognitive demand that a task or activity imposes on a person (Aranguren, 2014). This concept has evolved over time, from its origins in cognitive psychology and ergonomics to its applications in various fields, such as occupational psychology, engineering, and occupational health. Historically, mental workload dates back to the 1950s, when cognitive psychologists began studying how individuals limited cognitive abilities affected their ability to complete tasks. It was educational psychologist John Sweller who introduced the concept of cognitive load in the 1980s.

Cognitive load is considered one of the most impactful psychosocial risk factors associated with the characteristics of the activity performed, and being exposed to mental load conditions at work can lead to significant health problems in workers (Ormaza, 2018). High mental load can lead to a series of negative consequences that severely affect the physical and mental health of some individuals (Ossa, 2023). Among these are fatigue and stress, which generate a sensation of chronic tiredness, a decrease in the performance of cognitive skills, and some individuals may experience physical health issues ranging from colitis to facial paralysis, as well as distancing from those around them due to irritability and lack of patience (Rivera, 2022). As previously stated, companies generally focus on preventing workplace accidents but overlook these ailments affecting their employees.

There are different ways to measure workload, including: performance measures, physiological measures, and subjective measures. Each has advantages and disadvantages due to its nature. Subjective methods allow us to measure workers' perceptions of the mental load involved in performing tasks (Ceballos, 2014). Among the questionnaires that subjectively measure mental load is the NASA TLX, which stands for Task Load Index, designed to determine the cognitive load that the evaluated individuals can perceive when performing a work or personal activity. It covers six dimensions, including: mental demands, physical demands, temporal demands, performance, effort expended, and level of frustration. For each dimension, a value between 0 and 100 is assigned, understanding that the closer it is to 100, the higher the level of mental load for the dimension being evaluated. It is generally implemented in research facilities, cognitive load assessment systems, and some critical mission scenarios such as aviation, medicine, and engineering, allowing for a detailed understanding of the mental workload of individuals performing a specific activity (Díaz, 2010).

A programming language is a set of symbols and rules that allow the programmer to write instructions that the computer can execute. Although there are 3 types of programming languages: machine language is the only language that computers have, its communication is based on a set of 0s and 1s, also called binary language, which is a system that only uses two digits and is utilized by most electronic devices. Meanwhile, low-level language uses symbols that are easier for humans to read than binary, handling specific addresses of memory hardware. Finally, high-level language is the language closest to humans, generally describing instructions using words that we can understand, mostly in English. It is the most commonly used by software developers, with main examples being C++, C#, Java, Python (González, 2018).

Among the traditional programming languages, C++ is used based on several branches ranging from desktop application development, use of libraries, operating systems, and even video game creation. In the 80s, it was notable for its flexibility and efficiency in building computer systems. Traditionally used for teaching programming due to its multipurpose nature, it is also because it can often be simpler to learn another language if one was first learned in this. It is a compiled language that for its implementation must first have correct syntax, as well as a transformation process into an executable object for the machine. While it is true that nowadays there are other programming languages that have gained ground, C++ remains relevant for software developers. Below in fig. 1, shown an example of printing a message in C++.

```cpp
#include <iostream>

using namespace std;

int main()
{
    cout<<"ejemplo de c++";

    return 0;
}
```

Figure 1. Example of C++

Another language worth analyzing is Python, a quite popular language these days just like C++. It belongs to the type of high-level languages, the difference lies in being an interpreted language, which as it is executed, the computer, as its name implies, translates the instructions to machine language according to what it understands. This language stands out for its simplicity in writing, often confusing people with being a kind of pseudocode. Currently, it is widely used in the development of web applications, desktop applications, data science, artificial intelligence, among other applications. It is open and there are multiple libraries that allow software developers to have a broad scope to work with (Logroño, 2022). In terms of teaching, it is considered a language that benefits beginners in the programming world due to what was previously mentioned about its simplicity in writing, as well as having multiple communities of people who share a liking for this language (García, 2017). Below in fig. 2, an example of printing a message in Python is observed.

```python
Print ("ejemplo de python")
```

Figure 2. Example of Python.

3. METHOD

The present study employs a comparative quasi-experimental design. Thirty students from the 4th semester selected from the mechatronics and networks programs at the Universidad Tecnológica Paso del Norte, located in Ciudad Juárez, Chihuahua, were chosen.

For all participants, the Newton Raphson method was explained, which allows finding the root of an equation based on approximations, generally used for its simplicity in numerical analysis. Below, the iterative equation used for this method is observed (1). It is worth noting that both groups were given the same time limit to complete their exercise.

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)} \quad (1)$$

In the experiment, 15 students developed the solution to an exercise of the method described in C++ while another 15 students did so use Python. Then, the level of mental load was measured using the NASA TLX subjective questionnaire. Below in fig. 3, shown an activity diagram (HTA) that describes the process of this trial. A hypothesis test is also proposed in order to determine if there is a significant difference in the mental load consumed in one language or the other. Where M1 corresponds to C++ and M2 to Python. This is the hypothesis of the test: H0: M1=M2; H1:M1 ≠ M2

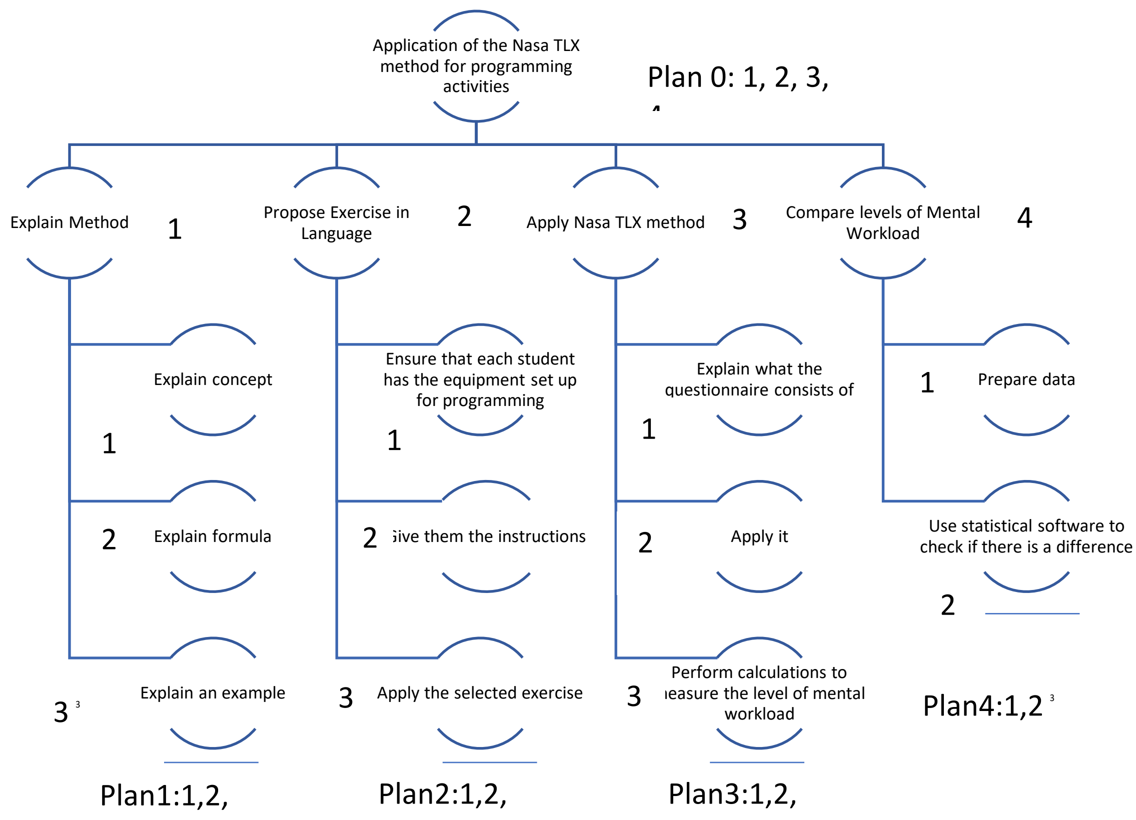


Figure 3. Diagram HTA of the test

Below is the implemented syntax to solve the proposed example using the Newton Raphson method. It was executed in an online compiler; the way each student designed their solution may vary. The image shows 18 lines of code for this problem and its solution, shown fig. 4.

main.cpp

```cpp
#include <iostream>
#include <cmath>
int main() {
    double x = 1;
    int iteraciones = 5;
    for (int i = 0; i < iteraciones; ++i) {
        double f_x = pow(x, 3) - x - 1;
        double f_derivada_x = 3 * pow(x, 2) - 1;
        if (f_derivada_x == 0) {
            std::cout << "La derivada se hace cero. No se puede continuar con el método." << std::endl;
            break;
        }
        x = x - (f_x / f_derivada_x);
        std::cout << "Iteración " << i + 1 << ": x = " << x << std::endl;
    }
    std::cout << "Aproximación final de la raíz: x = " << x << std::endl;
    return 0;
}
```

input

```
Iteración 1: x = 1.5
Iteración 2: x = 1.34783
Iteración 3: x = 1.3252
Iteración 4: x = 1.32472
Iteración 5: x = 1.32472
Aproximación final de la raíz: x = 1.32472
```

Figure 4. Solution in C++ code

While in Python 12 lines were used to carry out the process of obtaining the root using the Newton Raphson method. Below in fig. 5, shown the coding of the program and its execution.

main.py

```python
x = 1.0  # Valor inicial de x
iteraciones = 5
for i in range(iteraciones):
    f_x = x**3 - x - 1
    f_derivada_x = 3 * x**2 - 1

    if f_derivada_x == 0:
        print("La derivada se hace cero. No se puede continuar con el método.")
        break
    x = x - (f_x / f_derivada_x)
    print(f"Iteración {i + 1}: x = {x}")
print(f"Aproximación final de la raíz: x = {x}")
```

input

```
Iteración 1: x = 1.5
Iteración 2: x = 1.3478260869565217
Iteración 3: x = 1.325200398950907
Iteración 4: x = 1.3247181739990537
Iteración 5: x = 1.3247179572447898
Aproximación final de la raíz: x = 1.3247179572447898
```

Figure 5. Solution of the problem in C++ code

Once the activity was completed, the perceived workload level for each student in the experiment was measured using the subjective NASA TLX method, which was described in detail in later sections of this document. Then, using statistical software, it was determined whether there is a difference between the workload levels associated with the use of each programming language.

4. RESULTS

This section presents the results obtained from the NASA TLX questionnaire. After the experiment, the results were captured in an Excel workbook; below, the information is shown in a graph concerning the 15 individuals who completed their program in C++. The average for all participants for this language is 895.733333.

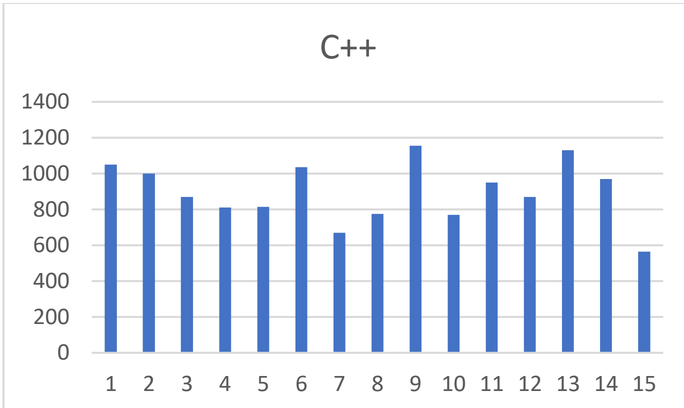


Figure 6. Results for C++

While the 15 students who carried out their activity using the programming language Python achieved similar results in terms of mental load, below is a graph with the information obtained. In addition, the average of the people who programmed in Python was 906.733333, see fig. 7.

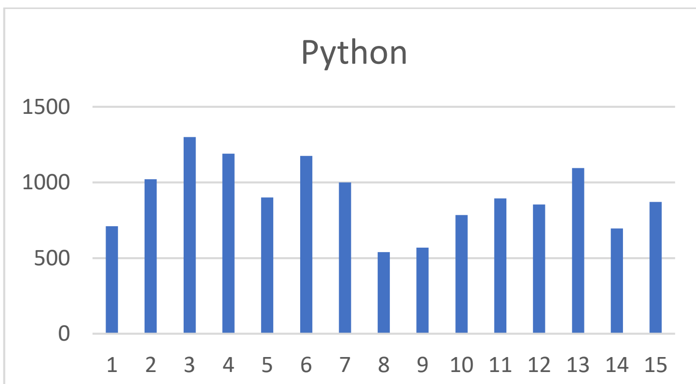


Figure 7. Results for Python

The NASA TLX Questionnaire consists of six dimensions that allow you to determine an individual's mental load, including mental, physical, temporal, performance, effort, and frustration. The following illustration summarizes the average results obtained for each dimension. It can be observed in the aspects of mental fatigue and frustration that the C++ language presents a higher average among the students. In the next figure, the averages for the 6 areas of study can be observed. To the C++ language, an average of 208.66 was obtained in the mental aspect, 26.8 in the physical aspect, 121.66 in the temporal aspect, 165.66 in performance, 150.6 in effort, and 229 in frustration. To the Python language, an average of 193.333 was obtained in mental, 4 in physical, 177.46 in temporal, 228.73 in performance, 165.2 in effort, and 151.33 in frustration, see fig. 8.

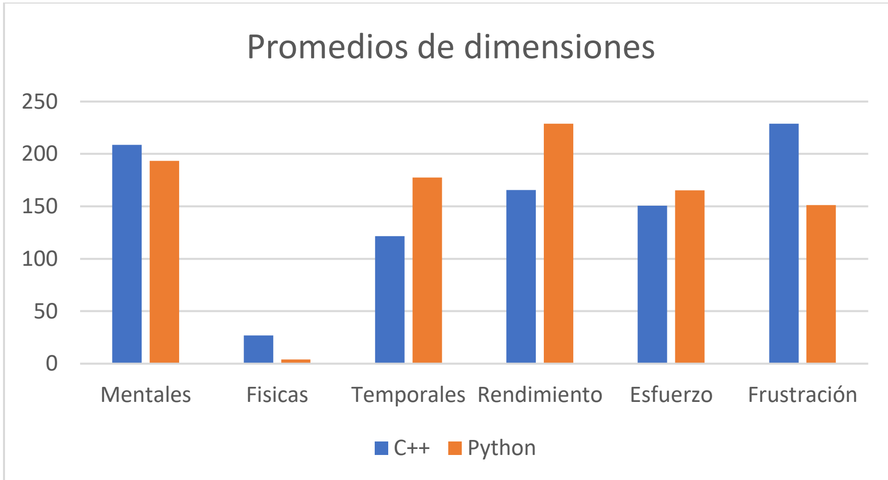


Figure 8. Averages of the test dimensions

The data were entered into the statistical software Minitab, after which the Anderson-Darling normality test was applied. The results will be shown next, where the sample data for the use of C++ are represented by a circle, while those for Python are shown with a square. For C++, it is observed that the P value is 0.925, while for Python it was 0.943, indicating that they are normally distributed, see fig. 9.

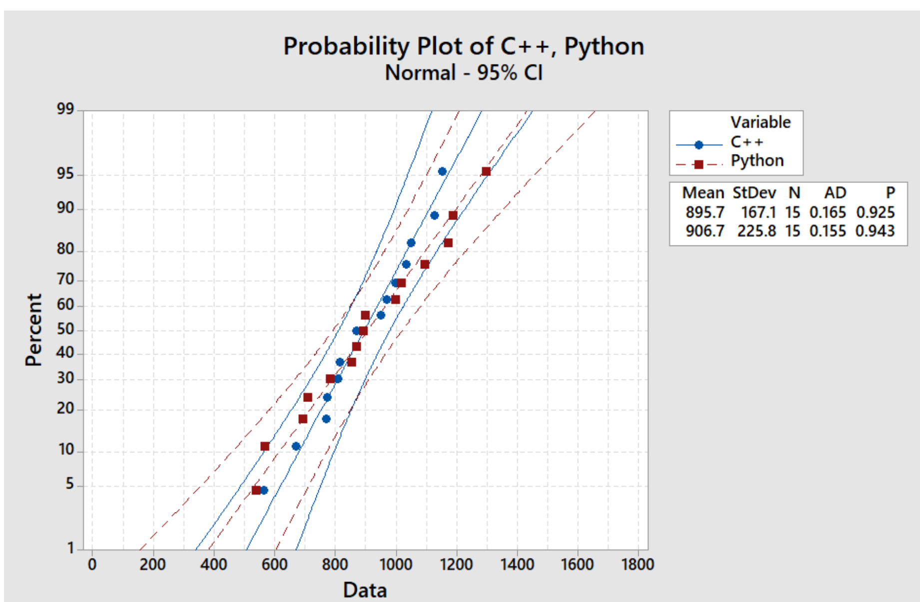


Figure 9. Normality Test

Then, the previously stated hypothesis test was executed in the Minitab software where we assume that both means are equal as the null hypothesis, the results of this test are presented below in the following illustration. Where we can observe that the p-value is greater than 0.05, so we can say that there is no statistical evidence to reject the null hypothesis, see fig. 10.

```
                                 SE
          N  Mean  StDev  Mean
C++      15   896    167    43
Python   15   907    226    58


Difference = μ (C++) - μ (Python)
Estimate for difference:  -11.0
95% CI for difference:  (-160.4, 138.4)
T-Test of difference = 0 (vs ≠): T-Value = -0.15  P-Value = 0.881  DF = 25
```

Figure 10. Statistical Test in Minitab.

5. CONCLUSIONS

The experiment consisted of developing a mathematical algorithm, specifically the Newton Raphson method, in both c++ and python. These languages were chosen because the former has traditionally been used as a foundation to teach programming to students, while the latter has gained great popularity recently, to the extent that schools are starting to opt for it as the first programming language that students learn. According to García Monsálvez (2017), Python, being a flexible and simple language for writing instructions, is increasingly being implemented as an introductory language for beginner programmers due to its ease of use.

For the experiment, the algorithm for obtaining roots was explained to them, and then they were given a time limit to convert this method into a program that provided the answer for the proposed exercise. While it is true that on average, python resulted in a slightly higher amount of mental load than C++, when conducting the means test in the statistical software, no significant difference was found between the means of both according to the statistical analysis performed. Therefore, we can affirm that there is no significant variation in the mental load of completing the exercise in either of the two languages. It is noteworthy that the mere act of implementing a mathematical algorithm already generates some mental load in the students, although during the development of the experiment it was observed that the individuals who programmed in python mostly finished their program before the time limit; the act of programming entails the implementation of cognitive skills. Likewise, there are other variables that may have affected the results, such as the fact that some students have greater expertise in programming.

It is recommended to carry out activities that do not themselves represent a greater consumption of mental load, such as mathematics. There are other popular languages today with different characteristics that benefit the construction of instructions, which could be analyzed with a larger number of students.

6. BIBLIOGRAPHY

Aguilar Enríquez, F. D. (2019). Uso de lenguajes de programación para desarrollar el razonamiento lógico matemático en los niños. *RCUISRAEL vol.6*.

Andrade Lotero, L. A. (2012). Teoría de la carga cognitiva, diseño multimedia y aprendizaje: un estado del arte. *Revista Internacional de Investigación en Educación*.

Aranguren Álvarez, W. (2014). Carga mental en el trabajo. *Sapienza Organizacional, vol. 1, núm. 1,*, pp. 9-20.

Cárdenas, D., Conde, J., & Perales, J. (2015). El papel de la carga mental en la planificación del entrenamiento deportivo. *Revista de Psicología del Deporte*, pp. 91-100.

Castillo, J. (2018). Crisis y oportunidades: El futuro del trabajo y de la ergonomía. *Escuela de Medicina y Ciencias de la salud, Colombia*.

Ceballos Vázquez, P., Paravic, T., Burgos Moreno, M., & Barriaga, O. (2014). VALIDACIÓN DE ESCALA SUBJETIVA DE CARGA MENTAL DE TRABAJO EN FUNCIONARIOS/AS UNIVERSITARIOS. *Red de Revistas Científicas de América Latina, el Caribe, España y Portugal*, pp. 73-82.

Challenger-Perez, I., Díaz-Ricardo, Y., & Becerra-García, R. (2014). El lenguaje de programación Python. *Ciencias Holguín, vol. XX, núm. 2*.

Díaz Ramiro, E., Rubio Valdehit, S., Martín Garcí, J., & Luceño Moreno, L. (2010). Estudio Psicométrico del Índice de Carga Mental NASA-TLX. *Revista de Psicología del Trabajo y de las Organizaciones*.

Díaz, C. (2010). Actividad Laboral y Carga Mental de Trabajo. *Ciencia & Trabajo*, 281-292.

Ferrer, R., & Dalmau, I. (2004). Revisión del concepto de carga mental: evaluación, consecuencias y proceso de normalización. *Anuario de Psicologia, Vol 35*, 521-545 .

García Monsálvez, J. C. (2017). Python como primer lenguaje de programación textual en la Enseñanza Secundaria. *Education in the Knowledge Society, vol. 18, núm. 2*.

González Jaimes, E., López Chau, A., Trujillo Mora, V., & Rojas Hernández, R. (2018). Estrategia didáctica de enseñanza y aprendizaje para programadores de software. *RIDE. Rev. Iberoam. Investig. Desarrollo*.

González Palacios, Y., Ceballos Vázquez, P., & Rivera Rojas, F. (2021). Carga mental en profesores y consecuencias en su salud: una revisión integrativa. *Cadernos Brasileiros de Terapia, 29*.

Logroño Naranjo, S., Estrada Brito, N., & Vásconez Núñez, V. (2022). Análisis del uso del lenguaje de programación Python para cálculos estadísticos. *Espirales revista multidisciplinaria de*.

Luna García, J. E. (2014). La ergonomía en la construcción de la salud de los trabajadores en Colombia. *Revista Ciencias de la Salud, vol. 12*.

Ormaza Murillo, M., Zambrano Rivera, A., & Zamora Napa, S. (2018). Carga mental de profesores de la Escuela Superior Politécnica Agropecuaria de Manabí. *Ingeniería Industrial, vol. XL, núm. 1*, pp. 3-13.

Ossa Cornejo, C., Jiménez Figueroa, A., & Gómez Urrutia, V. (2023). Salud mental y carga mental de trabajo en trabajadores de establecimientos educativos chilenos en contexto de COVID-19. *Rev. Port. de Educação vol.36 no.1*.

Peralta Fonseca, M., Egas García, J., Escudero Andino, F., & Muñoz Velazco, P. (2022). Mental workload in technical-technological higher education teachers. *Ciencias de la ingenierías y aplicadas*.

Rivera Rojas, F., Macaya Sazo, M., Fuentes Poblete, I., Faundez Osorio, P., Ábrigo Alcántara, V., & Olivares Riquelme, J. (2022). Percepción de carga mental de trabajo en personas funcionarias administrativas que se desempeñan en una municipalidad de Chile. *Enfermería Actual de Costa Rica n.43*.

Rolo González , G., Díaz Cabrera, D., & Hernández, E. (2009). Desarrollo de una Escala Subjetiva de Carga Mental de Trabajo (ESCAM). *Revista de Psicología del Trabajo y de las Organizaciones, Vol 25*.

Rubio Valdehita, S., Luceño Moreno, L., García, J., & Díaz, J. (2007). Modelos y procedimientos de evaluación de la carga mental de trabajo. *EduPsykhé: Revista de psicología y educación. Vol 6*, 85-108.

Torres, Y., & Rodríguez, Y. (2021). Surgimiento y evolución de la ergonomía como disciplina: reflexiones sobre la escuela de los factores humanos y la escuela de la ergonomía de la actividad. *Revista Facultad Nacional de Salud Pública, vol. 39*.

Vargas, L., Coral, R., & Barreto, R. (2020). Carga mental en personal de enfermería: Una revisión integradora. *Rev. cienc. cuidad.*, 108-121.

COGNITIVE ERGONOMICS IN LEARNING FOR GIRLS AND BOYS WITH SENSORY AND INTELLECTUAL DISABILITIES

Raquel Muñoz, 0000-0002-4461-8027, Saúl Rangel Lara, https://orcid.org/0000-0003-1498-340X, José Miguel Alva Marquina, Andrea Molina Muñoz and Gabriel Joshua Villalobos Martínez

Dirección de Ingeniería Industrial
Universidad Politécnica del Valle de México
Av. Politécnica S/N
Col. Villa Esmeralda,
Tultitlán, Edo. México, 54900
raquel.munoz@upvm.edu.mx

Resumen En la presente investigación se analizan las estrategias para mejorar el aprendizaje de las niñas y niños con discapacidad sensorial e intelectual, recopilando todas aquellas estrategias que ya han sido investigadas, así como también proponer una estrategia para que los niños con discapacidad sensorial e intelectual aprendan de una manera más amigable. Con la finalidad de brindar a los docentes una perspectiva más amplia en estrategias de aprendizaje de niños con discapacidad sensorial e intelectual, ya que en México en el año 2013 la SEP dispuso que se integraran distintos programas que atendían a una población diversa como niños indígenas, migrantes, con discapacidad, con capacidades y aptitudes sobresalientes, entre otros, este nuevo programa fue llamado, Programa Nacional para la Inclusión y la Equidad Educativa (PNIEE). El principal objetivo de esta investigación es hacer llegar a estas estrategias de la educación especial en México, lenguaje incluyente, los instrumentos para el diagnóstico de la discapacidad sensorial e intelectual y por consiguiente la descripción de estas estrategias, y la importancia de la capacitación a docentes para atender este grupo vulnerable de la población.

Palabras clave: Inclusión, Equidad, Aprendizaje.

Relevancia para la ergonomía: Es importante para la Ergonomía porque incide directamente en el desarrollo de herramientas físicas y abstractas que apoyen las condiciones de vida y aprendizaje con base en la de usabilidad en el contexto señalado y mencionado de tal forma que apoye las condiciones de vida y aprendizaje desde la perspectiva de la Ergonomía Cognitiva.

Abstract: This research analyzes the strategies to improve the learning of children with sensory and intellectual disabilities, compiling all those strategies that have already been investigated, as well as proposing a strategy for children with sensory and intellectual disabilities to learn in a more friendly way. In order to provide teachers with a broader perspective on learning strategies for children with sensory

and intellectual disabilities, since in Mexico in 2013 the SEP ordered the integration of different programs that served a diverse population such as indigenous children, migrants, children with disabilities, children with outstanding abilities and aptitudes, among others, this new program was called the National Program for Inclusion and Educational Equity (PNIEE). The main objective of this research is to bring these special education strategies in Mexico, inclusive language, the instruments for the diagnosis of sensory and intellectual disabilities and therefore the description of these strategies, and the importance of training teachers to serve this vulnerable group of the population.

Keywords. Inclusion, Equity, Learning.

Relevance to Ergonomics: It is important for Ergonomics because it directly affects the development of physical and abstract tools that support living and learning conditions based on usability in the context indicated and mentioned in such a way that it supports living and learning conditions from the perspective of Cognitive Ergonomics.

1. INTRODUCTION

We are currently living in times of change regarding the concept of disability. Today, society advocates for diversity, integration and inclusion of all citizens. In this context, new frameworks of understanding are required, as well as new attitudes towards disability based on respect for differences and equal opportunities.

The main challenge faced is to be able to provide people with disabilities with equal conditions of education, recreation and, in general, personal development. Every individual has the right to a better Quality of Life and to meet their needs and goals regardless of whether or not they have a disability.

To achieve a level of Quality of Life, personal efforts are decisive, but the environment in which each person develops is also relevant, especially those with disabilities. Therefore, it is necessary to level and equalize the context, not only physical; also that of personal relationships regarding discriminatory attitudes, since no one is exempt from suffering damage and acquiring disabilities. This age range is considered, according to Attention Deficit Hyperactivity Disorder (ADHD) which are Instruments or tests to evaluate Intellectual Capacity (IQ), since these tests generally cannot be done until they are between 4 and 6 years old according to the Wechsler, McCarthy scales and the Raven progressive matrices test for intellectual disability.

Regarding sensory disability, which includes visual, additive and deafblindness, there are scales and tests for the detection of these disabilities, unlike intellectual disability, sensory disability can be detected according to the scale or test from 0 to 5 years.

In addition, this age range is considered since from a young age it is easier to implement these learning strategies according to their disability, since in Mexico according to the 2023 Census, the INEGI counted 20 million 838 thousand 108 people in the disability category, a figure that represents 16.5% of the population of Mexico. (INEGI, 2024).

Table 1.1 Population with limitations or disabilities, by type of limitation, with percentages. Prepared by the authors based on INEGI data. Source: INEGI

LIMITATIONS OR DISABILITIES	CANTIDAD	%
Limitation in walking	8, 096, 386	38.8%
In seeing	12, 727, 653	61.0%
In hearing	5,104,664	24.4%
In speaking or communicating	2,234,303	10.7%
In caring for oneself	2,430,290	11.6%
In remembering or concentrating	4,956,420	23.7%
Mental condition	1,590,583	7.6%
Total	**20,838,108**	**100%**

According to the results of the National Survey of Demographic Dynamics (ENADID) 2023, 38.5 million girls, boys and adolescents aged 0 to 17 reside in Mexico, representing 30.8% of the total population. Of this total population group,

19.6 million are men and 18.9 million are women. By age group, 9.2 million are four years old or younger; 10.8 million are between five and nine years old, 11.5 million are between 10 and 14 years old, and seven million are adolescents between 15 and 17 years old.

In this regard, data from ENADID 2023 show lower school attendance in the population with disabilities. Namely, 75.3% of girls, boys and adolescents aged 5 to 17 with disabilities attend school, compared to 88.4% of the population without disabilities in the same age range. By age group, the gaps are mainly intensified in the 10 to 14 age group, with a difference of 14.7 percentage points.

The population aged 15 to 17 with disabilities has a higher risk of dropping out of school compared to those who do not have this trait, not only due to their condition, but also to various social, economic and even geographic factors, which is why they demand greater attention from the National Education System (INEGI, 2024).

In addition to this information, this age range is also considered since the data presented indicate that the population aged 15 to 17 years old is more likely to drop out of school, which is when they are in the secondary to high school level of education and the age range selected for this research is at the primary level where it is considered an important factor when implementing these strategies and there may be less dropout or school delay.

The importance of studying this particular topic lies in the lack of knowledge of these strategies in basic education schools by teachers, since in Mexico in 2016 the Program for Inclusion and Educational Equity was created, where 177,100 students with disabilities have benefited according to data from the National Council for the Development and Inclusion of People with Disabilities, where teachers received students with different disabilities without receiving a specific course to serve all the girls and boys who are in this situation, it is for this reason to publicize and propose learning strategies that benefit girls and boys with specifically intellectual and sensory disabilities focused on improving learning.

According to Shalock, the quality of life can be considered in well-being: emotional, material, personal, physical and social inclusion. There are different types of disability; mental, intellectual, visual, auditory and physical; in the case of our study, inclusion is considered for three types of disability: visual, auditory and physical. (Romero, 2018).

2. OBJECTIVES

For the United Nations (UN), disability is a general term that covers impairments, activity limitations, and participation restrictions. Impairments are problems affecting a body structure or function; activity limitations are difficulties in performing actions or tasks, and participation restrictions are problems in participating in life situations. (Sabeth, 2022)The International Classification of Functioning, Disability, and Health (ICF) has as its main objective to provide a unified and standardized language and a conceptual framework for the description of health and "health-related" states. The ICF belongs to the "family" of international classifications developed by the World Health Organization (WHO), which can be applied to various aspects of health.According to the World Health Organization (WHO), through the International Classification of Functioning, Disability, and Health (ICF), disability is a generic term that includes deficits, activity limitations, and participation restrictions. It indicates the negative aspects of the interaction between an individual (with a "health condition") and his or her contextual factors (environmental and personal factors). (ONCE, 2022).

Environmental Factors have an effect on all components of functioning and disability and are organized from the individual's immediate environment to the general environment. Personal Factors are a component of contextual factors but are not classified in the ICF due to the great social and cultural variability associated with them.These factors interact with the person with a health condition and determine the level and extent of that person's functioning. Environmental factors are extrinsic to the person (e.g. societal attitudes, architectural features, the legal system) and are included within the Environmental Factors classification.

Both the educational environment and the inclusive labor market for the disabled population represent a complex but possible challenge, and its objective is to contribute to the strengthening and improvement of the strategies that are carried out in the process of integration of people with physical disabilities (limitation of strength, mobility or bodily stability), so that they can perform educational and productive activities efficiently, avoiding labor risks and the progression of preexisting deficiencies or the appearance of new ones.(Palomba, 2022).

The use of aids and technical means is related to: body position, the manipulation of objects and controls, the scope and the architectural transformation to eliminate physical barriers that impede their performance and mobility. (Romero, 2018).

Regarding the enjoyment of the right to education of people with disabilities, the CNDH official emphasized two essential concepts: accept and include, that is, provide the student with disabilities with all the pedagogical and didactic tools so that he or she acquires significant learning with the same learning opportunities as students without disabilities.

Based on the above, it is necessary to include another concept: Universal Design, which is a strategy for planning and designing products and environments aimed at achieving an inclusive society that ensures full equality and participation for all people.

Universal Design is the design of products and environments so that they can be used by all people, to the greatest extent possible, without the need for adaptation or specialized design.

Priority points to be modified according to the Universal Design Principles:

- The use of elevators in all buildings.
- Signage and use of ramps in auditoriums and hallways.
- Benches for left-handed people.
- Accessible bathrooms with handrails.
- Motorized chairs with lever control, for people with temporary or permanent disabilities.
- Signage appropriate to the conditions of the environment or the sensory capabilities of the user.
- Design of laboratory facilities that allow free access and movement within them with wheelchairs or any other accessory for people with disabilities.
- Stairs with protection at the bottom, since it is risky for a distracted or blind person who can hit themselves.

In the facilities, it is also necessary to make adjustments, such as: painting the edges of doors and windows with bright colors, placing ergonomic handrails on the stairs, placing mats attached to the floor without edges with protuberances to signal that there is an electric glass door below, the bathrooms must be enlarged since their size is very narrow and the person with their guide dog would not fit, with respect to lighting, excessive contrasts between the buildings and the exterior must be avoided.

Psycho pedagogical counseling to stimulate their capacities without emphasizing their altered functions, favoring the integral development of learning. In the case of disability in the sensory function, the tiflotechnical room will be implemented designed to support students who have a visual disability. In hearing disabilities, the Mexican Sign Language (LSM) interpretation service will be provided by interpreters. (Vázquez, 2021)

Cognitive Ergonomics studies mental processes such as perception, memory, reasoning, and physical response in interactions between people and the components of a system.

Its objective is to identify the perception process (identification, perception, establishment of patterns, among others), its thought or cognitive process (memory, analysis, recognition) and the response generated by them. It deals with studying the context in which the personnel operates in order to identify whether the responses and results obtained are a consequence of an interface between the environment and the individual, whether it is generated by conscious decisions or human errors and, most importantly, whether they were generated by the way in which information is processed in the mind of each individual. (STPS, 2023)

It highlights in a relevant way the mental workload in decision making, expert functioning, human-computer interaction, human reliability, stress, training and training, to the extent that these factors can be related to the design of the human-system interaction. Numerous models have been developed to explain how people process information. Many of these models consist of black boxes representing the various stages of processing. The generic model consists of four major stages or components; perception, decision, and response selection, response execution, memory, and attentional resources distributed across the different stages. The decision-making component, combined with working memory and long-term memory, can be considered the central processing unit, while the sensory store is a transitive memory, located at the input stage (Romero, 2018.)

3. METHODOLOGY

The Institution has open areas with many level changes and depressions where it is necessary to place signaling strips that a visually impaired person can detect with their feet (pododactiles) complementing with guide strips, to signal the path that a blind person can follow to reach their destination.

For people with low vision, optical aids have not been considered in any of the areas, which would be ideal for students to have access to teaching, but mainly in the library when consulting information, supporting them with hand magnifiers, support magnifiers, monoculars, binoculars, screen magnifying software and light filters. It is also necessary to include brochures and magazines with large print, as well as readjust the size of the tables and the color of the chair. (UTSC, 2015)

There are currently different concepts and myths about the concept of disability, which originated throughout the history of humanity, many of them erroneous and based on prejudices and erroneous opinions. Therefore, it is important to identify the barriers to the full participation of people with disabilities, which is essential to ensure their full integration into society.

In Mexico, according to data from the National Institute of Statistics and Geography (INEGI) 2024, 6.4% of the country's population (7.65 million people) reported having at least one disability. (INEGI, 2024)

This is also related to the lower educational level of this population group. Although the older the age, the more acute the educational difference, there is a high number of people with disabilities of school age who are not doing so, which is important to take actions for inclusion. The Institution has open areas with many level changes and depressions where it is necessary to place signaling strips that a visually impaired person can detect with their feet (pododactiles) complementing with guide strips, to signal the path that a blind person can follow to reach their destination. For people with low vision, optical aids have not been considered in any of the areas, which would be ideal for students to have access to teaching, but mainly in the library when consulting information, supporting them with hand magnifiers, support magnifiers, monoculars, binoculars, screen magnifying software and light filters. It is also necessary to include brochures and magazines with large print, as well as readjust the size of the tables and the color of the chair. (Palomba, 2022)

There are currently different concepts and myths about the concept of disability, which originated throughout the history of humanity, many of them erroneous and based on prejudices and erroneous opinions. Therefore, it is important to identify the barriers to the full participation of people with disabilities, which is essential to ensure their full integration into society.

In Mexico, according to data from the National Institute of Statistics and Geography (INEGI) 2014, 6.4% of the country's population (7.65 million people) reported having at least one disability. This is also related to the lower educational level of this population group. Although the older the age, the more acute the educational difference, there is a high number of people with disabilities of school age who are not doing so, which is important to take actions for inclusion.

The main objective of this section is to review inclusive language for people with disabilities, since they deserve to be treated with respect and this respect must begin with the way we express ourselves or the terms we use when referring to people. The importance of stopping using words in our vocabulary that can be discriminatory or compassionate is very important, since many of these words have become insults and so that we can understand the advances that special education has had in Mexico and how all these terms have evolved. (ANUIES, 2022)

The following table shows some terms that are incorrect and that can indicate inappropriate vocabulary to refer to people with disabilities and on the left side the correct way to express oneself is shown.

Table 2 Vocabulary with incorrect terms and correct expressions to refer to people with disabilities. Prepared from data from the course People with Disabilities: Transforming Barriers into Opportunities by the CNDH. (Romero Salcedo, A., 2018)

SAY:	INSTEAD OF:
People with disabilities	Disabled, handicapped, sick, incapacitated, different people, people with different abilities, people who suffer or have a disability.
He/she is a wheelchair user.	He/she is confined to a wheelchair,
She is a person with a physical-motor disability.	bedridden, crippled, handicapped, invalid
She is a person with a physical-motor disability.	She is lame, crippled
Person with autism	The deaf, deaf-mute
Person with intellectual disability	The autistic
Person with Down syndrome	Mentally retarded, retarded, dumb,
Person with visual disability/blind person	sickly.
Person with low vision	Down child, mongoloid,
Person with psychosocial disability	little mongoloid.
Children, women, youth with disabilities, indigenous people with disabilities, population with disabilities	The blind, blind child

4. RESULTS

The survey was conducted through a form on Google Classroom due to the pandemic. 25 basic education teachers were invited to complete this survey, of which only 20 teachers answered the survey.

Learning strategies for children with sensory and intellectual disabilities:

1. “Do exercises on tiptoe, make movements through music. Sensory, establish a routine for example of daily activities.”
2. “Through various visual tactile learning mechanisms.”
3. “Skills, video and musical activities.”
4. “Ordering sequences, selecting elements by categories, linking words with images, recognizing emotions, games with visual stimuli.”
5. “Motor disability.”
6. “Comprehension and reasoning test to measure the performance of the mental mechanism.”
7. “I notify the parents and have them go to a specialist.”
8. “An interview is conducted with the parents and they are induced to go to an institution or a specialist to make the relevant diagnosis.”
9. “I would refer him to a specialist.”
10. “Get help and show the instances that can support him.”
11. “Perform tests that refer to this situation, to inform and support from specialists.”
12. “Inform the parents of what was observed and request referral for evaluation.”
13. “Make adjustments to the plan using video and audio.”
14. “Refer him to a specialist.”

5. DISCUSSION/CONCLUSIONS

The implementation of PESI requires specialized work according to the particular needs of each institution. It must begin in parallel with the acquisition and development of teaching aids, changing attitudes due to the lack of information of some teachers and administrative staff about the problems of people with disabilities and their invisibility among their peers. The proposal of a learning strategy for girls and boys with sensory and intellectual disabilities, which was carried out taking into account the previous description of the strategies for girls and boys with sensory and intellectual disabilities and the needs of each NNA depending on the degree of disability that is had, for the realization of this strategy we must take into account that to achieve this learning focused on natural sciences it has to be contemplated to relate the scientific concepts defined or explained by means of examples that girls and boys with disabilities have around them and for it to become significant to reinforce with exercises or a series of questions on the specific topic ending with the experimental part, the importance of reaching this strategy is to take into account all the procedures mentioned above in this research that range from the early diagnosis of sensory and intellectual disability, the modification of the curriculum and even the selection of strategy so that education is completely inclusive and not only channel them with an expert, since as teachers we can make these modifications so that this learning in natural sciences can be acquired in girls and boys with sensory and intellectual disabilities. On the other hand, the adaptation part for accessibility for A student with a disability requires great sensitivity based on Universal Design, which, being a new concept, requires an Ergonomic culture; which we must gradually incorporate, breaking paradigms to achieve a more equitable coexistence.

6. REFERENCES

Asociación Nacional de Universidades e Instituciones de Educación Superior (ANUIES) y Presidencia de la República; 2022; "Manual para la Integración de Personas con Discapacidad en las Instituciones de Educación Superior"; México

Fundación ONCE. (2022). Nuevos conceptos. Recuperado de http://www.fundaciononce.es/SiteCollectionDocuments/Accesibilidad/Nuevos%20 Conceptos%20Jesús%20Hernández.pdf

INEGI, 2024 Características educativas de la población Recuperado de https://www.inegi.org.mx/temas/educacion/

Palomba, Rosella (2022) Calidad de Vida: Conceptos y Medidas. Institute of Population Research and Social Policies. Italia. En: http://www.eclac.org/celade/agenda/2/10592/envejecimientoRP1_ppt.pdf

Real Academia Española. (2021). Recuperado de: http://lema.rae.es/drae/?val=tiflotecnica

Romero Salcedo, A., 2018. GUÍA de diseño de espacios laborales ergonómicos para trabajadores con discapacidad. Segunda edición ed. México, D.F.: STPS.

Sabeth y Gómez-Varela, "Calidad de vida. Evolución del concepto y su influencia en la investigación y la práctica". Fuente: http://campus.usal.es/~inico/investigacion/invesinico/calidad.htm.

STPS. (2023). MANUAL de Organización General de la Secretaría del Trabajo y Previsión Social. Recuperado de http://www.stps.gob.mx/bp/secciones/conoce/ManualSTPS2015DOF.pdf

UTSC, 2015. Clasificación de la Discapacidad. 2015 ed. Monterrey, N.L.: UTSC.

Vázquez-Barquero, J. L. (2021). Clasificación Internacional del Funcionamiento de la Discapacidad y de la Salud. Santander: OMS

EVALUATION OF ERGONOMIC RISK FACTORS IN A STAINLESS STEEL FIBER MANUFACTURING COMPANY.

Guadalupe Ivonne Borja Gutiérrez[1], ORCID: 0009-0003-2047-3075[1], Olivia Guevara Galindo[1], ORCID:0000-0001-7233-2440[1], Ignacio Adrián Romero[1], ORCID: 0000-0002-6243-7940[1]

[1]Sección de Estudios de Posgrado e Investigación, ESIME-Azcapotzalco.
Instituto Politécnico Nacional
Avenida de las granjas 682
Colonia Santa Catarina, C. P. 02550
Ciudad de México, México.

Corresponding author's e-mail: gborjag1500@alumno.ipn.mx

Resumen: En este estudio se realizó un análisis de los puestos de trabajo en una empresa productora de fibras de acero inoxidable, con el propósito de identificar factores de riesgo ergonómicos que pudieran afectar la salud de los operarios. Se identificaron 14 tareas que conforman los puestos de trabajo, mediante los métodos de investigación ergonómica observación y entrevista; se determinaron once tareas críticas (1,4,5,6,7,8,9,10,11,13 y 14) y tres como tareas despreciables (2,3 y 12). Para evaluar el nivel de riesgo de las tareas críticas, se aplicó el método de evaluación ergonómica RULA (Rapid Upper Limb Assessment). Los resultados de los análisis indicaron que la tarea 4 obtuvo un nivel de 2 (se pueden requerir cambios); la tarea 11 obtuvo nivel 3 (se requieren cambios); las tareas 1, 5, 6, 7, 8, 9, 19, 13 obtuvieron un nivel 4, lo que implica la necesidad de realizar cambios inmediatos en las tareas. La aplicación de este método permitió identificar las tareas que requieren cambios inmediatos para evitar que se presente algún tipo de lesión en el operario, debido al inadecuado diseño que presentan actualmente los puestos de trabajo.

Palabras clave: Puesto de trabajo, fibras de acero, lesiones musculoesqueléticas, factores de riesgo ergonómico, método RULA.

Relevancia para la ergonomía: La relevancia de este estudio para la ergonomía radica en la identificación y evaluación de factores de riesgo ergonómicos en un proceso de manufactura, lo que permite determinar la rapidez con la cual se deben realizar mejoras en el diseño de los puestos de trabajo con la finalidad de reducir lesiones de tipo musculo esquelético a los operarios, para no afectar su salud y no causar ausencia o abandono de trabajo.

Con estudios de este tipo, se comprueba la importancia de la Ergonomía en diversos procesos de la industria manufacturera.

ABSTRACT: In this study, an analysis of the job positions in a stainless steel fiber manufacturing company was conducted to identify ergonomic risk factors that could affect workers' health. A total of 14 tasks that make up the job positions were identified through ergonomic evaluation methods, including observation and interviews. Eleven tasks (1,4,5,6,7,8,9,10,11,13, and 14) were classified as critical, while three (2,3, and 12) were deemed negligible. To assess the risk level of the critical tasks, the Rapid Upper Limb Assessment (RULA) ergonomic evaluation method was applied. The analysis results indicated that Task 4 received a risk level of 2 (changes may be required); Task 11 received a level of 3 (changes are required); and Tasks 1, 5, 6, 7, 8, 9, 10, and 13 received a level of 4, implying the immediate need for modifications. The application of this method allowed for the identification of tasks that require immediate changes to prevent potential injuries to workers due to the inadequate design of the current job positions.

Keywords: Job position, steel fibers, musculoskeletal injuries, ergonomic risk factors, RULA method.

Relevance to Ergonomics: The relevance of this study to ergonomics lies in identifying and evaluating ergonomic risk factors in a manufacturing process, which helps determine the urgency of implementing improvements in job design. These improvements aim to reduce musculoskeletal injuries among workers, thus protecting their health and preventing absenteeism or job abandonment. Studies like this demonstrate the importance of ergonomics in various manufacturing industry processes.

1. INTRODUCTION

Mexico faces a variety of occupational hazards in the manufacturing industry, ranging from falls to industrial accidents in production plants. These risks can lead to musculoskeletal injuries, chronic fatigue, and other disorders that affect workers' health, highlighting the importance of ergonomics in the workplace.

Ergonomics, as a discipline, seeks to adapt working conditions to human capabilities and limitations, reducing risk factors and improving employee safety and well-being (Dul & Weerdmeester, 2008).

Failure to comply with safety regulations, lack of monitoring, and insufficient staff training are factors that contribute to workplace accidents and occupational diseases. In this context, ergonomics plays a key role by providing strategies to design safer and more efficient work environments, minimizing workers' physical and mental strain, and preventing injuries caused by improper postures, repetitive movements, or excessive effort (Marras & Karwowski, 2006).

In Mexico, the Secretariat of Labor and Social Welfare (STPS) and the Mexican Institute of Social Security (IMSS) are the government entities responsible for workers' health and safety. Additionally, there are mandatory regulations that employers must comply with, such as the Federal Labor Law and the General Health

Law. The Official Mexican Standard NOM-019-STPS-2011 establishes guidelines for workplace safety and health (STPS, 2011).

These regulations aim to ensure that companies implement appropriate measures for occupational risk prevention and ergonomic improvements in workplaces.

1.1 Background of the Problem

Since 2019, a company located in Mexico City has been engaged in the manufacturing and commercialization of stainless steel fibers at both national and international levels. The final product is presented in the form of spirals, as shown in Figure 1.

Figure 1. Final presentation of stainless steel fibers.
Courtesy of the company.

The manufacturing of stainless steel fibers is a process that involves several stages. It begins with the raw material (stainless steel wire), which is transferred to the production stage. Here, the wire is fed into a machine that performs the drawing process (reducing the wire's thickness). The drawn wire is then passed to another machine, where it is woven to produce a semi-finished fiber in a spiral shape.

The semi-finished fiber then moves to the conditioning stage, where a worker applies pressure with their hands on the fiber to achieve the final shape. The fibers undergo a quality inspection to ensure they meet the required standards, verifying properties such as strength, uniformity, and integrity.

Once the fibers pass the quality inspection, they are properly packaged and prepared for shipping and distribution (packaging stage). Figure 2 illustrates the manufacturing stages, from raw material intake to the packaging of the finished fibers.

The job positions (production, conditioning, and packaging) were analyzed to determine the tasks involved. The importance of analyzing these tasks separately lies in identifying those that pose a high risk to workers. The tasks were classified into two types: negligible tasks and critical tasks.

A negligible task is one that does not endanger workers' health. In contrast, a critical task is an activity that could potentially cause injury to the worker.

Figure 2. Example of the stainless steel fiber manufacturing process.
Courtesy of the company.

1.2 General Objective

To analyze job positions to determine possible ergonomic risk factors that could affect workers' health through ergonomic research methods and the RULA ergonomic evaluation method.
Since productivity is essential for the company, the results of this study were used to identify areas of opportunity that contribute to the comprehensive improvement of job positions.

2. MATERIALS AND METHODS

The following materials and work methods were used to carry out this study.

2.1 Materials

a. A camera and video recorder were used to document the tasks involved in the job positions.
b. A design software was used to draw the working angles adopted by workers during task execution. The resulting images were utilized in applying the RULA ergonomic evaluation method.
c. The mannequins used in the RULA method application were modeled using MakeHuman and Blender software.
d. The tables containing the information for the RULA methodology were redesigned.

2.2 Methods

Two stages were applied in the development of the RULA methodology.

2.2.1 Identification of Critical and Negligible Tasks. Critical and negligible tasks that make up the job position were determined using ergonomic research methods, such as observation and interviews (Tamayo, 2014).

2.2.2 Application of the RULA Ergonomic Evaluation Method. The RULA ergonomic evaluation method was applied to the identified critical tasks.

2.2.3 RULA Ergonomic Evaluation Method

The primary objective of the RULA ergonomic evaluation method is to identify improper postures that may cause musculoskeletal disorders due to repetitive movements, prolonged exertion, or forced postures (McAtamney & Corlett, 1993). This methodology focuses on evaluating the upper limbs during a work shift. This method has been widely used to assess various processes in job positions within different manufacturing companies (Guevara-Galindo, O., Aguilar-Castro, E., & Romero, I. A., 2024); (Cota, Y., Flores, X., & Urías, S. M., 2021); (Saavedra Ángeles, D. R., & Urriburu Broncano, J. L., 2020); (Cermeño, 2019); (Mejía, R. S., Arévalo, F. J., Guerrero, A., Chávez, G. E., 2019), obtaining results that indicate the presence of ergonomic risk factors in job positions. The RULA method divides the human body into two groups: Group A, which analyzes the upper limbs, including the arms, forearms, and wrists. And the group B, which evaluates the neck, trunk, and legs (Asencio, S., Bastante, M. J., & Diego, J. A., 2012). Figure 2 illustrates the body parts analyzed in Groups A and B.

Figure 2. Body parts analyzed, divided into Group A and Group B according to the RULA method.

Using the tables associated with the method, a score is assigned to each body area based on the working angle it generates and the group to which it belongs. Subsequently, a score is determined depending on the type of activity. Additional values are assigned for loads or forces involved in the workers' tasks. Global score are then assigned to each group, leading to the final score, which determines the level of action that should be implemented in the job position. Figure 3 represents the methodology used to obtain the level of action.

Figure 3 methodology used to obtain the level of action.
Source: https://www.ergonautas.upv.es/metodos/rula/rula-ayuda.php.

Table 1 presents the final score values obtained through the RULA method for the analyzed task and its corresponding level of action.

Table 1. Leve lof actions to the final score obtained.
Source: https://www.ergonautas.upv.es/metodos/rula/rula-ayuda.php

Puntuación	Nivel	Actuación
1 o 2	1	Riesgo Aceptable
3 o 4	2	Pueden requerirse cambios en la tarea, es conveniente profundizar en el estudio
5 o 6	3	Se requiere el rediseño de la tarea
7	4	Se requieren cambios urgentes en la tarea

3.1 Task Description. The tasks performed by the operator at each job position are described to determine critical and negligible tasks.

3.1.1 Production

Task 1: Transporting reels from the warehouse to the workstation
The process begins when the operator arrives at their workstation and must go to the warehouse to retrieve the raw material (the wire). The operator walks approximately 5 meters to reach the warehouse. Each reel weighs between 5 to 16 kg, and the package contains two reels, which the operator carries as best as they can before placing them on the wire drawing machine to begin operations. This task

is considered critical because the operator adopts poor postures while carrying the reels. Figure 4 illustrates the activity performed by the operators.

Figure 4. Worker carrying a reel.
Courtesy of the company.

Task 2: Filling buckets with water for the reels

The next activity in this area involves placing the reels in water. Each worker has four buckets for soaking the wire reels. They empty the dirty water, refill the buckets with clean water, and place them back in their workstation. This task is considered negligible as it does not pose a risk to the operator. The movement is not repetitive, and the weight is not excessive enough to cause harm. Figure 5 illustrates the activity performed by each operator.

Figure 5. Operator carrying buckets of water.
Courtesy of the company.

Task 3: Inserting wire into the machine

With the reels placed in their respective water buckets, the operator begins inserting the wire into the machine to start the operation. This task is considered negligible as it does not pose any significant physical risk to the operator. The only potential hazard is the risk of cuts from handling the wire. Figure 6 illustrates the operator performing this activity.

Figure 6. Worker inserting wire into the machine.
Courtesy of the company.

Task 4: Placing a container in the machine

Once the operator starts the machine, they proceed to place a container to collect the fibers being produced. This task is considered critical due to the poor posture the worker adopts while performing the activity, which could lead to injuries. Additionally, it is a repetitive movement throughout the work shift, increasing the risk of musculoskeletal disorders. Figure 7 illustrates the operator performing this task.

Figure 7. Worker lifting a container to store fibers.
Courtesy of the company.

Task 5: Transporting the container with fibers to the release area
Each time a container is filled with fibers, the operators must carry it to the designated area where a quality control worker performs the release process. This task is considered critical because each container weighs approximately 7 to 9 kg, and workers adopt poor postures while lifting them. Since this task is repetitive throughout the work shift, it increases the risk of injuries. Figure 8 illustrates this activity.

Figure 8. Operator carrying a container with fibers.
Courtesy of the company.

3.1.2 Conditioning

Task 6: Carrying a container from storage to the workstation
The conditioning staff must retrieve fiber-filled containers from the storage area and transport them to their workstations. This task is considered critical because each container weighs 7 to 9 kg, and the movement is repeated throughout the work shift, increasing the risk of musculoskeletal injuries. Figure 9 illustrates this activity.

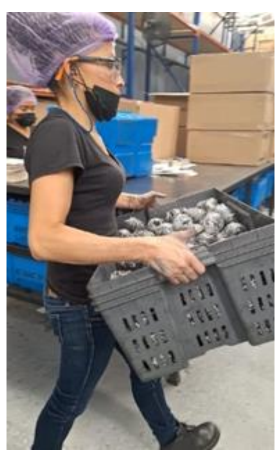


Figure 9. Worker carrying a container of fibers to the workstation.
Courtesy of the company.

Task 7: Placing the container on the work table

The conditioning staff places the fiber container at their workstation, positioning it under the worktable while placing one container on top to begin shaping the semi-finished fibers. This activity is considered critical due to poor handling of the containers, which weigh between 7 and 9 kg. Figure 10 illustrates the task.

Figure 10. Worker placing a container of fibers at their workstation.
Courtesy of the company.

Task 8: Manually conditioning the fiber

The conditioning staff manually shapes the stainless steel fibers by applying circular motions and pressing down on them.

This task is considered critical as it involves repetitive movements, with workers processing between 300 to 600 pieces per hour, which increases the risk of musculoskeletal injuries. Figure 11 illustrates this activity.

Figure 11. Worker pressing the semi-finished fiber to obtain the final shape.
Courtesy of the company.

Task 9: Placing the conditioned fiber container in the release area
After shaping the stainless steel fiber, it is placed into another container so that the conditioning staff can move it to the quality control release area, where it is inspected to ensure it meets the required standards. This task is considered critical since each container can weigh between 9 and 12 kg, potentially causing injuries to the workers. Figure 12 illustrates the activity.

Figure 12. Worker placing a container for quality inspection.
Courtesy of the company.

3.1.3. Packaging

Task 10: Transporting the conditioned fiber from storage to the workstation
The packaging staff must retrieve the conditioned fiber from the storage area and bring it to their workstation.
This task is considered critical because the containers weigh between 9 and 12 kg, posing a risk of injury. Figure 13 illustrates the activity.

Figure 13. Worker carrying a container to their workstation.
Courtesy of the company.

Task 11: Placing the container on the work table

The packaging staff places the containers under their workstation and then places one container on the table to begin the packaging process. This task is considered critical because the containers have a significant weight, which could potentially cause health issues. Figure 14 illustrates the activity.

Figure 14. Worker packaging the fiber.
Courtesy of the company.

Task 12: Placing the necessary materials in the work area

The packaging staff retrieves supplies from the storage area, such as individual boxes, protective paper, and final stacking boxes. These materials are then placed at their workstation, and the stainless steel fibers are packaged. This activity is classified as negligible, as the weight of the empty boxes is approximately 1 kg, posing no significant risk to workers' health. Figure 15 illustrates the activity.

Figure 15. Worker placing their supplies.
Courtesy of the company.

Task 13. Place the finished box at the release site.
Each time the packing personnel finish preparing a box with the requested requirements, they take it to the quality control release site. This task is considered critical because each box weighs between 7 and 8.5 kg and could cause injury. Figure 16 illustrates the activity.

Figure 16. Operator transferring the box to quality control. Courtesy of the company.

Task 14. Load the truck when necessary.
Every time the order is complete, the packing personnel carry the boxes one by one to a truck for transfer. This task is considered critical because the personnel climb on the racks without any protection and perform bad postures, mishandling the loads, which could cause damage to their health. Figure 17 shows the activity.

Figure 17. Operator storing finished product box. Courtesy of the company.

The results obtained from the analysis show that tasks 2, 3 and 12 are determined as negligible, tasks 1, 4, 5, 6, 7, 8, 9, 10, 11, 13 and 14 are determined as critical, Table 2 concentrates the results.

Table 2. Results of the analysis with the negligible and critical tasks.

TASK	DESCRIPTION	RESULT
1	Loading spools from storagee to the workstation	**Critical**
2	Loading buckets of wáter for the spools	Negligible
3	Inserting thread into the machinery	Negligible
4	Placing a container in its machine	**Critical**
5	Placing te fiber-filled container in the release area	**Critical**
6	Loading the container from storage to the workstation	**Critical**
7	Placing the container on the Workstation table	**Critical**
8	Conditioning the fiber by hand	**Critical**
9	Placing the conditioner fiber container in the reléase area	**Critical**
10	Loading the conditioner container from storage to the Workstation	**Critical**
11	Placing the container on the workstation table	**Critical**
12	Placing the corresponding supplies in the workstation	Negligible
13	Placing the finished box in the reléase área	**Critical**
14	Loading the truck when necessary	**Critical**

3.2 Application of the RULA ergonomic evaluation method to critical tasks.

Task 1. Loading of reels from the warehouse to the work place.

Figure 18 shows the images of the operator with the angles generated in his various working postures during the execution of the task.

Figure 19 shows the methodology indicated in Figure 3. Task 1 obtains a final score of 7. According to the information in Table 1, the corresponding action level is 4, which means that an urgent change in the task is required to avoid a possible injury affecting the operator's health.

Applying the development of the method to all critical tasks, the results are shown in Table 3.

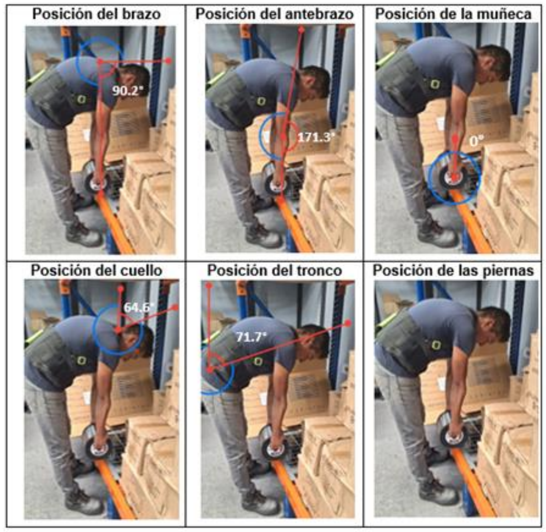


Figure 18. Operator angles used in the ergonomic analysis of task 1.

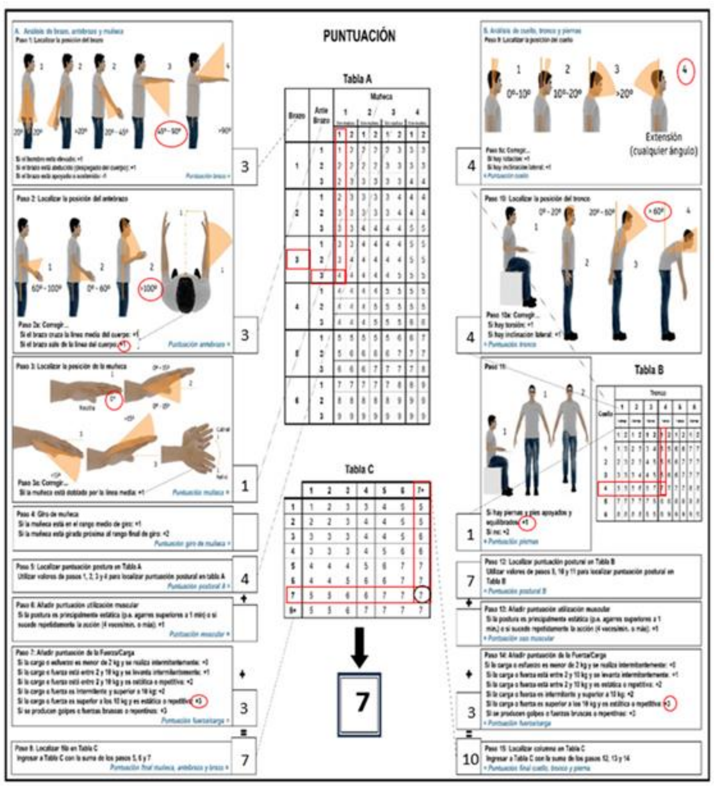


Table 3. Results of the critical tasks indicating the level of performance obtained.

Task	Overall Score	Sction level
Task 1: Loading spools from storage to the workstation	7	Level 4: Urgent changes are required in the task
Task 4: Placing a container in its machine	4	Level 2: Changes may be requiered in the task, it is advisable to conduct a deeper study
Task 5: Placing the fiber-filled container in the reléase area	7	Level 4: Urgent changes are required in the task
Task 6: Loading the container from storage to the workstation	7	Level 4: Urgent changes are required in the task
Task 7 Placing the container on the Workstation table	7	Level 4: Urgent changes are required in the task
Task 8: Conditioning the fiber by hand	7	Level 4: Urgent changes are required in the task
Task 9: Placing the container fiber container in the release area	7	Level 4: Urgent changes are required in the task
Task 10: Loading the conditioner container from storage to the workstation	7	Level 4: Urgent changes are required in the task
Task 11: Placing the container on the Workstation table	6	Level 3: Task redesign is required
Task 13: Placing the finished box in the release area	7	Level 4: Urgent changes are required in the task
Task 14: Loading the truck when necessary	7	Level 4: Urgent changes are required in the task

The results obtained show that task 4 obtained level 2, which means that changes may be required, although it is not urgent. Task 11 obtained level 6, meaning that there must be a change so that in the future there are no injuries to the operators. Tasks 1, 5, 6, 7, 8, 9, 19, 13 and 14 require urgent changes so as not to cause injuries that could affect the health of the operators in the short term.

During the study it was determined that the operators require a high level of physical effort, the movements are repetitive with excessive loads and the postures are uncomfortable. The workers suffered injuries or musculoskeletal discomfort during their activities, causing absence or abandonment of work.

4. CONCLUSIONS

In order to determine ergonomic risk factors in the operators of the stainless steel fiber manufacturing company, the corresponding research was carried out using an ergonomic evaluation methodology. The application of the RULA ergonomic evaluation method was appropriate because its implementation provided the necessary information to evaluate the tasks performed by the workers and to determine risk factors.

The use of design software was useful to obtain the angles generated by the operator in different postures during his activity and with which the method was applied; in addition, the computer program allows all the required changes to be made practically immediately, optimizing the work time.

The ergonomic research methods, observation and interview, were useful to identify postures, movements, among others; to record the elements that make up the work station, (machines, tables, benches, chairs, etc.) and to record the comments of the operators regarding the development of their activity.

The applications of ergonomic evaluation methods are not common in companies, mainly in small and medium-sized ones, due to lack of knowledge on this subject or because they remain skeptical about the results that ergonomic improvements could bring to the workplace and to productivity, or because they consider that investing in the redesign of workplaces is costly.

4.1 Recommendations.

It is recommended to proceed with the redesign of the workstations; it is necessary to adopt adequate measures to monitor and control the activities, including the provision of the necessary personal protective equipment, such as anti-cut gloves, ear protectors, belts, and skates; in addition to acquiring equipment such as conveyor belts to help move the products, and the design and manufacture of auxiliary elements; finally, to carry out general maintenance of the equipment.

The benefits that the company can obtain with the recommended changes is a lower payment of the risk premium before the IMSS, because the medical incapacities of the operators would be reduced or eliminated; it would contribute to reduce or avoid injuries that put at risk the health of the operators and finally the absence or abandonment of the work would be reduced or eliminated.

This research focused only on postures, but it is suggested to conduct studies on lighting and noise, because it is important to consider the entire work environment.

It is also recommended to invest in a comprehensive wellness program for all employees, creating a safer and more satisfying environment for them. The comprehensive approach will contribute to the sustainable growth of the company and strengthen its long-term competitiveness.

5. REFERENCES

Asencio, S., Bastante, M. J., & Diego, J. A. (2012). Evaluación ergonómica de puestos de trabajo. Ediciones Paraninfo.

Cermeño, H. (2019). Evaluación ergonómica de la labor de operador de taller de maestranza de una fundición. Ergonomía Investigación y Desarrollo, 1(2), 93-110. https://revistas.udec.cl/index.php/Ergonomia_Investigacion/article/view/1278

Cota, Y., Flores, X., & Urías, S. M. (2021). Analysis of the ergonomic conditions in the workstations of a maquiladora through the implementation of the rula method. Ergonomía Ocupacional. Investigaciones y Aplicaciones, 14, 128-138.
Ed. Sociedad de Ergonomistas de México. México. https://semac.org.mx/_src/pdf/libros/libro2021.pdf

Dul, J., & Weerdmeester, B. (2008). Ergonomics for beginners: A quick reference guide (3rd ed.). CRC Press.

Guevara-Galindo, O., Aguilar-Castro, E., & Romero, I. A. (2024). Análisis ergonómico de un puesto de trabajo de embalaje para determinar factores de riesgo. *Ergonomía, Investigación Y Desarrollo*, *6*(3), 80-94. https://doi.org/10.29393/EID6-20AEOI30020

Instituto Mexicano del Seguro Social. (2023). Memoria estadística 2023: Salud en el trabajo. https://www.imss.gob.mx/memoria-estadistica

Marras, W. S., & Karwowski, W. (2006). The occupational ergonomics handbook (2nd ed.). CRC Press.

McAtamney, L., & Corlett, E. N. (1993). RULA: A survey method for the investigation of work-related upper limb disorders. Applied Ergonomics, 24(2), 91-99. https://doi.org/10.1016/0003-6870(93)90080-S

Mejía, R. S., Arévalo, F. J., Guerrero, A., Chávez, G. E. (2019). Evaluación de puestos de trabajo por medio de los métodos Rodgers, Owas, Niosh y Rula. Ergonomía, Investigación y Desarrollo, 1(3), 118-137. https://revistas.udec.cl/index.php/Ergonomia_Investigacion/article/view/1352

Saavedra, Ángeles, D. R., & Urriburu Broncano, J. L. (2020). Aplicación del método RULA en posturas ergonómicas para reducir la accidentabilidad de colaboradores en BIZ SUPPORT SAC. Lima, 2020.
https://alicia.concytec.gob.pe/vufind/Record/UCVV_c1e169b34c72071011816859828188e1

Secretaría del Trabajo y Previsión Social. (2011). NOM-019-STPS-2011, Constitución, integración, organización y funcionamiento de las comisiones de seguridad e higiene en los centros de trabajo.
https://dof.gob.mx/nota_detalle.php?codigo=5185903&fecha=13/04/2011#gsc.tab=0

Tamayo, M. (2014). El proceso de la investigación científica (6ª ed.). Editorial Limusa. México.

INFORMATION BEHAVIOR IN THE CONTROL AREA OF THE QUALITY SYSTEM

Guadalupe Hernández-Escobedo, Orcid: https://orcid.org/0000-0002-7516-972X**; Alan Castillo-Salazar; Arturo Realyvázquez-Vargas, Orcid:** https://orcid.org/0000-0003-2825-2595**; Amalia Carmina Salinas-Hernandez, Corina Plata-Ante,** https://orcid.org/0000-0002-6453-9529

Departmento de Ingeniería Industrial
Tecnológico Nacional de México/Instituto Tecnológico de Tijuana
Calzada Tecnológico S/N
Fraccionamiento Tomás Aquino
Tijuana, Baja California 22414

Corresponding author's e-mail: ghernan@tectijuana.mx

Resumen: La finalidad de este proyecto fue el desarrollo e implementación de una base de datos dentro del departamento de documentación del sistema de gestión de calidad. Esto fue para reducir los tiempos de búsqueda e interpretación y uso de información y así incrementar la satisfacción del usuario en relación a su comportamiento informativo. Este comportamiento incluye la búsqueda, la localización y el uso (incluyendo interpretación) de la información que el usuario le dará a ésta. Estas actividades, no consideradas como tal, son llevadas a cabo por distintos departamentos de la empresa, ya que dentro de sus actividades rutinarias, requieren información de otro u otros departamentos para llevarlas a cabo y la mayoría de las veces, la búsqueda se hace de forma individual dentro del sistema. Por ello, se diseño e implementó una base de datos que incluía la mayoría de documentos e información que comunmente se usa. Con ello se logró la disminución de los tiempos de búsqueda e interpretación y uso de la información, así como el incremento en el uso de la base de datos. Los18 participantes de dicho estudio convergían de seis departamentos señalando un incremento de su satisfación de 23.34 % y reduciendo los tiempos empleados en la interpretación y uso de la información. Esto, a su vez, permitió confirmar las ventajas operacionales del uso de tecnologías para apoyar las diversas actividades de los usuarios impactando directamente en el comportamiento informativo, escasamente estudiado y mejorado en contextos naturales.

Palabras clave: Comportamiento informativo, sistema de calidad, base de datos, herramientas abstractas

Relevancia para la ergonomía: El presente proyecto sirvió para mejorar el comportamiento informativo dentro de un contexto laboral. Esto ayudó a incrementar la productividad en el área de calidad, principalmente en las actividades de búsqueda e interpretación de la información. Esto fue a través de la comprensión de las actividades desarrolladas por los usuarios y su toma de conciencia y el impacto dentro de sus actividades rutinarias de trabajo. De ahí que este proyecto permitió comprender y evaluar la utilización del enfoque de la Ergonomía Cognitiva en contextos que han sido parcialmente empleados en ello, encontrando ventajas en su uso donde el ser humano es el principal factor considerando alineando las herramientas tecnológicas para facilitar las actividades laborales a desarrollar en los contextos participantes.

Abstract: The purpose of this project was the development and implementation of a database within the documentation department of the quality management system. This was to reduce the search and interpretation times and use of information and thus increase user satisfaction in relation to their information behavior. This behavior includes the search, location and use (including interpretation) of the information that the user will give to it. These activities, not considered as such, are carried out by different departments in the company, since within their routine activities, they require information from another or other departments to carry them out and most of the time, the search is done individually within the system. Therefore, a database was designed and implemented that included most of the documents and information that are commonly used. With this, the reduction of search and interpretation times and use of information was achieved, as well as the increase in the use of the database. The 18 participants in the study from six departments reported an increase in their satisfaction of 23.34% and a reduction in the time spent interpreting and using information. This, in turn, confirmed the operational advantages of using technologies to support the various activities of users, directly impacting the information behavior, which has been little studied and improved in natural contexts.

Keywords. Information behavior, quality system, database, abstract tools

Relevance to Ergonomics: This project served to improve information behavior within a work context. This helped to increase productivity in the quality area, mainly in the activities of searching and interpreting information. This was done through the understanding of the activities developed by users and their awareness and impact within their routine work activities. Hence, this project allowed to understand and evaluate the use of the Cognitive Ergonomics approach in contexts that have been partially used on it, finding advantages in its use where the human being is the main factor, considering aligning the technological tools to facilitate the work activities to be developed in the participating contexts.

1. INTRODUCTION

Information behavior is little known as a behavior despite being part of the human being. In Mexico, there are various investigations regarding this behavior, but these are focused on studies that involve students and information in their respective school contexts, as well as the management of libraries, information in books, research, etc. In the state of Baja California, there are studies focused on farmers and mainly on winemakers, since in a part of the state the wine industry predominates.

However, in Tijuana, this behavior is not given importance in manufacturing companies. In these, having the necessary information at hand, it is relevant to carry out one or more processes or activities and it is suggested to do. In the same way, having the information available with easy access helps to reduce the time that a worker spends looking for information in different sections of the company's server; in addition, the knowledge of processes, that are within their reach, is improved.

Likewise, it is important to point out that information search processes must be simple and quick to manipulate, so that later, the activities, required to find it, are done in the best way, hoping to be efficient. Because, when the complete process is pointed out in information behavior, in particular, it could go beyond just searching for information, but also how mentioned information is going to be used. That is, because it is useless to find something in a shorter time, if the data found is not correct or does not meet the necessary characteristics for the user, who requires it. Hence, the present project performs the analysis of information behavior in the quality area of a company located in Tijuana. The mentioned area is the documentation department of the quality management system, where activities such as the satisfaction survey in the search and use of information were carried out; in addition, the measurement of the time required to carry out the activities in the mentioned area.

The first part will describe the history of the participating company, the problems encountered, the objective of the project and its justification. The second part will present the theoretical foundation, displaying topics related to the information behavior, and databases. Later, the third part exhibits the methodology used during the study to address the problems encountered. The fourth part shows the results obtained after the development of the project, displaying the initial and subsequent situations after the implementation of the activities aimed to improve the information behavior, focusing on the search and interpretation of information for later use. The next part shows the conclusions obtained through the achievement of the commented objective. In this part, it is relevant to point out the impact on the routine operation of the improvement in information behavior. Finally, the last part lists the areas of opportunity discovered during the project and after the implementation of the improvement within the context under study. That is, some improvements to be developed in the future of the context are presented, in addition, to the personal and professional experiences acquired during the project.

Therefore, the objective of this study is to improve information behavior by implementing a database within the quality management system in order to reduce the time for searching and interpreting information. This project addresses activities that lead to a reduction in the time for searching and interpreting information for later use. The activities can generate documents that are required in the decision-making process and, by containing errors, there is the possibility of increasing the time for using information and thus making errors in commented processes. Therefore, it is relevant to point out that the information search process is a procedure that involves various resources and the fact of not having access to information through media would lead to decision-making processes where additional resources would be required to obtain the required information and thus subsequently make decisions.

Therefore, it is relevant to consider the users of mentioned information and take their perceptions and suggestions regarding the best means or instruments to have information available for decision-making processes, particularly in the area of quality. This involves addressing the social perspective of the user and making available to them various tools aimed at user satisfaction when accessing the required information, while simultaneously seeking to obtain the information required to make decisions in accordance with the needs of their responsibilities. This would also perhaps involve involving other participants such as suppliers and internal users or members of other areas or departments within and outside of the company.

2. BACKGROUND

In this section, information behavior, databases, and seek and interpret information are presented.

2.1 Information Behavior

With a focus on information science, Wilson (2000) states that information behavior is "the totality of human behavior in relation to information sources and channels, including active and passive searching, as well as the use of information" (p. 49). In relation to this, there are three behaviors: searching, finding and using information. Information seeking behavior involves the intentional search for information as a consequence of the need to satisfy a certain objective that involves information (Wilson, 2000). Behavior to find information is a "micro-level" of behavior used by the user when interacting with an information system and includes both physical actions (for example, use of the mouse, number of clicks, opening links) and intellectual actions (use of Boolean operators or application of criteria to select content) (Wilson, 2000). Finally, information use behavior consists of the set of physical and mental acts involved in internalizing the information found and incorporating it into prior knowledge. This behavior includes underlining techniques, marginal notes, extraction of main ideas and critical analysis of the content, among others (Wilson, 2000).

Along these lines, Calva González (1998) points out that when people require information, they exhibit a behavior that shows commented need that must be satisfied. That is, this need must be covered regarding the phenomenon, fact or object of interest. Hence, information behavior can be understood as the behavior that shows the information needs of subjects, which are exhibited from the lack of information and knowledge of something of interest, and those needs to be satisfied in reference to a situation, fact or phenomenon. Hence, Vázquez Velázquez (2006) indicates that information behavior is focused on those behaviors exhibited by individuals in different contexts in which they need to seek to manage, disseminate and use information. Also, Case (2006) points out that information behavior involves behaviors that include the search for information and involuntary or passive behaviors and those deliberate ones that are not considered the active avoidance of information. As part of the contexts that encompass such behavior or human information activity, it is unavoidable to underline the preponderance and rapid development of information and communication technologies and these have affected in all their extension the informational 'knowledge' and 'doings' of individuals.

2.2 Database

Databases are a set of related and non-redundant information; that is, there should not be repeated or duplicated information in different tables. This information is organized, systematized, and must be directed towards a specific purpose of a community (Nielsen, 1993). Likewise, it must meet the objectives of independence (ability to make modifications to the physical, or logical model without altering any application and data structure), integrity (consistency of the data, and in turn the values they possess, which must be valid according to the functional dependencies between the tables), and data security for the multiple users, who use it. This is because, any type of data used in a database is important so that it does not suffer changes by users, who are not properly accredited to carry out this activity.

Databases function as a kind of library in which the data is organized in cards and structured in a way in each field or place for this purpose. This structure is created to facilitate the process of searching for and using information in processes or activities of interest. That is, databases are organized work systems that allow information to be catalogued and classified, using tables that the system can use to quickly locate any information stored in them at a given time. Databases become common and powerful computer tools that exist today to organize information files in one place so as not to depend on various sources.

3. METHODOLOGY

For the development of the project, the used methodology consisted of the following primary activities, which are:

1. Sampling for the survey that was conducted with users. Prior to the preparation of the survey, an intentional sampling was determined, which consists of selecting individuals in a fast and optimal way without the need to perform any type of mathematical operation. This was done by choosing the appropriate users for the survey, selecting those who use the quality management system in their activities. 18 users who work in six departments are those who access the information mentioned above and are those who will form part of the sample available for this study. The respondents were: 4 users from Process Engineering; 2, from Document Control Engineering; 2, from Production; 2, from Purchasing; 7, from Quality Control and 1, from Human Resources.
2. Preparation of questions for the survey. The objectives were established and the questions were made based on: access to information from the quality management system; frequency of use of the system for use in decision making;

search motivations; the satisfaction of information search tools, and which media are used to search for information.

3. Application of the survey to users. The survey was applied to users and to achieve the objective, it was necessary to carry out a pilot test to verify the reliability of the survey and its potential results.
4. Time recording. This is the technique used to determine the time used to carry out a certain task with an arrangement according to a pre-established performance standard. This task is normally carried out with a stopwatch and according to: the execution of an operation, activity or task; the complaints from workers or their representatives about the times of operations; the delays that affect other operations; the establishment of standard times in an incentive system, and/or low performance or downtime of work teams. To do this, the operation to be measured is prepared; the measurement plan is executed; the aspects such as the work pace and assessment techniques are assessed; the delays, fatigue and tolerances are considered, and the standard error, frequency of elements, interferences and the calculation of standard time are considered.
5. Development of a database. The database was developed in an Excel file because it is a commonly used tool in the company and easily accessible to users. Here, commonly used files and documents were added, using the concept of usability intrinsic to this. Each document or file listed represented a link that provided easy access to it. It is relevant to mention that this file is continuously updated according to the information needs of each department involved.
6. Second application of the survey to users. This survey is intended to evaluate potential changes in the information behavior of users. This activity was carried out after the changes were made, including the development and implementation of the database.
7. Second time recording. The time recording was carried out to measure the time needed to carry out the operations of interest. This was done under the same considerations mentioned in the time recording phase. This activity was carried out after the changes were made, including the development and implementation of the database.

It is important to note that this project was carried out considering the human being as the main actor, and for this reason, each of the participants was informed of the ethical and confidentiality process, that was going to be carried out during the project. The activities carried out during the field work were in common agreement between the person, who collected the data in the context and the participants. This involved explaining how the information would be collected, handled, administered and used in the research. In addition, it was noted and agreed that, to ensure confidentiality in the process, the surveys and interviews would not contain the name of the participant and would be coded and added to an electronic database to be managed quickly and easily, making three copies to increase security in its management.

4. RESULTS

The results obtained were mainly in two aspects mentioned above: satisfaction in the use of the databases and the time required to interpret and use the information in the database within the activities carried out by the aforementioned users.

a. Survey after the database.

According to the data obtained during the development of the project and once the database containing the information of interest to the area or department was developed and implemented, it can be noted that user satisfaction increased by 23.34%. This was mainly due to making the required information available at the time it was requested. This allowed users to manipulate the database according to their information needs, also indicating freedom in the use of the information and for the purposes they deemed appropriate. The results obtained are presented in Figure 1.

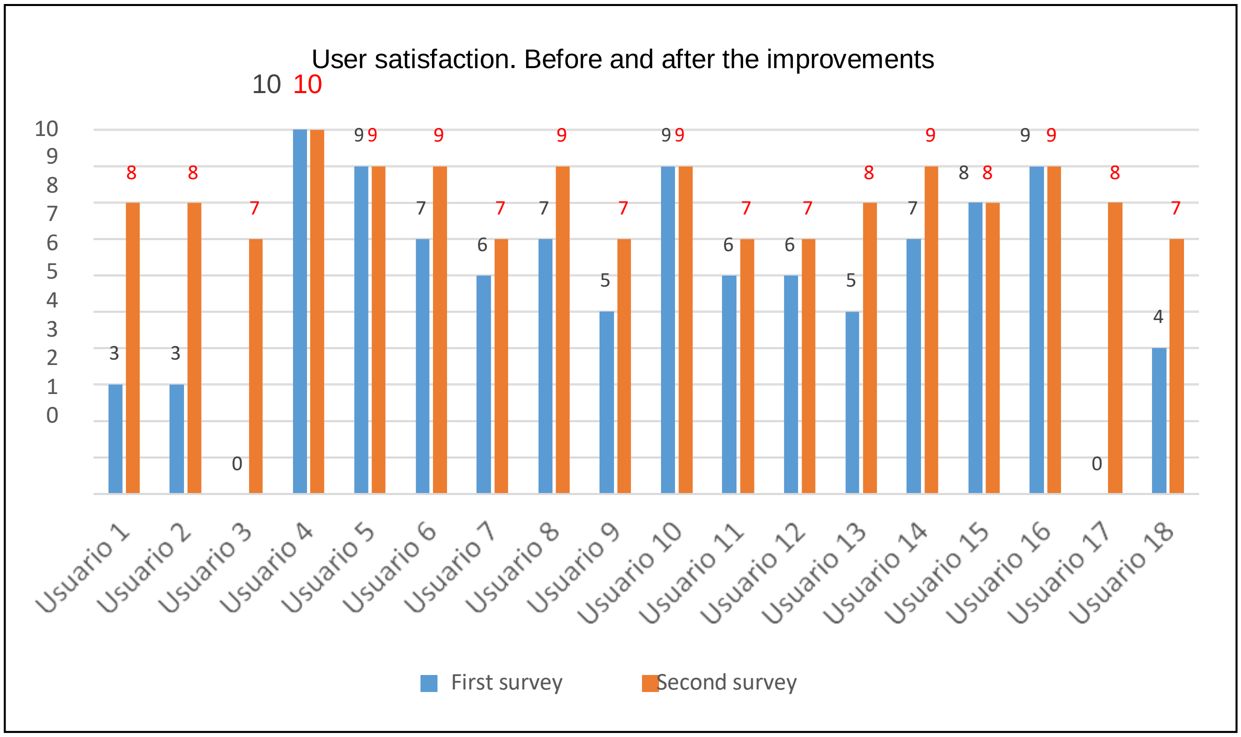


Figure 1. User satisfaction

b. Time collection after the database

The information search times at the beginning of the project were 10 minutes on average time, and after the measures implemented were reduced to 4.6 minutes on average time. This showed a notable reduction in time that impacted user satisfaction. Also, in reference to the interpretation of the information, initially 5 minutes were used and after the implementation of the activities and tools, the time was reduced to 2.6 minutes. Consequently, this allowed users to increase the activities carried out during their time at work and increased user satisfaction in the use of it. The results are presented in figure 2.

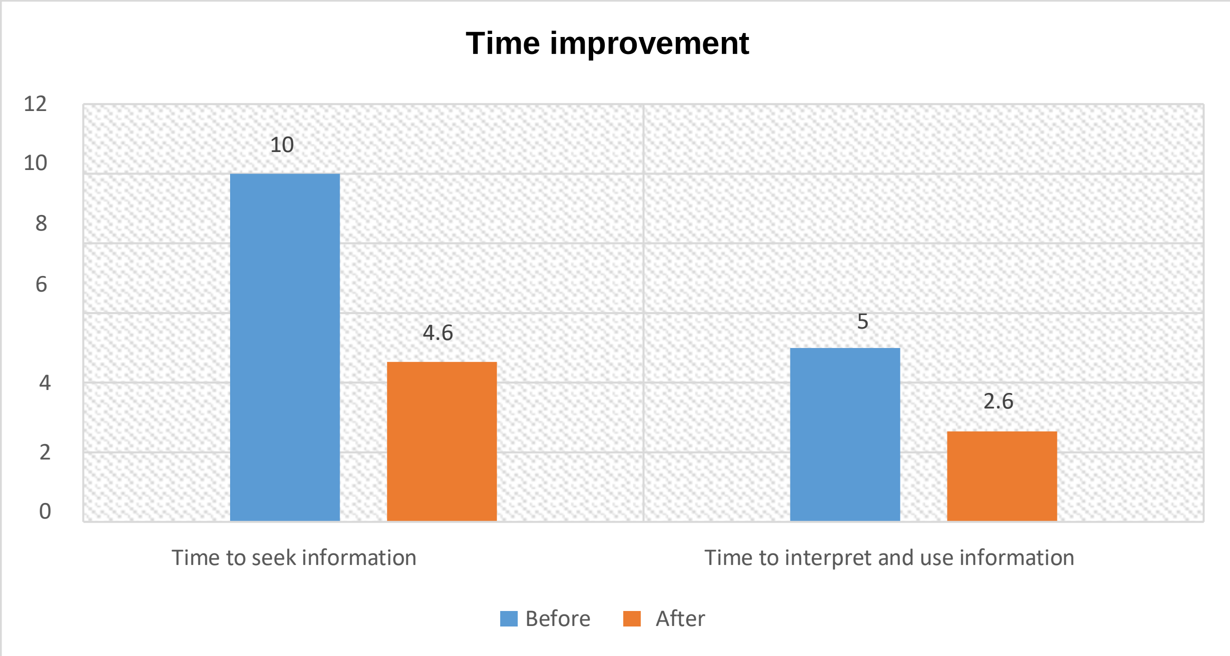


Figure 2. Time improvement

5. CONCLUSIONS

The results obtained allowed to conclude that user satisfaction in the process of using and searching for information increased by 23.34%, reaching 81.11%. This can be interpreted as a positive impact on information behavior by understanding the importance of it within the context under study. Likewise, the time spent searching for information was reduced by 54%, since initially it required 10 minutes on average and after the implementation of technological tools, now it required 4.6 minutes. This implied full knowledge of the functioning of the mentioned tools. Regarding the time required for the interpretation and use of information, it was reduced by 48%, initially using 5 minutes on average and later, 2.6 minutes on average. This was primarily to make sense of the information obtained in the implemented technological tools.

Based on the above, it was understood that the use of technological tools can have impacts on unknown behaviors, such as information behavior, and that the literature found has shown how behaviors can be visualized for the benefit of users and their environments or contexts. This is the case of information behavior, which is partially studied in contexts such as the one discussed in this project. Although, it is recognized as an innate behavior of the human being, it has been partially investigated in environments considered natural, or where the variables converge naturally in such a way that it represents a challenge to study and improve it for the benefit of those, who exhibit it and their environments.

This also allows to visualize the potential areas of opportunity that exist in natural contexts or in routine tasks. This includes the development of abstract and physical tools that support it for its benefit. In addition, it is relevant to discover with focused attention the elements or behaviors included in the informational behavior. That is, there are opportunities to study the sub-behaviors or main elements of the behavior indicated here.

6. ACKNOWLEDGMENTS

We would like to acknowledge to the TecNM/Instituto Tecnológico de Tijuana for funding the study. We would also like to thank to the participants and their organization for contributing with this study. The interpretations and views in this paper, however, are solely those of the authors.

7. REFERENCES

Calva González, J. J. (1998). Las necesidades de información de la comunidad académica como base en el desarrollo de las colecciones. En Seminario Internacional de Desarrollo de Colecciones (1: 1997: Ciudad de México, México). UNAM. Centro Universitario de Investigaciones Bibliotecológicas.

Case, D. O. (2006). Information behavior. *Annual review of information science and technology*, *40*(1), 293-327.

Nielsen, J. (1993). Usability Engineering. 1a Ed. United States of America. Academic Press.

Vásquez Velásquez, M. E. (2006). Las necesidades y el comportamiento informativo en adolescentes escolarizados de 12 a 15 años de edad en la Delegación Iztapalapa. México. IIBI.

Wilson, T. D. (2000). Human information behavior. *Informing science*, *3*, 49.

WORKSTATION ANALYSIS TO IMPROVE INVENTORY OPERATIONS MANAGEMENT IN A WOODWORKING SHOP, DIGITAL DASHBOARD DESIGN

Kitzia María Báez Duarte, ORCID 0009-0001-0165-3631, Ximena Yamileth Cruz León, ORCID 0009-0007-1718-8336, Quetzali Leal Armenta ORCID 0009-0000-0150-0291, Virgen del Rosario Obeso Millán ORCID 0009-0004-1059-6087, Emilia Estéfana Sauceda López, ORCID 0000-0003-4162-981X

Department of Industrial Sciences
Tecnológico Nacional de México- Instituto Tecnológico Superior de Guasave
Carretera a Brecha S/N, Ej. Burrioncito
Guasave, Sinaloa, CP. 81149

Email: emilia.sl@guasave.tecnm.mx

Resumen: El presente estudio se llevó a cabo en el taller de carpintería "De León" con el objetivo de mejorar la gestión de inventarios mediante la implementación de un tablero digital. La investigación se centró en el análisis de estaciones de trabajo para optimizar la organización y reducir errores operativos en el control de materiales e insumos. Para ello, se realizaron recorridos en la empresa, observando las condiciones de trabajo y evaluando los métodos de recolección de datos en los procesos de inventario. Desde un enfoque de ergonomía cognitiva, el tablero digital fue diseñado para facilitar la identificación de operaciones, mejorar la eficiencia en la planificación de tareas y reducir la fatiga laboral. Su estructura visual, basada en codificación por colores, permite a los operarios acceder rápidamente a la información, minimizando tiempos de búsqueda y errores en la gestión de insumos.

Palabras clave: Diseño de tablero, Análisis de estaciones, Gestión de inventarios, Ergonomía cognitiva

Relevancia para la ergonomía: El análisis de estaciones de trabajo en ergonomía es crucial para mejorar la eficiencia, la seguridad y el bienestar de los trabajadores en una carpintería. Al integrar un diseño de tablero digital, se optimiza la gestión de operaciones de inventarios, lo que permite un flujo de trabajo más ágil y una reducción de errores. Además, minimiza la sobrecarga de información, facilitando que los operarios mantengan el stock bajo control y tomen mejores decisiones sin distracciones ni confusión.

Abstract: This study was carried out in the "De León" carpentry workshop with the aim of improving inventory management through the implementation of a digital board. The research focused on the analysis of workstations to optimize the organization and reduce operational errors in the control of materials and supplies. To do this, tours were carried out in the company, observing the working conditions and evaluating the methods of data collection in the inventory processes. From a cognitive ergonomics approach, the digital dashboard was designed to facilitate the identification of operations, improve efficiency in task planning and reduce work fatigue. Its visual structure, based on color coding, allows operators to quickly access information, minimizing search times and errors in the management of supplies.

Keywords. Board Design, Station Analysis, Inventory Management, Cognitive Ergonomics.

Relevance to Ergonomics: Workstation analysis in ergonomics is crucial to improving efficiency, safety, and worker well-being in a woodshop. By integrating a digital dashboard design, inventory operations management is streamlined, allowing for a more streamlined workflow and reduced errors.

1. INTRODUCTION

This paper addresses the implementation of a digital dashboard in the carpentry workshop "De León" as a strategy to optimize inventory management, improve work organization and reduce operational errors. Inventory management refers to the process of monitoring and controlling a company's inventory, ranging from the acquisition of raw materials to the distribution of finished products. This process is essential to ensure that the right products are available at the right place at the right time, optimizing operational efficiency and reducing costs (Toledo, Diaz and Hernández, 2023). Woodworking, being a sector that depends on an efficient flow of materials and tools, requires innovative solutions that allow better resource management. In an environment where the organization and availability of inputs are essential to maintain productivity, the digital dashboard emerges as an effective and accessible solution, after performing an analysis of workstations to improve the management of inventory operations.

Cognitive ergonomics is the discipline that studies human mental processes, such as perception, memory, decision making and cognitive load, in the interaction with systems, environments and technologies (Ferreira, 2024). Its objective is to optimize the efficiency, safety and well-being of the user, reducing mental effort and minimizing errors in the execution of tasks (Correa, 2020).

One of its main approaches is the reduction of cognitive load, which is achieved through the organization of the workspace, the accessible arrangement of tools and the use of labels or color codes to identify materials quickly. This facilitates the execution of tasks without the need to remember multiple complex steps, reducing mental fatigue (Correa, 2021).

The digital dashboard is based on the use of cognitive ergonomics for its design so that the operator can identify operations, facilitating the monitoring of inputs and finished products, reducing waste and waiting times in production. Its intuitive design and accessibility contribute to a quick consultation by workers, allowing greater efficiency in task planning. In addition, it has been designed with a clear visual structure that uses color coding, which speeds up decision making and improves ergonomics in the work environment. With these features, the digital dashboard seeks to become a fundamental tool in the production process of the workshop.

The implementation of a digital dashboard within the carpentry workshop "De León" and its use will be limited to inventory management and task planning. Integration with external management systems and order automation is not contemplated. The digital dashboard is intended to function as an autonomous tool, without dependence on complex external software. Its development has been conceived with the purpose of facilitating its adoption without generating an additional burden on technological infrastructure or high implementation costs.

2. OBJECTIVE

Analyze workstations to improve inventory operations management in a woodworking shop by designing a digital dashboard.
Specific objectives:

- Identify the operations of the carpentry company.
- Analyze workstations to improve the management of inventory operations.
- Apply shrinkage reduction of warehouse operations management.
- Design a digital dashboard for operations to improve inventory control, through cognitive ergonomics.

3. METHODOLOGY

The following methodological phases were followed for the implementation of the workstation analysis and digital dashboard design:

1. A diagnosis of the company was made through tours, identifying the characteristics of the workers, as well as the workstations and the situation in which the company finds itself.
2. The work stations were analyzed for a certain period of time, and the inventory operations were identified, as well as the methods for collecting information in the process.
3. The applicable evaluation methods, to detect human errors in the data capture of the inventory operations, as well as the idle times in the workstations.
4. Design a digital dashboard to structure a work method for inventory operations through cognitive ergonomics.

1. RESULTS

4.1 Diagnosis areas

The company's diagnosis was analyzed and problems of disorganization, downtime at the workstations and errors in the registration of materials were identified. First, a diagnosis of the process was made, identifying the specific operations and the personnel that performs them. After the diagnosis, it can be seen in the images where they do not have an adequate administration and places for the realization of the product.

Figure 1. Workstations

4.2 Inventory operations and process data collection were identified.

- Loss of materials due to lack of an adequate control system.
- Excessive time spent searching for materials, which slowed down production.
- Lack of communication between areas, making efficient planning difficult.

4.3 Proposal for the implementation of the digital dashboard

We worked on the design of a digital dashboard based on reducing the mental workload of the operators. Color coding was incorporated to facilitate quick identification of materials and their inventory status. The recording of inputs and outputs was automated to avoid manual errors and improve traceability. Figure 2 shows the prototype of the developed board, in the image you can see the color-coded information according to the availability of each of the raw materials used in the carpentry shop.

Figure 2. Prototype of the proposed board.

The dashboard uses color codes to indicate inventory status:

Representative Colors	
Red	Alert (very insufficient materials)
Yellow	Precautionary (insufficient materials)
Green	All in order (sufficient materials)

Figure 3. Representative with respect to materials in stock.

This makes it easier for workers to quickly identify information without having to read large amounts of text or consult physical documents.

Figure 4. Location of the board in the woodwork

4.4 Impact of the Digital Dashboard on Work Organization

The implementation of the digital dashboard is intended to improve workflow by reducing waiting times in the search for materials, improving decision making, facilitating purchase planning and reducing waste, as well as reducing human errors in inventory management, improving the accuracy of records.

4.5 Functional testing of the dashboard.

Functional tests were carried out in the carpentry shop and its use and impact on workers' operations were evaluated; interviews were conducted with the workers, which yielded the information shown in the graph in Figure 5.

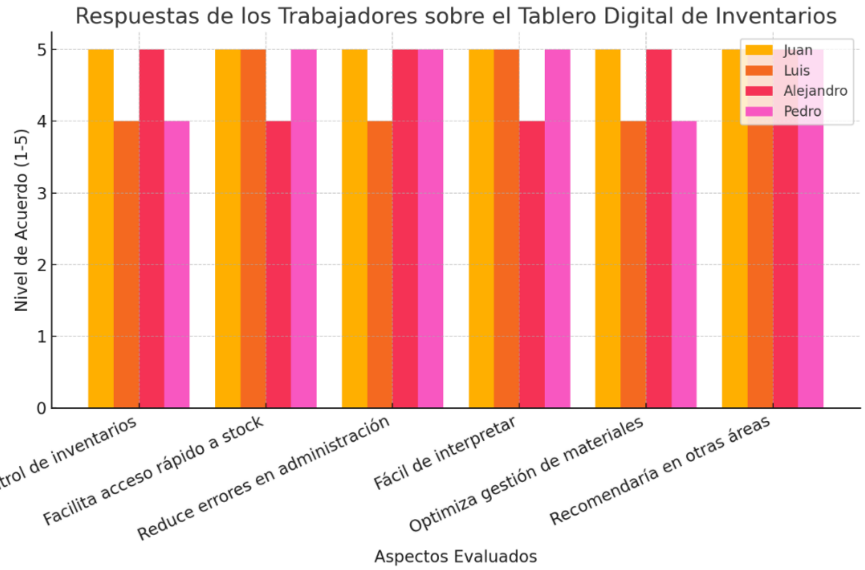


Figure 5. Graph of users' perception of the board in the carpentry shop.

4.6 Performance evaluation and benefits obtained

The pilot test showed a 30% reduction in the time required to search for materials at the workstations, a 40% reduction in errors in the inventory register, improved operational efficiency, allowing workers to concentrate on their tasks without unnecessary interruptions, and a reduction in work stress, thanks to the ease of access to information and the elimination of uncertainty in the management of supplies.

With the implementation of the digital dashboard, based on cognitive ergonomics principles, the following improvements were achieved, previously, carpenters had to constantly remember what materials were on hand or review long paper inventory lists. With the digital board, they can now see in real time what materials are in stock through a clear, visual interface, reducing mental workload and the risk of forgetfulness.

When a worker needs a specific wooden board, the dashboard immediately shows them if it is available and where it is located in the warehouse. If stock is low, the system generates an alert to request replenishment before it is completely depleted. This allows for better planning and avoids production delays.

5. CONCLUSIONS

The implementation of this digital dashboard with a focus on inventory management based on cognitive ergonomics principles, represents an effective and accessible solution to improve the organization of the workshop, the reduction of errors in data capture and improved decision making reflect the benefits of integrating technological tools in craft environments.

In addition, the use of an intuitive visual system not only improved operational efficiency, but also reduced the mental workload of the operators, allowing them to concentrate on their tasks, as well as focusing more on quality.

Before the implementation of the digital dashboard in the “De León” carpentry shop, labor fatigue was a constant problem that affected the performance and well-being of the workers. The disorganization of the inventory forced operators to make long trips in search of materials, increasing unnecessary physical effort and slowing down production. In addition, the lack of a structured control system generated a high cognitive load, as workers had to memorize what materials were available and in what quantities, which added stress and frustration to their workdays.

Burnout also manifested itself in decision making, as the lack of clear information on inventory status made planning inefficient, prolonged tasks and forced employees to work under pressure. All this resulted in increased physical and mental fatigue, downtime, and a general feeling of lack of control that affected productivity and quality of work.

With the implementation of the digital dashboard, there was a remarkable transformation in work management and, consequently, in the reduction of work fatigue. Thanks to its intuitive design based on cognitive ergonomics principles, the board allowed workers to immediately access information about materials and tools through a color-coded system. This eliminated the need to memorize data or review lengthy documents, decreasing mental workload and enabling faster and more accurate decision making.

This study confirms that the combination of technology and cognitive ergonomics can be an effective strategy to modernize processes in traditional workshops, optimizing productivity and improving working conditions for operators. The digitization of inventories in this context represents not only an organizational advance, but also an opportunity to foster a culture of innovation and efficiency in the craft industry.

REFERENCES

Agudelo Serna, D. A. (2018). *Dinámica de sistemas en la gestión de inventarios.* Ingenierías USBMed.

Castillo Martínez, J. A. (2007). *Elementos cognitivos para el análisis ergonómico del trabajo*. Repositorio Universidad del Rosario. https://repository.urosario.edu.co/server/api/core/bitstreams/15bdb010-7061-415b-b4de-0a5a3ba38665/content

Correa, A. (2020). Lecciones magistrales de Ergonomía Cognitiva. Curso de Ergonomía Cognitiva. Universidad de Granada.

https://doi.org/10.5281/zenodo.3351257Correa Torres, A. Factores Humanos y Egonomía Cognitiva

Ferreira Barreto, E. V. (2024). *Impacto de la ergonomía cognitiva sobre el estrés laboral en médicos radiólogos.* Universidad Nacional Abierta y a Distancia (UNAD), Escuela de Ciencias de la Salud (ECISA).

Toledo, J., Díaz, J., & Hernández, M. (2023). *Gestión de inventarios en organizaciones de emprendimiento: Una perspectiva estratégica*. Revista Venezolana de Gerencia, 28(2), 193-210. https://ve.scielo.org/scielo.php?pid=S2665-01692024000200193&script=sci_arttext

ERGONOMIC ANALYSIS OF WORK STATIONS OF A FLOUR PRODUCTS MARKETER, TO DETERMINE RISK FACTORS.

Grace Erandy Báez Hernández, ORCID 000-0003-1580-2199, Perla Julier Gaxiola Castro, ORCID 0009-0008-0141-3815, Ximena Muro Cota ORCID 0009-0008-3652-8233, German Parra Norzaray ORCID 0009-0009-1738-3857, Katya Paola Tirado Castro, ORCID 0009-0007-4858-2862

[1]División de Ciencias Industriales
Tecnológico Nacional de México-Instituto Tecnológico Superior de Guasave
Carretera a Brecha S/N, Ej. Burrioncito
Guasave, Sinaloa, CP. 81149

Corresponding author's e-mail grace.bh@guasave.tecnm.mx

Resumen Dentro de la región norte del estado de Sinaloa ubicamos una empresa de elaboración de tortillas de harina, así como la distribución de productos básicos con nombre "Súper Ariel, SA. DE CV.", en él, se comercializa diversidad de artículos y accesibilidad para los consumidores locales, siendo una microempresa de la región. Dentro de las actividades que se realizan Manejo manual de cargas y en la línea de producción se presentan problemas representativos de diseño, métodos de trabajo y condiciones no adecuadas para las operaciones de las estaciones de trabajo, así con un espacio reducido para la elaboración del producto, Esta línea la trabaja 3 operadores mujeres de un rango de edad de 30 a 35 años con una jornada de 8 horas diarias, mismas trabajadores presentan una rotación de personal debido a los problemas de salud, lesiones musculoesqueléticas y posturas inadecuadas de trabajo y tiempos muertos, registros de DTA, cuando realizan las actividades. Con base a esto surge la necesidad de hacer una investigación que tiene como objetivo Realizar un análisis ergonómico en las estaciones de trabajo de la línea de producción de tortillas e identificar las posturas con mayor riesgo, así como actividades que causen molestias y dolores en diferentes partes del cuerpo de los trabajadores cuando realizan sus tareas y así como espacios inadecuados para realizar el manejo manual de cargas y en área de producción.

Palabras clave: Método RULA, Ergonomía, Diseño, Factores de riesgo.

Relevancia para la ergonomía. El Análisis ergonómico dentro del área de trabajo constituye una importante aportación a la ergonomía, ya que se lograría minimizar el riesgo de lesiones musculares y fatiga mediante una mejor distribución del espacio, reduciendo movimientos innecesarios y la sobrecarga de trabajo. Estos cambios mejorarían la seguridad y el bienestar del trabajador.

Abstract Within the northern region of the state of Sinaloa we locate a company that makes flour tortillas, as well as the distribution of basic products with the name "Super Ariel, SA. DE CV.", in it, a variety of articles are marketed and accessible to local consumers, being a microenterprise in the region. Among the activities carried

out are manual handling of loads and the production line presents representative problems of design, work methods and conditions that are not adequate for the operations of the work stations, as well as a reduced space for the elaboration of the product. This line is worked by 3 female operators with an age range of 30 to 35 years with an 8-hour workday. The same workers present a staff turnover due to health problems, musculoskeletal injuries and inadequate work postures and downtime, DTA records, when they carry out the activities. Based on this, the need arises to carry out an investigation that aims to perform an ergonomic analysis at the work stations of the tortilla production line and identify the postures with the greatest risk, as well as activities that cause discomfort and pain in different parts of the workers' bodies when performing their tasks and as well as inadequate spaces for manual handling of loads and in the production area.

Keywords: RULA method, Ergonomics, Design, Risk factors.

Relevance to ergonomics. Ergonomic analysis within the work area constitutes an important contribution to ergonomics, since it would be possible to minimize the risk of muscle injuries and fatigue through a better distribution of space, reducing unnecessary movements and work overload. These changes would improve the safety and well-being of the worker.

1. INTRODUCTION

In Mexico, wheat grain is considered a strategic product because it is a food of enormous demand thanks to its high nutritional content, a factor that contributes to the strengthening of the food sector, in addition to being one of the most important resources in the diet of Mexicans. For human consumption, it requires the milling process, through which it is transformed into flour. Developing products such as; tortillas, breads, pastas, cakes, atoles and even fuels. (SADER, 2016).

The consumption of tortillas in our country is very relevant. In a study carried out by the National Autonomous University of Mexico (UNAM), published in the UNAM Gazette, it indicates that the daily per capita consumption is 75 kilograms per year per person, this is covered annually thanks to nearly 100,000 tortilla shops located in both large cities and small towns (Lugo, 2022).

In the production of flour products, occupational factors such as worker health, productivity and working conditions intervene. In relation to ergonomics, it is common for the operator to be in constant forced or repetitive postures, in addition to lifting and moving loads.

Exposure to high temperatures, noise from machinery and, in some cases, inadequate lighting, are common physical factors that tend to affect the health and performance of workers in these types of contexts. On the other hand, safety can be compromised by the risk of burns, accidents due to the improper use of machinery and lack of PPE.

Some occupational risks such as noise, trauma and ergonomic aspects represent a considerable part of the morbidity burden derived from chronic diseases: 37% of back pain and 8% of trauma.

The most frequent ergonomic risk factors are forced postures and repetitive movements with 22% and 14.7% respectively. But the risk of suffering from musculoskeletal disorders also increases since Mexico is the country where people work the most hours per year, according to 2018 figures from the Organization for Economic Cooperation and Development.

In Mexico, the IMSS (2016) indicated that CTS is the most frequent neuropathy of the upper extremity and is estimated to occur in 3.8%. This disease can occur at any age, gender, race or occupation, but it occurs more frequently in women than in men, between 40 and 60 years of age and in occupations where wrist movement is constant (Cuellar and Palí, 2023, p. 4).

This project is based on a flour tortilla making company and the distribution of basic products named “Súper Ariel, SA. DE CV.” which is an establishment located on Margarita Maza de Juárez Avenue, the main street of the community of Benito Juárez, Tamazula, belonging to the City of Guamúchil, Sinaloa, Mexico.

The aim is to carry out an ergonomic analysis of the workstations and develop a proposal to redesign one of its areas, the tortilla factory, because after offering this service for more than 20 years, the physical conditions of the place have deteriorated, resulting in great wear and tear in the specific work space.

2. OBJETIVE

Analyze the ergonomic risks of workstations of a flour product marketing company, to determine risk factors.

3. DELIMITATION.

The study was conducted at Super Ariel, in the tortilla factory area, which has kitchen equipment and a space of 2.5 × 4 × 2.5 meters. The place is built with bricks, barilla and cement, with tile walls, two entrances and an open area to serve the public. The work of women aged 30 to 35 was analyzed, who work 8 hours a day, dedicating 3 hours to cleaning and preparing dough, and the rest to making and selling tortillas.

4. METHODOLOGY

- The study was carried out in several stages:
- A diagnosis of the company was carried out through tours, identifying the characteristics of the workers, as well as the work stations and the situation in which the company is located.
- The work stations were analyzed for a certain time, and the activities that present risk factors were identified through the application of ergonomic principles carried out by the operator, showing musculoskeletal injuries in employees.

- Application of the ergonomic evaluation method (RULA Method), to determine and evaluate the station with the greatest problems and work risks, as well as the application of Mexican Official Standards (NOM) in the work station.

5. RESULTS

Through the application of Ergonomic Assessment Methods, it is possible to identify and assess the ergonomic risk factors present in the work stations where agents of negative impact on the worker were found, including incorrect postures during repetitive lifting and excessive load levels in the activities performed.

Two workers operate in the work area, whose ages range between 30 and 35 years, in charge of cleaning and maintaining the space, preparing the dough, shaping, cooking, cooling, packaging, storing, and distributing tortillas. During the first three hours of the workday, the initial activities of the process are carried out, which include cleaning the area, preparing the dough and processing it for shaping. Subsequently, in the following five hours, the remaining stages are executed..

The work space, approximately 5.5 m long x 3 m wide x 2.10 m high, is equipped with the machinery and equipment necessary for the execution of the corresponding operations. Its main equipment includes a heating griddle, a tortilla machine, a sink, a storage rack for trays with dough, a kneading table, a cooling rack, a scale, a sealer, a stove, etc.

There are multiple factors around the work area that affect operational efficiency, from a large icebox, whose function is destined for another area of the establishment, taking up considerable space, gas pipes installed at a low height from the ground, affecting the mobility and safety of the operator, bags of beans destined for another type of service, etc.

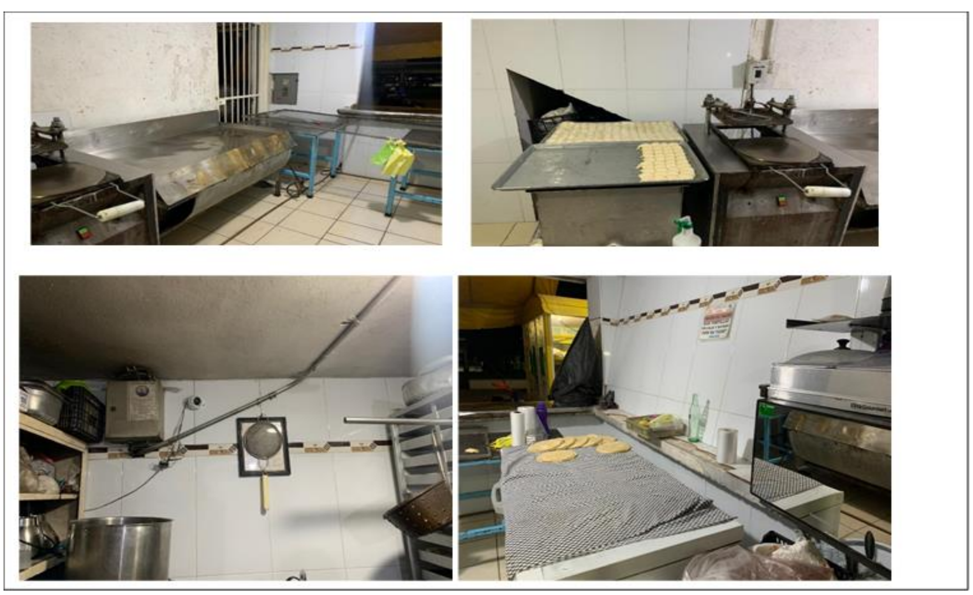


Figure 1. Company workstations

Table 1. List of Mexican Official Standards applied to the company's production process.

List of official Mexican Standards applied to the company's production process			
Company: Supermercado Ariel.			
Standard	The company complies with the regulations		Observations
	Yes	No	
Mexican Official Standard NOM-001-STPS-2008, Buildings, premises, facilities and areas in work centers-Safety conditions		X	The work space in general presents inadequate conditions for the development of activities, such conditions are visible in the physical structure of the place and the machinery used.
Mexican Official Standard NOM-015-STPS-1994, related to occupational exposure to high or low thermal conditions in the workplace..		X	The workers work more than 4 hours exposed to heat, due to the use of the tortilla flattening machine and griddle.
Mexican Official Standard NOM-251-SSA1-2009, Hygienic practices for the processing of food, beverages or food supplements.		X	The staff does not use personal hygiene equipment, gloves, face masks, caps, aprons
Mexican Official Standard NOM-004-STPS-1999, Protection systems and safety devices for machinery and equipment used in the workplace.		X	The road roller is switched on and off from the load center, which represents an imminent risk..
Mexican Official Standard NOM-036-1-STPS-2018, Ergonomic risk factors at work - Identification, analysis, prevention and control.		X	The activities carried out during the day are repetitive, employees must adapt to the work area and equipment, lighting and ventilation conditions are not adequate, which creates an unwelcome environment for operators. The road roller is turned on and off from the loading center, which represents an imminent risk.

Table 2. List of ergonomic principles applicable to the company's production process.

Principles	Observations
No.1 Keep everything within reach	Workers must reach for supplies such as dough, press and griddle. To reduce unnecessary effort, ingredients and tools must be organized at an appropriate distance to avoid excessive stretching or awkward postures.
No.2 Use elbow height as a reference	**The height of work surfaces, such as the table where dough is handled and the griddle where tortillas are cooked, should be aligned with each worker's elbow height to reduce strain on the back and shoulders. Some tasks are performed in a slightly bent position, which creates fatigue when maintaining the posture for long periods.**
No.4 Finding the right position for each task	To manipulate the dough and place the tortillas on the griddle, it is ideal to have a stable posture with your feet firmly planted on the ground..
No.5 Reduce excessive repetitions	**Making tortillas involves repetitive movements such as picking up, turning the dough, placing and removing tortillas from the comal.**
No.10 Maintain a comfortable environment	The temperature of the griddle and the press generates heat, which causes discomfort and affects performance. The lighting creates shadows and reflections that make visibility difficult.

Figure 2. Activity at workstation 1

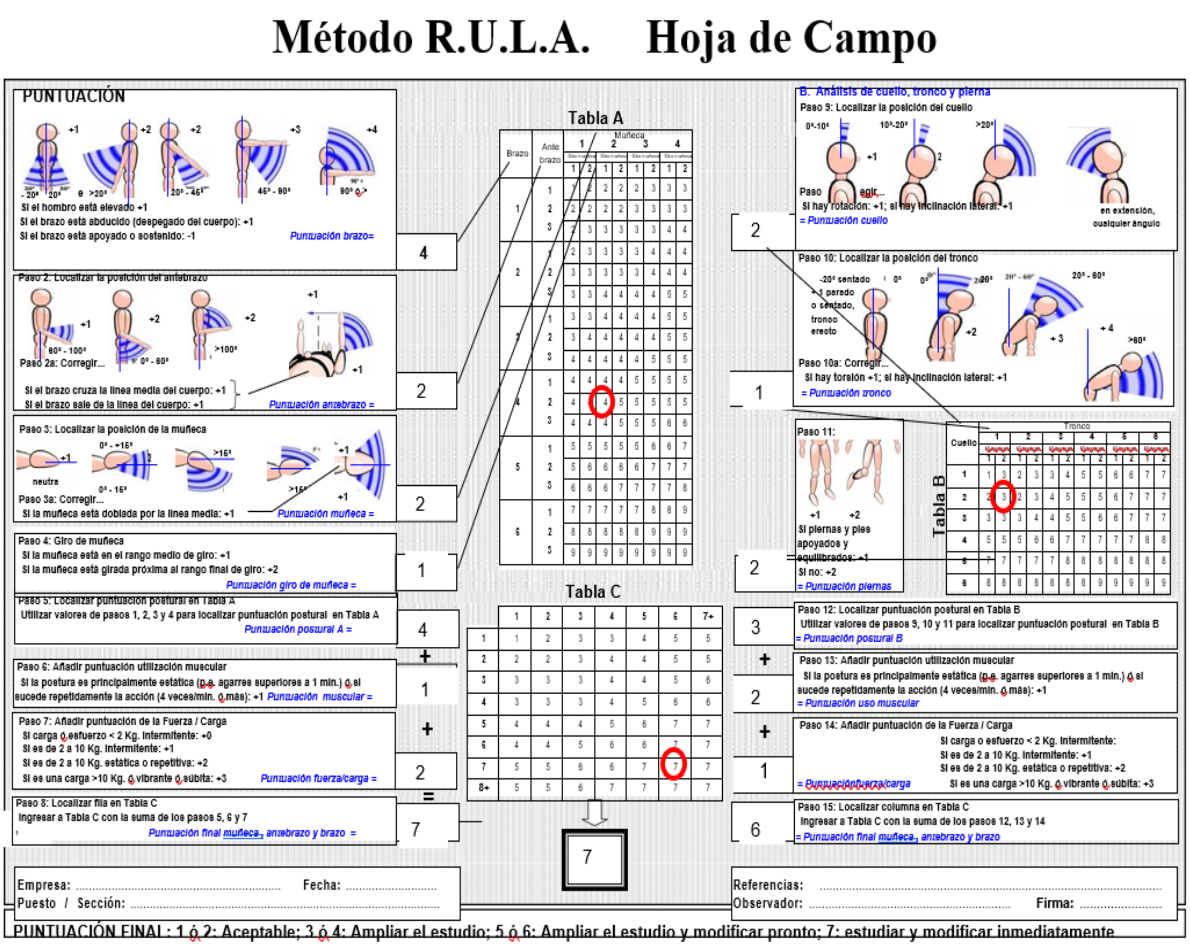


Figure 3. Application of the Rula Method at station 1

Result: A score of 7 was obtained, indicating that the workstation should be studied and modified immediately.

The redesign would improve the work environment from a visual and emotional perspective for those in charge of operating in the area, since the improvements allow for more comfortable postures, increase safety, promote a positive work environment, reduce work overload, qualities that contribute to a relaxing environment resulting in higher quality of the products delivered, which translates into an increase in customer satisfaction and the competitiveness of the company, as well as lower costs related to work accidents.

6. CONCLUSIONS

The ergonomic redesign of the tortilleria area at Super Ariel represents a significant improvement in both efficiency and worker well-being. Through a detailed analysis of the tortilleria, it was observed that some areas need to be reorganized, implementing ergonomic measures and principles.

By optimizing the workflow, reducing fatigue and minimizing injury risks, the productivity of the business would be positively impacted, a safer and more comfortable work environment would be possible, promoting staff satisfaction and performance. Overall, the modernization of this space demonstrates the importance of ergonomics in industrial environments and its key role in improving working conditions.

7. REFERENCES

Cuellar, C. J. Palí, C. R. de J. (2023). **Evaluación del riesgo ergonómico en el proceso de fabricación de la tortilla para la detección de trastornos musculoesqueléticos**. *Ergonomía, Investigación y Desarrollo*, 5(1), 62-77. https://doi.org/10.29393/EID5-5ERJR20005

Lugo, G. G. (2022). La nixtamalización, benéfica para la salud. *Gaceta UNAM*. https://www.gaceta.unam.mx/la-nixtamalizacion-benefica-para-la-Salud/

NORMA Oficial Mexicana NOM-001-STPS-2008, Edificios, locales, instalaciones y áreas en los centros de trabajo-Condiciones de seguridad. (2007, 13 noviembre). Diario Oficial de la Federación. https://www.dof.gob.mx/normasOficiales/3540/stps/stps.html

NORMA Oficial Mexicana NOM-015-STPS-1994, relativa a la exposición laboral de las condiciones térmicas elevadas o abatidas en los centros de trabajo. (1993, 19 julio). Diario Oficial de la Federación. https://dof.gob.mx/nota_detalle.php?codigo=4699279&fecha=30/05/1994#gsc.tab=

NORMA Oficial Mexicana NOM-251-SSA1-2009, Prácticas de higiene para el proceso de alimentos, bebidas o suplementos alimenticios. (2008, 10 octubre). Diario Oficial de la Federación. https://www.dof.gob.mx/normasOficiales/3980/salud/salud.html

NORMA Oficial Mexicana NOM-004-STPS-1999, Sistemas de protección y dispositivos de seguridad en la maquinaria y equipo que se utilice en los centros de trabajo. (1994, 13 junio). Diario Oficial de la Federación. https://www.dof.gob.mx/nota_detalle.php?codigo=4948965&fecha=31/05/1999#gsc.tab=0

NORMA Oficial Mexicana NOM-036-1-STPS-2018, Factores de riesgo ergonómico en el Trabajo-Identificación, análisis, prevención y control. Parte 1: Manejo manual de cargas. (2017, 29 noviembre). Diario Oficial de la Federación. https://www.dof.gob.mx/normasOficiales/7468/stps11_C/stps11_C.html

SADER. (27 de Junio de 2016). *GOBIERNO DE MÉXICO-Secretaría de Agricultura y Desarrollo Rural* . Obtenido de https://www.gob.mx/agricultura/es/articulos/por-que-el-trigo-en-grano-es-tan-valioso

USABILITY TESTING OF A PRESSURE SENSOR MAT FOR POSTURE DETECTION

Patricia Eugenia Sortillón González[1] 0000-0002-9716-6693, José Rafael Benito Noriega Luna [2] 0000-0002-9716-6693, Esteban Jesús Ramos Martínez[3]0009-0005-5391-3481, José Sergio López Bojórquez[4] 0000-0002-6920-2829, Leonel Ulises Ortega Encinas[5]0000-0002-8054-917X

[1] Department of Industrial Engineering
Universidad de Sonora
Ave. Rosales S/N, Col. Centro
Hermosillo, Sonora CP 83000

[2,3]Department of Electronics
Universidad de Sonora
Ave. Rosales S/N, Col. Centro
Hermosillo, Sonora CP 83000

[1,4,5] Department of Manufacturing Industrial Engineering
Universidad Estatal de Sonora
Ley Federal del Trabajo S/N, Col. Apolo
Hermosillo, Sonora 83100

Corresponding author's e-mail: patricia.sortillon@unison.mx

Resumen: La prevalencia de posturas sedentes no neutras es un problema de salud pública debido al sedentarismo de los entornos laborales. Permanecer sentado de forma prolongada contribuye a la aparición de trastornos musculoesqueléticos (TME). La integración de la tecnología de sensores para analizar las posturas sedentes ha cobrado importancia en los campos de la ergonomía y la salud laboral. Sin embargo, aunque la funcionalidad tecnológica de estos sistemas es fundamental, su eficacia depende de su usabilidad. La evaluación de la usabilidad puede garantizar que estos sistemas sean intuitivos, cómodos y se integren en las rutinas diarias de los usuarios. Este estudio evalúa la usabilidad de un dispositivo basado en sensores de presión diseñado para evaluar posturas sedentes y riesgos ergonómicos asociados. Participaron en este estudio 116 estudiantes universitarios y público en general. Los participantes completaron la encuesta de usabilidad (SUS por sus siglas en inglés) tras una sesión de prueba con el dispositivo. La facilidad de uso se midió en una escala Likert de cinco puntos. Se calcularon las puntuaciones de usabilidad. Se realizó un análisis de correlación de Pearson para evaluar la relación entre las puntuaciones SUS y las variables demográficas. Se realizó una comparación mediante una prueba T de las puntuaciones de usabilidad entre los participantes con formación ergonómica y aquellos sin formación. Para explorar las dimensiones subyacentes de la usabilidad, se llevó a cabo un análisis factorial exploratorio (AFE). La puntuación global SUS de 74,5, indicó una usabilidad aceptable. Los participantes lo consideraron intuitivo

y útil para evaluar la postura, aunque algunos manifestaron sentirse incómodos durante el uso prolongado. Los resultados sugieren que el dispositivo de sensores de presión es una herramienta ergonómica útil que puede perfeccionarse para mejorar la experiencia del usuario. No se encontraron correlaciones significativas entre las puntuaciones de usabilidad y la edad (r=0,12; p=0,21) o el sexo (t=0,52; p=0,061). Los participantes con formación ergonómica previa tuvieron puntuaciones SUS ligeramente más altas (μ=76,2) que los que no la tenían (μ=72,4), pero la diferencia no fue estadísticamente significativa (t=1,89, p=0,0673). Estos resultados sugieren que los factores demográficos tienen una influencia mínima en las percepciones de usabilidad, aunque los conocimientos ergonómicos previos pueden contribuir a unos niveles de satisfacción ligeramente superiores. Un análisis factorial exploratorio mediante análisis de componentes principales mostró que dos factores que explican el 72,4% de la varianza: facilidad de uso (λ=3,42, 41,3%) y utilidad percibida (λ=2,71, 31,1%). Estos factores indican que las percepciones de usabilidad están impulsadas principalmente por el funcionamiento intuitivo del dispositivo y la evaluación de la postura. Se identificó un área de mejora, en relación con la incomodidad del dispositivo durante el uso prolongado. Los usuarios con formación ergonómica previa obtuvieron puntuaciones de usabilidad ligeramente superiores, lo que sugiere que la formación ergonómica mejora la adopción del dispositivo. Estos resultados subrayan la importancia de perfeccionar los dispositivos de evaluación ergonómicas para mejorar la comodidad y la integración, al tiempo que destacan el papel de los programas de formación para maximizar sus beneficios. La investigación futura podría explorar la integración de funciones avanzadas como la retroalimentación personalizada y el análisis de datos para mejorar la experiencia y la eficacia del usuario.

Palabras clave: Detección de postura, usuario, evaluación.

Relevancia para la ergonomía: Este estudio contribuye al campo de la ergonomía al evaluar la usabilidad de un tapete de presión diseñado para detectar posturas sedentes no neutras, un problema crítico en el lugar de trabajo moderno. Al centrarse en la aplicación práctica de la tecnología de detección de la presión, la investigación aporta información valiosa sobre la eficacia y la aceptación por parte de los usuarios de dispositivos ergonómicos para el control de la postura en tiempo real. Los resultados pueden servir de base para el diseño de dispositivos ergonómicos más intuitivos y fáciles de usar, contribuyendo así al objetivo más amplio de reducir los trastornos musculoesqueléticos (TME) y mejorar la salud y el bienestar generales de los trabajadores. Además, esta investigación avanza en la comprensión de cómo las tecnologías portables y basadas en sensores pueden integrarse en el entorno laboral para promover mejores hábitos posturales y prevenir los efectos negativos a largo plazo del comportamiento sedentario. En última instancia, el estudio supone un paso adelante en la reducción de la brecha entre la innovación tecnológica y la práctica ergonómica, con potencial para una aplicación generalizada tanto en entornos laborales como académicos.

Abstract: The prevalence of prolonged non-neutral sitting postures has become a significant public health concern due to the increasing sedentary nature of modern work environments. Prolonged static sitting is a known contributor to musculoskeletal disorders (MSDs), which lead to workplace absenteeism and reduced productivity. In recent years, the integration of sensor technology for analyzing and correcting sedentary postures has gained prominence in the fields of ergonomics and occupational health. However, while the technological functionality of such systems is critical, their effectiveness in real-world settings largely depends on their usability. Evaluating usability is essential to ensure that the device is intuitive, comfortable, and seamlessly integrates into users' daily routines. This study evaluates the usability of a pressure sensor-based device designed to detect improper sitting postures and assess ergonomic risks. A total of 116 university students and the public participated in the study. Usability assessment was conducted in a controlled environment, with participants completing the SUS survey after testing session with the device. The survey measured ease of use, functionality, and user satisfaction on a five-point Likert scale. Usability scores were systematically calculated to assess the overall user experience with the pressure mat. A Pearson correlation analysis was conducted to assess the relationship between SUS scores and demographic variables. A T-test comparison of usability scores between participants with prior ergonomic training and those without training were performed. To further explore the underlying dimensions of usability, an exploratory factor analysis (EFA) was conducted. The device received an overall SUS score of 74.5, indicating acceptable usability. Participants found it intuitive and helpful for posture awareness, though some reported discomfort during prolonged use. No significant correlations were found between usability scores and age ($r=0.12$, $p=0.21$) or gender ($t=0.52$, $p=0.061$). Participants with prior ergonomic training had slightly higher SUS scores ($\mu=76.2$) than those without ($\mu=72.4$), but the difference was not statistically significant ($t=1.89$, $p=0.0673$). These results suggest that demographic factors have a minimal influence on usability perceptions of the pressure mat, though prior ergonomic knowledge may contribute to slightly higher satisfaction levels. An exploratory factor analysis revealed two emerging factors that explain 72.4% of the variance: Ease of use ($\lambda=3.42$, 41.3%) and perceived usefulness ($\lambda=2.71$, 31.1%). These factors indicate that usability perceptions are primarily driven by the device's intuitive operation and its effective feedback on posture aassessment. Areas for improvement were identified, including discomfort during prolonged use. Users with prior ergonomic training reported slightly higher usability scores, suggesting that ergonomic education enhances device adoption. These findings underscore the importance of refining ergonomic tools for better comfort and integration while also emphasizing the role of training programs in maximizing their benefits. Future research should explore long-term effects on worker health and productivity, as well as the integration of advanced features such as personalized feedback and data analytics to enhance user experience and effectiveness.

Key words: Posture detection, user, evaluation.

Relevance to Ergonomics: This study provides a contribution to the field of ergonomics by evaluating the usability of a pressure mat designed to detect non-neutral sitting postures, a critical issue in the modern workplace. By focusing on the practical application of pressure sensing technology, the research provides valuable insights into the effectiveness and user acceptance of ergonomic devices for real-time posture monitoring. The findings can inform the design of more intuitive and user-friendly ergonomic devices, contributing to the broader goal of reducing musculoskeletal disorders (MSDs) and improving the overall health and well-being of workers. In addition, this research advances the understanding of how wearable and sensor-based technologies can be integrated into the workplace environment to promote better posture habits and prevent the long-term negative effects of sedentary behavior. Ultimately, the study provides a step forward in bridging the gap between technological innovation and ergonomic practice, with the potential for widespread application in both occupational and academic settings.

1. INTRODUCTION

The prevalence of prolonged non-neutral sitting postures has become a significant public health concern globally (Bonnet, & Barela, 2021). The technological revolution and the increasing number of jobs that require extended periods of sitting, particularly in front of computers or while performing office tasks, have transformed lifestyles in many societies, amplifying the risks associated with these postures (Goyal & Rakhra, 2024). Sedentary work is predominant in industrialized nations and is growing in developing economies (Sakakibara et al, 2023). Approximately 60–85% of the global population leads a sedentary lifestyle (Odesola et al., 2024). Long hours spent in front of screens, infrequent movement breaks, and the adoption of improper postures have collectively increased the risk of health problems associated with sedentary behavior (Park al., 2020). In regions such as the United States, Japan, and much of Europe, where office-based work dominates, ergonomic issues are highly prevalent (Sakakibara et al, 2023).

Prolonged static sitting has been linked to the onset of musculoskeletal disorders (MSDs), a common health concern across Europe (Markova et al., 2024). These findings highlight the urgent need for interventions to address the health risks posed by sedentary work environments. Prolonged sedentary activities and non-neutral postures are significant contributors to the development of musculoskeletal disorders (MSDs), which rank among the leading causes of workplace absenteeism and reduced productivity (Yang et al, 2022).

In recent years, the integration of sensor technology and neural networks for analyzing and correcting sedentary postures has gained prominence in the fields of ergonomics, occupational health, and biomedical research (Krauter et al., 2024). Advances in this area have focused on the development of technologies capable of automatically detecting improper postures to prevent MSDs and enhance ergonomic practices in both professional and academic environments (Varas et al., 2024). According to Yan et al. (2017), sensor technologies have emerged as a widely adopted method for posture monitoring due to their ability to capture motion and position data in real time. Their application enables precise tracking and analysis of body movements, making them invaluable for ergonomic evaluations. For example, a study conducted by Lee et al. (2021), demonstrated the effectiveness of sensor technology in detecting sitting postures and providing real-time feedback to users. These findings highlight the potential of such technologies to mitigate the risks associated with prolonged sedentary behavior and support interventions aimed at improving musculoskeletal health. A device (mat) utilizing pressure sensors was developed to detect non-neutral postures with the objective of determining ergonomic posture risks associated with improper sitting. Pressure sensors offer a practical and efficient means of capturing real-time data on body weight distribution and posture, enabling the system to identify and provide feedback on potentially harmful sitting behaviors. However, while the technological functionality of such systems is critical, their effectiveness in real-world settings largely depends on their usability. Evaluating usability is essential to ensure that the device is intuitive, comfortable, and seamlessly integrates into users' daily routines. Usability assessments help identify potential barriers to adoption, such as complexity, discomfort, or lack of clarity in feedback mechanisms, which could hinder widespread implementation and effectiveness. By prioritizing usability, this system aims to maximize user engagement and ensure its practical application in promoting ergonomic awareness and reducing the risks associated with non-neutral postures.

The purpose of this research is to evaluate the usability of a device designed to detect sitting postures and determine ergonomic risks using pressure sensors. Usability evaluation is a critical step in determining the practical effectiveness of the device in real-world settings, beyond its technical performance. By assessing factors such as user interaction, comfort, ease of operation, and clarity of feedback, this research seeks to identify potential strengths and areas for improvement in the system’s design. The evaluation aims to ensure that the device not only achieves its intended functionality but also meets the needs and expectations of its target users. Ultimately, the findings will inform design refinements to enhance user acceptance, promote consistent use, and maximize the device's potential for improving ergonomic practices and reducing health risks associated with non-neutral sitting postures.

2. OBJECTIVES

The purpose of this study is to evaluate the usability of a pressure mat designed to detect non-neutral sitting postures in the workplace. Using the System Usability Scale (SUS), this study aims to assess the effectiveness, efficiency, and user satisfaction of the device as an ergonomic tool for monitoring sitting postures and determine associated ergonomic risk.

This research addresses the growing need for innovative and practical solutions to mitigate the adverse health effects of prolonged sedentary work. In addition, the findings will help improve the design and functionality of pressure-based systems, ensuring their suitability for real-world applications in both occupational and academic environments.

3. METHODOLOGY

This research aimed to evaluate the usability of a pressure mat designed to detect non-neutral sitting postures and associated ergonomic risk using the SUS (see figure 1).

Figure 1. Pressure mat to detect non-neutral postures

This methodology allows for a comprehensive assessment of the pressure mat’s usability, providing valuable information on its potential for integration into workplace environments and its capacity to contribute to ergonomic improvements.

3.1 Participants

A total of 116 (half of them with ergonomic training) participants comprising university students and public, were recruited for the study. The participants were selected to ensure a diverse representation of users who would potentially benefit from the ergonomic device in real-world scenarios. The participants were predominantly male (56.5%), aged 18 to 75 years, BMIs ranging from 21.83 to 38.89 kg/m2. The judgment sampling method was applied to conform sample according to the following inclusion criteria: 1) The participant should be over 18 years of age; 2) The participant should not have been pregnant or be under medical treatment. Prior to the usability testing, participants signed a consent form and were given a brief orientation on how to use the pressure mat, which was placed on their chair in accordance with the manufacturer’s guidelines. During the testing period, participants used the mat while adopting a set of diverse postures involving different posture angles in the sagittal and transverse planes. This process aimed at establishing ergonomic postural risks by analyzing variations in seated posture.

3.2 Survey design and administration

The usability evaluation was conducted in a controlled environment to minimize external distractions and ensure that participants could focus on the task at hand. Each participant was asked to use the pressure mat during the testing time. After completing the session with the pressure mat, participants filled out the SUS scale survey, a widely recognized instrument for assessing the usability of various products and systems. The SUS consists of 10 statements related to the ease of use, functionality, and user satisfaction with the device, which participants rated on a five-point Likert scale ranging from strongly disagree to strongly agree. The responses were then analyzed to determine the overall usability score, which provides a composite measure of user satisfaction and the effectiveness of the device.

3.3 Data capture and screening

To ensure the reliability and validity of the collected data, a thorough review process was conducted to assess completeness and accuracy. Each participant's responses were carefully examined to identify any missing or inconsistent information that could compromise the integrity of the analysis. Participants who provided incomplete responses or displayed inconsistencies in their data were excluded from the final dataset to maintain the robustness of the study. Additionally, an outlier analysis was performed to detect potential errors on usability scores. This step was crucial in identifying any anomalies that could skew the results, allowing for a more precise and meaningful interpretation of the data. Following this screening process, a structured database was compiled, ensuring that only high-quality, reliable data were included for further statistical analysis and interpretation.

3.4 Data analysis

Usability scores were systematically calculated to assess the overall user experience with the pressure mat. A Pearson correlation analysis was conducted to assess the relationship between SUS scores and demographic variables. A T-test comparison of usability scores between participants with prior ergonomic training and those without training were performed. To further explore the underlying dimensions of usability, an exploratory factor analysis (EFA) was conducted using SPSS version 26 (IBM, Armonk, NY, United States). This statistical approach allowed for the identification of key usability factors, helping to determine the main components influencing user perceptions of the device. In addition to the quantitative analysis, qualitative data were gathered through open-ended questions included at the end of the survey. These responses provided valuable insights into participants' experiences, preferences, and specific suggestions for improving the pressure mat's design, functionality, and user interaction. By integrating both quantitative and qualitative data, the study aimed to obtain a comprehensive understanding of the device’s usability, highlighting areas of strength and opportunities for refinement to enhance its effectiveness in real-world applications.

4 RESULTS

This section presents the findings from the usability assessment of the pressure mat, conducted using the System Usability Scale (SUS). The analysis explores key usability aspects, including user satisfaction, ease of use, and overall functionality, while also identifying potential areas for improvement. Additionally, correlations between usability scores and demographic factors are examined, along with an exploratory factor analysis to determine the primary dimensions influencing user perceptions. These insights contribute to a comprehensive understanding of the pressure mat’s practicality and potential for integration into ergonomic interventions. The usability evaluation of the pressure mat, assessed using the SUS scale, yielded insightful findings regarding user satisfaction, ease of use, and overall functionality of the device.

User satisfaction and ease of Use

The overall SUS score for the pressure mat was calculated to be 74.5, which falls within the range of “acceptable” usability, according to standard SUS interpretation benchmarks. This suggests that, on average, participants found the device usable and relatively easy to interact with. The highest ratings were given to questions regarding the ease of learning how to use the pressure mat and its ability to provide useful feedback on posture. Many participants indicated that the device was intuitive and easy to incorporate into their daily routines. However, several participants noted that the initial setup and placement of the pressure mat on their workstation could be slightly improved for easier integration, especially for users who were less familiar with ergonomic tools. The lowest ratings were observed in questions related to the comfort of the pressure mat during long usage periods. Some participants reported that prolonged contact with the mat led to discomfort, particularly when shifting posture frequently during work activities. Most participants mentioned that the pressure mat helped raise awareness of their sitting posture. Several users expressed that they felt more mindful of their posture after using the mat, contributing to a more ergonomic seating position during work hours. Some participants suggested enhancing the mat’s surface material to make it more comfortable for extended use, as well as incorporating features such as adjustable sensitivity to better accommodate different body types and seating preferences. Additionally, the inclusion of more detailed feedback (e.g., posture graphs or specific corrective actions) was proposed by users who were eager to receive more in-depth insights into their posture patterns.

Correlation and group comparison of usability perceptions

A Pearson correlation analysis was conducted to assess the relationship between SUS scores and demographic variables (age, gender, and prior ergonomic experience). No statistically significant correlation was found between SUS scores and age ($r=0.12$, $p=0.21$), indicating that age did not influence usability perceptions. Similarly, an independent samples t-test revealed no significant difference in SUS scores between male ($\mu=74.8$, sd=6.875) and female participants ($\mu=74.1$, sd=6.345); $t=0.52$, $p=0.061$).

However, a comparison of usability scores between participants with prior ergonomic training and those without showed a slightly higher mean SUS score for the trained group ($\mu=76.2$, sd=5.947) compared to the untrained group ($\mu=72.4$, sd=6). An independent samples t-test indicated that this difference ($t = 1.89$, $p = 0.0673$) was not statistically significant, suggesting that prior ergonomic knowledge might have a modest impact on usability perceptions.

Exploratory factor analysis

An exploratory factor analysis (EFA) using principal component analysis (PCA) with varimax rotation was conducted to identify underlying usability dimensions in the System Usability Scale (SUS) responses. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.82, indicating that the data were suitable for factor analysis. Bartlett's test of sphericity was significant ($\chi^2(45) = 236.57$, $p < 0.001$), confirming the presence of intercorrelations among the variables. According to scree plot (Figure 1) two principal factors emerged, explaining 72.4% of the total variance:Ease of Use ($\lambda = 3.42$, 41.3% variance explained included items related to the simplicity of device operation, ease of learning, and integration into daily routines.

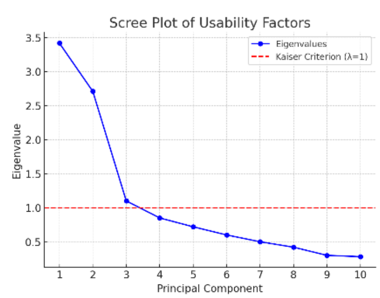


Figure 1. Scree plot of usability factors

High loadings were observed for statements (see figure 2) such as "I found the device easy to use" (0.78) and "I felt comfortable using the device without additional guidance" (0.75). Perceived Usefulness ($\lambda = 2.71$, 31.1% variance explained) captured participants' perceptions of the pressure mat's ability to provide real-time feedback and its effectiveness in promoting better posture awareness. Items such as "The device provided useful feedback on my posture" (0.82) and

"Using the pressure mat made me more conscious of my sitting habits" (0.79) loaded strongly on this factor.

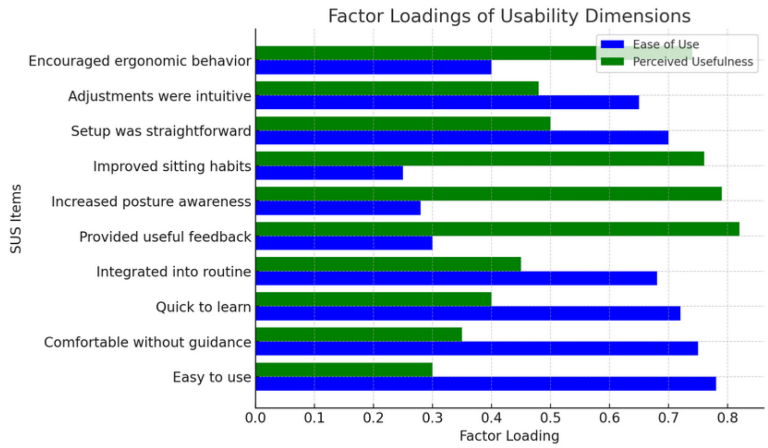


Figure 2. Factor loadings plot of usability dimensions

These findings suggest that usability perceptions were primarily driven by the ease of interacting with the pressure mat and the perceived effectiveness of its feedback in improving posture awareness. Future iterations of the device could benefit from optimizing its comfort during prolonged use while maintaining its intuitive functionality and real-time monitoring capabilities.

5. CONCLUSIONS

The results from the usability testing of the pressure mat provide a valuable understanding of its strengths and areas for improvement in the context of ergonomics and posture monitoring. The mean SUS score of 74.5 indicates that the pressure mat falls within the “acceptable” usability range, which suggests that, overall, users found the device relatively easy to use and effective in helping them monitor and correct their posture. The highest ratings were observed in aspects of ease of learning and the ability of the pressure mat to provide useful feedback. These findings are particularly important in terms of user experience, as ease of use is a crucial factor in ensuring that workers adopt and integrate ergonomic devices into their daily routines. Users’ positive feedback on the real-time posture monitoring feature of the pressure mat suggests that such feedback is a key motivator for behavior change. However, the study also identified areas for improvement. Notably, some users experienced discomfort during prolonged use, especially when adjusting their posture frequently. This feedback points to the need for more comfortable surface material or design improvements that can accommodate extended sitting periods. Additionally, the setup process, although rated positively overall, still presented minor challenges for users unfamiliar with ergonomic tools. Furthermore, the correlation between higher usability scores and participants with prior ergonomic training suggests that users with greater awareness of posture-related health issues may have a more positive view of the pressure mat's effectiveness. This insight highlights the importance of ergonomic education in maximizing the benefits of such devices and suggests that workplace interventions could be more successful if paired with training programs. In conclusion, the usability evaluation of the pressure mat demonstrated that it is a promising tool for posture monitoring and ergonomic improvement in workplace settings. The device achieved an acceptable level of usability, with participants generally reporting positive experiences in terms of ease of use and the usefulness of posture feedback. Despite some limitations regarding comfort and initial setup, the pressure mat shows considerable potential as a cost-effective solution for promoting better posture and reducing musculoskeletal disorders in sedentary workers. The findings underscore the importance of continued refinement of ergonomic tools like the pressure mat to enhance comfort and ease of integration into diverse work environments. Additionally, the results suggest that ergonomic education and training programs may further increase the effectiveness and user satisfaction of such devices. Future research could focus on exploring long-term effects of using the pressure mat on worker health and productivity, as well as investigating the potential of integrating more advanced features, such as personalized feedback and data analytics, to further improve the user experience and overall effectiveness of the system.

Declaration of Competing Interest

The authors declare that there were no commercial or financial relationships that could be interpreted as a conflict of interest during the conduct of the study.

6. REFERENCES

Andreoni, G. (2023). Investigating and Measuring Usability in Wearable Systems: A Structured Methodology and Related Protocol. *Applied Sciences*, *13*(6), 3595. https://doi.org/10.3390/app13063595.

Bastien, J. M. C. (2010). Usability testing: A review of some methodological and technical aspects of the method. *International Journal of Medical Informatics*, *79*(4). https://doi.org/10.1016/j.ijmedinf.2008.12.004.

Bonnet, C. T., & Barela, J. A. (2021). Health Issues Due to the Global Prevalence of Sedentariness and Recommendations towards Achieving a Healthier Behaviour. *Healthcare (Basel, Switzerland)*, *9*(8), 995. https://doi.org/10.3390/healthcare9080995.

Brooke, J. (1996). SUS: A 'quick and dirty' usability scale. In P. Jordan, B. Thomas, & B. Weerdmeester (Eds.), *Usability Evaluation in Industry* (pp. 189–194). London, UK: Taylor & Francis.

Goyal, J., & Rakhra, G. (2024). Sedentarism and Chronic Health Problems. *Korean journal of family medicine*, *45*(5), 239–257. https://doi.org/10.4082/kjfm.24.0099.

Kalankesh, L. R., Nasiry, Z., Fein, R. A., & Damanabi, S. (2020). Factors Influencing User Satisfaction with Information Systems: A Systematic Review. *Galen medical journal*, *9*, e1686. https://doi.org/10.31661/gmj.v9i0.1686.

Keenan, H. L., Duke, S. L., Wharrad, H. J., Doody, G. A., & Patel, R. S. (2022). Usability: An introduction to and literature review of usability testing for educational resources in radiation oncology. *Technical innovations & patient support in radiation oncology*, *24*, 67–72. https://doi.org/10.1016/j.tipsro.2022.09.001.

Keogh, A., Dorn, J. F., Walsh, L., Calvo, F., & Caulfield, B. (2020). Comparing the Usability and Acceptability of Wearable Sensors Among Older Irish Adults in a Real-World Context: Observational Study. *JMIR mHealth and uHealth*, *8*(4), e15704. https://doi.org/10.2196/15704.

Krauter, C., Angerbauer, K., Sousa Calepso, A., Achberger, A., Mayer, S., & Sedlmair, M. (2024). Sitting posture recognition and feedback: A literature review. *Proceedings of the CHI Conference on Human Factors in Computing Systems*, 1–20. https://doi.org/10.1145/3613904.3642657.

Lee, R., James, C., Edwards, S., Skinner, G., Young, J. L., & Snodgrass, S. J. (2021). Evidence for the Effectiveness of Feedback from Wearable Inertial Sensors during Work-Related Activities: A Scoping Review. *Sensors*, *21*(19), 6377. https://doi.org/10.3390/s21196377

Li, H., Zhang, W., & Yan, J. (2024). Physical activity and sedentary behavior among school-going adolescents in low- and middle-income countries: insights from the global school-based health survey. *PeerJ*, *12*, e17097. https://doi.org/10.7717/peerj.17097.

Maqbool, B., & Herold, S. (2024). Potential effectiveness and efficiency issues in usability evaluation within Digital Health: A systematic literature review. *Journal of Systems and Software*, *208*, 111881. https://doi.org/10.1016/j.jss.2023.111881.

Markova, V., Markov, M., Petrova, Z., & Filkova, S. (2024). Assessing the impact of prolonged sitting and poor posture on lower back pain: A photogrammetric and machine learning approach. *Computers*, *13*(9), 231. https://doi.org/10.3390/computers13090231.

Odesola, D. F., Kulon, J., Verghese, S., Partlow, A., & Gibson, C. (2024). Smart Sensing Chairs for Sitting Posture Detection, Classification, and Monitoring: A Comprehensive Review. *Sensors (Basel, Switzerland)*, *24*(9), 2940. https://doi.org/10.3390/s24092940.

Osses Coloma , M. . (2022). EVALUACIÓN DE FACTORES ERGONÓMICOS, EN LA INTERACCIÓN ENTRE USUARIOS Y DISPOSITIVOS DE AUTOATENCIÓN.: ERGONOMÍA Y DISEÑO. *Atacama Journal of Health Sciences*, *1*(Supl.2). Recuperado a partir de //salud.uda.cl/ajhs/index.php/ajhs/article/view/69.

Park, J. H., Moon, J. H., Kim, H. J., Kong, M. H., & Oh, Y. H. (2020). Sedentary Lifestyle: Overview of Updated Evidence of Potential Health Risks. *Korean journal of family medicine*, *41*(6), 365–373. https://doi.org/10.4082/kjfm.20.0165.

Sakakibara, K., Miyanaka, D., Tokita, M., Kawada, M., Mori, N., Hamsyah, F., Lin, Y., & Shimazu, A. (2023). Association of Work-Related Sedentary Behavior With Mental Health and Work Engagement Among Japanese White- and Blue-Collar Workers. *Journal of occupational and environmental medicine*, *65*(11), e695–e702. https://doi.org/10.1097/JOM.0000000000002952.

Yan, X., Li, H., Li, A. R., & Zhang, H. (2017). Wearable IMU-based real-time motion warning system for Construction Workers' Musculoskeletal Disorders Prevention. *Automation in Construction*, *74*, 2–11. https://doi.org/10.1016/j.autcon.2016.11.007.

Yang, Y., Zeng, J., Liu, Y., Wang, Z., Jia, N., & Wang, Z. (2022). Prevalence of Musculoskeletal Disorders and Their Associated Risk Factors among Furniture Manufacturing Workers in Guangdong, China: A Cross-Sectional Study. *International journal of environmental research and public health*, *19*(21), 14435. https://doi.org/10.3390/ijerph192114435.

Varas, M., Chang, L., Garcia, J.-C., & Moreira, E. (2024). Risk assessment of musculoskeletal disorders using Artificial Intelligence. *E3S Web of Conferences*, *532*, 02001. https://doi.org/10.1051/e3sconf/202453202001

ERGONOMIC DESIGN OF THE WORK AREA FOR THE PREPARATION OF FROZEN PRODUCTS.

Grace Erandy, Báez Hernández, ORCID 000-0003-1580-2199, Moisés López Valenzuela, 0009-0003-8555-7296, Carlos Alberto Parra Sánchez, 0009-0004-8567-182X, José Carlos Robles Cruz, 0009-0009-7176-7528, Anna Jael Vea López, 0009-0000-6826-4924.

División de Ciencias Industriales
Tecnológico Nacional de México-Instituto Tecnológico Superior de Guasave
Carretera a Brecha S/N, Ej. Burrioncito
Guasave, Sinaloa, CP. 81149

Corresponding author's e-mail: grace.bh@guasave.tecnm.mx

Resumen En el presente trabajo se muestran el rediseño de área de trabajo que se realizó en un proceso de producción de una empresa de productos congelados en Guasave, Sinaloa. Las actividades principales de la empresa es la elaboración de Nieve y congelados. La Investigación tiene como objetivo Rediseñar el área de trabajo para la elaboración de productos congelados, a través del análisis las operaciones e identificar los desórdenes de trauma acumulativo (DTA´s). Analizar los principios ergonómicos, así como la normatividad referente a las condiciones físicas del lugar, se aplicaron distintos métodos de análisis ergonómicos, como el método Corlett & Bishop, que con él se identifica las áreas del cuerpo donde los trabajadores presentaban dolores y molestias, así como un test de fatiga laboral. El método Rula se aplicó para determinar los DTA, riesgos y posturas no adecuadas a los que están expuestos los trabajadores, y proponer soluciones a dichas problemáticas, para obtener un mejor ambiente de trabajo que proteja la integridad física y psicológica del trabajador y mejorar la productividad. Se realizó un rediseño ergonómico, con el fin de disminuir los problemas de rotación de personal, lesiones musculoesqueléticas y aumentar productividad en los operadores.

Palabras clave: Lesiones musculoesqueléticas, condiciones ambientales, método RULA, condiciones ergonómicas.

Relevancia para la ergonomía. La ergonomía es la interacción entre los seres humanos y otros elementos de un sistema. Este estudio aporta información que contribuye a la mejora de las condiciones de trabajo en las empresas de congelados de la región.

Abstract This paper shows the redesign of the work area that was carried out in a production process of a frozen products company in Guasave, Sinaloa. The main activities of the company are the production of ice cream and frozen foods. The objective of the research is to redesign the work area for the production of frozen products, through the analysis of the operations and to identify cumulative trauma disorders (DTA's). To analyze the ergonomic principles, as well as the regulations regarding the physical conditions of the place, different ergonomic analysis methods are applied, such as the Corlett & Bishop method, which identifies the areas of the body where workers have pain and discomfort, as well as a work fatigue test. The Rula method was applied to determine the DTA, risks and inappropriate postures to which workers are exposed, and to propose solutions to these problems, to obtain a better work environment that protects the physical and psychological integrity of the worker and improves productivity. An ergonomic redesign was carried out in order to reduce staff turnover problems, musculoskeletal injuries and increase operator productivity.

Keywords: Musculoskeletal injuries, environmental conditions, RULA method, ergonomic and sustainable conditions.

Relevance to ergonomics. Ergonomics is the interaction between humans and other elements of a system. This study provides information that contributes to improving working conditions in frozen food companies in the region.

1. INTRODUCTION

Ergonomics is a scientific discipline related to the understanding of the interactions between humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design to optimize human well-being and overall system performance. (IEA, 2020).

According to the SME Registration Directory in Guasave, Sinaloa, there are 14 frozen food and ice cream production establishments in the municipality. These establishments generate an economic sector and provide employment for the population. (Pymes, 2020).

The activities carried out in these establishments involve manual handling of loads by the operator, which may result in musculoskeletal injuries due to product transfer, workload, and manual load handling.

This research seeks to develop an alternative to improve the working conditions of operators, staff turnover and improve labor productivity in the activities of ice cream and frozen food production. The objective is to redesign the work area for the production of frozen products, through the analysis of operations and to identify cumulative trauma disorders (CSDs). (Guillen Fonseca, 2006). To analyze the ergonomic principles, as well as the regulations regarding the physical conditions of the place, different ergonomic analysis methods were applied, such as the Corlett & Bishop method, to identify the areas of the body where workers had pain and discomfort, as well as a work fatigue test. The rula method will be applied to determine CSD, and to propose solutions to these problems, to obtain a better work environment that protects the physical and psychological integrity of the worker and improve productivity. An ergonomic redesign was carried out, in order to reduce staff turnover problems, musculoskeletal injuries and increase productivity in operators**.**

2. OBJETIVE

Make a proposal for ergonomic redesign of the work area for the production of frozen products to improve worker productivity.

3. DELIMITATION.

The analysis refers to a proposal for improvement through a redesign of the work area to generate ergonomic and sustainable conditions within the process and achieve productivity in the frozen food company. Evaluating the workers and activities carried out in the work stations.

4. METHODOLOGY

The study was carried out in several stages:

- A diagnosis of the company was carried out through tours, identifying the characteristics of the workers, and the operations of the work stations and the situation in which the company is located.
- The work stations were analyzed for a certain time, and the activities that present risk factors for the operator were identified, in this case the work station and details of the product, as well as the office staff, showing musculoskeletal injuries in the workers.
- Apply ergonomic evaluation methods, RULA Method, with which the risk that the worker runs in his work area was evaluated, as well as the application of Mexican Official Standards (NOM).
- Make the proposal for the redesign of the work station in the production of frozen products.

5. RESULTS

Through the application of Ergonomic Assessment Methods, ergonomic risk factors and physical fatigue present in the work stations can be identified and assessed, where agents of negative impact on the worker were found, including incorrect postures in repetitive movements and excessive load levels in the activities performed. In the analysis of the work stations, two key areas are identified: the mixing preparation station and the centrifugation and cooling station. In the first, the combination of ingredients is carried out according to the desired flavor, where the operators must have all the necessary materials and tools within reach to avoid unnecessary movements; however, accessibility problems and inadequate postures have been observed that generate fatigue and increase the risk of injury. On the other hand, in the centrifugation and cooling station, the mixture is subjected to centrifugation to homogenize the ingredients while the temperature gradually drops to 5°C - 6°C, although the lack of a digital monitoring system that indicates the completion time of the process has been identified, which causes delays in production.

Figure 1. Company workstations

Regarding working conditions and proposed improvements, a redesign of the work area is suggested, including the installation of ergonomic shelves to improve access to ingredients and tools, as well as a reorganization of equipment and utensils to avoid unnecessary movement and reduce work fatigue. The implementation of a digital display to monitor temperature and process times without the need for constant manual intervention is also proposed. Regarding the work schedule, there are two 46-year-old operators in charge of both stations and a 21-year-old newcomer to the company, who is learning the ropes. Both work six hours a day and make between 30 and 50 batches of mix per day, with the final mix stored at -18°C to -20°C until distribution.

Table 1. List of Mexican Official Standards applied to the company's production process.

List of official Mexican Standards applied to the company's production process			
Company: Neveria Genesis			
Standard	The company complies with the regulations		Observations
	Yes	No	
Mexican Official Standard NOM-001-STPS-2008, Buildings, premises, facilities and areas in work centers-Safety conditions		X	The work space in general presents inadequate conditions for the development of activities, such conditions are visible in the physical structure of the place and the machinery used.
NOM-251-SSA1-2009 – Hygiene practices for processing food, beverages, or dietary supplements	x		There are hygiene standards within the company to ensure product quality.
NOM-011-STPS-2001 – Safety and hygiene conditions in workplaces where noise is generated		X	No specific measures have been implemented to reduce noise in the work area
NOM-026-STPS-2008 – Safety and hygiene colors and signs		X	Specific safety and hygiene colors or signs have not been implemented in the work area.
Mexican Official Standard NOM-036-1-STPS-2018, Ergonomic risk factors at work - Identification, analysis, prevention and control.		X	The activities carried out during the day are repetitive, employees must adapt to the work area and equipment, lighting and ventilation conditions are not adequate, which creates an unwelcome environment for operators. The road roller is turned on and off from the loading center, which represents an imminent risk.
NOM-017-STPS-2008 – Personal protective equipment. Selection, use and handling in the workplace..		x	Operators do not have protective equipment that guarantees 100% safety when carrying out the process

Table 2. List of ergonomic principles applicable to the company's production process.

Principles	Observations
No.1 Keep everything within reach	The preparation area has been reorganized so that materials and tools are within reach of the worker, avoiding unnecessary movements.
No.2 Use elbow height as a reference	**Ergonomic shelves have been designed to keep ingredients at a suitable height, avoiding the worker having to bend or stretch.**
No.4 Finding the right position for each task	Redesigning the space and training in the efficient use of the new layout ensure that workers adopt correct postures for their tasks.
No.5 Reduce excessive repetitions	**While some repetitive movements have been reduced by reorganizing the space, not all repetitive tasks have been addressed in detail.**
Nº 6: Minimize fatigue.	**Reorganizing the workspace and implementing a digital whiteboard reduces physical fatigue of operators**
Nº 8: Adjustment and change of posture.	The implementation of the RULA method allows the worker's posture to be corrected when performing operations
Nº 9: Provide spaces and access	The workspace has been optimized and access to tools and materials has been improved, facilitating the workflow
Nº 11: Highlight clearly to improve understanding.	The ergonomic digital dashboard and tool location signage provide better understanding and use of the workspace..
Principio Nº 12: Improve work organization.	Staff training and reorganizing the work area contribute to better organization and efficiency in daily tasks..

Figure 2. Activity at station 2

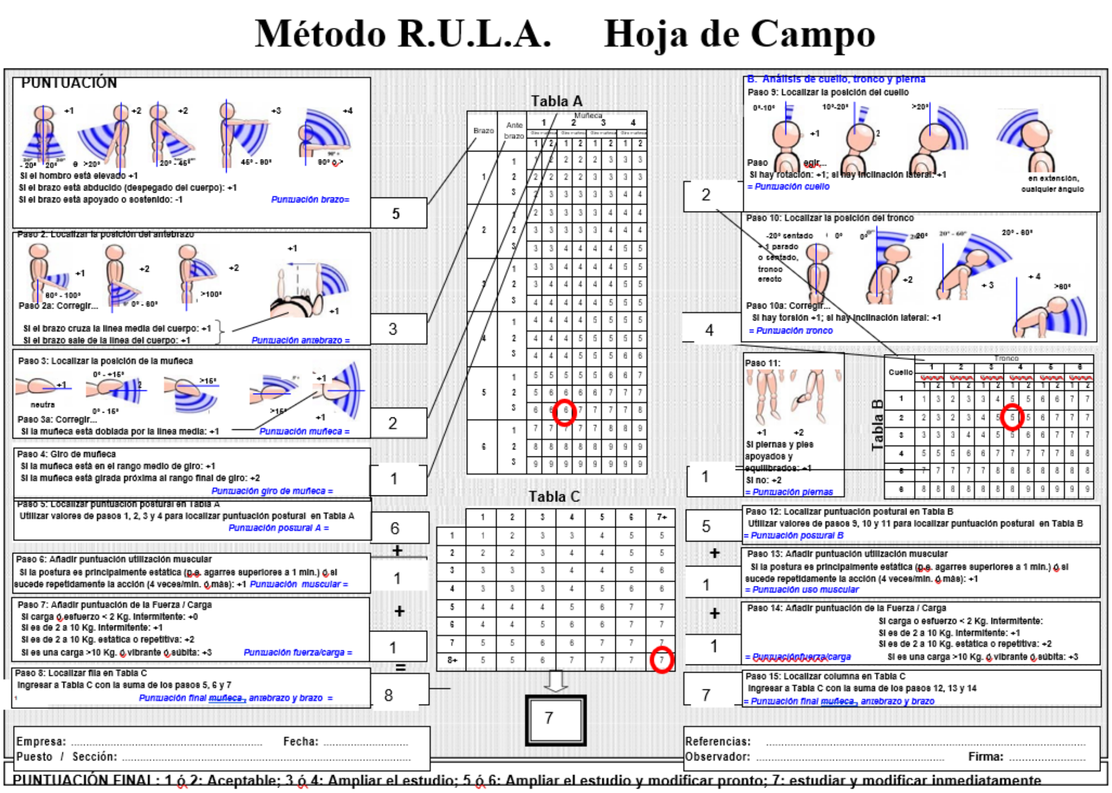


Figure 3. Application of the Rula Method at station 2

Result: A score of 7 was obtained, indicating that the workstation should be studied and modified immediately.

Figure. 4 Redesign of workstations in the company.

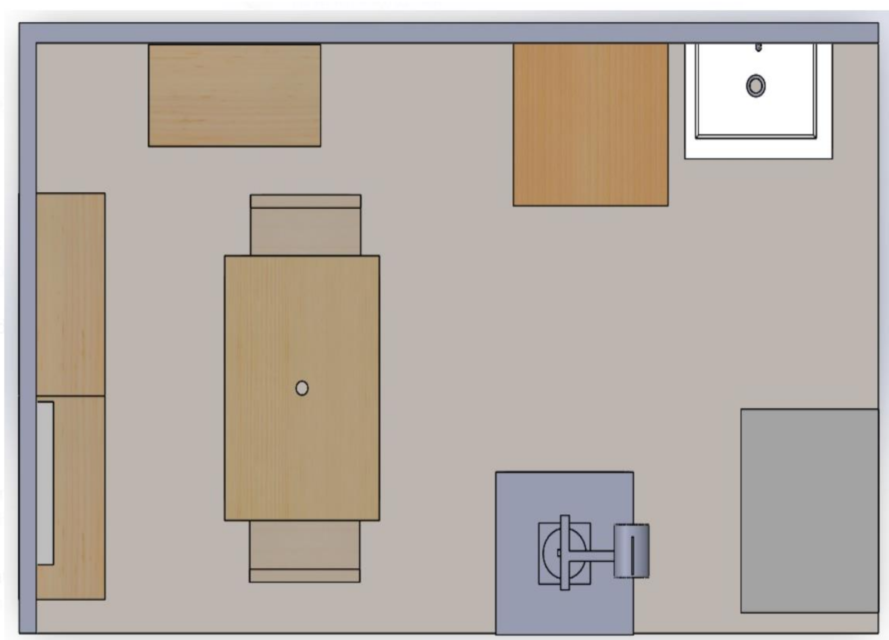


Figure 5. Layout of the company workstations

6. CONCLUSIONS

The changes resulted in a significant reduction in physical fatigue, an increase in productivity and a lower incidence of human errors. The ergonomic redesign using the Rula and Corlett and Bishop method allowed to identify and mitigate ergonomic risks, and fatigue, improving both comfort and operational efficiency.

This allows to detect the risk factors to which workers are exposed when performing operations at station 1 and 2. The environmental conditions, such as temperature and humidity to which workers are exposed, develop a low performance, presenting physical exhaustion, lack of concentration, fatigue from the 3rd day of work, both for station 2. The inadequate postures that the worker presents when performing the task, both at station 1 and station 2, develop cumulative trauma disorders in the following areas: Neck, shoulders, upper arms, knees, as well as lower, middle and upper back. With the application of the RULA Method in the posture with the highest risk, level 7 is detected. One proposal is the application of the official Mexican standards NOM-002-STPS-2010, NOM-026-STPS-2014, NOM-017-STPS-2008 and NOM-036-1-STPS-2018, since there is no accident prevention, the assignment of personal protective equipment, as well as the identification of ergonomic risks at work. There is NO training for the operator on how to perform load handling.

7. REFERENCES

Guillen Fonseca, M. (2006). Ergonomia y la relación con los factores de riesgo en salud ocupacional . *Revista cubana Enfermeria*.

IEA. (2020). *Asociacion internacional de ergonomia* . Obtenido de https://iea.cc/

NORMA Oficial Mexicana NOM-001-STPS-2008, Edificios, locales, instalaciones y áreas en los centros de trabajo-Condiciones de seguridad. (2007, 13 noviembre). Diario Oficial de la Federación. https://www.dof.gob.mx/normasOficiales/3540/stps/stps.htm

NORMA Oficial Mexicana NOM-015-STPS-1994, relativa a la exposición laboral de las condiciones térmicas elevadas o abatidas en los centros de trabajo. (1993, 19 julio). Diario Oficial de la Federación. https://dof.gob.mx/nota_detalle.php?codigo=4699279&fecha=30/05/1994#gsc.tab=

NORMA Oficial Mexicana NOM-251-SSA1-2009, Prácticas de higiene para el proceso de alimentos, bebidas o suplementos alimenticios. (2008, 10 octubre). Diario Oficial de la Federación. https://www.dof.gob.mx/normasOficiales/3980/salud/salud.html

NORMA Oficial Mexicana NOM-004-STPS-1999, Sistemas de protección y dispositivos de seguridad en la maquinaria y equipo que se utilice en los centros de trabajo. (1994, 13 junio). Diario Oficial de la Federación. https://www.dof.gob.mx/nota_detalle.php?codigo=4948965&fecha=31/05/1999#gsc.tab=0

NORMA Oficial Mexicana NOM-036-1-STPS-2018, Factores de riesgo ergonómico en el Trabajo-Identificación, análisis, prevención y control. Parte 1: Manejo manual de cargas. (2017, 29 noviembre). Diario Oficial de la Federación. https://www.dof.gob.mx/normasOficiales/7468/stps11_C/stps11_C.html

Guillen Fonseca, M. (2006). Ergonomia y la relación con los factores de riesgo en salud ocupacional . *Revista cubana Enfermeria*.

IEA. (2020). *Asociacion internacional de ergonomia* . Obtenido de https://iea.cc/

Pymes, D. d. (2020). Obtenido de https://pymes.org.mx/municipio/guasave-8b13.html

ENHACING ENGLISH LANGUAGUE STUDENT'S LEARNING AND SATISFACTION THROUGH ERGONOMIC CLASSROOM DESIGN

Patricia Eugenia Sortillón González[1,4], 0000-0002-9716-6693, María Georgina Fernández Sesma[2], 0000-0002-8981-7062 , Sofía Amavizca Montaño[3], 0000-0002-9469-1986

[1] Manufacturing Industrial Engineering Program
Universidad Estatal de Sonora
Hermosillo, Sonora 83100

[2] English Teaching Program
Universidad Estatal de Sonora
Hermosillo, Sonora 83100

[3] Tourism Bussiness Administration Program
Universidad Estatal de Sonora
Hermosillo, Sonora 83100

[4] Department of Industrial Engineering
Universidad de Sonora
Hermosillo, Sonora 83000

Corresponding author's e-mail: patricia.sortillon@unison.mx

Resumen: Este estudio explora el impacto del diseño ergonómico del aula de clases, en el confort, la concentración, y el rendimiento académico de los estudiantes de enseñanza del Inglés en una institución educativa. Examina como es que factores como altura de mesas de trabajo, ajustes de sillas e iluminación influyen en los resultados del aprendizaje cuando estas actividades son asistidas con una computadora. La muestra se conformó de n=100 participantes de distintos grupos de edad. Se empleó un diseño cuasi experimental, se emplearon dos aulas, una con un diseño convencional y la otra optimizada con criterios ergonómicos como sillas con ajuste, escritorios ajustables, e iluminación adecuada, esta última se diseñó para aumentar la comodidad y facilidad de uso de la computadora. El estudio investiga cómo las modificaciones ergonómicas influyen en las experiencias de aprendizaje de los estudiantes y en su bienestar general. Se utilizó un método mixto que incorporó pruebas T pareadas, evaluación de la carga cognitiva (método NASA-TLX), análisis de varianza con un nivel de significancia del 5%, así como el análisis de información cualitativa procedente de entrevistas y grupos discusión. El estudio comprendió diez y seis semanas, durante las cuales, las primeras ocho semanas los estudiantes estuvieron atendiendo su clase en el aula no ergonómica y el resto en el aula con adecuaciones ergonómicas. Los resultados indicaron que, aunque el rendimiento académico no mostró diferencias significativas, los alumnos que utilizaron el aula adecuada ergonómicamente declararon una menor carga mental, niveles de frustración más bajos y un mayor confort físico. Las pruebas T pareadas confirmaron mejoras en cuanto al uso de mesas y sillas con ajustes e iluminación, que contribuyeron la mejorar la concentración y reducir la fatiga. El análisis temático de los datos corroboró estos resultados, indicando percepciones positivas sobre las intervenciones ergonómicas. Esos resultados subrayan la importancia del diseño ergonómico en los entornos educativos para mejorar el bienestar y el compromiso de los estudiantes.

Palabras clave: Confort, desempeño académico, diseño ergonómico.

Relevancia para la ergonomía: Esta investigación refiere a la aplicación de principios ergonómicos en entornos educativos, específicamente en el contexto aprendizaje de estudiantes de enseñanza del Inglés que emplean computadoras enra su formación. Al evaluar el impacto de las intervenciones ergonómicas en el confort de los estudiantes, la carga cognitiva y el rendimiento académico, el estudio contribuye con un cuerpo de conocimiento sobre cómo los factores ergonómicos influyen en la productividad y el bienestar en entornos que requieren un uso prolongado de computadoras. Los hallazgos presentan implicaciones prácticas para el diseño de espacios de aprendizaje que mejoren la concentración de los estudiantes y reduzcan el malestar físico, lo que podría conducir a mejores resultados educativos. Además, el estudio resalta la importancia de integrar ajustes ergonómicos en los entornos de aula, no solo para mejorar la salud física, sino también para optimizar la función cognitiva y el éxito académico.

La investigación también subraya la necesidad de explorar más a fondo el papel de la ergonomía en los entornos de aprendizaje digital, particularmente en la educación superior, donde la tecnología juega un papel central en el proceso de aprendizaje. A través de estas contribuciones, el estudio enfatiza la relevancia de la ergonomía como un elemento clave para crear experiencias educativas más efectivas y de apoyo.

Abstract: This study explores the impact of ergonomic classroom design on the comfort, focus, and academic performance of English Learning Teaching students. It examines how factors such as desk height, seating arrangements, and lighting influence engagement and learning outcomes, particularly during computer-assisted language activities. This study involved 100 ELT students' group and proficiency levels enrolled in computer-assisted language learning (CALL) programs. Participants were recruited from a single educational institution and categorized based on age, gender, proficiency level, and computer usage frequency. A quasi-experimental design was employed. Two classrooms were selected: one following standard ergonomics and another optimized with adjustable desks, ergonomic chairs, proper lighting, and strategic seating arrangements. The optimized classroom was designed to enhance comfort and support prolonged computer use, aiming to reduce physical strain and improve engagement. A mixed-methods approach was used, incorporating standardized tests (Paired T-tests), cognitive load assessments (NASA-TLX assessment), ANOVA with a 5% significance level, and ergonomic self-evaluations, alongside qualitative insights from interviews and focus groups. The study lasted 16 weeks, with students working in the non-ergonomic classroom for the first eight weeks and in the ergonomic classroom for the following eight weeks. Pre- and post-assessments were conducted during this period. Results indicate that while academic performance showed no significant differences, students in ergonomically optimized classrooms reported reduced cognitive load, lower frustration levels, and greater physical comfort. Paired t-tests confirmed significant improvements in workstation adjustability, lighting, and postural support, contributing to better focus and reduced fatigue. Thematic analysis of qualitative data supported these findings, highlighting students' positive perceptions of ergonomic interventions. These results emphasize the importance of ergonomic design in educational settings to enhance student well-being and engagement.

Keywords: Comfort, academic performance, ergonomic design.

Relevance to Ergonomics: This research provides insights into the application of ergonomic principles in educational settings, specifically in the context of language learning using computers. By evaluating the impact of ergonomic interventions on student comfort, cognitive load, and academic performance, the study contributes to a growing body of knowledge on how ergonomic factors influence productivity and well-being in environments that require prolonged computer use. The findings offer practical implications for the design of learning spaces that enhance student focus and reduce discomfort, potentially leading to better educational outcomes. Moreover, the study underscores the importance of integrating ergonomic adjustments in classroom settings, not only for improving physical health but also for optimizing cognitive function and academic success. This research also highlights the need for further exploration into the role of ergonomics in digital learning environments, particularly in higher education, where technology plays a central role in the learning process. Through these contributions, the study emphasizes the significance of ergonomics as a key element in creating more effective and supportive educational experiences.

1. INTRODUCTION

In recent years, there has been growing recognition of the impact that physical environments have on student learning outcomes (Villarreal et al., 2023). Ergonomics, the science of designing workplaces and educational settings to promote comfort, efficiency, and well-being, has become increasingly relevant in enhancing educational experiences (Smith, 2007). In particular, the role of ergonomic design in language learning has garnered attention, with a focus on how classroom environments can influence students' engagement, focus, and academic performance (Said et al., 2023). This is especially pertinent for English language Teaching students (ELTS), who often face additional challenges in acquiring a second language due to both cognitive and environmental factors. According to Perks et al. (2016) classroom discomfort, poor seating arrangements, and inadequate lighting can create physical strain, which may negatively affect students' ability to concentrate, process information, and participate effectively in language activities. The importance of ergonomics in the educational context is particularly evident when considering the needs of ELTS, who may be required to spend long hours sitting while engaging in activities such as reading, writing, and listening comprehension exercises. Studies (Adu et al., 2024., Markova et al., 2024; Caromano et al., 2015) have shown that prolonged sitting, especially in poorly designed learning environments, can lead to musculoskeletal discomfort, reduced focus, and decreased productivity. The present research aims to explore how ergonomic classroom design influences the comfort, focus, and academic performance of English language learners. By investigating the impact of factors such as desk height, seating arrangement, and lighting on ELTS's ability to engage with language lessons, this study seeks to provide insights into how environmental modifications can optimize learning experiences and contribute to the academic success of students. The findings from this study could offer practical recommendations for language schools, universities, and educators seeking to improve the learning environment for English language learners. By addressing the physical discomforts that may hinder performance, the research aspires to contribute to the development of classroom environments that support the cognitive and linguistic needs of ELLs, ultimately enhancing their language acquisition journey. By evaluating the impact of ergonomic classroom design on ELTS's comfort, focus, and academic performance, particularly during computer-assisted learning, this research aims to provide valuable insights that can help shape future educational environments. The findings could inform the development of more effective, ergonomically optimized classrooms that support the use of computers and enhance the learning experience for English language learners worldwide.

2. OBJECTIVES

The design of educational environments plays a critical role in shaping students' learning experiences, particularly for ELTS who often face unique challenges in language acquisition. Ergonomic classroom design, which emphasizes the alignment of physical spaces with human needs and capabilities, has the potential to significantly impact comfort, focus, and academic performance. By addressing factors such as desk height, seating arrangements, and lighting, educators can create environments that not only reduce physical strain but also foster greater engagement and concentration. This study aims to explore the influence of ergonomic interventions on ELTS, identifying specific factors that contribute to improved learning outcomes and examining students' perceptions of how physical comfort affects their ability to focus. Through a comprehensive analysis, this research seeks to bridge the gap between ergonomic design and effective language instruction, providing valuable insights for optimizing educational spaces for diverse learners. The general objective is to investigate the impact of ergonomic classroom design on the comfort, focus, and academic performance of ELTS, with the aim of identifying specific ergonomic factors and interventions that enhance engagement and reduce physical strain during language learning activities. The specific objectives are the following: 1) To analyze the relationship between ergonomic classroom design and its effects on the comfort and focus levels of ELTS during learning sessions, 2) To identify which ergonomic factors, such as desk height, seating arrangement, and lighting, are most strongly correlated with improvements in ELTS's performance in language acquisition tasks, 3) To evaluate the effectiveness of ergonomic interventions, such as adjustable desks and ergonomic chairs, in enhancing ELTS engagement with English lessons and reducing physical discomfort.

3. METHODOLOGY

The methodology for this research has been structured to assess the impact of ergonomic classroom design, particularly when students use computers during their language learning process. The study will adopt a mixed-methods approach, combining both quantitative and qualitative data collection techniques to provide a comprehensive analysis of the effects of ergonomic interventions on ELTS, with an emphasis on computer use in the classroom.

3.1 Participants

The study involved a total of 100 ELTS from diverse age groups and proficiency levels, enrolled in various language courses that integrate computer-assisted language learning (CALL) programs. Participants had been recruited from one educational institution. To ensure a representative sample, students will be categorized based on age, gender, English proficiency levels (beginner, intermediate, and advanced), and frequency of computer use in their studies. Consent was obtained from participants prior to the study. All participants were informed about the purpose of the study, and their participation was voluntary. Confidentiality and anonymity were maintained throughout the study, and students were allowed to withdraw at any stage without consequence.

3.2 Study design

A quasi-experimental design was used to compare the academic performance, focus, and comfort of ELTS in classrooms with different ergonomic setups, particularly considering the use of computers in the learning process. Two classrooms with contrasting ergonomic environments were selected: one that adheres to standard classroom ergonomics and one that was optimized based on ergonomic principles (i.e., adjustable desks, ergonomic chairs, proper lighting, and optimal seating arrangements). The optimized classroom was designed based on established ergonomic principles, with a focus on supporting the use of computers during language learning. This included ergonomic chairs with adjustable seat heights, backrests, and lumbar support, designed for prolonged computer use; desks that can be adjusted to fit the students' body size and sitting posture while using a computer; proper lighting that reduces glare on computer screens and minimizes eye strain; a classroom layout that promotes comfortable seating arrangements and easy movement while maintaining sufficient space for computers and monitors.

3.3 Data capture

This study examines the effects of ergonomic classroom design on students' academic performance, focus, and comfort during computer-assisted learning. A combination of quantitative and qualitative data collection methods was used to assess these factors. Qualitative data included standardized language proficiency test, the NASA-TLX scale for cognitive assessment, and the computer workstation ergonomics self-assessment checklist (CWES) for physical comfort evaluation. Qualitative insights were gathered through interviews and focus groups with students and teachers to better understand their experiences.

The study lasted 16 weeks, with an ergonomic intervention introduced midway, followed by post-intervention assessments to evaluate its impact on learning and well-being. The following is a detailed explanation of the process for the capture of both qualitative and quantitative data.

3.3.1 pre-and post-Intervention academic performance.

Students' performance on standardized language proficiency tests and periodic quizzes were assessed to measure the impact of ergonomic design on language acquisition. These tests were administered both before and after the intervention period.

3.3.2 Focus and Attention Measurement.

The NASA Task Load Index (NASA-TLX) (Hart, & Staveland, 1988). was used to assess students' focus and cognitive load during computer-assisted learning activities. This provided insights into how ergonomic design influences students' ability to concentrate while using computers.

3.3.3 Comfort Assessment.

The Computer Workstation Ergonomics self-assessment checklist (CWES) (OSHA, 2024) was used to measure students' physical comfort levels during lessons involving computer use. Questions assessed discomfort related to seating, posture, lighting, computer screen position, and general classroom conditions.

3.3.4 Interviews and focus groups.

Semi-structured interviews and focus group discussions were conducted with a subset of students (n= 20) to gather in-depth feedback on their experiences in the ergonomic classroom. Participants were asked about their comfort, focus, and perceived learning effectiveness while using computers in the redesigned classroom environment. These qualitative insights helped to explain the quantitative findings and provide a deeper understanding of the students' experiences.

3.3.5 Teacher feedback

Teachers provided feedback through interviews regarding changes in student engagement, participation, and overall classroom dynamics before and after the ergonomic intervention.

The study was carried out over 16 weeks. Initially, all participants will take part in a baseline assessment, which includes a pre-intervention academic performance test, comfort survey, and a focus assessment during computer-assisted learning activities. The ergonomic intervention was implemented midway through the semester, and the participants will spend the remaining weeks in the newly designed classroom environment with optimized ergonomics for computer use. Following the intervention, a post-intervention assessment was conducted to measure the changes in students' academic performance, comfort, and focus during computer-based tasks. In addition, qualitative data was collected through interviews and focus groups conducted at the end of the intervention period.

3.4 Data analysis

To evaluate the impact of ergonomic classroom design on students' learning experience, a mixed-methods approach was employed, combining quantitative and qualitative analyses. Statistical methods, including descriptive analysis, paired sample t-tests, and ANOVA, were used to assess changes in comfort, academic performance, and focus before and after intervention. Thematic analysis of interviews and focus groups provided deeper insights into student's experiences, engagements, and perceived learning outcomes. These methods are explained in detail in the following paragraph.

Quantitative Data: Descriptive statistics were used to analyze comfort levels, academic performance, and focus before and after the intervention. Paired sample t-tests and ANOVA were conducted to assess significant differences between pre- and post-intervention measures. A significant level of confidence level of 5% waws considered for all tests. Qualitative Data: Thematic analyses were used to analyze the interview and focus group data. Key themes related to students' comfort, engagement, and perceived learning outcomes while using computers were identified and compared across different levels of English proficiency and between the two classroom environments.

4. RESULTS

The results of this research may reveal significant differences in student comfort, cognitive load, and academic performance between students who utilized ergonomically optimized learning setups versus those who worked in less ergonomic environments.

4.1 Academic performance

Students in both the ergonomic and non-ergonomic groups did not show significant differences in academic performance. The mean score for the ergonomic group is 75% (SD = 5.7), while the mean score for the non-ergonomic group is 74% (SD = 6.3). This suggests that a more comfortable and supportive learning environment does not improve academic performance by reducing distractions associated with physical discomfort and mental fatigue.

4.2 Focus and attention measurements

Students completed the NASA-TLX scale after the learning session once each week. Descriptive statistics are shown in table 1 which considers the following scales: mental demand, physical demand, temporal demand, performance, effort, and frustration.

Table 1. NASA-TLX scores.

Ergonomic Factor	Ergonomic Classroom (Mean ± SD)	Non-Ergonomic Classroom (Mean± SD)	Effect Size (Cohen's d)	Effect
Mental demand	45.2 ± 9.3	68.4 ±10.2	2.3	Large
Physical demand	23.5 ± 5.8	52.1 ± 8.7	3.5	Very large
Temporal demand	41.8 ± 7.5	60.3 ± 9.1	2.0	Large
Performance	78.6 ± 6.2	58.2 ± 7.4	2.8	Large
Effort	48.9 ± 8.5	72.6 ± 9.8	2.5	Large
Frustration	21.3 ± 4.9	65.7 ± 10.1	4.0	Very large

According to table 1, students in the non-ergonomic classroom (68.4) experienced significantly higher cognitive load than those in the ergonomic setting (45.2). Higher effort was needed in the non-ergonomic classroom (72.6), likely due to discomfort and poor posture. Students felt three more frustrated (67.5 versus 21.3) in the non-ergonomic classroom, indicating negative impacts on focus and learning quality. Significantly higher in the non-ergonomic classroom (52.1 versus 23.5), confirming ergonomic design reduces fatigue. Students felt pressured by time (60.3 versus 41.8), suggesting discomfort reduced task efficiency. High frustration (65.7) and effort (72.6) negatively affect focus, leading to cognitive overload.

Repeated measures ANOVA showed significant classroom condition effect on mental demand (F32.5, $p=0.0253$), frustration ($F=47.8$, $p= 0.0345$), and effort ($F=39.6$, $p=0.0158$).

4.3 Comfort

The study evaluated fifty students who used both ergonomic classrooms and non-ergonomic classrooms at different times. The CWES checklist was applied after After each session to measure postural comfort, workstation adjustability, lighting, monitor placement, and overall satisfaction over a period of sixteen weeks. The evaluations for all comfort variables were then averaged. The students spent eight weeks in a non-ergonomic classroom and the remainder of the study period in an ergonomic classroom. Since the same participants were evaluated under both conditions, a paired t-test was conducted to assess differences in perceived ergonomics between the two settings. Table 1 shows the results regarding overall comfort variables.

The ergonomic classroom received a high comfort rating ($\mu=4.8$, SD=0.5), while the non-ergonomic classroom scored much lower ($\mu=2.6$, SD= 1.2). Students reported less back, neck and wrist discomfort in the ergonomic setting. Chair comfort and adjustability ($\mu=4.6$ versus $\mu=2.7$, $p=0.0235$ and the desk height and space ($\mu=4.4$ versus $\mu=3.0$, $p=0.0378$) were significantly better in the ergonomic classroom. Many students found the fixed furniture in the non-ergonomic classroom restrictive, making long study sessions uncomfortable. In the ergonomic setup, monitor placement ($\mu=4.3$ versus $\mu=2.9$, $p=0.0178$) and keyboard/mouse positioning ($\mu=4.7$ versus $\mu=3.3$, $p=0.0258$) were rated better. The non-ergonomic setting caused increased wrist strain and neck flexion due to poor device alignment. Lighting conditions were more favorable in the ergonomic classroom, the ergonomic classroom had better anti-glare lighting, while the non-ergonomic classroom had glare and shadow issues, leading to eye strain and fatigue. Students reported being more productive and comfortable in the ergonomic classroom. The largest difference was observed in overall satisfaction with students preferring the ergonomic setup for long-term use.

Table 2. Ergonomic factors and paired t-test results.

Ergonomic Factor	Ergonomic Classroom (Mean ± SD)	Non-Ergonomic Classroom (Mean± SD)	t- value	p-value
Chair comfort and adjustability	4.6 ± 0.5	2.7 ± 0.9	12.24	<0.0235
Desk Height and space	4.4 ± 0.6	3.0 ± 1.0	9.85	<0.0378
Monitor placement	4.3 ± 0.7	2.9 ± 0.8	8.97	<0.0178
Keyboard, mouse position	4.5 ± 0.6	3.1 ± 0.9	9.14	<0.0297
Lighting conditions	4.7 ± 0.5	3.3 ± 1.1	8.62	<0.0258
Postural comfort	4.8 ± 0.5	2.6 ± 1.2	13.02	<0.0259
Overall satisfaction	4.7 ± 0.5	2.5 ± 0.9	14.13	<0.0158

Paired t-tests showed highly significant differences ($p<0.05$) for all variables, confirming that students perceived major ergonomic benefits in the well-designed classroom. Effect sizes (Cohen's d) were large for all factors ($d>1.2$), with the most pronounced effects on postural comfort ($d=2.1$) and overall satisfaction ($d=2.4$). Postural comfort and monitor placement were the strongest predictors of overall satisfaction ($R^2= 0.78$). Students who reported better adjustability and lighting also had higher productivity scores.

4.4 Interviews and focus groups

A subsample n=20 from the total study population participated in semi-structured interviews and focus group discussions in the following areas: comfort, mental load and perceived learning effectiveness. Table 3 shows the thematic analysis key findings:

Table 3. Thematic analysis findings

Theme	Student feedback	Impact on learning
Increased physical comfort	“I no longer feel back pain after long study sessions” “The adjustable chairs make a huge difference-I can finally sit properly and focus”	Less physical strain Improved concentration and engagement
Better posture and reduced fatigue	“Before, I would slouch a lot and feel tired quickly; now, I can sit up straight without discomfort!	Lower fatigue. Longer sustained attention
Enhanced focus and reduced distractions	It’s easier to concentrate because I don’t have to adjust my posture all the time” “With proper lighting, I don’t get eye strain or headaches”	Fewer distractions and higher task efficiency
Improved learning and productivity	“I feel like I absorb information better when I ‘m comfortable” I don’t have to take breaks as often because I don’t feel exhausted”	Increased learning retention and productivity
Higher motivation and engagement	“I look forward to studying now because the environment is more comfortable” “I used to dread long computer sessions, but now they feel manageable”	Positive learning attitude and greater participation

Regarding focus groups observations, the students reported significant reduction in muscle fatigue and back pain. Lighting adjustments minimized eye strain, increasing session duration without discomfort. Table 4 summarizes some aspects considered in focus groups meetings:

Table 4. Contrasting experiences

Aspect	Before (non-ergonomic classroom)	After (Ergonomic classroom)
Comfort	“My back and neck always hurt after class”	“I feel comfortable and can sit for longer periods”
Focus	“I kept adjusting my seat because it was uncomfortable”	“I barely notice my posture now: I can focus on work”
Energy levels	“I felt drained after just and hour of studying”	“I can work for longer without feeling exhausted”
Engagement	“I had trouble paying attention because I was uncomfortable	“I participate more because I don’t feel as restless”
Learning experience	“It was hard to focus on difficult topics for long”	“I understand concepts better now that I can concentrate fully”

These study findings support the growing body of evidence that ergonomically optimized learning environments could have significant positive effects on student comfort, cognitive load, and academic performance. The results indicate that students using ergonomically designed setups report greater comfort, which aligns with existing research suggesting that physical discomfort from poor posture and improper workstation design can distract from learning and cause mental fatigue (Gumasing et al., 2023). Furthermore, the significant reduction in cognitive load for students in the ergonomic group suggests that a well-designed learning environment may allow students to focus more effectively on their tasks without the added strain of physical discomfort, leading to better mental performance (Kalakoski et al. 2018).

The improvement in academic performance did not present a connection between physical well-being and cognitive function. This finding is consistent with previous study (Tanner, 2008) indicating that physical comfort in educational settings is correlated with higher academic achievement, as students can devote more cognitive resources to learning rather than managing discomfort. The data also highlights a strong positive perception of ergonomics among students who were exposed to ergonomic setups, with 85% reporting favorable views on the impact of ergonomic adjustments on their learning experience. This aligns with research suggesting that students are likely to appreciate environments that support their physical health, as they directly contribute to a more comfortable and productive learning experience (Gumasing et al., 2023). This research emphasizes the importance of ergonomic design in educational settings, particularly for students who spend extended hours using computers. The results suggest that ergonomically optimized environments contribute to higher comfort and reduced cognitive load. These findings provide valuable insights for educators, educational institutions, and policymakers seeking to improve learning outcomes through better environmental design. Future research could explore longitudinal effects of ergonomic interventions on academic success, as well as the potential for incorporating ergonomic training for students and educators. By considering the role of ergonomics in educational environments, we can ensure that students are provided with the best conditions to thrive academically and personally.

5. CONCLUSIONS

This study provides evidence that an ergonomically designed classroom significantly enhances student comfort, postural health, and overall workstation usability compared to a non-ergonomic classroom. Students consistently rated ergonomic setups higher, particularly to reduced physical discomfort and greater satisfaction. These findings emphasize the need for ergonomic interventions in educational environments to support student well-being and productivity. Students in ergonomic environments experience lower frustration, effort, and mental demand, resulting in higher engagement and learning efficiency. According to results, non-ergonomic classrooms increase fatigue, increases frustration leading to cognitive overload. Besides, students felt more time pressure, reducing efficiency and performance. Thus, ergonomic interventions should be a priority in educational settings to optimize cognitive and physical well-being.

Declaration of Competing Interest

The authors declare that there were no commercial or financial relationships that could be interpreted as a conflict of interest during the conduct of the study.

6. REFERENCES

Adu, S., Adu, G., Boadi, A. A., & Antwi, K. (2024). Relationship between learning environment design and musculoskeletal disorders in learners. *International Journal of Kinanthropometry*, *4*(2), 44–56. https://doi.org/10.34256/ijk2425

Agudelo Serna, D. A. (2018). *Dinámica de sistemas en la gestión de inventarios.* Ingenierías USBMed.

Caromano, F. A., Amorim, C. A., Rebelo, C. de, Contesini, A. M., Fávero, F. M., Frutuoso, J. R., Kawai, M. M., & Voos, M. C. (2015). Prolonged sitting and physical discomfort in university students. *Acta Fisiátrica*, *22*(4). https://doi.org/10.5935/0104-7795.20150034

De Arquer, I., & Nogareda, C. (1999). *Estimación de carga mental del trabajo: el método NASA TLX. INSHT.* Obtenido de Instituto Nacional de Higiene y Seguridad en el Trabajo: https://www.insst.es/documents/94886/327064/ntp_544.pdf/0da348cc7006-4a8a-9cee-25ed6f59efdd

Ferreira Barreto, E. V. (2024). *Impacto de la ergonomía cognitiva sobre el estrés laboral en médicos radiólogos.* Universidad Nacional Abierta y a Distancia (UNAD), Escuela de Ciencias de la Salud (ECISA).

Guillen Fonseca, M. (2006). Ergonomia y la relación con los factores de riesgo en salud ocupacional . *Revista cubana Enfermeria*.

Gumasing, M. J. J., Cruz, I. S. V. D., Piñon, D. A. A., Rebong, H. N. M., & Sahagun, D. L. P. (2023). Ergonomic Factors Affecting the Learning Motivation and Academic Attention of SHS Students in Distance Learning. *Sustainability*, *15*(12), 9202. https://doi.org/10.3390/su15129202

Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. *Advances in Psychology*, 139–183. https://doi.org/10.1016/s0166-4115(08)62386-9

Huarhua Ludeña, B. &. (2020). *Diseño de un plan de mejoras en el área de almacén e inventarios de un taller de ataúdes.* Universidad Antonio Ruiz de Montoya.

IEA. (2020). *Asociacion internacional de ergonomia* . Obtenido de https://iea.cc/

Kalakoski, V., Selinheimo, S., Valtonen, T., Turunen, J., Käpykangas, S., Ylisassi, H., Toivio, P., Järnefelt, H., Hannonen, H., & Paajanen, T. (2020). Effects of a cognitive ergonomics workplace intervention (CogErg) on cognitive strain and well-being: a cluster-randomized controlled trial. A study protocol. *BMC psychology*, *8*(1), 1. https://doi.org/10.1186/s40359-019-0349-1

Lopez, P. (25 de Julio de 2012). *Memorama como un facilitador de aprendizaje* . Recuperado el 28 de Noviembre de 2019, de http://imced-memorama.blogspot.com/2012/07/memorama-preescolar.html

Markova, V., Markov, M., Petrova, Z., & Filkova, S. (2024). Assessing the Impact of Prolonged Sitting and Poor Posture on Lower Back Pain: A Photogrammetric and Machine Learning Approach. *Computers*, *13*(9), 231. https://doi.org/10.3390/computers13090231

Martin, L. (2015). *Posturas y sus consecuencias* . Recuperado el 01 de Diciembre de 2019, de https://rehabilitacionpremiummadrid.com/blog/laura-martin/postura-consecuencias/

Occupational Safety and Health Administration. (n.d.). *Computer workstation ergonomics: Self-assessment checklist*. Retrieved December 5, 2024, from [https://ors.od.nih.gov/sr/dohs/Documents/checklist-ergonomics-computer-workstation-self-assessment.pdf

Pymes, D. d. (2020). Obtenido de https://pymes.org.mx/municipio/guasave-8b13.html

Perks, T., Orr, D., & Al-Omari, E. (2016). Classroom re-design to facilitate student learning: A case study of changes to a university classroom. *Journal of the Scholarship of Teaching and Learning*, *16*(1), 53–68. https://doi.org/10.14434/josotl.v16i1.19190

Quezada, V. (28 de Mayo de 2018). *One Digital* . Recuperado el 26 de Octubre de 2019, de http://onedigital.mx/2018/05/28/5-beneficios-de-la-ergonomia-en-el-trabajo-que-no-conocias/

SADER. (27 de Junio de 2016). *GOBIERNO DE MÉXICO-Secretaría de Agricultura y Desarrollo Rural* . Obtenido de https://www.gob.mx/agricultura/es/articulos/por-que-el-trigo-en-grano-es-tan-valioso

Said, R., El-Bayaa, M., El-Henawy, W., & El Bassuony, J. (2023). Using ergonomics based instruction in teaching English language integrated skills. *Port Said Journal of Educational Research*, *2*(1), 105–131. https://doi.org/10.21608/psjer.2023.181595.1013

Smith, T. J. (2007). The ergonomics of Learning: Educational Design and Learning Performance. *Ergonomics*, *50*(10), 1530–1546. https://doi.org/10.1080/00140130701587608

Tanner, C. K. (2008). Explaining relationships among student outcomes and the school's physical environment. *Journal of Advanced Academics*, *19*(3), 444–471. https://doi.org/10.4219/jaa-2008-812

Villarreal Arroyo, Y. P., Peñabaena-Niebles, R., & Berdugo Correa, C. (2023). Influence of environmental conditions on students' learning processes: A systematic review. *Building and Environment*, *231*, 110051. https://doi.org/10.1016/j.buildenv.2023.110051.

ERGONOMIC ANALYSIS OF THE WORKSTATION IN THE PACKAGING AREA OF THE SHRIMP FREEZING COMPANY.

Grace Erandy Báez Hernández, ORCID 000-0003-1580-2199, Emilia Estéfana Sauceda López, ORCID 0000-0003-4162-981X, Brenda Guadalupe Delgado Jiménez, ORCID[1] 0000-0002-8289-4823, Roxana Rivas Solis, ORCID 0009-0000-2670-002X

División de Ciencias Industriales
Tecnológico Nacional de México /Instituto Tecnológico Superior de Guasave
Carretera a Brecha Sin Número, Ej. Burrioncito
Guasave, Sinaloa, State 81149

Corresponding author´s e-mail: grace.bh@guasave.tecnm.mx

Resumen: El presente proyecto muestra información de una investigación que se desarrolló con el propósito de generar un análisis ergonómico en la estación de trabajo en el área de empaque de la empresa congeladora de camarón. Esta empresa se dedica a la compra y venta de camarón, en donde, dentro de ella, tiene un proceso de calidad, en el municipio de Guasave, Sinaloa. Con el objetivo de tener un control de sanidad y calidad al momento de procesar el producto de diferentes lotes, teniendo en cuenta la salud y la seguridad del trabajador, para ello, se realizó un análisis ergonómico que se centra en problemas auditivos, lesiones musculoesqueléticas y condiciones ambientales que se presentan día tras día los operadores en las áreas de empaque, se la metodología fue una investigación mixta porque se observó el proceso y se aplicó metodo de evaluación ergonómica, Método RULA, aplicación de Normas oficiales Mexicanas NOMS y elementos de manejo manual de cargas en área de empaque, identificar las causas que generan lesiones musculoesqueléticas y hacer una propuesta de diseño ergonómico para dar solución, brindando seguridad y salud ocupacional.

Palabras clave: Método Rula, Diseño ergonómico, DTA, congeladora de camarón

Relevancia para la Ergonomía: La ergonomía es la interacción entre los seres humanos y otros elementos de un sistema. En este sentido, la investigación se posiciona como un recurso valioso, analizando las operaciones del área de empaque que puede afectar la salud, el bienestar y el desempeño de los empleados.

Abstract: This project presents information from a research project developed to generate an ergonomic analysis of the workstation in the packaging area of a shrimp freezing company. This company is dedicated to the purchase and sale of shrimp, and has a quality assurance process in the municipality of Guasave, Sinaloa. In order to have a health and quality control system when processing products from different batches, taking into account the health and safety of workers, an ergonomic analysis was carried out focusing on hearing problems, musculoskeletal injuries, and environmental conditions that operators encounter day after day in the packaging areas. The methodology used was a mixed-method study, as the process was observed and the ergonomic evaluation method, RULA Method, was applied, along with the application of official Mexican Standards (NOMS) and elements of manual handling of loads in the packaging area. The causes of musculoskeletal injuries were identified, and an ergonomic design proposal was made to provide a solution, providing occupational health and safety.

Keywords: Rula Method, Ergonomic Design, DTA, Shrimp Freezer

Relevance to Ergonomics: Ergonomics is the interaction between humans and other elements of a system. In this sense, research is positioned as a valuable resource, analyzing packing area operations that can affect employee health, well-being, and performance

1. INTRODUCTION

The country's aquaculture industry has developed rapidly, focusing primarily on shrimp farming, primarily in coastal areas. In the Mexican Pacific, the majority of processed shrimp (97.6 percent) is processed for export in frozen form, with only 1.5 percent being canned, and a small fraction (0.9 percent) undergoing other processes (SAGARPA, 2015).

The Municipality of Guasave has 100 shrimp aquaculture farms, with an estimated surface area of 7,000 hectares. Of the water surface, 5,500 hectares are currently in operation. This generates 800 permanent jobs, 3,000 temporary jobs, and produces 10,000 tons of shrimp, with an average selling price of $50,000. (SEMARNAT, 2022).

Shrimp aquaculture has become an important source of regional employment for both men and women. These individuals are responsible for different operations in each of the processes. Loading, unloading, handling, and storage are primarily focused on men due to the amount of effort required. However, shrimp cleaning and deheading operations are mostly reserved for women. However, job analysis and risk assessment in the work environment are topics that apply to any direct or indirect operation in the organization.

Based on this, a research proposal is presented. It focuses on understanding the characteristics of the operations through an ergonomic analysis of the shrimp freezing packaging process. The goal is to identify and evaluate potential musculoskeletal injuries through the application of ergonomic assessment methods and to present alternative solutions for occupational health and safety.

2. OBJECTIVE

Conduct a specific ergonomic analysis of the shrimp freezer packaging process to identify and assess potential musculoskeletal injuries. This will allow for the correct design of the company's current operating conditions.

3. DELIMITATION

The project is designed to analyze and design the production process, specifically focusing on worker postures while performing activities in the packaging area of the freezing company located in Casa Blanca, in the municipality of Guasave, Sinaloa. The company currently operates on a contract basis and has a 12-hour workday, 6 days a week.

4. METHODOLOGY

The research was conducted as follows:

1. Conduct a current analysis of the company's production process through walkthroughs, identifying worker and workstation characteristics that may be detrimental to worker health and safety.

2. Identify the workstations in the packaging area, such as those that pose the greatest risk to worker well-being, and identify the NOM-STPS and ergonomic principles.

3. Conduct assessments to identify musculoskeletal injuries and cumulative trauma disorders using ergonomic assessment methods.

4. Propose ergonomic and safety conditions at the workstation in the packaging area during the production process.

5. RESULTS

The specific objectives of the research were developed during the analysis carried out in the aquaculture facility. There are eight work areas in the aquaculture facility, where the greatest occupational health and safety problems were identified in the packing area. It was identified that the movements performed by operators are inadequate and pose risk factors to their health and safety.

For the current analysis of the production process in the packing area, the operations, workers, and workstations involved in this area were identified.

Table 1. List of Standards Applicable to the Packaging Area

STANDARD	Complies		OBSERVATIONS
	YES	NO	
NOM-011-STPS-2001, Safety and Hygiene Conditions in Workplaces Where Noise Is Generated..		X	Packaging area operators are exposed to noise generated in the plant throughout their workday

NOM-006-STPS-2014, Handling and Storage of Materials - Occupational Health and Safety Conditions.		X	There is no supervision to ensure that manual handling of loads is performed correctly, nor is there any assurance that workers are fit to carry such loads, in addition to lacking training.
NOM-036-1-STPS-2018, Ergonomic Risk Factors at Work - Identification, Analysis, Prevention, and Control. Part 1: Manual Handling of Loads.		X	The organization does not establish safety measures for its operators or provide training for manual handling of loads.
NOM-017-STPS-2008, Personal Protective Equipment - Selection, Use, and Handling in the Workplace.	X		The organization provides the necessary PPE for operators to perform their tasks in the packaging area.
NOM-030-STPS-2009, Preventive Occupational Health and Safety Services - Functions and Activities..		X	The company does not offer preventive occupational health and safety services
NOM-001-STPS-2008, Buildings, Premises, Facilities, and Workplace Areas - Safety Conditions.	X		The company does comply with the requirements for restrooms, cafeterias, disinfection areas, etc.
NOM-025-STPS-2008, Lighting Conditions in Workplaces.	X		The packaging area has adequate lighting to carry out its activities satisfactorily.
NOM-024-STPS-2001, Vibrations - Safety and Hygiene Conditions in Workplaces.	X		The packaging area does not present vibrations that could affect operators

Table 2. List of ergonomic principles applied in the packaging área

Principle	Complies	Does not complies	Observations
1. Keep everything within reach	X		
2. Use elbow height as a reference..		X	Not at the appropriate height.
3. The grip style reduces strain.		X	They do not have proper grips that reduce strain.

4. Find the correct position for each task.		X	They have inadequate postures
5. Reduce excessive repetitions.		X	The work they perform is completely repetitive.
6. Minimize fatigue.		X	Operators do not have rest time during their shift. .
7. Minimize direct pressure.		X	Operators perform activities with incorrect postures, which are uncomfortable..
8. Adjust and change posture.		X	They work in the same posture throughout the shift.
9. Provide spaces and access.		X	They do not have sufficient spaces
10. Maintain a comfortable environment.		X	There is a lot of noise in the area.
11. Highlight clearly to improve understanding.		X	There is no proper signage
12. Improve work organization.		X	There are factors that prevent workers from being completely comfortable

There are 12 people working in the packing area, all men, as this area is subject to very heavy operations involving the loading of shrimp.

During the operations, the work was analyzed and most operations were performed linearly; there are some that were not, such as labeling and box assembly. Regarding the time taken, the operators are very skilled, but there were still delays of 8 seconds to 15 minutes in the taping operation and rework in the labeling operation.

Furthermore, the workbench where the strapping operation is performed is very wide, and the worker has to do his work sideways, leaning slightly to the right, creating poor posture. Finally, another observation is that there is a lot of noise pollution in the area, and workers are not provided with safety earplugs. They choose to play loud music instead, due to the noise generated by the cold rooms and some machines around the work area.

Figure 1 Work postures of operator 2 at workstation 1

At workstation 1, an ergonomic assessment was conducted using the RULA method to analyze the cardboard box lifting operation. The results of this assessment indicated that the workstation presented a significant ergonomic risk level, with a total score of 7.

The RULA assessment score (Figure 1) was a clear indicator that immediate modifications to the workstation were necessary. A RULA score of 7 suggests significant ergonomic issues that require urgent attention to prevent potential musculoskeletal injuries and improve worker comfort and efficiency.

6. DISCUSSION/CONCLUSIONS

Thanks to all the activities carried out throughout the project, areas of opportunity were identified and used as a reference when developing the final redesign proposal.

In accordance with the initial objectives, work was done to identify the activities in the production process, and the environmental conditions of the packaging area were also studied and analyzed. It was determined that they did not comply with regulations or the ergonomic principles required for a work area to ensure efficient operation and that operator performance is not affected by these conditions.

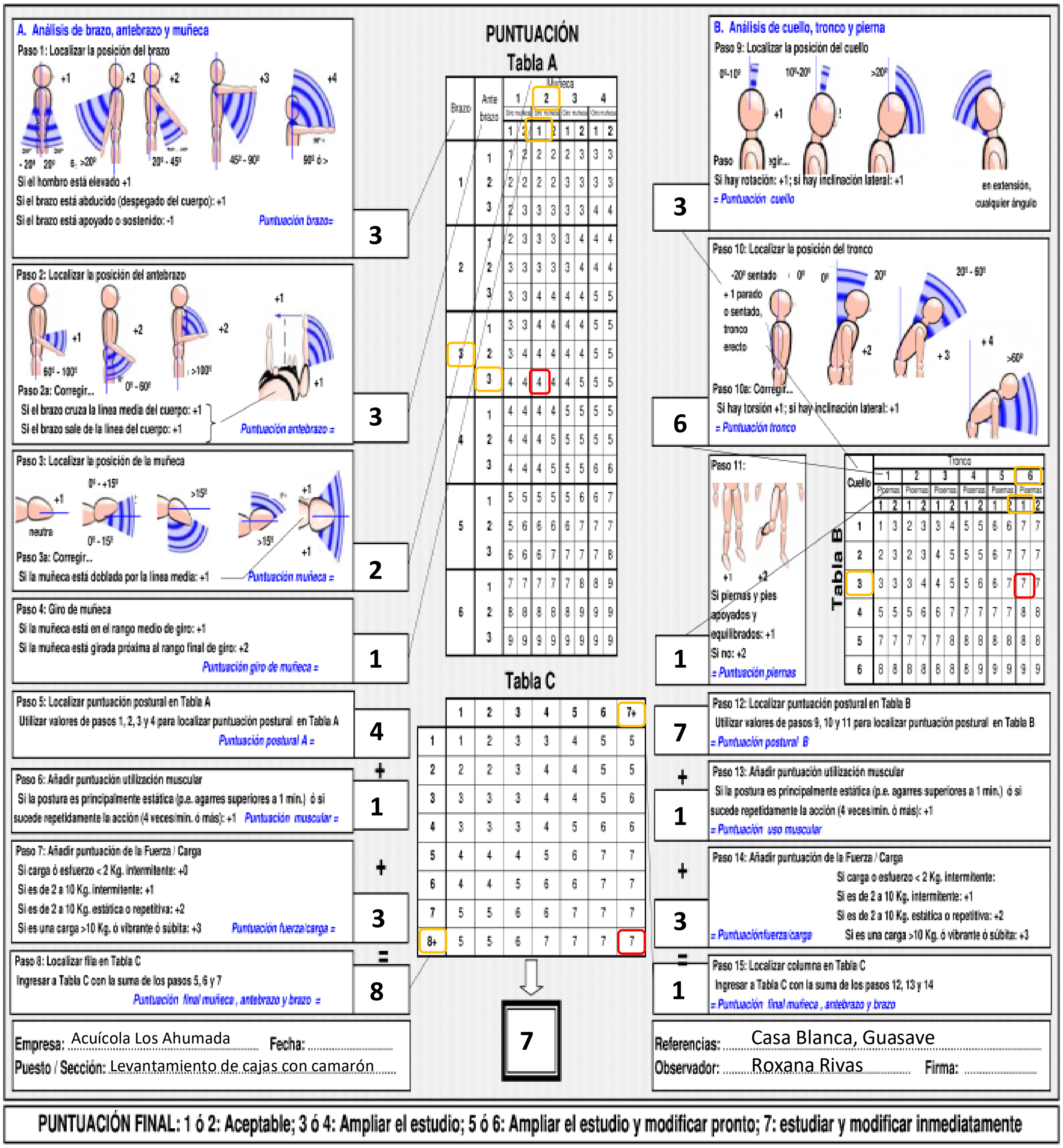


Figure 3 Application of the RULA Method to the working posture of operator 2 at workstation 1

Manual load handling that is not performed correctly, as well as tasks that are often repetitive and not performed correctly, were identified through the application of the RULA ergonomic evaluation method. The results presented are high, indicating that a redesign is necessary to improve working conditions and streamline the process. The proposed worker health and safety conditions include rearranging the continuous strapping table with the metal detector so that they are at the same level and width to avoid improper movements that could affect the operator.

Furthermore, it is proposed that box lifters rotate their duties, as these tasks are often heavy due to the repetitive nature of the workday. Furthermore, the company is recommended to comply with the regulations required to ensure worker well-being and ensure they can operate under safe conditions, such as NOM-036-1-STPS-2018, Ergonomic Risk Factors at Work - Identification, Analysis, Prevention, and Control. Part 1: Manual Handling of Loads. It is also recommended that NOM-011-STPS-2001, Safety and Hygiene Conditions in Workplaces Where Noise Is Generated. It is also recommended that NOM-017-STPS-2008, Personal Protective Equipment - Selection, Use, and Handling in Workplaces. Together, these regulations will improve worker conditions.

7. REFERENCES

Acuacultura. (s. f.). Recuperado de http://guasave.gob.mx/s/acuacultura/

Asana, T. (2022, 12 noviembre). Flujo de un proceso. *Team*. https://asana.com/es/resources/process-flow

Data México. (2023). *Sinaloa: Economía, empleo, equidad, calidad de vida, educación, salud y seguridad pública | Data México*. https://www.economia.gob.mx/datamexico/es/profile/geo/sinaloa-si?redirect=true

INEGI. (2022). *Instituto Nacional de Estadística y Geografía (INEGI)*. https://www.inegi.org.mx/

Organización Internacional del Trabajo. (2a. C.). *La Salud y la Seguridad en el Trabajo ERGONOMIA*. Recuperado 8 de diciembre de 2023, de https://training.itcilo.org/actrav_cdrom2/es/osh/ergo/ergonomi.htm

Orozco Acosta, E. E., Ortiz Ospino, L. E., & De la Hoz Reyes, R. J. (s. f.). Distribución de Plantas con Planeación Sistemática de Layout. UNIVERSIDAD SIMÓN BOLÍVAR—.

Pérez, J. A. (2019). *Selección de métodos de evaluación ergonómica de puestos de trabajo*. Universidad Politécnica de Valencia. https://www.ergonautas.upv.es/herramientas/select/select.php

Rae. (2001). *Camarón, Camarona | Diccionario de la Lengua Española (2001)*. «Diccionario esencial de la lengua española». https://www.rae.es/drae2001/camar%C3%B3n

SafetyCulture. (2023, 25 julio). Identificar los 6 tipos de riesgos laborales | SafetyCulture. Recuperado de https://safetyculture.com/es/temas/riesgos-laborales/

SAGARPA. (2015). *SAGARPA*. Obtenido de https://www.gob.mx/cms/uploads/attachment/file/347534/Camaron_Reporte_Ejecutivo.pdf

SEMARNAT. (2022). *Manifestación de Impacto ambiental modalidad particular .* Obtenido de https://apps1.semarnat.gob.mx:8443/dgiraDocs/documentos/sin/estudios/2022/25SI2022HD019.pdf

EVALUATING THE USABILITY OF AN INERTIAL SENSOR SUIT FOR POSTURE ASSESSMENT

Patricia Eugenia Sortillón González[1], 0000-0002-9716-6693, Aide Aracely Maldonado Macías[2], 0000-0002-4959-161X, David Saénz Zamarrón[3], 0000-0002-5045-4997, Juan Luis Hernández Arellano[4], 0000-0002-5045-4997, Enrique Javier De la Vega Bustillos[5], 0000-0002-0761-6858

[1,2,4]Department of Electrical Engineering and Computing
Universidad Autónoma de Ciudad Juárez
Ciudad Juárez, Chihuahua 32310

[3]Electronics Department
Instituto Tecnológico de México/Instituto Tecnológico de
Ciudad Cuauhtémoc,
Cd. Cuauhtémoc, Chihuahua 31500

[5] Department of Industrial Engineering
Instituto Tecnológico de México/ Instituto Tecnológico de Hermosillo
Avenida Tecnológico S/N Col el Sahuaro
Hermosillo, Sonora, 83100

Corresponding author's e-mail: patricia.sortillon@unison.mx

Resumen: La tecnología de sensores inerciales es ampliamente utilizada en biomecánica, ergonomía y ciencias del deporte para el análisis del movimiento en tiempo real. Los trajes con sensores inerciales (ISS), compuestos por unidades de medición inercial (IMU), ofrecen una alternativa portátil a los sistemas tradicionales de captura de movimiento. Sin embargo, su adopción depende de su usabilidad, considerando factores como comodidad, facilidad de uso e integración en el flujo de trabajo. Este estudio evalúa la usabilidad de un ISS mediante la Escala de Usabilidad del Sistema (SUS). Se reclutó a 68 participantes de entre 19 y 24 años, principalmente con formación en ingeniería. Aproximadamente la mitad tenía experiencia con sensores inerciales. Los criterios de inclusión contemplaron el ser mayores de 18 años y no presentar afecciones musculoesqueléticas. Antes de la prueba, los participantes recibieron una breve orientación y firmaron un consentimiento informado. La evaluación se llevó a cabo en un entorno controlado para evitar distracciones. Durante la prueba, los participantes usaron el ISS mientras realizaban una tarea de amasado en escultura y luego completaron la versión validada en Español de la encuesta SUS. La encuesta SUS comprende 10 afirmaciones calificadas en una escala Likert de cinco puntos, midiendo facilidad de uso, funcionalidad y satisfacción. Se realizó un análisis de datos para garantizar su integridad y fiabilidad, eliminando respuestas incoherentes o incompletas. También se aplicó un análisis de valores atípicos creando una base de datos estructurada para el análisis estadístico. El ISS obtuvo una puntuación media de 78.5 en la escala SUS, lo que indica una buena usabilidad. La mayoría de los participantes (82%)

expresaron satisfacción con el dispositivo, destacando la característica de seguimiento del movimiento en tiempo real. Sin embargo, el 23% experimentó dificultades durante la configuración, principalmente en la colocación y calibración de los sensores. El análisis de correlación de Pearson mostró una relación negativa moderada entre la edad y la percepción de usabilidad ($r=-0.35$, $p<0.05$), lo que sugiere que los participantes de mayor edad encontraron el ISS menos fácil de usar. Los usuarios con experiencia previa en sensores obtuvieron puntuaciones significativamente más altas ($p<0.05$), evidenciando el impacto de la familiaridad en la percepción de usabilidad. No se encontraron diferencias significativas entre géneros. El análisis factorial exploratorio (AFE) identificó tres dimensiones clave de usabilidad, explicando el 68% de la varianza: eficiencia percibida (38%), relacionada con la precisión y el tiempo de respuesta; facilidad de uso (22%), que abarca la comodidad y la configuración; y confianza del usuario (8%), asociada a la fiabilidad del sistema. Las sugerencias de los participantes resaltaron la necesidad de mejorar la estabilidad de los sensores, así como el entrenamiento para los usuarios principiantes. Se sugirió perfeccionar las instrucciones de configuración y desarrollar tutoriales interactivos o interfaces adaptables. El potencial del ISS es muy amplio para la evaluación de la postura. Sin embargo, se podría optimizar su usabilidad, mejorando la configuración y la asistencia al usuario. En estudios futuros se podría analizar su adaptación a largo plazo, así como su comparación con otras tecnologías de captura de movimiento, asegurando su integración eficiente en aplicaciones ergonómicas del mundo real.

Palabras clave: Diseño centrado en el usuario, movimiento humano, análisis, sensor portable, usabilidad.

Relevancia para la ergonomía: El traje con sensores inerciales, con sus capacidades para la evaluación de la postura en tiempo real, ofrece un enfoque novedoso para identificar las posturas no neutras que contribuyen a los trastornos musculoesqueléticos (TME). Al evaluar la facilidad de uso de este sistema, la investigación aporta datos sobre su viabilidad, facilidad de uso y potencial de integración en intervenciones ergonómicas. Los resultados subrayan la importancia de diseñar dispositivos portátiles que no sólo midan con precisión los movimientos corporales, sino que también den prioridad a la comodidad y facilidad de uso. Además, el estudio ofrece un marco fundamental para el desarrollo de herramientas ergonómicas que puedan ayudar en estrategias preventivas y correctivas en el lugar de trabajo. En última instancia, esta investigación ayuda a salvar la brecha entre la tecnología avanzada de sensores portables y las aplicaciones ergonómicas cotidianas, apoyando los esfuerzos para reducir el riesgo de lesiones relacionadas con la postura, mejorar la salud y la productividad general en el lugar de trabajo.

Abstract: Inertial sensor technology is widely used in biomechanics, ergonomics, and sports science for real-time motion analysis. Inertial sensor suits (ISS), consisting of strategically placed inertial measurement units (IMUs), provide a portable alternative to traditional motion capture systems. Their usability, however, is critical for adoption, as factors like comfort, ease of use, and workflow integration influence user satisfaction and data reliability. This study evaluates the usability of an ISS using the System Usability Scale (SUS) and examines its effectiveness in ergonomic assessments. A total of 68 participants, aged 19 to 24, primarily from an engineering background, were recruited. Approximately half were familiar with sensor technology. Participants met inclusion criteria—being over 18 and free of musculoskeletal conditions. Before testing, they received a brief orientation and provided informed consent. The usability evaluation took place in a controlled environment to minimize distractions. Participants used the ISS while performing a kneading sculpting task and then completed the validated Spanish version of the SUS survey. The SUS survey, consisting of 10 statements rated on a five-point Likert scale, measured ease of use, functionality, and satisfaction. Data screening ensured completeness and reliability, removing inconsistent or missing responses. An outlier analysis was conducted to detect anomalies, and a structured database was created for statistical analysis. The ISS received an average SUS score of 78.5, indicating good usability. Most participants (82%) expressed satisfaction with the device, particularly its real-time motion tracking. However, 23% encountered challenges during setup, especially with sensor positioning and calibration. A Pearson correlation analysis revealed a moderate negative relationship between age and usability scores ($r=-0.35$, $p<0.05$), suggesting older participants found the ISS slightly less user-friendly. Users with prior sensor experience reported significantly higher SUS scores ($p<0.05$), highlighting the impact of familiarity on usability perceptions. No significant usability differences were found between male and female participants. Exploratory factor analysis (EFA) identified three key usability dimensions, explaining 68% of the variance: perceived efficiency (38%), which included response time, accuracy, and workflow integration; ease of use (22%), covering setup challenges and comfort; and user confidence (8%), reflecting reliability and error handling. These findings emphasize the importance of optimizing sensor attachment, calibration, and user guidance. Qualitative feedback from open-ended survey questions further highlighted user preferences and suggestions for improvement. While most participants praised the ISS, recommendations included enhancing setup instructions, refining sensor stability, and incorporating interactive tutorials or adaptive interfaces. These enhancements could improve usability, particularly for novice users. This study underscores the ISS's potential in ergonomic assessments and occupational health applications, demonstrating its effectiveness for posture evaluation. However, addressing setup complexity and improving instructional design would further enhance its usability. Future research could explore long-term user adaptation, field testing in diverse work environments, and comparisons with alternative motion-tracking technologies. By refining the ISS design, this technology can be more effectively integrated into real-world ergonomic applications, ensuring both usability and functional reliability.

Keywords: User centered design, human motion, analysis, wearable sensor, usability.

Relevance to Ergonomics: The inertial sensor suit, through its real-time posture tracking capabilities, offers a novel approach to identifying non-neutral postures that contribute to musculoskeletal disorders (MSDs). By evaluating the usability of this system, the research provides valuable insights into its practicality, user-friendliness, and potential for integration into ergonomic interventions. The findings underscore the importance of designing wearable devices that not only accurately measure body movements but also prioritize user comfort and ease of use. Furthermore, the study offers a foundational framework for developing ergonomic tools that can assist in both preventive and corrective strategies within workplace settings. Ultimately, this research helps bridge the gap between advanced sensor technology and everyday ergonomic applications, supporting efforts to reduce the risk of posture-related injuries and improve overall workplace health and productivity.

.

1. INTRODUCTION

Inertial sensor technology has demonstrated significant potential in various fields, including biomechanics, sports science, and ergonomics, particularly in measuring body postures in three dimensions (Morouço, 2024). Inertial sensor suits have emerged as a powerful tool for measuring body joint angles with high precision and reliability, revolutionizing applications in fields like biomechanics, ergonomics, and sports science (Lim & D'Souza, 2020). These suits utilize an array of inertial measurement units (IMUs) placed strategically on different body joints to capture motion data in real time (Gu et al., 2023). Each IMU typically integrates accelerometers, gyroscopes, and sometimes magnetometers to calculate the orientation of individual body joints in three-dimensional space (Sabatini, 2011). By analyzing the relative orientation between body joints, these systems provide accurate measurements of joint angles and overall posture dynamics (Lim & D'Souza, 2020). This capability makes them invaluable for tasks such as assessing movement efficiency, identifying potential ergonomic risks, and optimizing athletic performance. Compared to traditional motion capture systems, inertial sensor suits offer enhanced portability, the ability to function in diverse environments, and lower setup requirements, making them a practical choice for both laboratory and field studies. Their ability to deliver detailed body joint angle data enables researchers and practitioners to gain deeper insights into human movement, fostering innovations in injury prevention, ergonomic intervention, and performance enhancement (Wirth et al., 2019).

The suitability of inertial sensor technologies is a critical factor that determines their effectiveness, adoption, and long-term usability in practical settings (Domingos, 2022). Devices designed to capture precise data, such as those used in biomechanics, ergonomics, or healthcare, must prioritize user comfort, intuitiveness, and accessibility to ensure seamless integration into daily workflows (Izahrani, & Ullah, 2024). If a device is difficult to operate, uncomfortable to use, or overly complex, it can lead to frustration, reduced user compliance, and inconsistent data collection. User-centered design ensures that the device aligns with the physical and cognitive needs of the target audience, allowing for efficient setup, ease of use, and minimal intrusion during tasks (Andreoni, 2023). Moreover, suitable measurement devices enhance reliability by reducing errors associated with improper use or misinterpretation of instructions. By focusing on usability, developers can create tools that not only meet technical requirements but also foster user trust and satisfaction, ultimately driving innovation and broader adoption across various fields (Maqbool & Herold, 2024). While technology offers advanced capabilities for measuring body joint angles and postures, its effectiveness ultimately depends on how well it integrates into the user's workflow and meets their needs (Salisu, et al., 2023). Factors such as comfort, setup complexity, data accuracy, and the intuitiveness of the user interface significantly influence user satisfaction and the likelihood of consistent usage (Kalankesh, 2020). A system that is cumbersome, difficult to operate, or uncomfortable to wear can undermine its adoption, even if it delivers precise data (Keenan et al., 2022). The user's feedback can help identify potential barriers and areas for improvement, ensuring the system is user-friendly, reliable, and efficient (Bastien, 2010). Moreover, understanding user experiences aids in tailoring the technology to diverse scenarios, such as ergonomic assessments, sports training, or clinical rehabilitation, fostering broader acceptance and maximizing its impact across fields.

The concept of usability of wearable sensor systems has been addressed in a few studies. Keogh et al. (2020) chose the System Usability Scale (SUS) (Brooke, 1996) to investigate the usability and acceptability of wearable sensors in older people. Liang et al. (2018) used the SUS form and the Intrinsic Motivation Inventory (IMI) to assess participants' experiences of the activity involved in wearing the device. Similarly, Domingos et al. (2022) explored the user experience of wearing an activity tracker in a cohort of older adults; usability and acceptance were assessed with the Technology Acceptance Questionnaire (CAT) (Davis, 1989) and the SUS (Broke, 1996). Bendig et al. (2022) conducted comprehensive usability evaluations with 18 patients with Parkinson's disease using a mixed-methods usability questionnaire battery comprising the SUS form.

In this research the usability of an inertial sensor suit was evaluated. The assessment utilized the SUS, a well-established method for evaluating system usability and user satisfaction. A sample of sixty-eight individuals answered the SUS questions during a measurement session while performing a kneading sculpting task. By involving users in determining the usability of the sensor suit, it is possible to refine the suit's design and functionality, ensuring it meets the needs of those relying on it for ergonomic assessments and interventions. Additionally, this user validation will also contribute to the enhancement of the system, ensuring its reliability, accessibility, and effectiveness in promoting safer and more ergonomic work environments.

2. OBJECTIVES

This study aims to explore the usability of an inertial sensor suit designed for measuring body joint angles, focusing on its practical application and user experience. Specifically, the study seeks to determine the SUS-based usability score, examine participants' satisfaction and ease of use when interacting with the suit, and identify usability challenges that may hinder its implementation.

Additionally, a comparative analysis of usability scores between different user groups, such as experienced and novice users, will provide further insights into how diverse user profiles influence system interaction. These objectives collectively aim to ensure that the inertial sensor suit is not only technically effective but also user-friendly and adaptable to various contexts.

3. METHODOLOGY

This research aimed to evaluate the usability of an inertial sensor suit in measuring body joint angles as illustrated in figure 1.

Figure 1. Inertial sensor suit for measuring joint angles.

3.1 Participants

The sample consisted of 68 participants, aged between 19 and 24. Participants were recruited from a pool of individuals with backgrounds in engineering, however about fifty percent had familiarity with the technical aspects of the sensor suit. Prior to participation, informed consent was obtained from each participant, ensuring they understood the purpose of the study and the data collection procedures. The participants were predominantly male (65.217%). The judgment sampling method was applied to conform sample according to the following inclusion criteria: 1) The participant should be over 18 years of age; 2) The participant should not have previous musculoskeletal problems or be under medical treatment. Prior to the usability testing, participants signed a consent form and were given a brief orientation on how to use the inertial sensor suit. During the measuring process, participants used the suit while performing a kneading sculpting task.

3.2 Survey design and administration

The usability evaluation was conducted in a controlled environment to minimize external distractions and ensure that participants could focus on the task at hand. Each participant used the inertial sensor suit during the measuring process. Following the conclusion of the measurement session, participants completed the Spanish version of the SUS survey validated in previous study (Sortillón et al, 2024). The SUS survey is a widely recognized instrument for assessing the usability of various products and systems.
The SUS survey comprises 10 statements related to the ease of use, functionality, and user satisfaction with the device, which participants rated on a five-point Likert scale ranging from strongly disagree to strongly agree. The responses were then analyzed to determine the overall usability score, which provides a composite measure of user satisfaction and the effectiveness of the device.

3.3 Data capture and screening

To guarantee the reliability and validity of the collected data, a review was carried out to evaluate its completeness and accuracy. Each participant's responses were analyzed to detect any missing or inconsistent information. Those who submitted incomplete data or exhibited inconsistencies were excluded from the final data set to preserve the study's integrity. Furthermore, an outlier analysis was conducted to identify potential errors in usability scores. This step was essential in detecting anomalies that could distort the results, enabling a more accurate and meaningful data interpretation. After this screening process, a structured database was created, anomalies that could distort the results, enabling a more accurate and meaningful data interpretation. After this screening process, a structured database was created, ensuring that only high-quality, dependable data were included for further statistical analysis and interpretation.

3.4 Data analysis

Usability scores were computed to evaluate the overall user experience with the inertial sensor suit. A Pearson correlation analysis examined the relationship between SUS scores and demographic variables. Additionally, a T-test was conducted to compare usability scores between participants familiar with sensor technology and those without prior experience. To further investigate the underlying dimensions of usability, an exploratory factor analysis (EFA) was carried out using SPSS version 26 (IBM, Armonk, NY, United States). This statistical method helped identify key usability factors, shedding light on the main components that influence user perceptions of the device.

Beyond the quantitative analysis, qualitative data were collected through open-ended questions included at the end of the survey. These responses provided valuable insights into participants' experiences, preferences, and suggestions for enhancing the design, functionality, and user interaction of the inertial sensor suit. By combining both quantitative and qualitative data, the study aimed to develop0' a comprehensive understanding of the device's usability, identifying its strengths and areas for improvement to optimize its effectiveness in real-world applications.

4 RESULTS

This section presents the findings from the usability assessment of the inertial sensor suit, conducted using the SUS. The analysis explores key usability aspects, including user satisfaction, ease of use, and overall functionality, while also identifying potential areas for improvement. Additionally, correlations between usability scores and demographic factors are examined, along with an exploratory factor analysis to determine the primary dimensions influencing user perceptions. These insights contribute to a comprehensive understanding of the inertial sensor suit practicality and potential for integration into ergonomic interventions.

The usability evaluation of the ISS, assessed using the SUS scale, yielded insightful findings regarding user satisfaction, ease of use, and overall functionality of the device.

4.1 User satisfaction and ease of use

The usability evaluation, conducted using the SUS Spanish version, resulted in an average usability score of 78.5 (sd= 9.2), indicating good usability according to SUS benchmarks. Regarding the satisfaction item, 82% of users reported being satisfied or very satisfied with the ISS. According to the ease-of-use item, 75% of participants found the ISS easy to use, though 23% noted initial set up challenges related to sensor positioning and calibration. Besides, regarding functionality, users praised the device's real-time motion tracking about sensor stability during extended use.

4.2 Correlation and group comparison of usability perceptions

To explore the relationship between usability scores and demographic factors, a Pearson correlation and independent t-tests were performed. Regarding age and usability perception, a moderate negative correlation ($r=-0.35$, $p<0.05$) was observed, suggesting that older participants reported slightly lower usability scores. Users with prior experience reported significantly higher SUS scores ($\mu= 82.4$, sd= 8.1) compared to those with no prior experience ($\mu=74.3$, sd= 9.8); $t= 2.34$, $p< 0.05$. No significant differences in usability scores were found between male and female participants ($p>0.05$).

4.3 Exploratory factor analysis

An exploratory factor analysis (EFA) was conducted to identify underlying usability dimensions. A kaiser-Meyer-Olkin (KMO) test of 0.78 and Barlett's test of sphericity (χ^2 = 412.3, $p < 0.001$) confirmed suitability for factor analysis. Three main factors emerged (see figure 1) explaining 68% of the total variance. Factor 1 (perceived efficiency – 38%) referred items to response time, accuracy and integration into workflows. Factor 2 (ease of use – 22%) comprised items concerning setup difficulty and comfort. Factor 3 (user confidence – 8%) referred items reflecting perceived reliability and error handling.

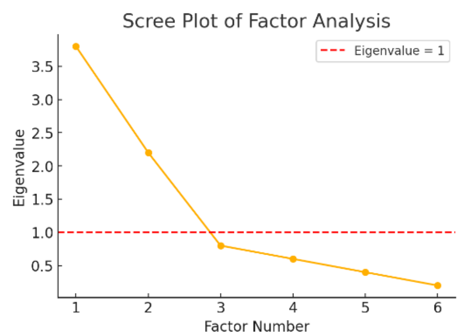


Figure 1. Scree plot of usability factors

Figure 2. Factor loadings plot of usability dimensions

The ISS demonstrated good usability, with high satisfaction and ease of use ratings. However, age and prior experience influenced usability perceptions, and factor analysis highlighted efficiency, ease of use, and user confidence as key usability dimensions. These findings suggest that improving set up guidance and senso stability could further enhance usability, particularly for users unfamiliar with wearable technology.

The usability assessment of the ISS provided critical insights into the practically, ease of use, and overall user experience. The findings highlight both strengths and areas of improvement in the device's design and functionality, particularly in relation to user demographics and the factors influencing usability perceptions. The ISS achieved a high usability score, positioning it within the good usability range of the SUS scale. Most users (82%) expressed satisfaction with the device, particularly appreciating its real-time motion tracking capabilities. However, despite these positive perceptions, 23% of users reported challenges related to initial setup, particularly in sensor calibration and attachment. These findings suggest that while the ISS is generally well-received, refining setup procedures and providing clearer instructional guidance could further improve the user experience. The analysis of usability perceptions revealed a moderate negative correlation in age, indicating that older users tended to report lower usability scores, possibly due to familiarity issues with wearable technology. Moreover, users with previous experience rated the ISS significantly higher than those without, suggesting that prior exposure to similar technology enhances ease of use and overall satisfaction. Besides, gender seems that does not influence usability perceptions. Future ISS versions could incorporate adaptive onboarding process to better accommodate novice users. Exploratory factor analysis identified three dimensions, explaining 68% of variance, validating their relevance. These results align with previous usability studies on wearable sensor technology, reinforcing the need for intuitive user experience and system reliability. Improving sensor attachment mechanisms and streamlining software interactions could further enhance user confidence in the ISS. The findings underscore the potential of the ISS for ergonomic applications but also highlight areas requiring refinement. Recommendations for future development include providing interactive tutorials or augmented reality guidance for new users, reducing set up complexity through ergonomic adjustments and more intuitive mounting systems. Besides, implementing adaptive interfaces that adjust based on user expertise could enhance ISS design. Overall, these insights contribute to a deeper understanding of how inertial sensor technology can be effectively integrated into ergonomic assessments, paving the way for further refinements that enhance both usability and functional reliability.

5. CONCLUSIONS

From an ergonomic and industrial application perspective, these findings underscore the potential of the ISS as a valuable tool for workplace posture assessment and intervention. However, for successful integration into real-world settings, future iterations should emphasize accessibility, user adaptation, and enhanced instructional design. Addressing these factors will not only improve user acceptance but also expand the applicability of the ISS in various ergonomic research and occupational health domains.

Ultimately, this study contributes to the broader discussion on the usability of wearable sensor technologies in ergonomic assessment. By identifying key usability drivers and areas for improvement, these findings lay the foundation for refining the ISS to maximize its effectiveness and user adoption in both research and practical applications. Future studies could further explore longitudinal user experiences, field testing in diverse work environments, and comparative evaluations with alternative motion-tracking solutions to ensure continuous enhancement and innovation in wearable ergonomic assessment technologies.

Declaration of Competing Interest

The authors declare that there were no commercial or financial relationships that could be interpreted as a conflict of interest during the conduct of the study.

6. REFERENCES

Keogh, A.; Dorn, J.; Walsh, L.; Calvo, F.; Caulfield, B. (2020). Comparing the Usability and Acceptability of Wearable Sensors among Older Irish Adults in a Real-World Context: Observational Study. JMIR Mhealth Uhealth, 8, e15704.

Liang, J.; Xian, D.; Liu, X.; Fu, J.; Zhang, X.; Tang, B.; Lei, J. (2018). Usability Study of Mainstream Wearable Fitness Devices: Feature Analysis and System Usability Scale Evaluation. JMIR Mhealth Uhealth, 6, e11066.

Domingos, C.; Costa, P.; Santos, N.; Pêgo, J. (2022). Usability, Acceptability, and Satisfaction of a Wearable Activity Tracker in Older Adults: Observational Study in a Real-Life Context in Northern Portugal. J. Med. Internet Res., 24, e26652. Available online: https://www.jmir.org/2022/1/e26652 (accessed on 12 February 2023).

Davis, F.D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q., 13, 319–340.

Brooke, J. (2013). SUS: A retrospective. *Journal of Usability Studies*, *8*(2), 29–40.

Cliff, N. (1987). *Analyzing multivariate data*. Orlando, FL: Harcourt, Brace, Jovanovich.

Bendig, J.; Spanz, A.; Leidig, J.; Frank, A.; Stahr, M.; Reichmann, H.; Loewenbrück, K.; Falkenburger, B. (2022). Measuring the Usability of eHealth Solutions for Patients with Parkinson Disease: Observational Study. JMIR Form. Res., 6, e39954.

Sortillón González, Patricia Eugenia; Maldonado Macías, Aide Aracely; Saenz Zamarron, David; Hernández Arellano, Juan Luis; De la Vega Bustillos, Enrique Javier (2024). Análisis factorial del formulario de usabilidad de un sistema de sensores portables para la identificación de factores de riesgo posturales en una tarea de escultura. CECEN Vol. 11 No. 1 (Eds.) Congreso Estatal de Ciencias Exactas y Naturales: 11 (pp. 243-260). UNISON.

Morouço, P. (2024). Wearable Technology and Its Influence on Motor Development and Biomechanical Analysis. *International Journal of Environmental Research and Public Health*, *21*(9), 1126. https://doi.org/10.3390/ijerph21091126.

Lim, S., & D'Souza, C. (2020). A Narrative Review on Contemporary and Emerging Uses of Inertial Sensing in Occupational Ergonomics. *International journal of industrial ergonomics*, *76*, 102937.

Gu, C., Lin, W., He, X., Zhang, L., & Zhang, M. (2023). IMU-based motion capture system for rehabilitation applications: A systematic review. *Biomimetic Intelligence and Robotics*, *3*(2), 100097. https://doi.org/10.1016/j.birob.2023.100097

Sabatini, A. M. (2011). Estimating Three-Dimensional Orientation of Human Body Parts by Inertial/Magnetic Sensing. *Sensors*, *11*(2), 1489-1525. https://doi.org/10.3390/s110201489

Wirth, M. A., Fischer, G., Verdú, J., Reissner, L., Balocco, S., & Calcagni, M. (2019). Comparison of a New Inertial Sensor Based System with an Optoelectronic Motion Capture System for Motion Analysis of Healthy Human Wrist Joints. *Sensors*, *19*(23), 5297. https://doi.org/10.3390/s19235297.

Domingos, C., Costa, P., Santos, N. C., & Pêgo, J. M. (2022). Usability, Acceptability, and Satisfaction of a Wearable Activity Tracker in Older Adults: Observational Study in a Real-Life Context in Northern Portugal. *Journal of medical Internet research*, *24*(1), e26652. https://doi.org/10.2196/26652.

Izahrani, A., & Ullah, A. (2024). Advanced biomechanical analytics: Wearable technologies for precision health monitoring in sports performance. *Digital health*, *10*, 20552076241256745. https://doi.org/10.1177/20552076241256745.

Andreoni, G. (2023). Investigating and Measuring Usability in Wearable Systems: A Structured Methodology and Related Protocol. *Applied Sciences*, *13*(6), 3595. https://doi.org/10.3390/app13063595.

Maqbool, B., & Herold, S. (2024). Potential effectiveness and efficiency issues in usability evaluation within Digital Health: A systematic literature review. *Journal of Systems and Software*, *208*, 111881. https://doi.org/10.1016/j.jss.2023.111881

Kalankesh, L. R., Nasiry, Z., Fein, R. A., & Damanabi, S. (2020). Factors Influencing User Satisfaction with Information Systems: A Systematic Review. *Galen medical journal*, *9*, e1686. https://doi.org/10.31661/gmj.v9i0.1686.

Keenan, H. L., Duke, S. L., Wharrad, H. J., Doody, G. A., & Patel, R. S. (2022). Usability: An introduction to and literature review of usability testing for educational resources in radiation oncology. *Technical innovations & patient support in radiation oncology*, *24*, 67–72. https://doi.org/10.1016/j.tipsro.2022.09.001.

Bastien, J. M. C. (2010). Usability testing: A review of some methodological and technical aspects of the method. *International Journal of Medical Informatics*, *79*(4). https://doi.org/10.1016/j.ijmedinf.2008.12.004

Brooke, J. (1996). SUS: A ‘quick and dirty’ usability scale. In P. Jordan, B. Thomas, & B. Weerdmeester (Eds.), *Usability Evaluation in Industry* (pp. 189–194). London, UK: Taylor & Francis.

ERGONOMIC REDESIGN OF THE “EDGE PROFILER” HAND TOOL

Indeliza Armenta Acosta, Ana Maria Arenivas Mena, Manuel Antonio Mundo Ruelas, Euder Armando Pacheco Rivera, Gonzalo Alejandro Pérez Yáñez

Industrial Engineering Department
Instituto Tecnológico de Los Mochis
Boulevard Juan de Dios Bátiz
Postal Code 81259
Los Mochis, Sinaloa

Corresponding author’s e-mail: indeliza.aa@mochis.tecnm.mx

Resumen: El uso prolongado de herramientas manuales en la carpintería aumenta significativamente el riesgo de lesiones musculo esqueléticas, como tendinitis y síndrome del túnel carpiano, debido a posturas inadecuadas (como flexión constante de muñecas y codos) y movimientos repetitivos (como el agarre continuo de la herramienta y el esfuerzo de presión durante el uso). En particular, el diseño actual del perfilador de bordes manual presenta deficiencias ergonómicas que incrementan la probabilidad de accidentes laborales, como cortaduras ocasionadas por el contacto directo con las cuchillas y lesiones por impactos, derivadas de un agarre ineficiente.

Este estudio propone un rediseño ergonómico de la herramienta con el objetivo de mejorar la seguridad y comodidad del operario, optimizando su funcionalidad y reduciendo los riesgos asociados a su uso. Las mejoras implementadas incluyen un mango ergonómico que distribuye la presión de manera uniforme, un sistema de chicotes de acero para minimizar la tensión en los dedos y una palanca antideslizante que incrementa el control y estabilidad de la herramienta, reduciendo la probabilidad de accidentes.

Para validar la efectividad del rediseño, se realizaron pruebas con carpinteros experimentados, evaluando parámetros clave como comodidad, precisión y facilidad de uso. Los resultados evidenciaron una disminución significativa en la fatiga muscular, una menor incidencia de lesiones por cortaduras e impactos accidentales, y una mejora sustancial en la eficiencia operativa. Además, los operarios reportaron mayor control sobre la herramienta, permitiéndoles ejecutar acabados más precisos con menor esfuerzo físico.

Palabras clave: Perfilador de bordes, Rediseño, Riesgos ergonómicos, Carpintería.

Relevancia para la ergonomía: El rediseño del perfilador de bordes tiene un impacto directo en la salud y eficiencia de los trabajadores. La herramienta original, al carecer de características ergonómicas, genera fatiga muscular y molestias en las manos y muñecas, lo que puede resultar en lesiones musculares esqueléticas. El rediseño propuesto incorpora mejoras como un mango adaptado y una palanca que reduce la presión en los dedos, optimizando la comodidad y seguridad del operario. Este cambio no solo previene daños a la salud, sino que también mejora la precisión y productividad en las tareas, contribuyendo a un ambiente de trabajo más saludable y eficiente.

Abstract: The prolonged use of hand tools in carpentry significantly increases the risk of musculoskeletal injuries, such as tendonitis and carpal tunnel syndrome, due to improper postures (such as constant flexion of wrists and elbows) and repetitive movements (such as continuous gripping of the tool and pressure stress during use). In particular, the current design of the manual edge profiler presents ergonomic deficiencies that increase the probability of occupational accidents, such as cuts caused by direct contact with the blades and impact injuries resulting from inefficient gripping.

This study proposes an ergonomic redesign of the tool with the objective of improving operator safety and comfort, optimizing its functionality and reducing the risks associated with its use. The implemented improvements include an ergonomic handle that distributes pressure evenly, a steel whip system to minimize finger strain, and a non-slip lever that increases tool control and stability, reducing the probability of accidents.

To validate the effectiveness of the redesign, tests were conducted with experienced carpenters, evaluating key parameters such as comfort, precision and ease of use. The results showed a significant decrease in muscle fatigue, a lower incidence of cut and accidental impact injuries, and a substantial improvement in operational efficiency. In addition, operators reported greater control over the tool, allowing them to execute more precise finishes with less physical effort.

Keywords: Edge profiler, Redesign, Ergonomic risks, Carpentry.

Relevance to Ergonomics: The redesign of the edge profiler has a direct impact on the health and efficiency of workers. The original tool, lacking ergonomic features, generates muscle fatigue and discomfort in the hands and wrists, which can result in skeletal muscle injuries. The proposed redesign incorporates improvements such as an adapted handle and a lever that reduces pressure on the fingers, optimizing operator comfort and safety. This change not only prevents health damage, but also improves task accuracy and productivity, contributing to a healthier and more efficient work environment.

1. INTRODUCTION

According to the book written by Teresa Álvarez Bayona, Carlos Sánchez Villar, and Antonio Merayo Sánchez under the direction of the Instituto Nacional de Seguridad e Higiene en el Trabajo (INSHT), in which a detailed and practical analysis is made of the aspects to be considered in the selection, design, and use of hand tools. This document, especially oriented to prevention technicians, presents an accessible guide in identifying risks, applying ergonomic criteria, ensuring health and safety at work with hand tools in which it details that the main causes of risks are caused by poor design and use of poor quality materials of the tools (Teresa Álvarez Bayona, 2016). Likewise, in the present, the project is proposed to redesign the manual tool called "edge profiler," improving its current design to optimize its functionality and ergonomics. This tool is essential in the area of carpentry since it allows precise finishes on different materials. However, prolonged use of this type of tool can lead to repetitive strain-related injuries and other physical discomfort, reinforcing the need for a more ergonomic and efficient redesign.

The study entitled Application of Ergonomics to Improve Labor Productivity in the Carpentry Area of the MAINVA Woodworking Shop, Huaraz 2020, prepared by Osorio Calvo, and Diego Reynaldo (2021) demonstrates that the application of ergonomic principles not only improves operator comfort but also increases productivity by reducing time lost due to injuries. Ergonomics, in this context, plays a fundamental role in optimizing performance in tasks in the carpentry area by minimizing musculoskeletal disorders and physical fatigue, which in turn allows for greater efficiency in operations. (Osorio Calvo, 2021) Therefore, ergonomics should be seen not only as a safety measure but also as a strategic tool to improve results and efficiency for this reason the purpose of this project has a focus on improving safety and ergonomics. It is expected that this redesign will not only minimize the risk of injury and optimize the user experience, but significantly increase operator productivity by facilitating more efficient and comfortable work.

2. OBJECTIVES

General objective: To redesign a manual edge profiling machine to optimize its ergonomics, improving its functionality, comfort, and safety during use.

Specific objectives:

- Incorporate a handle of the tool to make it more ergonomic, and adaptable to the operator's hand, and feature materials that improve grip.
- Improve safety and avoid any type of musculoskeletal injury in the use of the tool.
- Reduce muscle fatigue with the repetitive movements required by the tool.

3. METHODOLOGY

As proposed in the book "METHODOLOGY OF ERGONOMIC ANALYSIS, ORIENTATIONS" the ergonomic analysis methodology is a systematic process used to evaluate working conditions and their impact on the health, safety, and performance of workers. It includes the identification of ergonomic risks, the collection of data on postures, movements and physical loads, and the use of tools such as checklists, direct observation and biomechanical measurements.

Subsequently, the data is analyzed to propose improvements in the design of the work environment, equipment, and tasks, with the aim of reducing fatigue, preventing musculoskeletal disorders, and optimizing work efficiency (Chile, 2024).

In this study, various methodologies were used with the aim of obtaining a comprehensive view of the ergonomic factors associated with the use of the manual edge profiler in carpentry. These methodologies include direct observation, the application of a survey to carpenters to identify possible long-term damage derived from the use of the tool, the use of an anthropometric card to analyze the physical characteristics of the workers and their relationship with the design of the profiler, as well as Corlett & Bishop mapping to evaluate the most affected areas of the body.

3.1 Direct observation and ergonomic analysis.

The direct observation was carried out in a carpentry located in Los Mochis, Sinaloa, specializing in the manufacture of wooden furniture. A sample of five workers was selected to analyze the use of the edge profiler, observing key aspects such as:

- Movements made during the task.
- Positions adopted.
- Physical efforts required.

The observation periods were 10 to 15 minutes per worker, depending on the time of use of the tool in each process. This analysis made it possible to identify ergonomic risks such as forced postures, repetitive movements, and excessive pressure on the wrist and fingers.

3.2 Application of the survey to workers.

A survey was conducted of carpentry workers to know their experience in the prolonged use of the edge profiler and the possible musculoskeletal damage derived from its handling. The main findings pointed to recurrent discomfort in the wrist, muscle fatigue in the hand, and difficulty in maintaining a firm grip due to the design of the profiler.

Table 1. Survey format applied to carpenters

1. Have you ever experienced pain or injury to your wrists when using the manual edge profiler? • Answer: Yes / No • If the answer is yes, how many times have you suffered from this condition? ____________________ **2. Have you had injuries in your arms or forearms after using the tool?** • Answer: Yes / No • If the answer is yes, how many times have you suffered from this condition? ____________________ **3. Have you ever suffered sprains or muscle strains due to the use of this tool?** • Answer: Yes / No

- If the answer is yes, how many times have you suffered from this condition? ________________

3.3 Preparation of the anthropometric certificate.

To ensure that the redesign of the manual edge profiler is optimally adapted to the workers, an anthropometric analysis of the dominant hand of the workers was carried out. This study, based on the 0.5 percentile, made it possible to define key measures that ensure an appropriate ergonomic design for most users. The anthropometric card, together with the direct observation and the survey applied to the workers, made it possible to identify mismatches between the current dimensions of the tool and the physical characteristics of the workers.

Table 2. Format of anthropometric survey applied to carpenters

Name	Anthropometric measurements					
	Height (cm)	Weight (kg)	Hand's length (cm)	Length of the palm (cm)	Width of the hand's palm (cm)	Inner grip diameter (cm)

3.4 Método de evaluación mapeo de Corlett & Bishop

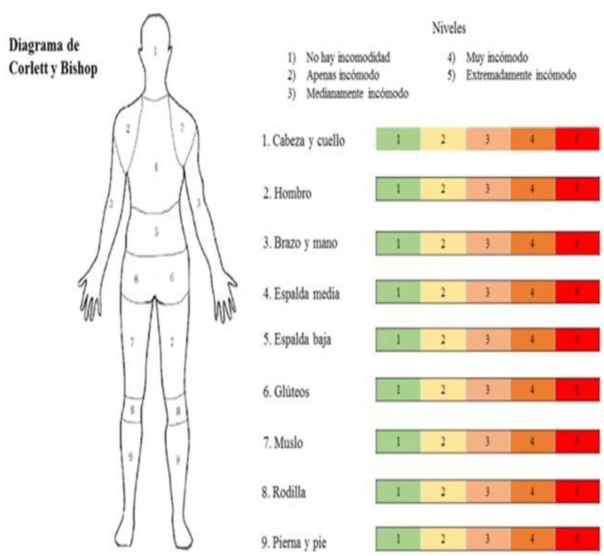


Figure 1. Diagrama de Corlett & Bishop

The Corlett & Bishop mapping method is a technique used in ergonomic evaluation to analyze and classify the postural load in the work environment. Its main objective is to identify the risk of musculoskeletal injuries derived from inadequate postures, through the observation of the postures adopted by workers while performing their tasks. This method allows assigning a value to each part of the body, determining the level of discomfort experienced by the worker, with a scale of 1 to 5. On this scale, level 1 indicates no discomfort, and level 5 reflects a high level of discomfort or risk of injury. In this study, Corlett &Bishop's method to evaluate postures was applied.

Adopted by workers when using the manual edge profiler in a carpentry. The postures of the workers during their task with the tool were recorded and evaluated on a scale of 1 to 5, assigning a score according to the level of discomfort or perceived risk in the different parts of the body involved in the use of the tool (Tosic, 2022). Special attention was paid to the joints and movements of the hands, wrists, elbows and shoulders, as these are the areas directly involved in the use of the edge profiler. In addition, the movements of the torso and possible torsions of the neck will be considered, since these can also influence the general postural load.

3.5 Ergonomic redesign of the edge shaper

Figure 2. Original edge profiler

The manual edge profiler used in carpentry presents several areas for improvement from an ergonomic perspective. The size and shape do not fit properly to the worker's hand, which generates discomfort and muscle fatigue. In addition, the material of which it is composed is rigid and lacks non-slip characteristics, increasing the effort on the hand and wrist. The current working angle requires forced postures on the wrists and elbows, which can lead to long-term musculoskeletal injuries. Also, the small size of the tool is considerable, which increases the effort required during its prolonged use. The current design does not allow custom adjustments to fit different hand sizes or grip preferences. Therefore, it is necessary to redesign the tool, improving the handle, the material, the working angle and the size, to optimize the comfort, safety and efficiency of the workers.

3.6 Evaluation of the redesign of the manual edge profiler

The modified version of the manual edge profiler was used by five carpenters, who performed an analysis of the tool based on key parameters such as comfort, precision, fatigue reduction and ease of use. Preliminary results showed a substantial improvement in the ergonomics of the tool, which resulted in a notable decrease in the physical effort required for its use.

In order to validate these findings, a new evaluation was carried out using the Corlett & Bishop method. This second evaluation made it possible to compare the postures adopted by the workers before and after the modification, identifying any change in the postural load and the risk associated with possible musculoskeletal injuries.

In addition, the injury and accident survey was applied to workers to obtain a complete assessment of comfort and fatigue reduction, which will provide a more complete analysis of the effectiveness of the redesign. This combined assessment approach will make it possible to accurately determine the impact of the modifications made to the tool and the improvement in the working conditions of carpenters. Modifications made to the tool and the improvement in the working conditions of carpenters.

Table 3. Survey of occupational injuries and accidents among carpenters

1. Have you ever experienced pain or injury to your wrists when using the manual edge profiler?

- Answer: Yes / No
- If the answer is yes, how many times have you suffered from this condition? ____________________

2. Have you had injuries in your arms or forearms after using the tool?

- Answer: Yes / No
- If the answer is yes, how many times have you suffered from this condition? ____________________

3. Have you ever suffered sprains or muscle strains due to the use of this tool?

- Answer: Yes / No
- If the answer is yes, how many times have you suffered from this condition? ____

4. RESULTS

4.1 Results of direct observation and ergonomic analysis.

Figure 3. Worker observation

During the direct observation, various injuries and accidents were recorded that affect the health of the workers due to the prolonged and repetitive use of the tool.

1. Paresthesia in the fingers: Sensations of numbness and tingling in the fingers due to the pressure exerted on the handle of the tool, which indicates a circulatory problem caused by the design of the grip.
2. Accidental cuts: Injury to the hands and fingers of workers, caused by contact with the blades of the tool, especially when control of the tool is lost or handled incorrectly.
3. Blows due to loss of control of the tool: Bruised injuries caused by the loss of control of the tool when the blades get locked in the material, causing the tool to slip unexpectedly and hit the operator.

Table 4. Results of the carpenters' observations

Injury/ Accident	Worker 1	Worker 2	Worker 3	Worker 4	Worker 5
Observation time	12 min	10 min	15 min	14 min	13 min
Paresthesias in the fingers	No	Yes (1 time)	No	Yes (1 time)	Yes (1 time)
Accidental cuts	Yes (1 time)	No	Yes (1 time)	No	Yes (1 time)

Blows for loss of control	Yes (1 time)	Yes (1 time)	Yes (1 time)	Yes (1 time)	Yes (1 time)

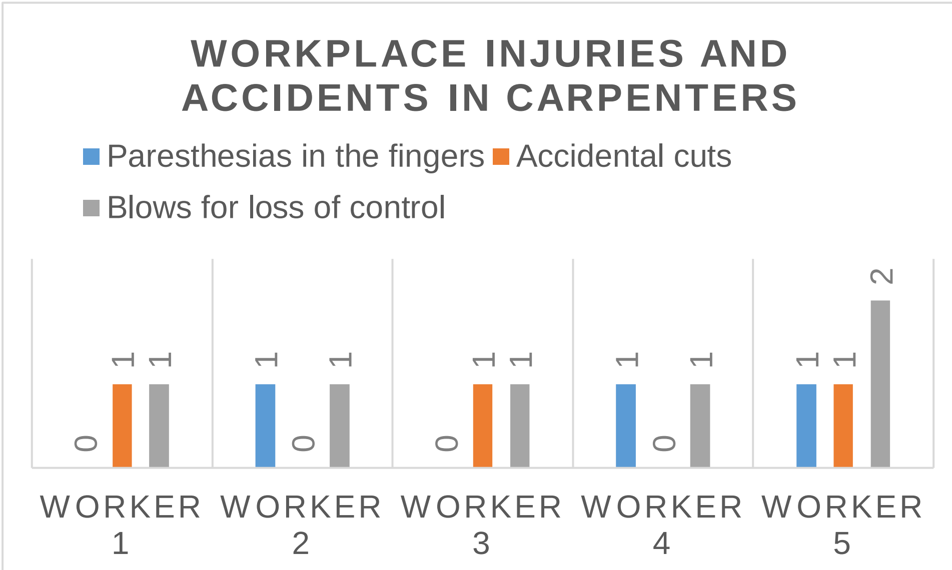


Figure 4. Injuries and Accidents in Carpenters' Workplaces

The results show that the use of the manual edge profiler is associated with several occupational hazards. Through direct observation of the workers while using the tool, it was identified that 60 % of them had paresthesia in their fingers, indicating excessive grip pressure. As for accidental cuts, 60 % suffered injuries due to contact with the blades, while 100 % experienced shocks due to loss of control of the tool, of which 20 % recorded two incidents of the same type.

4.2 Results of survey applied to workers.

A survey was applied to five carpenters with experience in the use of the manual edge profiler to assess the impact of its prolonged use on health. The objective was to identify the frequency and severity of musculoskeletal discomfort associated with the design and repetitive use of the tool.

The main conditions detected include:

1. Wrist injuries: Pain due to forced postures and repetitive effort without adequate rest.
2. Injuries to the forearm and arm: Muscle tension and stiffness due to the constant grip of the tool.
3. Sprain or muscle strain: Pain related to repetitive movements and the unergonomic design of the tool, which causes muscle overload.

These results will make it possible to propose improvements in the design of the tool to reduce the risk of injury and improve the safety and comfort of the worker.

Table 5. Working Time and Musculoskeletal Injuries in Carpenters

Injury/Accident	Worker 1	Worker 2	Worker 3	Worker 4	Worker 5
Working time	5 years	3 years	7 years	4 years	6 years
Wrist injury	Yes (2 times)	Yes (1 time)	Yes (3 times)	Yes (2 times)	Yes (1 time)
Forearm injury/ Arm	Yes (1 time)	Yes (2 times)	Yes (2 times)	Yes (1 time)	Yes (1 time)
Sprain or Muscle Distension	Yes (1 time)	No	Yes (1 time)	No	Yes (2 times)

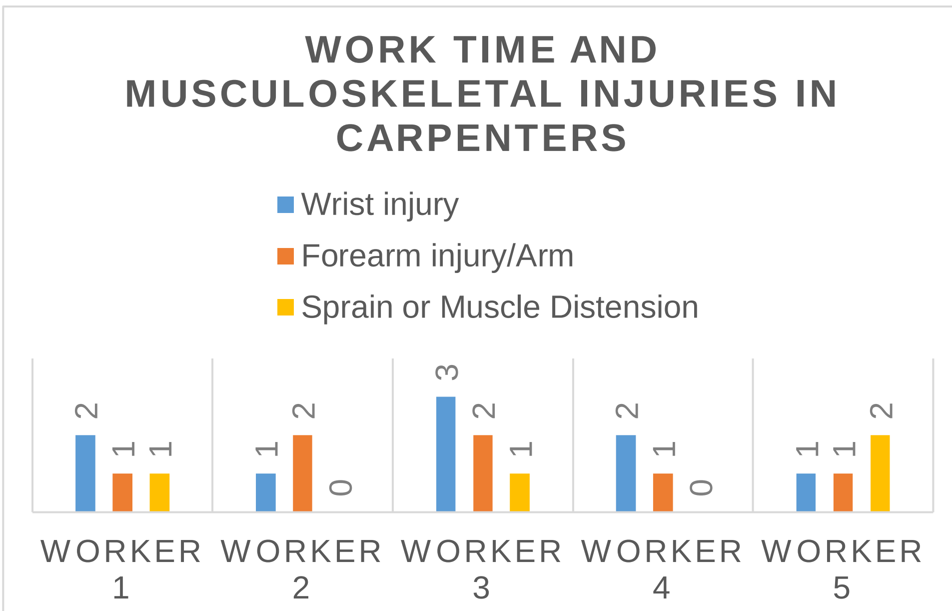


Figure 5. Working Time and Musculoskeletal Injuries in Carpenters

The survey results reflect a clear relationship between the prolonged use of the manual edge profiler and the occurrence of various musculoskeletal injuries in carpenters. According to the data collected, 80% of the workers reported having experienced wrist injuries, which are attributed to the adoption of forced postures and the mainly repetitive execution of movements during tool operation.

Likewise, 100% of the respondents reported having suffered some type of injury to the forearm or arm, which is directly related to the muscular tension generated by the constant and sustained grip of the profiler. This prolonged tension not only affects the user's comfort, but also increases the risk of fatigue and muscle overload.

On the other hand, 60% of the carpenters reported having suffered muscle sprains or strains, suggesting that the unergonomic design of the tool contributes significantly to the development of these conditions. The lack of a proper design that favors a natural posture and reduces physical stress on the joints could be a key factor in the recurrence of these injuries.

4.3 Anthropometric ID

An anthropometric analysis was carried out in order to evaluate the physical characteristics of the workers who operate the manual edge profiler. This analysis aims to determine if the dimensions of the tool are suitable for the size and shape of the operators' hands, which influences its comfort and safety during use.

Table 6. Anthropometric Measures of Carpenter Workers

Name	Anthropometric measurements					
	Height (cm)	Weight (kg)	Length of the hand(cm)	Length of the palm (cm)	Width from palm to hand (cm)	Inner grip diameter (cm)
Worker 1	170	80	16	9	8	5
Worker 2	169	95	15	9	8	7
Worker 3	174	88	16	9	9	5
Worker 4	177	100	18	10	9	6
Worker 5	178	85	17	11	11	5

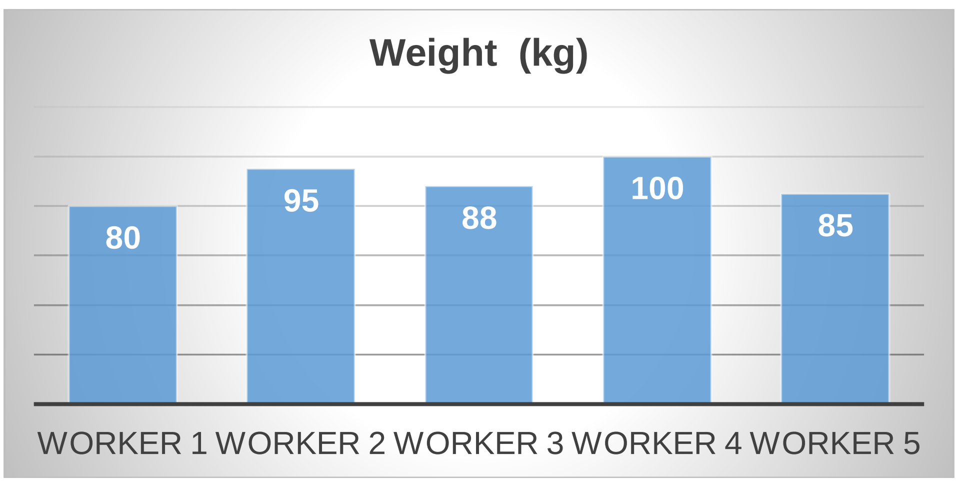
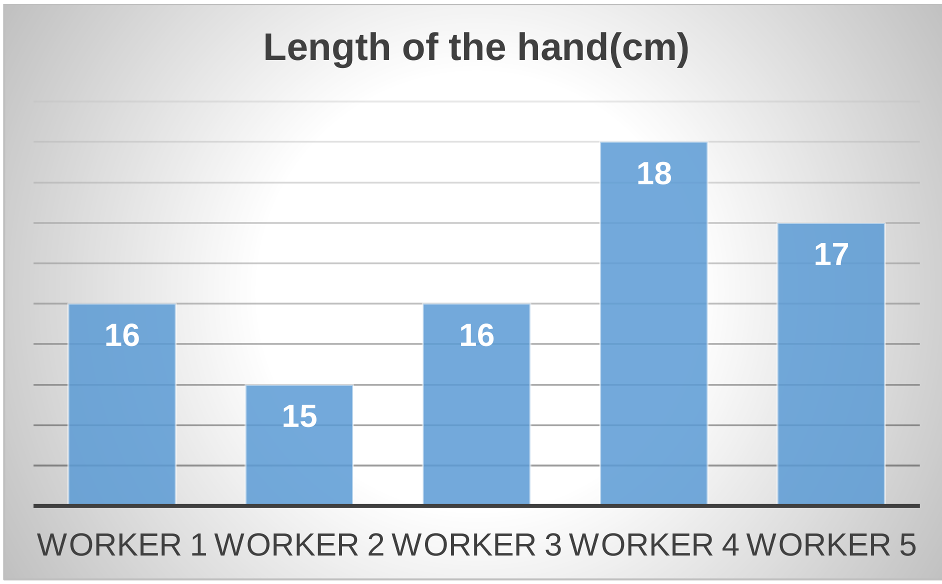


Figure 6. Weight of workers

This graph shows the weight of the operators of the profiler, in it it can be observed that the workers have a very similar weight, weight that at the time of work is transformed into pressure for the material and thus move the profiler to perform its task.



23

Figure 7. Length of the hand

In the figure you can see the measurement of the length of the operators' hand, in this you can notice a lot of variation in each worker. But this data is necessary to be able to calculate the grip diameter of each hand and in this way adapt the new design to all workers equally.

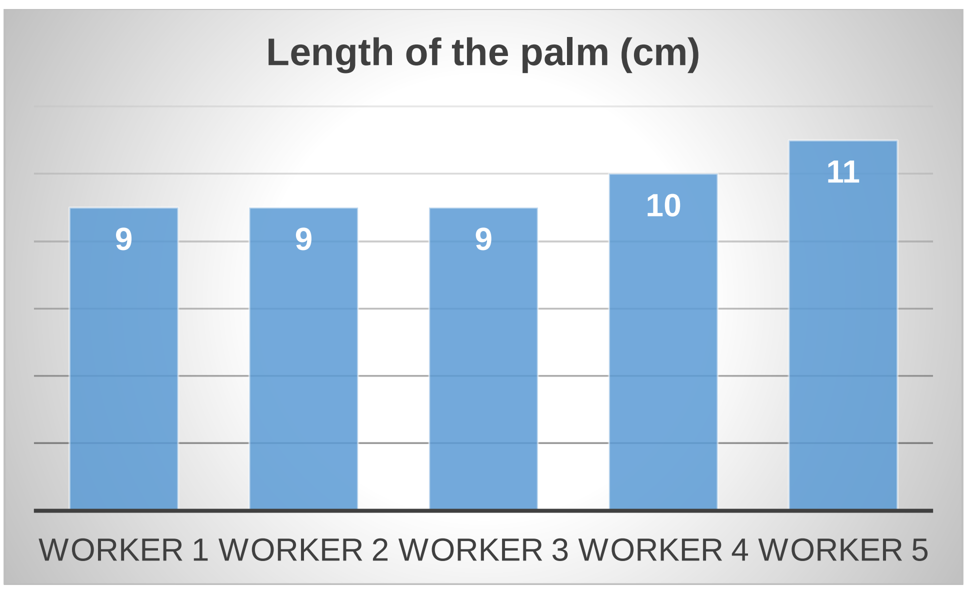


Figure 8. Palm length

Comparing figure 3 with the previous figure, it can be seen that the variation has disappeared almost completely, but the length of the hand is important to give an approximation of the pressure that can be made to the tool.

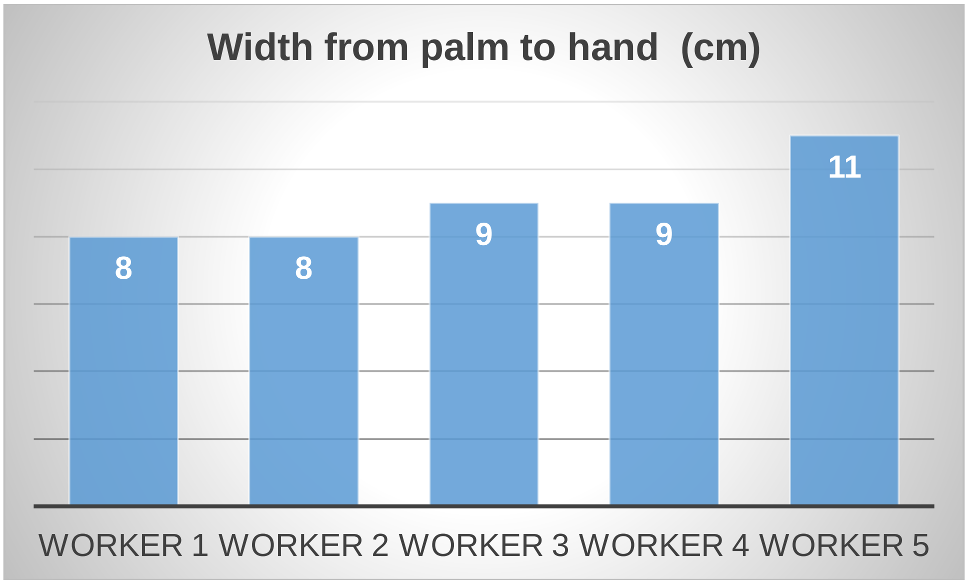


Figure 9. Width of the palm of the hand

The previous graph shows the width of the operators' hand, which is important to know to give an adequate length to the auxiliary grip of the new profiler, also give a correct measurement to the handle that will adapt to the profiler.

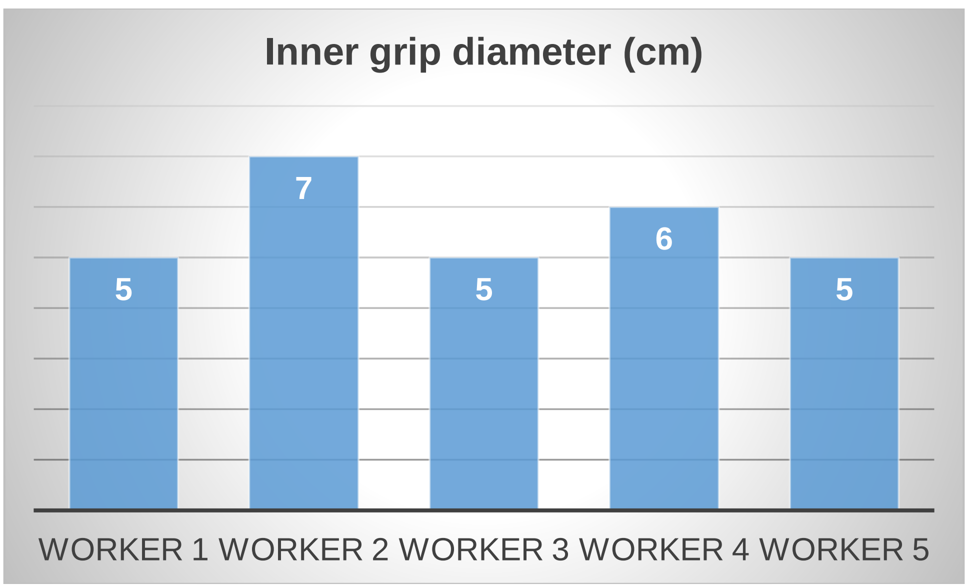


Figure 10. Inner grip

Finally, this graph shows the measurements that both the handle and the auxiliary handle of the redesigned profiler can take. To make the redesign friendly and suitable for all operators, the smallest measure of the samples is taken into account, in this case 5 cm.

4.3.1 Percentiles

In order to analyze the distribution of these measures within the group of workers, the percentiles of the most relevant anthropometric variables were also calculated.

These percentiles indicate the variations within the group in terms of height, weight and dimensions of the hand, which helps determine the adequacy of the tool design for different morphologies of the operators.

Table 7. Percentiles of Anthropometric Measurements

Percentile	Height (cm)	Weight (kg)	Length of the hand(cm)	Length of the palm (cm)	Width from palm to hand (cm)	Inner grip diameter (cm)
0.05	169.20	81.00	15.20	9.00	8.00	5.00
0.5	174.00	88.00	16.00	9.00	9.00	5.00
0.9	177.60	98.00	17.60	10.60	10.20	6.60
Heighest point	178.00	100.00	18.00	11.00	11.00	7.00
Lowest point	169.00	80.00	15.00	9.00	8.00	5.00
Average	173.60	89.60	16.40	9.60	9.00	5.60

4.4 Results of the Corlett & Bishop Mapping Evaluation Method

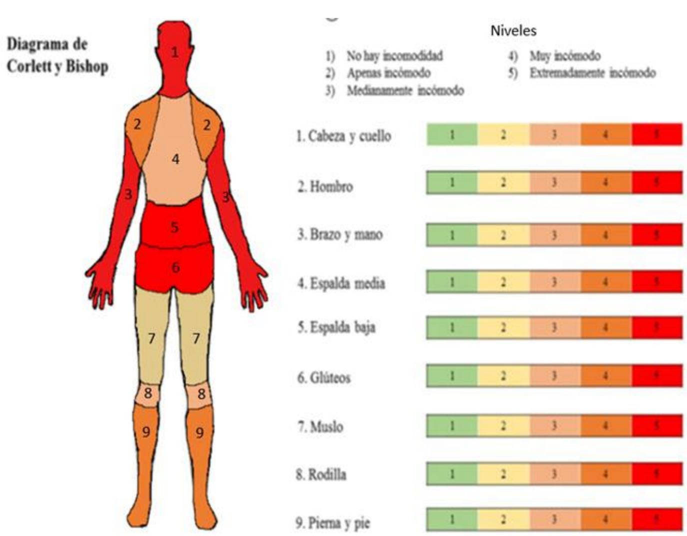


Figure 11. Application method Corlett & Bishop

To assess the discomfort and ergonomic impact of the manual edge profiler on workers, the Corlett & Bishop mapping method was used. Through this evaluation, it was identified that, at the end of the working day, workers experienced a general feeling of "very uncomfortable", reaching a level 4 on the evaluation scale. Analysis of the data collected shows that the discomfort is mainly concentrated in the upper limbs, particularly in the wrists, forearms and shoulders. This result suggests that the design of the manual profiler generates an excessive load on these areas, which can lead to muscle fatigue and increase the risk of long-term musculoskeletal disorders.

In addition, the evaluation revealed that the discomfort is not only due to repetitive effort, but also to factors such as the pressure exerted to manipulate the tool and the posture adopted during its use. This confirms that the manual profiler, in its original design, is not ergonomically suitable for prolonged use, which justifies the need for a redesign that reduces discomfort levels and protects the health of workers.

4.5 Ergonomic redesign of the edge profiler

The redesign of the edge profiler was carried out with the aim of reducing the discomfort reported by the workers and minimizing the risk of muscle and nerve injuries derived from the prolonged use of the tool. To achieve this, structural and ergonomic modifications were made based on the anthropometric study, the analysis of Corlett & Bishop and the direct observation of the workers in the carpentry.

4.5.1 Improvements Implemented in Redesign

Incorporation of Steel whip

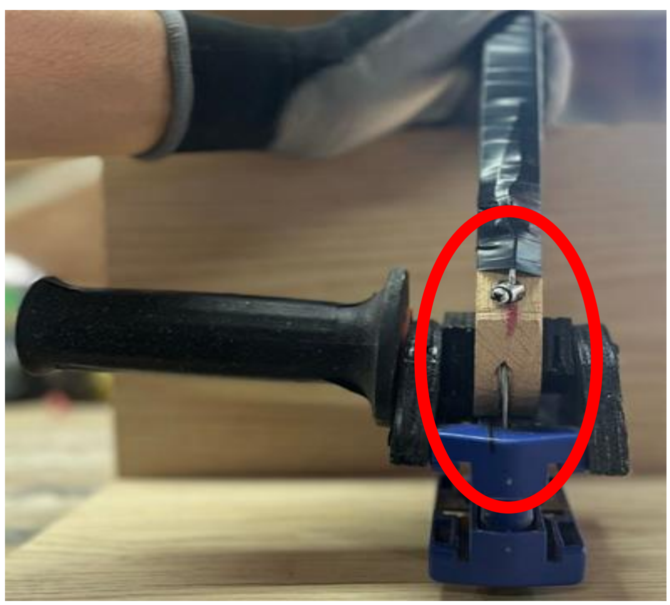


Figure 12. Location of the steel whip

One of the main problems detected in the use of the manual profiler was the constant pressure that the fingers had to exert on the tool to operate the clamping mechanism. To solve this, steel whips were implemented in the design.

- **Location**: They were introduced through two perforations made in the interior compartment of the tool, where the springs are housed.
- **Function**: Allows you to operate the mechanism without the need to apply continuous pressure with the fingers, significantly reducing the muscle load in the hand.

Design and Implementation of a Lever. To further improve ergonomics, a lever was incorporated that allows the steel sticks to be operated without additional effort.

Figure 13. Axial lever

- **Mechanism of action**: The lever allows the whips to open the bottom of the profiler without requiring constant manual pressure.
- **Lever Measurements:** Based on the 0.5th percentile of the anthropometric ID, the lever was designed with the following dimensions.
    - **Length**: 15 cm, for optimal reach without the hand losing control during use.
    - **Width**: 5 cm, ensuring that the lever can be operated comfortably with your fingers without applying too much force.
- **Material**: The lever was coated with a polymer that prevents the tool from slipping to improve grip and prevent slipping during use.

Adjustment in the Main Handle Based. On the anthropometric ID, the dimensions of the handle are optimized to improve its ergonomics.

- **Diameter**: 5 cm (percentile 5) to provide a comfortable grip without generating tension in the muscles of the hand.
- **Length**: 9 cm, guaranteeing a firm and controlled grip.
- **Tilt**: The angle of the handle was modified to 15° with respect to the base of the tool, allowing a more natural posture of the wrist and reducing the effort on the forearm.
- **Material**: The handle was coated with a polymer that prevents the tool from slipping to improve grip and prevent slipping during use.

Figure 14. Main handle

Optimization of Handle Stability and Reduction of Fatigue Risk

The new ergonomic levers, the optimization of the handle with more suitable materials and the design of the new parts, such as the levers, have increased the control that the operator has over the tool. This has reduced the effort required to maneuver it, contributing to a more precise and comfortable handling, thus reducing muscle fatigue.

4.5 Evaluation of the redesign of the manual edge profiler

Table 8. Results of the redesign evaluation

Injury/Accident	Worker 1	Worker 2	Worker 3	Worker 4	Worker 5
Working time	5 days	5 days	5 dias	4 days	5 days
Wrist injury	No	No	No	No	No

Forearm injury/Arm	No	No	No	No	Yes (1 time)
Sprain or muscle strain	No	Yes (1 time)	No	No	No

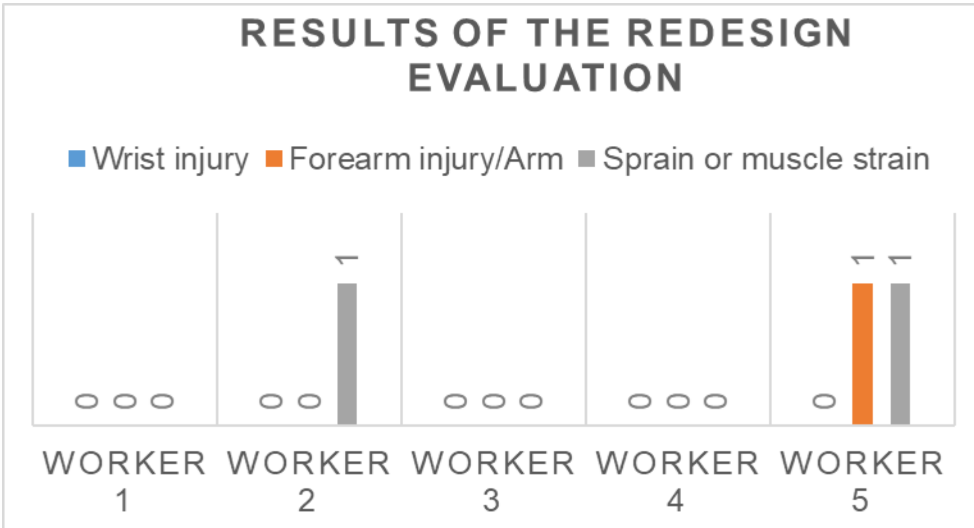


Figure 15. Results of the redesign evaluation

The table above shows the results of the survey already applied the redesign of the profiling, in which it can be noticed that the operators have a completely different sensation from that obtained in the first observation. And in the words of the workers themselves "the new tool is more comfortable to use."

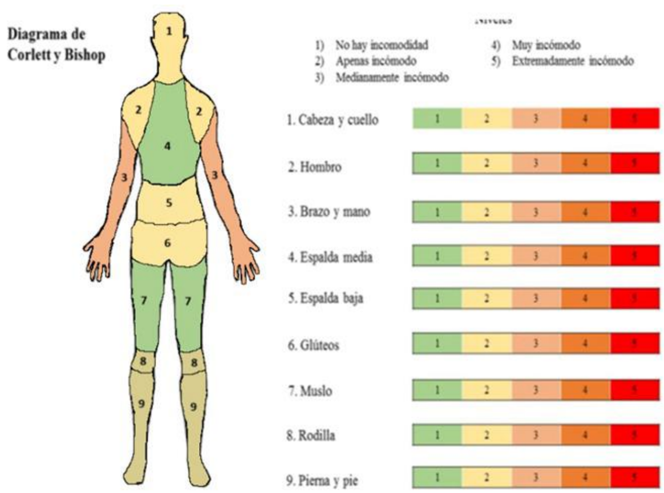


Figure 16. Mapping of Corlett & Bishop with the redesign

After the implementation of the redesigned edge profiler, a new evaluation was carried out using the same method. The results reflect a significant reduction in perceived discomfort, obtaining a level 2 on the scale, which corresponds to a feeling of "barely uncomfortable". This improvement has a positive impact on the physical integrity of workers, reducing the risk of injuries derived from prolonged use of the tool.

5. CONCLUSION

The present study showed that the ergonomic redesign of the manual edge profiler generates significant benefits in the safety, comfort and efficiency of workers in carpentry. Through ergonomic analysis, direct observation and the application of evaluation tools such as the Corlett & Bishop method, the main risk factors associated with prolonged use of the tool were identified, such as muscle fatigue, forced postures and repetitive effort. The modifications implemented in the redesign, including an ergonomic handle with non-slip materials, a steel whip system to reduce the load on the fingers and an adjustable lever to improve control, allowed to reduce discomfort and the risk of musculoskeletal injuries. The validation of the new design with experienced workers showed a reduction in muscle fatigue, a lower incidence of accidents and an improvement in the accuracy of the work. The results of the research confirm the importance of applying ergonomic principles in the design of hand tools to optimize working conditions. The implementation of these changes not only improves the health and well-being of operators, but also increases efficiency and productivity in the carpentry process. This study highlights the need to continue innovating in the development of ergonomic tools, guaranteeing a safer and more comfortable work environment for workers.

6. BIBLIGRAPHY

Chile, I. d. (2024). *METODOLOGÍA DE ANÁLISIS ERGONÓMICO, ORIENTACIONES.* Santiado de Chile: Primera versión. Obtenido de file:///C:/Users/Usuario/Downloads/METODOLOGIA-DE-ANALISIS-ERGONOMICO-v1-2024.pdf

Osorio Calvo, D. R. (2021). *Aplicación de la ergonomía para mejorar la productividad laboral del área de carpintería en la maderera MAINVA, Huaraz 2020.* Huaraz.

Teresa Álvarez Bayona, C. S. (2016). *Herramientas manuales: criterios ergonómicos y de seguridad para su selección.* Madrid: Instituto Nacional de Seguridad e Higiene en el Trabajo (INSHT). Obtenido de chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.insst.es/documents/94886/789635/Herramientas+manuales.pdf/22e23d1f-4f32-4d29-80c5-718ad99f56e9?t=1605802888811

Tosic, L. T. (2022). *Evaluation of patient Stress level caused by radiological Investigations in early Postoperative phase After Craniotomy.* Obtenido de https://doi.org/10.1136/bmjopen-2022-061452

ERGONOMIC AND DESIGN ANALYSIS OF A MOTORIZED SHOPPING CART

Ma. Fernanda Gutiérrez Torres https://orcid.org/0000-0001-9646-8078

Universidad Nacional Autónoma de México
Facultad de Estudios Superiores Aragón
Licenciatura en Diseño Industrial
Av. Universidad Nacional s/n
57130 Nezahualcóyotl, Estado de México, México

Email: fernandagutierrezd4@aragon.unam.mx

Resumen: Según la información demográfica, se observa que el número de adultos mayores ha aumentado sobre todo en áreas urbanas y por lo tanto se ofrecen una amplia variedad de productos para ayudarles a realizar sus actividades de forma independiente y segura. En países con tecnología avanzada, como Estados Unidos de América, se han desarrollado artículos adecuados para personas mayores y que aunado a la edad pueden presentar dificultad para moverse, debido a enfermedades o accidentes; con el fin de ayudarles a desempeñar sus actividades diarias. Este es el caso de los carros eléctricos unipersonales diseñados para utilizarse en espacios interiores. En México, ciertas empresas, como supermercados, han adquirido estos vehículos eléctricos y los ofrecen a los clientes -adultos mayores- durante el tiempo que lo requieran para llevar a cabo sus compras.

El objetivo de este trabajo es presentar el análisis de los carros eléctricos unipersonales para identificar sus ventajas y desventajas con usuarios adultos mayores.

Palabras clave: análisis, ergonomía, diseño, carro eléctrico.

Relevancia para la Ergonomía: El análisis al inicio del proceso de diseño coadyuva a destacar el vínculo entre la realidad y el aprendizaje en el aula. En el caso de los estudiantes es muy útil ya que, apoyándose en sus saberes y habilidades, se estimula en ellos una actitud para investigar, y así comprendan integralmente a los usuarios y profundizar en la relación entre la ergonomía y el diseño. Y en consecuencia obtener información imprescindible para diseñar.

La publicación de este artículo ayuda a promover y ratificar la importancia del vínculo entre Ergonomía y Diseño, mismo que se puede identificar en la aplicación de diferentes métodos de diseño.

Abstract: According to demographic information, the number of older adults has increased, especially in urban areas, and therefore a wide variety of products are offered to help them carry out their activities independently and safely. In technologically advanced countries, such as the United States of America, products have been developed that are suitable for older people who, combined with age,

may have difficulty moving due to illness or accidents; in order to help them carry out their daily activities. This is the case with single-person electric carts designed for indoor use. In Mexico, certain companies, such as supermarkets, have acquired these electric vehicles and offer them to customers - older adults - for as long as they need them to carry out their shopping.

The objective of this work is to present the analysis of single-person electric cars to identify their advantages and disadvantages with older adult users.

Keywords: analysis, ergonomics, design, electric cart.

Relevance for Ergonomics: Analysis at the beginning of the design process helps to highlight the link between reality and classroom learning. In the case of students, it is very useful because, based on their knowledge and skills, it encourages an attitude of inquiry, helping them to fully understand users and the relationship between ergonomics and design. And consequently, to obtain essential information for design. The publication of this article helps to promote and ratify the importance of the link between Ergonomics and Design, which can be identified in the application of different design methods.

1. INTRODUCTION

This document presents the work carried out with the perspective that incorporates two disciplines: Ergonomics and Industrial Design. The first phase of design process is Analysis in order to understand the problem to be solved. In this phase, data is collected and information is applied where Ergonomics plays a very important role in understanding the relationship established between object-machines and users in order to provide suitable solutions. It should be noted that Ergonomics is an inherent part of many design methods. The knowledge of both disciplines can be merged or combined to formulate requirements in order to propose novel responses that are, above all, appropriate to the needs of users. The requirements state the important characteristics that design must meet, the objectives (Boeijen, et al., 2014).

2. OBJECTIVES

The aim of this research is to determine, through ergonomic analysis, whether the indoor electric vehicle or cart is suitable for use by older adults with limited mobility to move safely around a supermarket and purchase items.

More precisely, to analyze, based on design and ergonomics, an American product called *ValueShopper (Motorized shopping cart),* an electric cart or vehicle that is being used in self-service stores to assist elderly customers with or without physical impairments. Also to learn about the characteristics, advantages and disadvantages of the product in relation to these special users.

Secondary objectives:

To prepare a report with the results of the analysis.
To promote the dissemination of the results among the community interested in ergonomics, as well as among students of industrial design.
To open up the perspective for designing similar products that promote the technological training of industrial design students focused on people with disabilities and elderly.

3. DELIMITATION

The limits of this research take as a reference the object of study of ergonomics, according to: (Avila Chaurand, 2007) “environment-user-object”. Each element of the trinomial is divided in order to achieve a better understanding of the parts that integrate a design problem.

The specific environment is located inside some self-service shops or supermarkets in the Benito Juárez Mayor's Office in Mexico City.

The user refers to elderly, of both sexes. The object we are referring to is the product called *ValueShopper (Motorized shopping cart),* an electric cart that is being used in supermarkets.

4. METHODOLOGY

Considering that analysis is the beginning of the design process and that in the case that concerns us in this research, its importance stands out as a didactic tool for getting to know the products and evaluating them. To achieve a complete analysis, different qualitative and/or quantitative techniques and methods are used. The following are mentioned:

- Photographic record of the user-object-environment relationship. Analysis of images and videos.
- Description and analysis of the product and its specifications provided by the manufacturer, complemented by observation of the user and his or her relationship with the object.
- Analysis of selected anthropometric data and its relationship to some product measurements: seat height and width, trolley base dimensions, steering wheel dimensions, for example.
- Description and analysis of the controls and dashboard - dimensions and location - taking into account safety, usefulness and ease of use, considering the user experience, identification of positive and negative emotions (Ortiz Nicolás, 2023).
- Persona technique to get to know the users.
- Generate a glossary of terms.

5. SOCIAL CONTEXT

Since the world population has grown, attention is now being paid to the elderly sector, which is concentrated in urban areas.

In this document, the population of the metropolitan area of Mexico City was taken as an important reference to demonstrate or illustrate the importance of the issue.

Mexico City is located in the south-central region of the Mexican Republic. It is the country's capital and the smallest state, with a population that is 99% urban and covering an area of 1495 km^2. Based on the 2020 population and housing census, there are 9,209,944 inhabitants, which represents 7.3% of the country's total population. It is the largest urban center in Mexico and is considered the most important cultural and financial center in the country. (INEGI, 2020).

For this research, the Benito Juárez Mayor's Office (Alcaldía Benito Juárez) in Mexico City was selected, one of the sixteen territorial demarcations into which it is divided.

Its boundaries were defined in 1970 and it is worth noting that urban development began in the first decades of the last century, in an area of 26.63 km^2 at an altitude of 2,232 meters above sea level. Figure 1 shows the location of the Benito Juárez Mayor's Office in Mexico City in dark blue.

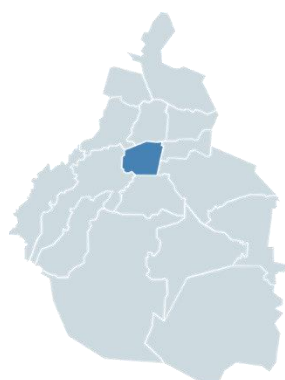
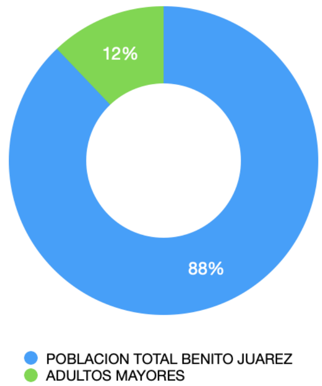
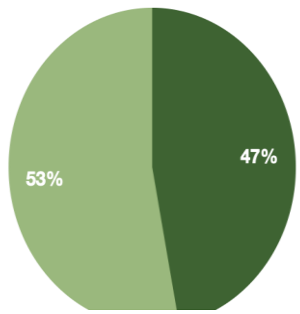


Figure 1

To explain better the demographic composition in this municipality, it has a total population of 434,153 inhabitants, of which 59,837 are elderly. This is interpreted as 16.9% of the total elderly population in Mexico City, making it the district with the highest percentage, followed by Coyoacán with 14.6%, Miguel Hidalgo with 14.5%, Venustiano Carranza with 13.7%. In particular, 46.6% are men (dark green) and 53.4% are women, as can be seen in Figures 2 and 3.





Figures 2 and 3

It is briefly mentioned that the Alcaldía Benito Juárez has an urban infrastructure that has grown in an orderly manner, which is reflected in most of the neighborhoods in the area, with various land uses, especially housing and residential complemented by commercial services of various types and ranges. In the 1960s, the first shops known as self-service stores and even the first shopping center (https://es.wikipedia.org/wiki/Bodega_Aurrera) developed in this area.

6. ENVIRONMENT

To continue with the description, which has proceeded from the general to the specific, we start from the intrinsic three-way relationship between user-object and environment that is presented in the Industrial Design Curriculum 2025. Similarly, Avila Chaurand and co-authors (2014) mention that the field of action and research of ergonomics covers three spheres: the first corresponds to the human being or user; the second refers to the object in a broad sense, covering any element produced by man to facilitate the performance of various activities. The third sphere corresponds to the environment, which is the physical space, which in this document is referred to as a self-service shop where social interactions take place.

This type of environment is where the situation being analyzed is located, considering the presence of older adults as preferential users.

The interior offers a wide variety of items such as food, beverages, cleaning supplies, clothing, perfumes, among others. They are large in size, which forces people to walk significant distances from the outside or parking lot to locate the food or products they wish to purchase.

The stores have been remodeled and updated and, as a result, attention has been paid to the mobility needs of the different people who go there, especially the elderly.

To continue with the logic of the three spheres approach, we pay attention to elderly and their relationship with objects that are provided such as traditional wheelchairs, wheelchairs with front baskets and electric carts that offer autonomy and freedom of movement inside the store.

7. USER: ELDERLY

The group of users that is considered in this user-object-environment relationship is the elderly person whose desire is to carry out their daily activities independently and safely. According to Burlano (2018) and collaborators, aging is the result of several factors, the most important being technological development that benefits the population and allows the life expectancy indicator to grow.

According to WHO- World Health Organization - experts (https://www.who.int/news-room/fact-sheets/detail/ageing-and-health) and other authorities who understand the problem, they corroborate that older adults prefer to carry out their daily activities in the immediate and known environment, which ensures certainty, tranquility, confidence and self-esteem, resulting in a better quality of life.

To complement that information and to learn more about the user, it is worth consulting specialized sources that mention maintaining people's physical abilities, which includes walking and moving freely, which contributes significantly to the perception of health in older adults. Therefore, it is essential to avoid the limitations derived from physical, cognitive and psychosocial barriers.

Specialists in the field suggest that the different environments in which people, especially older adults, carry out their activities, should be safe everywhere, to facilitate all their activities, movements and travel. Thus, all kinds of auxiliary elements have been designed, ranging from the simple and traditional cane for support, crutches, walkers, wheelchairs with different configurations according to needs and beyond, “motorized carts” to move around inside the shops where people usually go to satisfy their needs when purchasing different items.

PERSONS
Archetypical representation of intended users, describing and visualizing their behavior, values and needs. Personas help you to be aware of and communicate these real-life behaviors in design work.

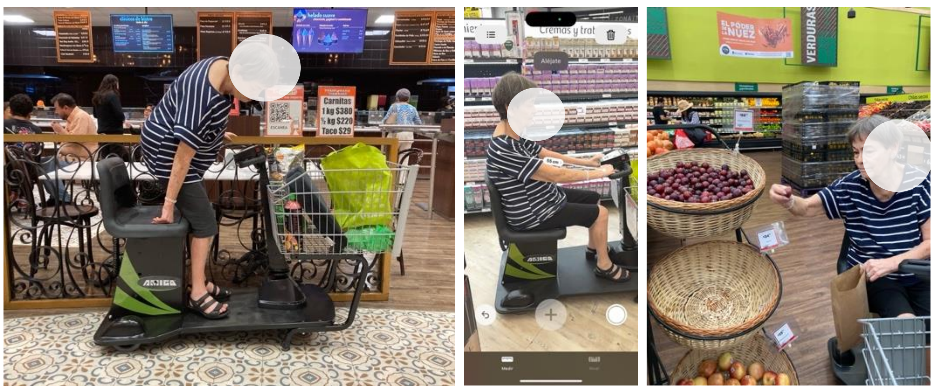
References and further reading in Boeijen et al., 2014, p.95.

Factors considering the elderly include the following:

- Hand strength is reduced about 16 - 40%
- Arm strength is reduced about 50%
- Leg strength is reduced about 50%
- Air intake reduced about 35%
- Most body breadth decreases with increasing age
- Weight can increase 2 kg (4.4 lb) every ten years

References and further reading in Henry Dreyfuss Associates, 2002
The Measure of Man and Woman, John Wiley &Sons, Inc.

Person 1



Figures 4, 5, 6

Female Gender 73 years old

Uses an adult walker for short distances.
Enjoys shopping for groceries and other personal items.
Using the cart gives her the freedom to move confidently around the store and choose what she needs.
At the checkout she requires assistance to place items on the conveyor belt to be able to pay and exit
Usually accompanied for all activities.

Figures 4, 5 and 6 show the woman interacting with the cart within the store in Mexico City, Alcaldía Benito Juárez. She climbs easily onto the cart. The height of the seat is suitable for resting her feet and sitting comfortably. She controls the cart and approaches easily the vegetables.

These images are created by the author of this document.

Tables 1, 2, 3 includes: Anthropometric data (quantitative) of the users

Table 1

Stature	161	cm	
Weight	57	kg	
Grip width	75	mm	Right hand
Hand length	170	mm	
Grip width	65	mm	Left hand
Hand length	160	mm	
Age	73	years old	

Adapted from Avila Chaurand, R. (2011). *Dimensiones antropométricas de lapoblación latinoamericana.* Graphic: head, foot, hand. Elderly. Female. 60 to 90 years old, p. 106.

Table 2

	Dimensiones	P5	P50	P95
27	Seated knee height	402	466	541
28	Popliteal height	325	363	396
29	Elbow width	415	495	586
30	Hip width sitting	318	380	456
31	Buttock to knee	507	553	602

Adapted from Avila Chaurand, R. (2011). *Dimensiones antropométricas de la población latinoamericana.* Graphic: Seated position. Elderly. Female. 60 to 90 years old, p. 105.

Person 2

Figures 7, 8, 9, 10.

Masculine gender. 88 years old
Enjoys shopping for groceries and other personal items.
He uses a walking aid to move around
Using the cart gives him the freedom to move confidently around the store and choose what he needs.
At the checkout requires assistance to place items on the conveyor belt to be able to pay and exit
Usually accompanied when shopping

Figures 7, 8, 9 and 10 show the men interacting with the cart within the store in Mexico City, Alcaldía Benito Juárez.
These images are created by the author of this document.

Table 3

Stature	172	cm	
Weight	80	kg	
Grip width	110	mm	Right hand
Hand length	190	mm	
Grip width	105	mm	Left hand
Hand length	185	mm	
Seated knee height	470	mm	
Buttock to knee	580	mm	
Age	88	years old	

Adapted from Avila Chaurand, R. (2011). *Dimensiones antropométricas de la población latinoamericana.* Graphic: head, foot, hand. And Seated position.
Elderly. Male. 60 to 90 years old, p. 110.

Person 3

Figures 11, 12.

Masculine gender. 70 years old
He is supported by crutches due to his injured left foot, which is protected with an orthopedic boot
Enjoys moving freely around the shop and he is able to arrange the selected items in the basket
At the checkout requires assistance to place items on the conveyor belt to be able to pay and exit
Figures 11 and 12 show the woman interacting with the cart within the store in Mexico City, Alcaldía Benito Juárez.
These images are created by the author of this document.

Table 3

Stature	180	cm	
Weight	95	kg	
Grip width	75	mm	Right hand
Hand length	170	mm	
Grip width	65	mm	Left hand
Hand length	160	mm	
Age	70	years old	

Adapted from Avila Chaurand, R. (2011). *Dimensiones antropométricas de la población latinoamericana.* Graphic: head, foot, hand. Elderly. Male. 60 to 90 years old, p. 110.

These three examples briefly illustrate how the Persona technique can be developed in the ergonomic analysis of objects/products with the purpose of identifying possible users in the scenario that the other stages of the design are continued through the synthesis and simulation stages to validate the requirements. Boeijen et al. (2014) consider that a designer “still needs real people to test and evaluate design”.

The position adopted in the Valueshopper trolley is a seated position, at a height where the majority of users, both women and men, can rest their feet on the floor.

The size and configuration of the seat are such that the popliteal hollow is not compressed and, at the same time, the ischium are supported to maintain an upright position.

The upright position makes it easier to look ahead and observe the surroundings and to handle and select food items with confidence and ease, by turning the neck and torso slightly when approaching shelves and refrigerators (horizontal and vertical).

Depending on the seated position adopted by the user, the REBA analysis can be used to determine important features of the arm, hand and wrist when lifting fruit, vegetables or other groceries.

When choosing fruit or something else, the subject leans forward or turns trunk left and right, raises a product with one or both arms. places the products in the front basket. This action involves bending the trunk forward. Some people do not do it because they go to the shop attended by a relative, a friend or ask the staff for help.

Results of observational method

After observing the subjects carrying out the different actions during the minutes and/or seconds they take to select the items, these tables are based on the RULA method

Table 4: Score by type of activity

	Activity	Score
Fruit: papaya or any other object	Load or force of less than 2 kg, maintained or intermittent	**0**
Watermelon, dog food or any other product	Load between 2 and 10 kg held intermittently	**+ 1**

Adapted from RULA Method assessment. Ergonautas. Universidad Politécnica de Valencia.

Table 5: Score by position

Position	Score
Sitting, well supported with the trunk-hips at an angle >90°	1
Flexion between 0 and 20 degrees	2

Adapted from RULA Method assessment. Ergonautas. Universidad Politécnica de Valencia.

8. OBJECT: ELECTRIC INDOOR VEHICLE

For this research, the electric cart produced in the United States of America was chosen, available in Mexico in most of the places visited with the purpose of observing the users. It is an electric vehicle used by elderly in those places described above.

The product brand is Amigo and the model is *Valueshopper.*

Based on the description referred on the website, it is described as:

- The front drive motor
- Modular components
- Front drive with tight turning radius
- Made in the U.S.A.

- Measurements:
  Length: 140 cm
  Height: 90 cm
  Width: 65 cm

- Rider capacity: 227 kg (500 lbs)
- 24-volt battery system charges in a 110V outlet
- LED Battery level indicator and troubleshooting codes
- Quiet movement

Standard basket
Weight capacity: up to 56.69 kg (125 lbs)
The standard basket is the perfect size for most grocery stores.

Safety items:

- SmartSensor: collision avoidance system for Amigo motorized carts.

It reduces the risk of carts bumping into people, objects or store displays. This small vehicle has sensors at the front that detect when it is approaching a physical obstacle or, when approaching someone that the driver has not seen and heard in time.

- Safety seat switch – cart will not move unless driver is seated
- Speed limit

Data available from the company's website: https://www.myamigo.com/retail/motorized-shopping-carts/valueshopper-xl/#highlights

General description:
The structure of the cart and the base are made of reinforced steel to support the weight of the equipment and batteries, together with the maximum weight of 227 kg (500 pounds) of the user plus the 57 kg (125 pounds) of the products that are purchased. Non-slip floor. Two rear wheels.

Colors: black on the visible parts with green details, in this case. Although the manufacturer offers different colors according to the image that identifies the business.

Seat:
The height and position of the seat are suitable for people to access easily and be at a appropriate distance to operate the controls and get close enough to deposit the products in the basket at the front.

The seat has no adjustable features. It is designed to fit everybody.

Placing a heavy object, such as a large piece of fruit, is not easy for adults as it is an extreme position and difficult to achieve from the seat. (Figure 9).

To remove products from a vertical refrigerator, several movements must be carried out:

First place, open the door keeping a distance to achieve this,
second, get as close as possible to reach the product on one of the upper shelves.

Third, place the product in the basket and move away to close the door.
There could be an inconvenience with the temperature contrast in some cases.

(Figure 10).

Controls:
The shopping cart is operated by a steering wheel located at the top of a column at the front of the cart at a distance that allows getting on and off without obstacles, appropriate distance for people with measurements in the 95th percentile, considering American population as seen on figures 13 and 14.

Figures 13 y 14

In Figure number 15 the male user can be seen in relation to the control of the cart. He uses both hands effortlessly to drive it. According to the description, the physical and graphic elements of the control described previously, can be observed distinctly in figure number 16.

Figures 15 and 16

In Figure number 15 the male user can be seen in relation to the control of the cart. He uses both hands effortlessly to drive it. According to the description, the physical and graphic elements of the control described previously, can be observed distinctly in figure number 16

The cart is operated with both hands, which must be placed on the steering wheel. The instructions are printed on the center panel and shows information legibly.

On the right-hand side there is a button to start the movement and it is also de STOP red button indicated with a red arrow.

At the top, the battery is indicated with four segments (100, 75, 50, 25 and 0) to indicate the charge when using the cart.

Two large arrows, one positive, i.e., with a light background pointing upwards, and the second negative or with a dark background pointing downwards. It should be interpreted as moving forward or backward.

On both sides, there are small levers that correspond to the information on the arrows described to indicate moving forward, with right pointing down and left if moving down, indicating movement backwards.

Note that some have a bugle symbol, on the right, to indicate that it produces a horn sound to alert other shop assistants.

In summary, it is easy to operate with both hands and, considering that it is an electric cart, starting the movement can sometimes be a sudden reaction, although it does not imply any danger as it has a sensor that prevents it from crashing into something.

All images and tables were created by the author of this document.

9. SEQUENCE OF ACTIVITIES

Table 4

1	The user arrives at the store's parking lot and leaves their car in the special spaces for people with disabilities, areas reserved so that they can get in and out of their vehicle comfortably; located near the entrances of the shopping center.
2	The user gets into the place and looks for an electric cart Valueshopper or a traditional wheelchair with a basket

3	The user chooses the nearest shopping cart, with a full battery charge, so that "the customer" can move around the shop and choose their products.
4	The users start the route according to what they have planned to purchase. They can look for the edible items that are furthest from the entrances. Moving through different aisles and shelves, vertical and horizontal refrigerators with frozen goods.
5	The customer chooses the products and places them in the basket at the front of the cart. The fruits and vegetables are placed in different bags to identify the corresponding code for payment. Each bag weighs differently and involves **repeatedly bending the trunk forward** to place them in the basket. Care should be taken not to mishandle them. Both arms or the dominant arm must be used. Extension of the upper limb occurs.
6	Vertical refrigerators When the customer opens the refrigerator doors, they have to carry out several movements. They have to move back to open the hinged door and then move forward to take out the frozen products.
7	Horizontal refrigerators; upper door of the refrigerator and the depth prevent the items from being at hand. User must bend down or forward.
8	Heavy and big products in plastic bags as soap, detergent or dog food.

9	At the end, the customer must go to the checkout to pay and place each one of the objects on the conveyor belt so that the cashier can proceed to register the payment. At this stage, another person must help as there is a difference in height between the cart and the conveyor band. Someone could help, be the companion or those who help to pack or arrange the groceries in the bags in the basket or in the supermarket trolleys that can be moved to the checkout and out to the parking lot.
10	All the goods are being changed to the automobiles trunk and taken to customers-user home. The elderly or relative drives back home or take a cab. At home, all the goods should be stored in the kitchen, refrigerator or whatever is appropriate.

- People with previous experience in driving cars drive confidently in the aisles of the store.
- These small cars are in perfect condition, as they were incorporated a few months ago, maybe a year of service, so all sensors and controls are working properly.
- The dimensions, shapes, position, colors and textures of the controls are well-matched to operate with little force and the reactions of the vehicle are smooth.
- The customers enjoy using these shopping carts.

10. RESULTS

The results of this analysis will contribute to emphasize the link between experience and learning in the classroom, by providing current technological knowledge and skills that will contribute with elements to broaden the vision and creativity of students to design more complex objects, as well as to achieve meaningful learning in a wider range of subjects.

The results can be introduced through images, graphics and other appropriate techniques to publish ergonomics content.

It is a great advantage to have access to these small vehicles that are used in commercial spaces and that could be used in other spaces where adults can live together and generate conditions of autonomy and that in terms of appearance, they can be pleasant and above all accessible and easy to handle.

To fulfill the objectives of user centered design on special users in this case, older adults, within the university training and to promote it for future designers.

The sources of information retrieved provided documents and information on elderly from different points of view.

- Recommendations to enable architectural spaces to transform them to help elderly carry out their activities without risk and in good conditions.
- Specialized literature on geriatrics
- Assessment methods and techniques
- The themes related to: mobility, aids for older adults: walking sticks, wheelchairs, different types of carts. Manufacturer options, power supply, different options that consider user-centered design and other specialized methodologies.
- Technological improvements that allow adults to live better in cities in special care
- Suggested activities for older adults

11. References

Ávila, R., Rey Galindo, J.A. y Prado, L. (2014). *Ergonomía en el diseño de productos.* Guadalajara: Universidad de Guadalajara.

Ávila, R., Prado, L. y González, E. (2007). *Dimensiones antropométricas de la población latinoamericana.* Guadalajara: Universidad de Guadalajara.

Boeijen, A., Daaljuizen, J., Zijlstra, J. y Schoor, R. (Edits.) (2016). *Delft Design Guide. Design methods.* Amsterdam: BIS Publishers.

Bridger, R.S. (2017). *Introduction to Human Factors and Ergonomics.* CRC Press, Taylor & Francis Group, United Kingdom.

Burlano C, Cusano I. *Growing old and keep mobile in Italy. Active ageing and the importance of urban mobility planning strategies*. Tema J Land Use. 2018:43–52. Mobility and Environment.

Censo de Población y Vivienda 2020. http://bit.ly/43ceyE0

Kroemer, K.H.E. (2006). *"Extraordinary" Ergonomics. How to accomodate small and big persons, the disabled and elderly, expectant mothers, and children.* CRC Press, Boca Raton, FL

Ortiz-Nicolás, JC y Hernández López, I. (2018). Emociones específicas en la interacción persona-producto: un método de identificación causal. *Economía Creativa.* 09), mayo-octubre, pp.122-162.

Proyecto de Modificación del Plan y Programas de Estudio de la Licenciatura en Diseño Industrial (2025). Facultad de Estudios Superiores Aragón, UNAM.

RULA Method. Rapid Upper Limb Assessment. https://www.ergonautas.upv.es/metodos/rula/rula-ayuda.php

Sattele, V. and Ortiz, J.C. (2024). Generating user personas with AI: Reflecting on its implications for design, in Gray, C., Heskert, P., Forlano, L., Ciuccarelli, P. (eds.), *DRS2024:* Boston, 23-28 June, Boston, USA.

Simón-Sol, G. (2009). *La trama del diseño.* México, Editorial Designio.

Soto Ramírez, E. and Escribano, E. (2019). El método estudio de caso y su significado en la investigación educativa en D.M. Arzola Franco *(coord.). Procesos formativos en la investigación educativa. Diálogos, reflexiones, convergencias y divergencias (pp. 203-221). Chihuahua, México: Red de Investigadores Educativos Chihuahua.*

Tilley, A.R. (2002). *The Measure of Man. Human Factors in Design.* USA: John Wiley & Sons, Inc.

Vilchis Esquivel, L. *(2014). Metodología del diseño. Fundamentos teóricos.* México: Designio.

Wang, J. (s.f.) *Personas in the User Interface Design.* Alberta: University of Calgary.pdf (https://cspages.ucalgary.ca/~saul/wiki/uploads/CPSC681/topic-wan-personas.pdf)

World Health Organization WHO. https://www.who.int/

ERGONOMIC DESK DESIGN USING THE ANTHROPOMETRIC MEASUREMENTS OF THE STUDENT POPULATION OF THE UNIVERSIDAD DE LA SIERRA

Cristian Vinicio López Del Castillo, Natan Suja Ruelas, Matilde Bermúdez Márquez, Dinora Monroy Meléndez, María Jesús Moreno Peralta

Ingeniería Industrial en Productividad y Calidad
Universidad de la Sierra
Carretera Moctezuma-Cumpas
Moctezuma, Sonora

Corresponding author's e-mail: clopez@unisierra.edu.mx

RESUMEN: En México, la ergonomía sigue siendo un aspecto poco implementado en el diseño de mobiliario, maquinaria y herramientas, lo que impacta negativamente en la comodidad y salud de los usuarios. En el ámbito universitario, esta problemática se vuelve más evidente, ya que los estudiantes pasan en promedio 30 horas semanales en las instalaciones de la institución, de las cuales aproximadamente el 80% transcurren sentados en mobiliario que no siempre cumple con los estándares ergonómicos adecuados. Esto puede generar problemas musculo esqueléticos, fatiga, cansancio, tensión muscular y otros malestares físicos, afectando su bienestar general y, en consecuencia, su rendimiento académico.

Para abordar esta situación, se llevó a cabo un análisis detallado del mobiliario escolar utilizado por los estudiantes universitarios. El objetivo principal fue diseñar un mesabanco ergonómica que se adaptara a las necesidades antropométricas de los usuarios, garantizando así un mayor nivel de comodidad y seguridad postural. Para ello, se realizaron mediciones antropométricas a los alumnos de la Universidad de la Sierra, en Moctezuma, Sonora, con el propósito de obtener datos precisos sobre sus dimensiones corporales y establecer las medidas óptimas para el mobiliario.

Además, se llevó a cabo una investigación documental sobre diseños factibles y estándares ergonómicos aplicables a mobiliario escolar. Se analizaron referencias de modelos existentes, identificando sus ventajas y deficiencias en términos de ergonomía. A partir de esta información, se diseñó un prototipo de mesabanco que busca minimizar los riesgos de afectaciones físicas en los estudiantes y mejorar su experiencia académica.

Este diseño ergonómico se fundamenta en principios que favorecen una postura adecuada, reducen la fatiga y permiten mayor comodidad durante largas jornadas de estudio. Su implementación no solo ayudaría a prevenir problemas de salud relacionados con una mala postura, sino que también contribuiría a una mejora en la concentración y el desempeño académico de los estudiantes.

Este proyecto destaca la importancia de la ergonomía en el entorno educativo y resalta la necesidad de adaptar el mobiliario escolar a las características antropométricas de los usuarios. La incorporación de mobiliario ergonómico en las aulas universitarias representa una solución viable para garantizar un ambiente de estudio más saludable, eficiente y propicio para el aprendizaje.

Palabras Clave: Mesabanco, Ergonomía, Antropometría, Prototipo y Salud.

Relevancia para la ergonomía: Este proyecto representa una contribución significativa a la ergonomía en el ámbito educativo al abordar los problemas posturales y de confort derivados del uso de mobiliario inadecuado en las aulas universitarias. Su impacto se manifiesta en los siguientes aspectos: Mejora del bienestar y salud estudiantil, Optimización del desempeño académico, y Aplicación de la ergonomía en el diseño de mobiliario

Abstract: In Mexico, ergonomics continues to be a poorly implemented aspect in the design of furniture, machinery and tools, which has a negative impact on the comfort and health of users. In the college environment, this problem becomes more evident, since students spend an average of 30 hours per week in the institution's facilities, of which approximately 80% are spent sitting on furniture that does not always meet the appropriate ergonomic standards. This can generate musculoskeletal problems, fatigue, tiredness, muscle tension and other physical ailments, affecting their general wellbeing and, consequently, their academic performance.

To address this situation, a detailed analysis of the school furniture used by college students at Universidad de la Sierra was carried out. The main objective was to design an ergonomic desk that would adapt to the anthropometric needs of the users, thus ensuring a higher level of comfort and postural safety. To this end, anthropometric measurements were taken of college students in order to obtain precise data on their body dimensions and establish the optimal measurements for the furniture.

In addition, a documentary research on feasible designs and ergonomic standards applicable to school furniture was carried out. References of existing models were analyzed, identifying their advantages and deficiencies in terms of ergonomics. Based on this information, a desk prototype was designed to minimize the risks of physical affectations in students and improve their academic experience.

This ergonomic design is based on principles that promote proper posture, reduce fatigue and allow for greater comfort during long study days. Its implementation would not only help prevent health problems related to poor posture, but would also contribute to improved concentration and academic performance of students.

This project highlights the importance of ergonomics in the educational environment and emphasizes the need to adapt school furniture to the anthropometric characteristics of the users. The incorporation of ergonomic furniture in university classrooms represents a viable solution to ensure a healthier, more efficient and conducive learning environment.

Keywords: Desk, ergonomics, anthropometry, health and prototype.

Relevance to ergonomics: This project represents a significant contribution to ergonomics in education by addressing postural and comfort problems arising from the use of inadequate furniture in university classrooms. Its impact is evident in the following aspects: Improved student health and well-being, Optimized academic performance, and Application of ergonomics in furniture design.

1. INTRODUCTION

In the academic environment, ergonomics plays a fundamental role in the prevention of musculoskeletal disorders and in optimizing student performance. Several studies have shown a direct correlation between the lack of ergonomic furniture and the prevalence of physical discomfort in students, which has a negative impact on their academic performance. Postural overload generated by the prolonged use of inadequate furniture can lead to fatigue, muscle tension and long-term health problems, affecting both physical well-being and the ability to concentrate in the classroom.

Faced with this problem, the need arises to develop anthropometric studies that allow the design and manufacture of school furniture adapted to the body dimensions of the users. In this context, a study was carried out at Universidad de la Sierra, with the objective of evaluating the existing furniture based on surveys and anthropometric measurements applied to the student community. Through this analysis, we seek to generate ergonomic design proposals that contribute to the improvement of the learning environment and the promotion of postural health in students.

Under this premise, it is hypothesized that “the use of an ergonomic desk in college significantly improves academic performance, as well as the physical and mental health of students”. To test this hypothesis, a desk prototype was designed based on anthropometric data and ergonomic criteria, with the purpose of reducing the risks associated with inadequate postures and improving comfort during study sessions.

The development of this project faces several challenges, including the availability of time for data collection and construction of the prototype, as well as the economic limitations for the manufacture of the furniture. However, it is expected that the results obtained will not only validate the hypothesis proposed, but also encourage the implementation of ergonomic solutions in the educational environment, promoting healthier and more efficient learning environments.

At Universidad de la Sierra, a significant deficiency has been identified in the ergonomics of the furniture used in the classrooms, which has a direct impact on the wellbeing and academic performance of the students. The lack of adaptation of the desks to the anthropometric characteristics of the users generates inadequate postures that can lead to musculoskeletal discomfort, fatigue and distraction during study sessions.

Prolonged use of non-ergonomic furniture increases the risk of developing musculoskeletal disorders, mainly affecting the lumbar, cervical and upper extremities. These conditions can lead to constant discomfort, decreased ability to concentrate and, consequently, a reduction in students' academic performance.

Given this problem, the implementation of an ergonomic desk within the university facilities is proposed, with the purpose of improving the postural comfort of the students, reducing the incidence of musculoskeletal injuries and optimizing the learning environment. Ergonomics applied to educational furniture not only promotes physical well-being, but also positively influences cognitive capacity and academic performance by allowing students to focus on their activities without the distractions caused by discomfort.

This project seeks to address this deficiency through the design and manufacture of a workbench adapted to the anthropometric needs of students, providing an adequate work space that favors their health, comfort and academic performance.

2. OBJECTIVES

General Objective

Design an ergonomic desk based on anthropometry to improve the academic performance of students at Universidad de la Sierra.

Specific Objectives

1. Improve academic performance with the implementation of an ergonomic design in the desks, in order to promote greater learning.
2. Reduce ergonomic risks with the application of anthropometry for better student comfort.
3. Prepare anthropometric charts of the student population of Universidad de la Sierra.

3. DELIMITATION

This project is based on the existing problems in the facilities of our university; The convenience and comfort of the classrooms are an area that requires improvement for greater student learning. Some of the existing problems involve physical and mental fatigue, as well as distractions due to not having a work area that is correctly designed to achieve the maximum academic performance expected by each student and institution.

4. METHODOLOGY

4.1 Conducting an experiment

This was done after taking anthropometric measurements in the ergonomics laboratory, where 236 samples were collected from students from different educational programs at the Universidad de la Sierra. Likewise, surveys were applied, collecting a minimum of 50 responses from students who are using the different types of desks that the university has; to begin an analysis of the situation in which the students find themselves and to know what problems to focus on specifically in terms of comfort and ergonomics of the desks.

With the information gathered from the surveys and the anthropometric measurements, a design was made in the SolidWords software, then the VR eDrawing program was used to properly visualize the prototype and consequently pass it through the Cura program to the 3D filament printer in the innovation center to start with the first prints of the assembled prototype.

4.2 Data collection

For data collection, "google forms" a tool provided by google was used, which allowed to apply a survey of seven questions to a representative sample of students, with this it was possible to analyze the problems and successes of conventional desks. As well as the previously collected anthropometric measurements of the 5th percentile and the 95th percentile, the student population was taken into account for the creation of the ergonomic redesign of the benches.

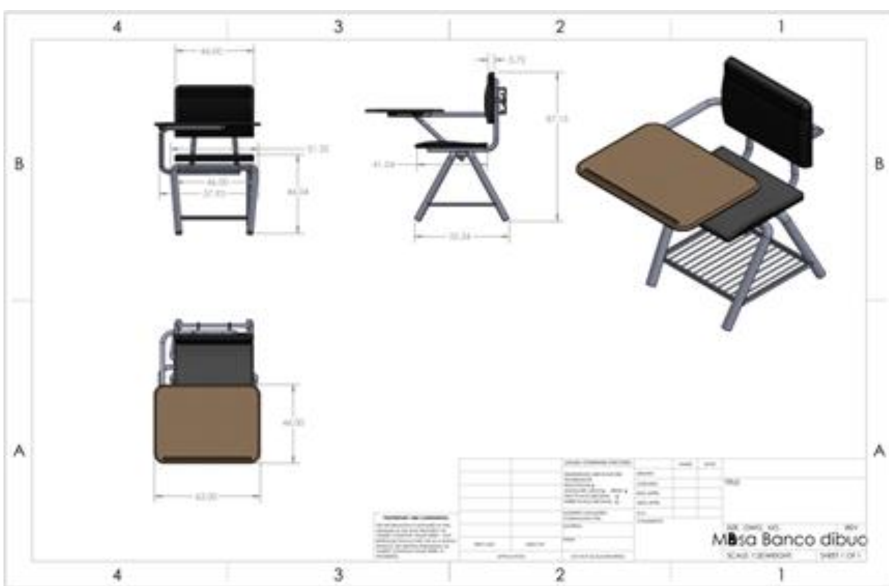


Figure 1. Design of the prototype using SolidWorks

4.3 Analysis of the results.

The survey showed that 37.3% of the students think that the comfort of the desks is neutral (indifferent), while 33.3% and 21.6% think that they are very uncomfortable or uncomfortable, respectively.
56.9% of the student body affirms that the desktop palette of the desks is adequate, while 43.1% of the student body affirms that the desktop palette of the current desks is inadequate for working. The percentage who thinks that the desktop palette is inadequate speak about one of the types of desks used within the university (Psychology area desk).

The survey showed that 54.9% of the university students think that the height of the desk in relation to writing comfort is adequate; 29.4% and 7.8% of the sample think that the height of the desk in relation to writing comfort is low and very low, respectively; 3.9% and 3.9% consider it high and very high, respectively.

According to the survey, 41.2% of the students think that there is very little adequate posture, 6.3% said little, 13.7% said that they do, and 39.2% think that the desks do not allow an adequate posture to avoid discomfort.

33.3% of the students frequently experience pain or physical discomfort after using the desks for a prolonged period of time, while 23.5% have experienced pain or physical discomfort sometimes, 21.6% have rarely experienced some type of discomfort, 15.7% have always experienced pain or physical discomfort after using the benches, and finally, 5.9% have not experienced any discomfort.

We can observe that 78.4% of the sample suggest improvements in the bench seat, 72.5% suggest improvements in the bench backrest and lastly 51.0% suggest improvements in the desktop paddle.

4.4 Anthropometric Table

The 11 measurements are shown in the following table, used for the adaptation and redesign applied to the desk, as well as the average of the measurements, the standard deviation and the percentiles, both the 5th percentile and the 95th percentile, which will be used as a reference in the design of the prototype to suit the entire student population of the university.

Table 1. Anthropometric measurements for the design of the ergonomic bench table

Anthropometric Measurement	Average	Standard deviation	5 percentile	50 percentile	95 percentile
Weight (Kgs) (920)	74.55	18.39	52.80	70.00	114.5
Height (805)	167.27	11.47	154.33	168.00	181.99
Height at elbow at 90° seated (312)	25.19	3.94	19.75	25.00	29.56
Thigh height, seated (856)	15.33	2.52	11.92	15.10	19.94
Floor to seat height (4FGM)	40.84	3.21	36.50	40.90	46.11
Length from the back of the knee to the back of the chair (200)	48.91	4.05	42.24	48.80	56.13

Knee to chair back length (194)	61.67	4.99	53.00	62.00	69.35
Height from the ground to the back of the knee(678)	42.54	3.77	37.00	42.40	48.82
Floor to knee height (529)	51.71	3.72	46.07	51.70	58.08
Hip width, seated (459)	38.13	4.60	30.75	37.80	46.85
Thigh width with knees together (859)	33.65	4.54	28.00	33.30	42.23

With the results obtained the following prototype (Design) was made to which modifications for improvement are included according to the existing needs. Modifications to the backrest were made by placing an ergonomic backrest design in it, as well as an adjustable desktop paddle so that it adapts to all students. The discomfort caused by the current desks was also taken into account, which is why ergonomic seats and backrests have been included in the redesign to allow for proper posture. This has reduced the risk factor for lumbar injury and mental fatigue.

4.5 Ergonomic Desk manufacturing process.

1. Start by grabbing the base of a bench that is no longer in use, a bench which has the base from which the design was inspired.
2. The base is adapted to this design by making the necessary adaptations and expansions.
3. Then, start with the adaptation for the measurements and levels of the backrest, using it three levels were welded with the percentiles that were already calculated.
4. Start with the adaptation of the backrest which a system was made so that it can be easily hooked to the levels previously made, this has a swivel to make it easier to hook and move from level to level.
5. The seat and backrest are covered with padding to make them more comfortable, but in the case of the backrest it is given a form of lumbar support.
6. A rail system is made for the desktop pallet with three levels and then welded to the structure of the bench.
7. Then the whole structure is painted gray.
8. Finally, the seat and the back of the desk are assembled.

4.6 Evaluation of Desk with the ROSA method

The ROSA method calculates the deviation between the characteristics of the evaluated job and those of an office job with ideal characteristics. For this purpose, scoring diagrams are used for each of the elements of the position.

A 21 year old student from the Universidad de la Sierra, who has been studying at the institution for three years with an average of 8 hours a day sitting at a desk was evaluated.

In this case, the traditional desk was changed with the ergonomic prototype of the desk.

In table A, in the first row, the information for the armrest plus backrest scores were gather and in the first column the seat height plus seat width information were also gather. At the intersection of the two scores it gave a figure to which a value for the time of use is added and the final figure resulting from the above is the chair's score.

In table A, the representative part of the armrest plus the backrest was assigned a value of 1 and in the column of seat height plus seat depth it gave a value of 4 points, which led to the intersection being assigned a value of 3 points, plus the sum of the score corresponding to the time of use, resulting in a rating of 4 points.

Finally, as mentioned above, the value of 4 was maintained, which indicates that it is a level 1 risk that can be improved, and in terms of performance, some elements can be improved. (This is according to the table shown below).

Table 2. Risks and Action Levels ROSA

Puntuación	Riesgo	Nivel	Actuación
1	Inapreciable	0	No es necesaria actuación.
2 - 3 - 4	Mejorable	1	Pueden mejorarse algunos elementos del puesto.
5	Alto	2	Es necesaria la actuación.
6 - 7 - 8	Muy Alto	3	Es necesaria la actuación cuanto antes.
9 - 10	Extremo	4	Es necesaria la actuación urgentemente.

5. ANALYSIS OF RESULTS

The desk was evaluated with a score of four points, leaving it at risk of level 1 improvement, in which some elements could be improved. This is due to the fact that it does not have adjustable seat height and depth.

As a final result of the project, a functional prototype of an ergonomic desk was obtained, designed based on anthropometric and ergonomic principles, with the objective of improving the comfort, posture and academic performance of students. This design is conceived as a first version, with possibilities for optimization and refinement in future iterations.

The main improvements incorporated in the prototype include:

- Padded seat and backrest with lumbar support: Designed to provide greater comfort and reduce pressure on the lumbar area, preventing musculoskeletal injuries and improving the user's posture during long academic days.
- Lateral extensions: Implemented to increase the work area and allow a higher level of comfort and functionality, facilitating the use of study materials and electronic devices.

Figure 2. Images of student testing the prototype desk.

- Adjustable backrest and desktop paddle: Designed to adapt to the individual needs of the user, allowing height and angle adjustment according to the optimal posture of each student.
- Adaptation to anthropometric measurements: The design of the furniture is based on anthropometric data obtained from the student population, considering the 5, 50 and 95 percentile, with the purpose of guaranteeing that most of the users can use the desks in a comfortable and ergonomic way.

This prototype represents an integral solution to mitigate the problems derived from the use of disergonomic furniture in the academic environment. Its implementation in university classrooms would significantly contribute to the reduction of fatigue, musculoskeletal discomfort and distractions, favoring a healthier and more efficient learning environment.

6. CONCLUSIONS

From the results obtained, it can be concluded that the prototype developed effectively meets the ergonomic needs expressed by the students. The proposed design adjusts to the anthropometric dimensions of the users, allowing an adequate posture and significantly reducing the risk of musculoskeletal disorders derived from the prolonged use of inadequate furniture.

The analysis of the surveys and anthropometric measurements confirms that the implementation of an ergonomic desk has a positive impact on the academic experience, as it provides a more comfortable working environment, reduces fatigue and favors concentration. The incorporation of adjustable elements, such as the backrest and desktop paddle, allows each user to adapt the furniture to their specific needs, optimizing its functionality and ergonomics.

From an ergonomic perspective, the prototype design complies with the principles of postural adjustment, weight distribution and lumbar support, fundamental elements to prevent musculoskeletal injuries and improve comfort during prolonged study sessions. This translates into a longer stay in a healthy posture, which indirectly contributes to better academic performance and physical well-being.

In terms of applicability, the development of this furniture represents a viable alternative for the improvement of conditions in university classrooms. However, there is a need for future optimizations in materials and adjustment mechanisms to ensure greater durability and efficiency in its large-scale implementation.

With this ergonomic redesign of the desks, it is expected to have a better school performance in the students of the university, as well as a better physical health; since one of the most important factors attributed to the concentration of a student is the comfort and the environment in which he/she is working. With the use of technology and the science of ergonomics it has been possible to jointly develop a prototype capable of improving learning in the classroom.

REFERENCES

Aguilar Carrasco, J. I., Flores Ramírez, Á. E., Arvizu Acosta, R., Ortíz Ramírez, A., & Rivas Escojido, L. F. (2021). Diseño de un mesa banco ergonómico considerando la antropometría de estudiantes de nivel medio superior. Revista Ingeniantes , 11-16.

Aguilar Saenz, M. A. (2023). Athropometry of the Studet Populatio for Design of University School Furniture. En E. De la Vega Bustillos, C. Espejo Guasco, E. Chacón Martínez, A. A. Maldonado Macías, & F. O. López Millán, Ergonomía ocupacional (pág. 570). SEMAC.

Angulo de la Fuente, V. (2024). Sillas y mesas escolares como agentes de aprendizaje: Reflexiones históricas y actuales. Enfoques educacionales, 256-269.

Consejo Colombiano de Seguridad. (2024). sura. Obtenido de Trabajo en posición sentado:https://www.arlsura.com/index.php/846#:~:text=La%20postura%20sentada%20es%20la,precisi%C3%B3n%20en%20las%20acciones%20desarrolladas.

Cotrina Sinti, J. E., Oliveira Haro, T. A., & Alegría Lazo, K. M. (2024). La Antropometría y Diseño de Mobiliario Escolar de Nivel Primario de la I.E. N°0094-Banda de Shilcayo. Ciencia Latina Revista Científica Multidisciplinar, 8(5), 6060-6073.

Guevara Tirado, A., & Sánchez Gavidia, J. J. (2022). Grado de dolor, trastornos musculoesqueléticos más frecuentes y características sociodemográficas de pacientes atendidos en el Área de Terapia Física y Rehabilitación de un centro médico de Villa El Salvador, Lima, Perú. Horiz. Med. vol.22 no.3 Lima.

Paredes Pérez, N. C. (2017). El riesgo ergonómico y el derecho del trabajador a la seguridad y salud en el trabajo, en el distrito metropolitano de Quito, año 2016. Quito, Ecuador: Universidad Central del Ecuador.

Parra Cruz, A. (2019). Factores de riesgo ergonómico en personal administrativo, un problema de salud ocupacional. ITSUP.

Ramírez Amaya, L., Montiel Reyes, A., & López Ruiz, P. (2024). Guía 2024, Equipamiento de Planteles Educativos. Ciudad de México: Secretaría de Educación Pública.

Valencia Romero, J. F., Anchundia Franco, R. F., Zambrano Garcés, K. A., & Álava Navarrete, O. D. (2022). Ergonomía, una prioridad en la salud ocupacional. Polo del conocimiento, 2270- 2281.

ERGONOMIC TOOL: THE EFFICORT TREE PRUNER

Cristian Vinicio López Del Castillo, Yoselin Durazo Salcido, Axel Uriel Careaga Marrujo, Daniel Isidro Mendivil Villa, Dinora Monroy Meléndez

Ingeniería Industrial en Productividad y Calidad
Universidad de la Sierra
Carretera Moctezuma-Cumpas
Moctezuma, Sonora

Corresponding author's e-mail: clopez@unisierra.edu.mx

Resumen. En nuestra constante búsqueda por mejorar la productividad y reducir el estrés en el lugar de trabajo, hemos diseñado y desarrollado una herramienta llamada "Podadora Efficort", una herramienta revolucionaria que combina la eficiencia y el diseño ergonómico para proporcionar una experiencia de usuario sin precedentes. Con esta herramienta ergonómica, hemos optimizado la funcionalidad para reducir en su totalidad el riesgo en caídas en el lugar de trabajo, mejorar la precisión y la eficiencia en las tareas diarias, incrementar la comodidad y la satisfacción del usuario y reducir el riesgo de lesiones y problemas de salud relacionados con el trabajo.

La "Podadora Efficort" es una herramienta ergonómica, diseñada específicamente para mejorar la seguridad, la funcionalidad y la eficiencia en el proceso de poda. Su diseño innovador reduce significativamente la fatiga y el estrés laboral, minimiza el riesgo de lesiones musculoesqueléticas y mejora la precisión operativa, incrementando la productividad de los trabajadores en entornos de uso prolongado.

Palabras clave: Ergonomía, Innovación y Eficiencia

Relevancia para la ergonomía: El proyecto aporta a la ergonomía una herramienta diseñada para reducir la fatiga, el estrés y los riesgos asociados con el trabajo prolongado en poda. Su diseño ergonómico optimiza la comodidad del usuario, minimiza el esfuerzo físico y mejora la seguridad, lo que contribuye a la prevención de lesiones musculoesqueléticas. Además, al integrar materiales ligeros, ajustes personalizables y un agarre antideslizante, facilita su uso incluso para personas con poca experiencia. Gracias a su desarrollo basado en estudios ergonómicos y pruebas de usabilidad, la podadora no solo incrementa la eficiencia y precisión en el trabajo, sino que también promueve un entorno laboral más seguro, saludable y productivo.

Abstract. In our constant search to improve productivity and reduce stress in the workplace, a tool called "Efficort Tree Pruner," has been desgned, a revolutionary tool that combines efficiency and ergonomic design to provide an unprecedented user experience. With this ergonomic tool, we have optimized functionality to completely eliminate the risk of falls in the workplace, improve precision and

efficiency in daily tasks, increase user comfort and satisfaction, and reduce the risk of injuries and work-related health problems.

The "Efficort Tree Pruner" is an ergonomic tool, specifically designed to enhance safety, functionality, and efficiency in the pruning process. Its innovative design significantly reduces fatigue and work stress, minimizes the risk of musculoskeletal injuries, and improves operational precision, increasing workers' productivity in prolonged-use environments.

Keywords: Ergonomics, Innovation, Efficiency

Relevance to ergonomics: The project contributes to ergonomics with a tool designed to reduce fatigue, stress, and risks associated with prolonged pruning work. Its ergonomic design optimizes user comfort, minimizes physical strain, and improves safety, contributing to the prevention of musculoskeletal injuries. Furthermore, its lightweight materials, customizable settings, and non-slip grip make it easy to use even for inexperienced users. Thanks to its development based on ergonomic studies and usability testing, the pruning shear not only increases work efficiency and precision but also promotes a safer, healthier, and more productive work environment.

1. INTRODUCTION

This modified tool features an intuitive and adaptable ergonomic design, strong and durable materials, advanced ad customizable functionalities, and an easy-to-use interface.

In this context, ergonomics plays a key role in the development of tools that optimize agricultural tasks, reducing physical effort and the risk of injuries.

This ergonomic tool for pecan trees or domestic use was designed to improve the productivity and confort of farmers, minimizing fatigue and maximizing efficiency in tasks such as pruning, harvesting, and tree maintenance. With an innovative design and lightweight but resistant materials, this tool not only simplifies daily work but also contributes to sustainable farming through safer and more efficient practices.

2. OBJECTIVES

- Increase efficiency and productivity in daily tasks.
- Adapt to the diverse needs and abilities of users.
- Facilitate the use and handling of tools, even for inexperienced users.
- Reduce costs related to health and safety in the workplace.
- Minimize errors and improve task precision.
- Extend the equipment’s lifespan through the use of high quality materials and optimized design.

3. DELIMITATIONS

There are two specific delimitations, which are the conceptual delimitations. These help the tool focus on improving ergonomics to reduce fatigue and stress in the workplace. This tool was designed for adult users or those who already experience issues in potentially affected areas of the body.

The focus will be on studying the features of the tool that aim to prevent injuries or facilitate the user's work. This includes the handle design, weight, cutting angle, vibration damping system, among other related elements.

4. METHODOLOGY

The design and development of the "Efficort Tree Pruner" focuses on meeting the needs of the worker, with the main objective of reducing the risk of accidents and improving the work experience. This process began with a thorough review, where previous studies related to ergonomics were analyzed. This initial stage made it possible to identify key principles that needed to be incorporated into the design to enhance safety and reduce physical fatigue.

An initial prototype was developed, integrating an adaptable ergonomic design, using materials selected for their durability and resistance. This conceptual model focused on minimizing the effort required by the user and facilitating its handling for long periods. Specific ergonomic principles were also applied at this stage to reduce physical stress and improve comfort, ensuring that the design was intuitive and suitable for a wide variety of users.

During the development and manufacturing phase, lightweight but strong materials, such as aluminum alloys, were carefully selected to ensure the durability and functionality of the tool. Advanced features, such as customizable adjustments, have been incorporated to adapt to different users and usage situations.

In the validation and continuous improvement stage, usability tests were carried out with groups of selected users, who evaluated aspects such as comfort, ease of use, and fatigue reduction. This optimization process ensured that the tool met the required quality and functionality standards.

4.1 Technical Specifications

- Materials: Made of high-strength aluminum alloy and cutting-edge polymers that guarantee durability and lightness.
- Cutting Mechanism: Reinforced steel blade system with effort reduction, operated by a tensioned cable with carbon fiber reinforcement.
- Modular Extension: Adaptable with aluminum tube that allows users to reach heights up to 3 meters without compromising stability.
- Operational Safety: Spring-loaded locking system that resets, which helps prevent accidental cuts.

4.2 Use and Functionality

The "Efficort Tree Pruner" is designed for precision pruning in agricultural, forestry, and gardening environments. Its assisted cutting system reduces the force applied compared to conventional tools, enabling users to work with less effort and greater efficiency. The modular extension allows pruning at height without the need for ladders, reducing the risks of falling and improving the stability of the operator.

4.3 Tool Development Process

The design focused on minimizing the aforementioned risks, promoting safer and more efficient work.

This tool was created by modifying old pruning shears that no longer worked, and what was done was to make a modification where a piece of a curved steel bar (solera) was adapted, where at the end a hole was made through which a cable passes through which a cable pulls the piece placed the blade to cut. A spring was added that prevents the blade from jamming. A base was adapted for a telescopic aluminum pole to reach higher branches safely.

4.4 Transforming the Workplace

With the “Efficort Tree Pruner,” the aim is to redefine how people interact with their work tools. A healthy and efficient work environment is strongly believed to be key to the success of any organization. This tool not only makes tasks easier, but also promotes a culture of well-being and satisfaction among users. The tool is primarily designed for tree maintenance workers.

Once the design was completed, usability tests were conducted with selected user groups. These tests allowed us to evaluate essential aspects such as comfort, ease of use, and the tool’s ability to reduce falls during operation. The feedback obtained during this stage was crucial for making adjustments and improvements to the design, ensuring that the tool met the required quality and functionality standards. Additionally, the impact of the pruner on productivity and workplace well-being was analyzed, ensuring that the “Efficort Tree Pruner” promoted a safer, more efficient and comfortable work environment for workers.

The “Efficort Pruner” represents an innovative solution in the workplace, combining ergonomic design and constant validation with end users. This comprehensive approach not only enhances worker safety and experience, but also contributes to productivity and quality of the work environment. The tool demonstrates how a well-founded design can meet the real needs of workers, promoting their well-being and significantly reducing the risks associated with physical labor.

5. RESULTS

- Fewer musculoskeletal problems, such as pain in the hands, wrist, back, or neck.

- Users work longer without physical or mental fatigue.
- Increased efficiency due to more comfortable and natural use of tool.
- Improved mood and motivation, creating a more positive work environment.
- More precise and controlled movements thanks to improved posture and stability.
- Less distraction due to physical discomfort.
- Reduction in costs related to medical treatments, therapy, or compensation claims.


Figure 1. “Efficort Tree Pruner”.

5.1 Benefits of the "Efficort Tree Pruner"

- Optimized ergonomics: The design focuses on user comfort, with adjustable handles and reduced weight for easier handling.
- Versatility: The "Efficort Tree Pruner" is ideal for a wide range of applications, from basic maintenance tasks to more demanding projects in different industries.
- Sustainability: Made with recyclable and eco-friendly materials, promoting sustainable work practices.
- Safety: Advanced safety features, such as automatic locking systems and overheating protection have been integrated, ensuring the user is always safe during operation.

5.2 Biomechanical Benefits

- Reduced biomechanical load: Decreases stress on hands, arms, and back by better distributing effort along the axis of the tool.
- Prevention of repetitive strain injuries: The assisted cutting mechanism reduces joint and tendon strain.
- Postural correction: The design supports a more ergonomic posture, avoiding excessive trunk bending and forced limb movements.

5.3 Main Risk Factors

The main risk factors foud to créate the tool are:

- Using inadequate or poorly placed ladders can cause instability, and that same instability can make you tremble and fall.
- When reaching to cut branches or reaching a certain spot, you can lose your balance and fall.
- If the hands are not use to support yourself while working, the risk increases.
- The branches being cut could fall on you or other people, causing injury.
- Not keeping both feet firmly on the ladder or standing on a step that is too high can cause loss of balance.
- Not using personal protective equipment (PPE) such as a helmet, safety glasses, gloves, and harness.
- Strong winds can affect the ladder's stability and the worker's balance.
- Rain can make both the ladder and the tools slippery.
- Having loose branches and trying to handle them could make you lose balance or cause them to fall, leading to injuries.
- Highly forced postures while working above head level with a tool weighing around 3 kilograms causes fatigue and strain in the shoulders or arms.

Figure 2. Showing risk factors while prunning

6. CONCLUSIONS

In conclusion, implementing ergonomic tools provides multiple benefits for both workers and organizations. First, it enhances workers' health and well-being by reducing the risk of musculoskeletal injuries and physical discomfort, especially during prolonged use. This not only improves workers' quality of life but also increases productivity by enabling more efficient, sustained work while minimizing fatigue and operational errors.

Additionally, ergonomic design boosts employee satisfaction by offering comfort and ease of use, leading to greater commitment and motivation. It also ensures compliance with safety standards, protecting workers and reducing legal risks. In the long term, ergonomic tolos such as the Efficort Tree Prunner, generate significant savings by reducing injury-related costs, medical leaves, and employee turnover. Finally, this investment reflects the organization's commitment to employee health, enhancing its reputation and fostering an inclusive, safe work environment.

7. REFERENCES

Abramuszkinová Pavliková, E., Robb, W., & Sácha, J. (2024). An ergonomic study of arborist work activities. *Heliyon*, 1-12.

Culligan, E. S. (s.f.). *Aplicación de la ergonomía ocupacional en el área de trabajo*. Obtenido de Agua de Eden: https://www.aguaeden.es/blog/aplicacion-de-la-ergonomia-ocupacional-en-el-area-de-trabajo

Nogareda Cuixart, S., Muñoz Gómez, F., & Lluís. (2013). Carga física en jardinería: principales riesgos y sus consecuencias para la salud. *Notas Técnicas de Prevención 964, Instituto Nacioal de Seguridad e Higiee en el Trabajo*, 1-6.

Unión Sindical de Comisiones Obreras de Aragón, F. p. (s.f.). *Las Caídas Durante el Trabajo.* Zaragoza: Unión Sindical de Comisiones Obreras de Aragón.

RECEPTION, INTEGRATION AND PROCESSING OF INFORMATION OF THE INDUSTRIAL DESIGNER IN THE CONCEPTUALIZATION STAGE: STUDENTS AND PROFESSIONALS

Claudia Cecilia Molina Enriquez[1], ORCID: 0009-0002-3133-1630[1], Juan Luis Hernández [2], ORCID: 0000-0002-8612-5132[2], Rutilio García Pereyra[3], ORCID: 0000-0003-0687-6495[3], and Pablo Antonio Muñoz Gutierrez[4], ORCID: 0000-0002 7070-4287[4]

[1]Department of Design Master's Degree in Creative Studies and Processes in Art and Design
Universidad Autónoma de Ciudad Juárez
Av. Del Charro #450 norte
Ciudad Juárez, Chihuahua 32310

[2]Department of Electrical and Computer Engineering
Universidad Autónoma de Ciudad Juárez
Av. Del Charro #450 norte
Ciudad Juárez, Chihuahua 32310

[3]Department of Design
Universidad Autónoma de Ciudad Juárez
Av. Del Charro #450 norte
Ciudad Juárez, Chihuahua 32310

[4]Department of Design Doctorate in Design
Universidad Autónoma de Ciudad Juárez
Av. Del Charro #450 norte
Ciudad Juárez, Chihuahua 32310

Corresponding author's e-mail: claudia.molina.109@gmail.com

Resumen: Este estudio analiza el proceso de recepción, integración y procesamiento de información en la etapa de conceptualización del diseño industrial, comparando estudiantes y profesionales. La conceptualización es una fase esencial del diseño, ya que define el enfoque del producto y guía su desarrollo. Durante este proceso, los diseñadores gestionan grandes volúmenes de información que influyen en la generación de propuestas innovadoras, dependiendo de su experiencia y contexto laboral. Se realizó una investigación con un enfoque mixto mediante un cuestionario aplicado a 52 participantes de diferentes universidades del país. El estudio evaluó el conocimiento sobre las etapas del diseño, la distribución del tiempo en cada fase, las percepciones sobre la creatividad y la planificación, y los factores que afectan la conceptualización. Los resultados indicaron que el 86.5% de los participantes están familiarizados con las etapas del diseño, considerando la investigación y el descubrimiento (36.5%) y la ideación y conceptualización (34.6%) como las más relevantes. Se identificó que la mayoría de los diseñadores combinan elementos técnicos y creativos en su proceso cognitivo (59.6%). Además, la evaluación de ideas se basa en su impacto en el usuario final y su diferenciación. Factores externos como el estrés afectan la capacidad creativa del 36.5% de los encuestados. Los hallazgos resaltan la importancia de la ergonomía cognitiva en el diseño industrial, enfatizando la necesidad de entornos y herramientas que optimicen la toma de decisiones y reduzcan la carga cognitiva. Este estudio proporciona una visión integral del proceso de conceptualización, destacando la influencia de la planificación, el contexto y los factores emocionales en la calidad del diseño de productos.

Palabras clave: Diseño industrial, conceptualización, recepción, integración, ergonomía cognitiva

Relevancia para la ergonomía: Este estudio contribuye a la ergonomía cognitiva al profundizar en el proceso mental de conceptualización en el diseño industrial, identificando cómo la recepción, integración y procesamiento de la información varían según la experiencia del diseñador. Los hallazgos revelan que la planificación y la creatividad en las etapas iniciales impactan significativamente en el resultado final, resaltando la importancia de diseñar entornos y herramientas que optimicen la toma de decisiones y reduzcan la carga cognitiva. Asimismo, la identificación de factores emocionales y externos, como el estrés y la disponibilidad de recursos, refuerza la necesidad de estrategias que faciliten un equilibrio entre los elementos técnicos y creativos.

Abstract: This study analyzes the process of reception, integration, and information processing in the conceptualization stage of industrial design, comparing students and professionals. Conceptualization is an essential phase of design, as it defines the product approach and guides its development. During this process, designers manage large volumes of information that influence the generation of innovative proposals, depending on their experience and work context. A mixed-method research was conducted using a questionnaire applied to 52 participants from different universities in the country. The study assessed knowledge about design stages, time distribution in each phase, perceptions of creativity and planning, and factors affecting conceptualization. Results indicated that 86.5% of participants are familiar with design stages, with research and discovery (36.5%) and ideation and conceptualization (34.6%) being considered the most relevant. It was identified that most designers combine technical and creative elements in their cognitive process (59.6%). Additionally, idea evaluation is based on its impact on the end user and differentiation. External factors such as stress affect the creative capacity of 36.5% of respondents.

Findings highlight the importance of cognitive ergonomics in industrial design, emphasizing the need for environments and tools that optimize decision-making and reduce cognitive load. This study provides a comprehensive view of the conceptualization process, emphasizing the influence of planning, context, and emotional factors on the quality of product design.

Keywords. Industrial design, conceptualization, reception, integration, cognitive ergonomics

Relevance to Ergonomics: This study contributes to cognitive ergonomics by delving into the mental process of conceptualization in industrial design, identifying how the reception, integration and processing of information vary according to the designer's experience. The findings reveal that planning and creativity in the early stages significantly impact the outcome, highlighting the importance of designing environments and tools that optimize decision making and reduce cognitive load. Likewise, the identification of emotional and external factors, such as stress and resource availability, reinforces the need for strategies that facilitate a balance between technical and creative elements.

1. INTRODUCTION

Conceptualization in industrial design is a fundamental phase for the development of innovative products, as it allows defining the product approach and guiding the subsequent stages. According to Norman and Verganti (2014), this phase represents a significant moment of innovation, when it is decided whether a product will follow an incremental or radical approach in its conception and development. Lawson and Dorst (2009) emphasize that conceptualization is based on the designer's ability to generate multiple possible solutions through the exploration and synthesis of ideas, culminating in the identification of a unique vision for the product. During this stage, designers receive, integrate and process large amounts of information that directly impact the formulation of design proposals, a process that may vary according to the designer's level of experience and work context. In this sense, Rosellini (2017) describes conceptualization as a "program synthesis", in which the concept becomes the essence of the product to be developed. Furthermore, Ulrich and Eppinger (2016) emphasize that the conceptualization process is key to defining the functions, objectives and overall structure of the design, elements that will guide the development and validation of the product.

2. DELIMITATION

This study explores the process of reception, integration and processing of information in the conceptualization phase of industrial design, comparing designers in training and graduated professionals. The research was carried out by means of a questionnaire applied to fifty-two participants from different universities in the country, including students and graduates. A mixed approach was used, combining multiple-choice and open-ended questions, with the aim of analyzing how context, decision-making and external factors influence the creation of innovative products.

3. METHODOLOGY

For this study, the design stages proposed by Barrionuevo (2017) were taken as a reference: Research and discovery, Ideation and conceptualization, Design development, Prototyping, Testing and validation, Manufacturing and launching. To collect data, a survey was designed in Google Forms, composed of 10 multiple choice questions, with the objective of capturing detailed perceptions of students and graduates of industrial design careers from various universities. The survey was distributed to the 52 participants, among students and professionals dedicated to industrial design, thus achieving a varied sample. Inclusion criteria such as gender or years of experience were not considered in the surveyed sample, which will be included in future research.

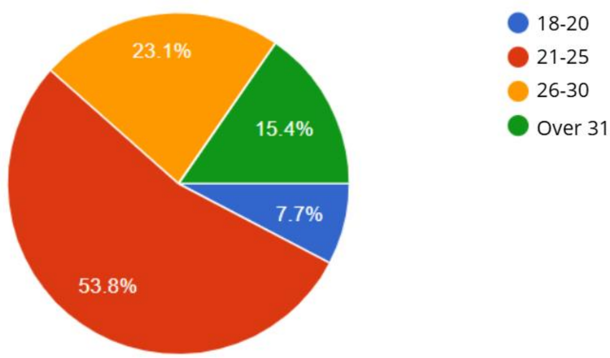


Figure 1: Source of own elaboration (2024)

Of the fifty-two respondents, 53.8% were between 21 and 25 years old, suggesting that the majority were students (see Figure 1). This diversity allowed us to compare the perspectives of those in training versus those who have already worked in the professional field.

4. RESULTS

4.1 Knowledge of the stages of the design process

86.5% of the participants acknowledged being familiar with the stages of the design process mentioned, while 13.5% indicated lack of knowledge or lack of application in their training (see Figure 2).

4.2 Importance of the design stages

Within the stages of the design process, the Research and discovery stage was considered the most relevant by 36.5% of the respondents, followed by Ideation and conceptualization with 34.6%, followed by testing and validation with 15.4%, leaving the stages of design development, prototyping, manufacturing and launching as the least important (see Figure 3).

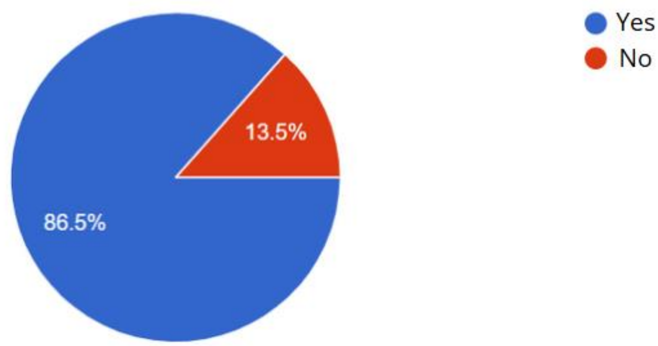


Figure 2: Source of own elaboration (2024)

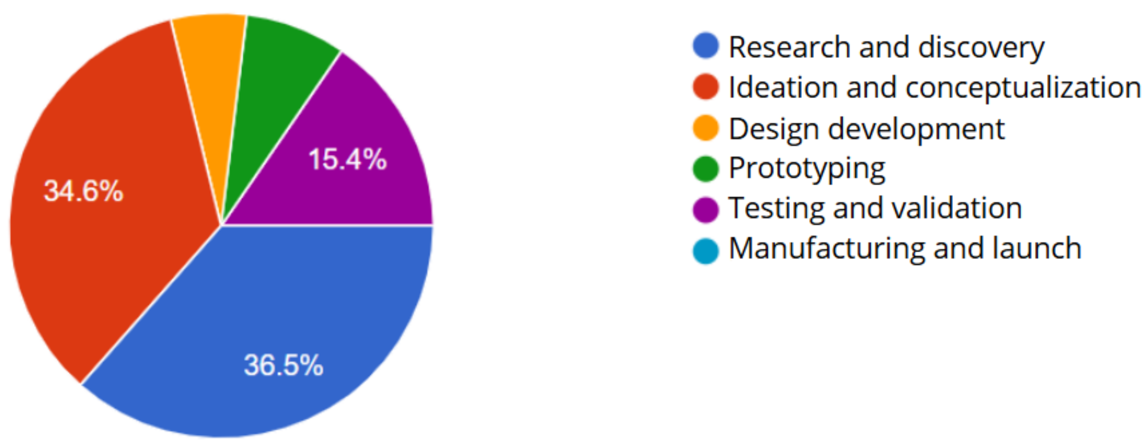


Figure 3: Source of own elaboration (2024)

Open-ended responses pointed to the need for solid research to inform design and conceptualization as the starting point for product development.

4.3 Distribution of time in the stages of the process

One of the questions explored the time designers spend at each stage of the design process. The results revealed that 36.5% of the participants adjust the time spent according to the specific stage they are working on, suggesting a flexible approach adapted to the demands of each phase. Reflecting different approaches to time management during product development in industrial design (see Figure 4).

4.4 Impact of planning and creativity

Question four examined the designers' perception of the importance of creativity and planning in the early stages of the design process. The results indicate that 57.7% of respondents believe that these elements in the ideation phase have a decisive impact on the outcome of the product, underscoring the relevance of a solid foundation to guide development (see Figure 5).

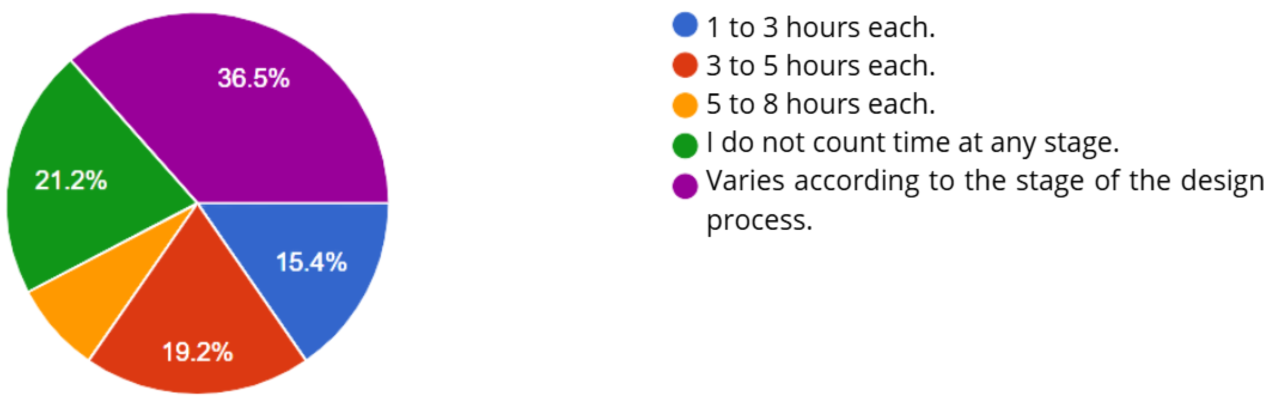


Figure 4: Source of own elaboration (2024)

Figure 5: Source of own elaboration (2024)

4.5 Description of the cognitive process

Regarding the description of the cognitive process involved in product development, 59.6% of respondents considered it to be a combination of technical and creative elements, suggesting an integrative view of the design process, in which both aspects complement each other to generate innovative solutions (see Figure 6).

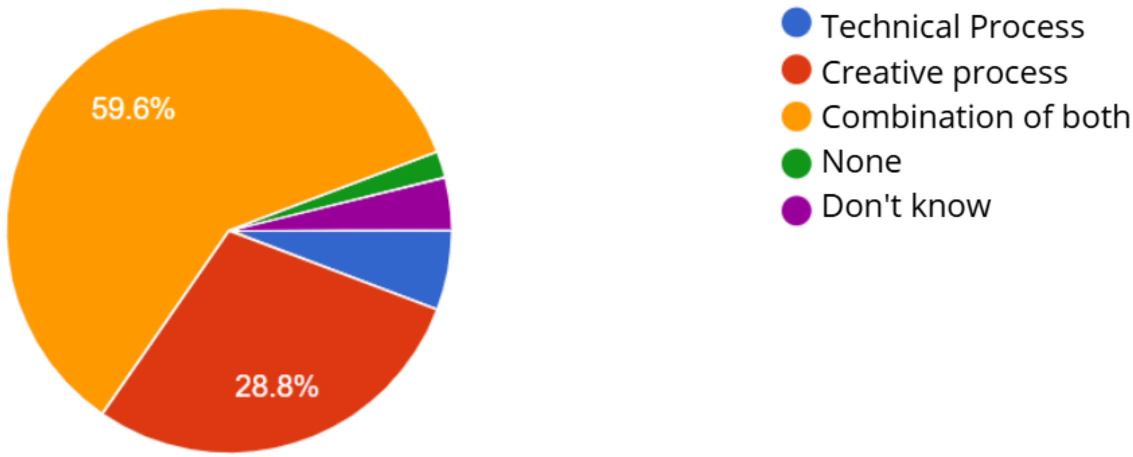


Figure 6: Source of own elaboration (2024)

4.6 Evaluation criteria and selection of ideas

In question seven, respondents were asked to identify the criterion that most influences their idea evaluation and selection process during the product conceptualization stage. The results showed that 17.3% of the participants agreed on the following criteria: evaluate how the idea meets the needs and expectations of the end user, look for novel ideas with a unique approach, and stand out compared to the competition. These results reflect a trend toward innovation and differentiation in the conceptualization process, along with the importance of satisfying the needs of the end user (see Figure 7).

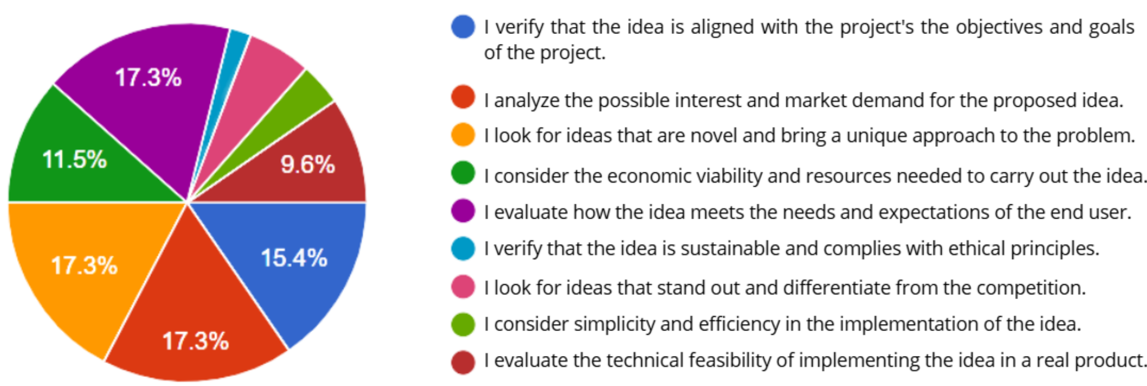


Figure 7: Source of own elaboration (2024)

4.7 External factors affecting conceptualization

In the final question (see Figure 8), respondents were asked to identify the external factor that most affects their idea conceptualization process. The results showed that 36.5% considered emotional factors, such as stress or personal concerns, to negatively influence their creative ability. Less significant factors included social influences and external opinions (5.8%) and disorganized physical environment (3.8%), highlighting the impact of emotional and resource factors on the quality of the creative conceptualization process.

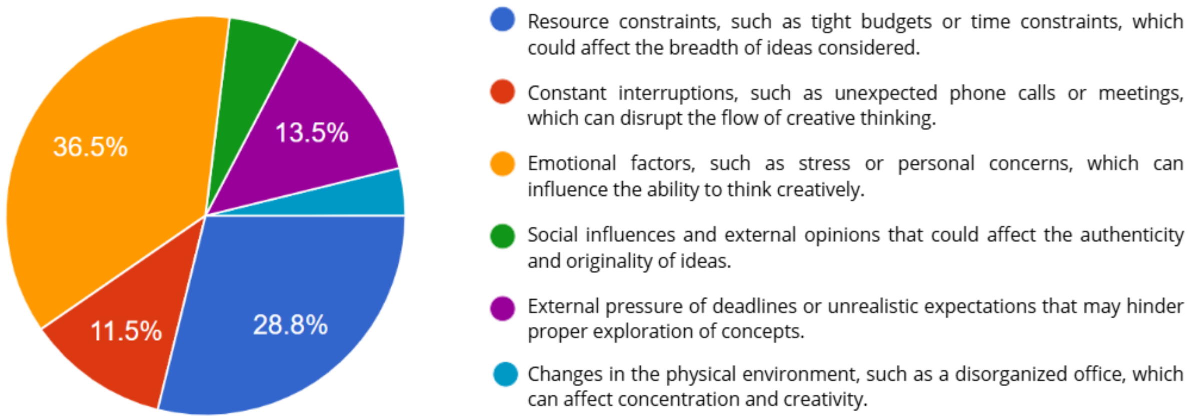


Figure 8: Source of own elaboration (2024)

5. CONCLUSIONS

The application of this survey was fundamental to confirm the relevance of the research topic on the cognitive process of conceptualization in industrial design, both for designers in training and for professionals. The findings show a diversity of approaches to the conceptualization stage, highlighting the perception of some participants who see this phase as a purely creative process, while others consider it technical, or a combination of both. In addition, the study reveals that success at this stage is highly dependent on solid prior research, which lays the groundwork for experimentation and the development of innovative ideas. Planning, context and emotional factors emerge as key elements in the conceptualization process.

6. REFERENCES

Armayor, E., Fontana, M., Moisset de Espanés, E., & Rosellini, F. (2017). The concept in the design process: Approaches and pedagogical experiences. In E. Armayor, M. Fontana, & E. Moisset de Espanés (Coords.), Design and pedagogy (pp. 11-55). Editorial de la Facultad de Arquitectura, Urbanismo y Diseño de la Universidad Nacional de Córdoba.

Barrionuevo, A. (2017). The concept in the design process: Approaches and pedagogical experiences. In E. Armayor, M. Fontana, & E. Moisset de Espanés (Coords.), Diseño y pedagogía (pp. 62). Editorial de la Facultad de Arquitectura, Urbanismo y Diseño de la Universidad Nacional de Córdoba.

Lawson, B., & Dorst, K. (2009). Design expertise. Routledge.

Norman, D. A., & Verganti, R. (2014). Incremental and radical innovation: Design research vs. technology and meaning change. Design Issues, 30(1), 78-96. https://doi.org/10.1162/DESI_a_00250.

Ulrich, K. T., & Eppinger, S. D. (2016). Product design and development (6th ed.). McGraw-Hill Education.

DESIGN OF AN ERGONOMIC DESK FOR THE POPULATION OF THE MOUNTAIN AREA

Cristian Vinicio López Del Castillo, Alí María Moreno Quijada, Danna Marisol Quijada Domínguez, Dania Ivette Acuña Cárdenas, Israel García Silva

Ingeniería Industrial en Productividad y Calidad
Universidad de la Sierra
Carretera Moctezuma-Cumpas
Moctezuma, Sonora

Corresponding author's e-mail: clopez@unisierra.edu.mx

Resumen: El presente proyecto tiene como objetivo diseñar un escritorio ergonómico adaptable a las necesidades de los usuarios, aportando comodidad, una postura adecuada y un aumento de la productividad. La ergonomía es fundamental en los entornos laborales, ya que un mobiliario mal diseñado puede provocar problemas de salud como fatiga, dolores musculares y disminución del rendimiento. El diseño del escritorio se basó en mediciones antropométricas tomadas en la Universidad de la Sierra, donde se recolectaron 236 datos de dimensiones corporales. Con esta información se establecieron los rangos óptimos de altura y ancho del escritorio, asegurando que sea funcional para personas con estaturas entre 1,50 y 1,90 metros. La altura ajustable del escritorio está diseñada para cubrir desde el percentil 5 hasta el 95, permitiendo adaptarse a una gran variedad de usuarios.

Se realizaron pruebas de uso y posturales con una porción representativa de los usuarios, verificando que el escritorio mejora la postura y la experiencia laboral. Se consideró incluir en el escritorio espacios para dispositivos electrónicos y compartimentos organizadores, para facilitar la integración tecnológica. El impacto ergonómico de este diseño es significativo ya que contribuye a reducir el riesgo de lesiones musculo esqueléticas, permite una mejor distribución del peso corporal y la adaptación a diferentes contextos laborales. Construido de manera que la altura y la disposición del escritorio sean ajustables, favorece el bienestar del trabajador, alineándolo con los principios ergonómicos que buscan mejorar la salud y el desempeño en el trabajo. El diseño de este escritorio responde a las necesidades de comodidad y funcionalidad de los usuarios, validando su efectividad mediante estudios ergonómicos. Por su diseño basado en datos antropométricos también asegura una mayor adaptabilidad a una amplia variedad de usuarios y promueve hábitos saludables en el lugar de trabajo.

Palabras clave: Ergonomía, Diseño, Productividad, Antropometría.

Relevancia para la Ergonomía: El diseño ergonómico del escritorio es clave para prevenir trastornos musculo esqueléticos ya que -entre otras cosas- permite regular la altura y mantener una postura corporal adecuada. Según datos antropométricos, es adecuado para una amplia variedad de usuarios. Reduce la fatiga y mejora el

confort, facilitando un entorno de trabajo saludable alineado con los principios ergonómicos de bienestar y eficiencia, lo que contribuye también a mejorar la productividad.

Abstract: The present project aims to design an ergonomic desk adaptable to the needs of users, bringing comfort, an appropriate body posture and an increase in productivity. Ergonomics is essential in work environments, since poorly designed furniture can cause health problems such as fatigue, muscle pain and decreased performance. The design of the desk was based on anthropometric measurements taken at Universidad de la Sierra, where 236 data on body dimensions were collected. By using this information, the optimal height and width ranges of the desk were established, ensuring that it is functional for people with heights between 1.50 and 1.90 meters. The adjustable height of the desk is designed to cover from the 5th to the 95th percentile, allowing to fit a wide variety of users.

Usage and postural test were carried out with a representative portion of users, verifying that the desk improves the posture and the work experience. Spaces for electronic devices and organizing compartments were considered to be included in the desk, to facilitate technological integration.

The ergonomic impact of this design is significant as it contributes to reduce the risk of musculoskeletal injuries, allows better distribution of body weight, and adaptation to different work contexts. Built in a way that height and layout of the desk are adjustable, it favors the well-being of the worker, aligning with the ergonomic principles that seek to improve health and performance at work. The design of this desk responds to the comfort and functionality needs of users, validating its effectiveness through ergonomic studies. Due to its design based on anthropometric data it also ensures greater adaptability to a wide variety of users and promotes healthy habits in the workplace.

Keywords: Ergonomics, Design, Productivity, Anthropometry.

Relevance to Ergonomics: The ergonomic desk design is key to preventing musculoskeletal disorders as -among other things- it allows height adjustment and to keep an appropriate body posture. Based on anthropometric data, it is suitable to a wide variety of users. It reduces fatigue and improves comfort, facilitating a healthy work environment aligned with the ergonomic principles of well-being and efficiency, which also contributes to improve productivity.

1. INTRODUCTION

In today's work environments, ergonomics has gained great importance, becoming the key to improve health, comfort and efficiency of workers. Poorly designed workplaces can lead to physical problems such as back and neck pain, and fatigue. This affects not only the quality of life of employees but also their productivity and overall performance. Addressing these challenges, this project focuses on designing an ergonomic adjustable desk, capable of adapting to the height and other physical needs of a wide variety of users.

This desk offers a flexible and adaptable solution that help users to maintain an appropriate body posture, minimizes the risk of musculoskeletal injuries and fosters a healthy work environment. By implementing ergonomic principles, we seek not only to improve employee comfort and well-being but also to contribute to an organizational culture that prioritizes the health and performance of workers.

2. GENERAL OBJECTIVE

To design and develop an ergonomic desk that is adaptable to the anthropometric characteristics and needs of the target population, with the purpose of improving the comfort, body posture and productivity of users, while promoting a healthy and functional work environment as well.

2.1 Specific Objectives:

- To improve user comfort: Designing a desk that allows workers to adjust the desk's height according to their needs and preferences, thus increasing their comfort and reducing fatigue.
- To prevent injuries: Minimizing the risks of musculoskeletal injuries from helping to keep an appropriate body posture, thus avoiding back, neck, and shoulder pain.
- To increase productivity: Keeping adequate and comfortable body posture that allows the worker to stay focused and with energy for longer, improving efficiency.
- To provide adaptability and flexibility: Creating a desk that can be adapted to different types of users and tasks, incentivizing its use in different work contexts.
- To foster a culture of well-being: Contributing to the creation of a work environment that prioritizes the health and well-being of employees, aligned with ergonomic principles.
- To facilitate mobility and sharing: Having the desk to be used by different employees, whether in shared workspaces or flexible offices.

3. DELIMITATION

The main objective of this project is to design an ergonomic desk which meets the physical, functional and work needs of people in the Sonora region, as users. This project intends to promote well-being, efficiency and to prevent musculoskeletal disorders associated to static work postures that are kept for long lasting periods of time.

1. **Application scope**: This design is primarily aimed at people who perform administrative tasks, graphic design or remote work from an office or from home. Focusing on adult people who work an average of 6 to 8 hours a day.

2. **Specific user characteristics**: The project follows standard anthropometric recommendations. It considers users whose height is in the range between 1.50 to 1.90 meters tall, and also considers the body proportions and gender differences.
3. **Physical environment**: The desk is designed for closed spaces with controlled environmental conditions (temperature, illumination, and noise) such as offices, studios or home work rooms.
4. **Included Components**:
   - Adjustable Dimensions: Height.
   - Accessory Spaces: Compartments for organizing tools, documents, or electronic devices.
   - Technology Integration: Support for electronic devices such as laptops, monitors, and peripheral accessories.

4. **Excluded Elements**: This project does not include the development of ergonomic chairs, specific desk lighting, or advanced technological systems such as wireless charging stations or connectivity ports.

4. METHODOLOGY

236 measurements in total were taken at Universidad de la Sierra, which were used for the design of our ergonomic desk.

Table 1. Anthropometric dimensions relevant to ergonomic design

	Floor to Knee Height	*Distance from the Wall to the Center of the Fist*	*Length from the Elbow to the Middle Finger*	*Lateral Width of the Arms*	*Height of the Elbow at 90° While Seated*
Percentile 0.95	58.53	85.9	51.08	170	90
Percentile 0.5	45.85	65.64	38.63	85	65

The previous measurements were calculated based on data from the book Anthropometry for the Design of Workstations by Enrique Bustillos V. (2019), published by the Technological Institute of Sonora. Basic body measurements are provided within the book, and the following images show examples of the measurements that were taken to develop the design of the ergonomic desk.

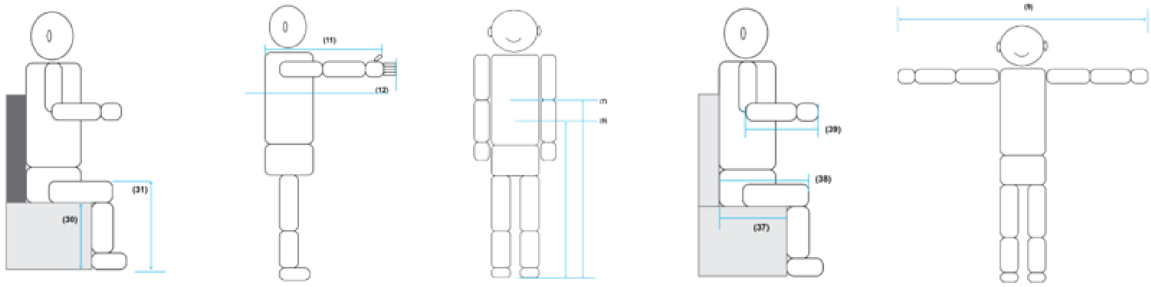


Figure 1. Anthropometric dimensions

It was analyzed that the desk's adjustable height will be set to the 95th percentile, while the lower height will be set to the 5th percentile. The distance from the desk to the arms will be based on the 5th percentile. Similarly, the width of the desk will be designed according to the 5th percentile, as the measurements taken at the university indicate that these dimensions are the most appropriate.

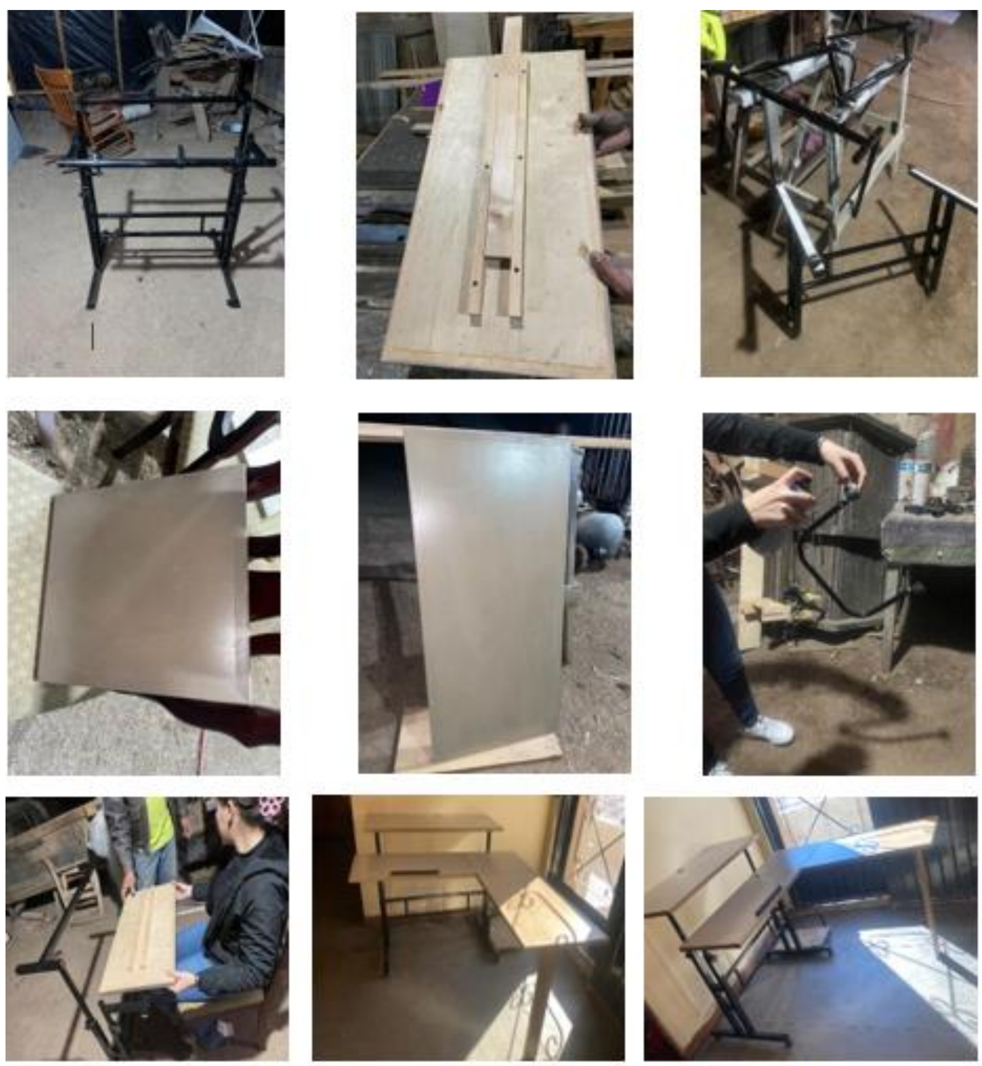


Figure 2. Process development

5. RESULTS

The ergonomic desk design project was carried out with a user-centered approach, based on anthropometric measurements from the population of the Sonora region; specifically: students from the University of Sierra. This approach leaded to the development of a personalized design that maximizes comfort, improves body posture, and the overall well-being of users. The key results obtained are as follows:

5.1 Design Based on Anthropometric Measurements

Anthropometric data were collected from a representative group of Sonora inhabitants, considering parameters such as height, arm length, arm reach, and the optimal angles when using technological devices.

The final desk dimensions (height and width) were determined to be set accordingly to the 5th to 95th percentiles, ensuring the desk to be functional for the vast majority of users.

5.2 Evaluation of Functionality

The effectiveness and functionality of the designed desk was tested by an evaluation on which the following instruments were used:

• Usability tests: Three representative users interacted with the desk in different scenarios (work, study, computer use).

• Postural analysis: An ergonomic method was used to verify body posture during desk use.

5.3 Desk Performance:

• Provides a functional and comfortable space that significantly enhances the user experience.

• Based on anthropometric data, its design ensures a suitable adaptation to the physical characteristics of the Sonora population.

• Tests showed that the desk meets ergonomic standards and helps keeping healthy habits during prolonged work or study sessions.

6. CONCLUSION

The development of the project: "Design of an Ergonomic Desk" represented an integral effort aimed at designing and manufacturing furniture that satisfying meets both the physical and functional needs of users in the Sonora region. Based on a detailed analysis of the anthropometric measurements of the local population, a personalized design that adapts to the specific body characteristics of the inhabitants of this region was achieved, thus optimizing comfort and reducing risks associated with inadequate body postures. Once the design and the manufacturing of the desk were completed, in order to validate its functionality and to make sure it meets the established ergonomic standards, a rigorous evaluation was carried out. The results demonstrated the desk not only meets comfortability requirements but also greatly improves the user experience in work and academic activities.

7. REFERENCES

Bustillos V. Enrique. (2019). Anthropometry for the Design of Work Stations. Instituto Tecnológico de Sonora.

Diego-Mas, J. A. (s/f). Ergonomics at Work and Prevention of Occupational Risks. Upv.es. Retrieved on December 7, 2024, from https://www.ergonautas.upv.es/

Hernández Arellano, J. L., & Bernal Andrade, C. (2007). Ergonomics: Design of Tasks, Jobs and Products. Alfaomega Editing Group.

Muñoz Alvarado, S., & Díaz Alvarado, J. (2012). Anthropometry and Its Application in Ergonomics. Universidad de Costa Rica.

ERGONOMIC MOBILE SUPPORT

Cristian Vinicio López Del Castillo, Alejandra Guadalupe Duran Galindo, Juan Luis López Encinas, Dinora Monroy Meléndez, Penélope Guadalupe Álvarez Vega

Ingeniería Industrial en Productividad y Calidad
Universidad de la Sierra
Carretera Moctezuma-Cumpas
Moctezuma, Sonora

Corresponding author's e-mail: clopez@unisierra.edu.mx

Resumen: Este proyecto de soporte móvil busca mejorar las condiciones laborales de trabajadores en sectores como mecánica, soldadura y agricultura, que realizan tareas en posturas forzadas, como cuclillas o apoyados en un pie. Se diseñó un prototipo de soporte ergonómico con rodilleras y asientos móviles para reducir la presión en las rodillas, tobillos y espalda, minimizando el riesgo de lesiones musculoesqueléticas. La implementación de este proyecto mejora la postura, reduce la fatiga y aumenta la productividad de los trabajadores, promoviendo un ambiente laboral más saludable y seguro.

Palabras clave: Ergonomía, Posturas forzadas, Lesiones musculoesqueléticas, Productividad, y Seguridad laboral

Relevancia para la ergonomía: Este proyecto aporta a la ergonomía al proponer soluciones innovadoras para mejorar la postura y reducir el esfuerzo físico de los trabajadores en sectores de alto riesgo. La implementación de soportes posturales como rodilleras y asientos móviles contribuye a la prevención de lesiones musculoesqueléticas, la mejora de la comodidad en el trabajo y la optimización de la productividad. La propuesta también promueve la importancia de adaptar los entornos laborales a las necesidades físicas de los trabajadores, lo que mejora la calidad de vida laboral y reduce el ausentismo debido a problemas de salud.

Abstract: This mobile support project aims to improve working conditions for employees in sectors such as mechanics, welding, and agriculture, where tasks require forced postures, such as squatting or balancing on one foot. A prototype of an ergonomic support with kneepads and mobile seats was designed to reduce pressure on the knees, ankles, and back, minimizing the risk of musculoskeletal injuries. The implementation of this project enhances posture, reduces fatigue, and increases worker productivity, fostering a healthier and safer work environment.

Keywords: Ergonomics, Forced postures, Musculoskeletal injuries, Ergonomic kneepads, Productivity, Fatigue, Workplace safety, Occupational health.

Relevance to ergonomics: This project contributes to ergonomics by proposing innovative solutions to improve posture and reduce physical strain on workers in high-risk sectors. The implementation of postural supports such as knee pads and mobile seats contributes to preventing musculoskeletal injuries, improving workplace comfort, and optimizing productivity. The proposal also promotes the importance of adapting work environments to the physical needs of workers, which improves the quality of work life and reduces absenteeism due to health problems.

1. INTRODUCTION

Workers in sectors such as construction, manufacturing, transportation, maintenance, and agriculture perform essential tasks, but often face working conditions that can impact their health and well-being. Exposure to forced postures, prolonged physical loads, and repetitive movements increases the risk of developing musculoskeletal disorders, particularly in the back, neck, shoulders, and lower limbs. These problems not only cause discomfort and chronic fatigue but also negatively affect productivity and can lead to increased workplace absenteeism.

This project aims to implement ergonomic improvements adapted to the needs of each sector to reduce physical effort and improve workers' comfort during their shifts. The proposed solutions include specifically designed tools to minimize physical load, such as mobile seats for squatting tasks, enabling workers to maintain healthier postures and reduce the impact of repetitive tasks.

2. OBJECTIVES

2.1 General Objective

Improve the health, safety, and productivity of workers in sectors such as mechanics, welding, harvesting, and stocking shelves in stores, where tasks are performed in squatting positions or while balancing on one foot. Additionally, the project seeks to reduce the risk of musculoskeletal injuries and increase job satisfaction.

2.2 Specific Objectives:

✓ Develop postural support equipment, such as ergonomic kneepads and mobile seats, to facilitate tasks requiring forced or prolonged postures.
✓ Design ergonomic tools that reduce physical effort and improve posture in repetitive activities such as welding, vehicle repair, and harvesting.
✓ Assess and adapt workplace conditions to make workspaces safer, more comfortable, and more efficient, minimizing injury risks.

3. DELIMITATION

This project focuses on the identification, analysis and proposal of ergonomic solutions for workers in sectors such as construction, manufacturing, transportation, maintenance, agriculture and other jobs that involve forced postures and prolonged physical efforts.

4. METHODOLOGY

4.1 Identification and Analysis of Needs

4.1.1 **Direct Observation:** Conducting visits to workplaces (mechanic shops, welding facilities, agricultural fields, stores, and other work environments) to observe tasks involving forced postures or squatting.
4.1.2 **Interviews and Surveys:** Gathering information from workers regarding the main physical challenges they face in their activities.
4.1.3 **Document Review:** Analyzing previous studies related to ergonomics in specific labor sectors.

4.2 Design and Selection of Ergonomic Solutions

4.2.1 **Prototype Design:** Creating models of ergonomic tools and equipment such as kneepads, mobile seats, or supports.
4.2.2 **Technical Evaluation:** Conducting prototype testing under real conditions to ensure functionality, comfort, and durability.
4.2.3 **Sector Adaptation:** Adjusting designs to meet the specific needs of each type of work.

4.3 Pilot Implementation

4.3.1 **Selection of Test Groups:** Identifying workers from each sector to participate in pilot tests.
4.3.2 **Training**: Providing instructions on the correct use of ergonomic equipment to maximize benefits.
4.3.3 **Monitoring:** Evaluating the performance of the equipment and its impact on the health, safety, and productivity of workers.

4.4 Impact Assessment

4.4.1 **Indicator Measurement:** Comparing pre- and post-implementation indicators such as musculoskeletal injury rates, perceived fatigue, and productivity levels.
4.4.2 **User Feedback:** Collect opinions of workers to identify areas for improvement in designs and their implementation.

4.5 Final Adjustments and Scaling

4.5.1 **Design Optimization:** Incorporating necessary improvements based on pilot test results.

4.5.2 **Project Scaling:** Proposing the large-scale implementation of ergonomic solutions in the involved labor sectors.

Table 1. Ergonomic Analysis of different jobs

Work Area	**Activities**	**Knee Risks**	**Ankle Risks**	**Risks from Prolonged One-Foot Support**
Welders	Squatting, kneeling, or bending while using heavy tools	Prolonged pressure on joints due to uncomfortable postures	Strain from forced positions and lack of proper floor support	Muscle fatigue from asymmetric postures while operating equipment
Mechanics	Repairs under vehicles, working in confined spaces	Overload on knees from kneeling or squatting for long periods	Injuries from sudden movements or repetitive position changes	Muscle pain from shifting weight onto one leg while handling tools
Harvesters	Crop picking while squatting or bending	Accumulated tension and knee wear from repetitive and prolonged posture	Risk of sprains from moving over uneven terrain	Muscular imbalance when carrying loads and supporting most weight on one foot
Shelf Stockers	Organizing merchandise on low levels	Strain from bending or kneeling to arrange products	Pain from repetitive foot movements	Overload on one foot due to asymmetric postures

5. ANALYSIS OF RESULTS

5.1 General Observations:

- **Knees:** The most affected due to constant pressure or uncomfortable postures, increasing the risk of joint wear and injuries.
- **Ankles:** Often damaged by poor posture, forced positions, or sudden movements.
- **One-Foot Support:** Leads to muscle fatigue and body imbalance, contributing to chronic pain and long-term postural issues.
- **Back:** Excessive forward bending instead of maintaining an upright posture causes lower back discomfort.

5.2 Design Ideas:

- Introduce ergonomic kneepads and padded supports to reduce knee pressure.
- Use safety footwear with proper ankle support.
- Implement scheduled breaks and posture alternation to reduce lower limb fatigue.
-

5.3 Prototype

1. Name: "Mobile Support"

The prototype was tested with different materials, including square PTR (rectangular tubular profile), tubes, and rods. The best option was a ¾-inch, 16-gauge conduit tube, commonly used for electrical wiring. This material was selected for its ability to support approximately 90 kg while maintaining an aesthetic appearance and lightweight structure.

2. Procedure:

2.1 Design and adaptation of the structure: An attempt was made to bend or shape the tube to achieve a curved form that met the design requirements. However, due to the lack of appropriate tools for this process, welding was used to assemble the pieces and give them the required shape. The curve was designed considering suitable measurements for individuals of medium and short height, with a maximum range of up to 1.90 meters.
2.2 Once the structure was ready**,** the tubes were painted black to enhance their aesthetic appearance and provide a more professional finish.
2.3 Finally, knee pads specifically designed for heavy-duty work that requires kneeling were incorporated. These were screwed onto the ends of each tube and strategically distributed as follows:
2.3.1 The first knee pad was placed at the front, aligned with the knee area, to provide support and comfort during work.
2.3.2 The second knee pad was installed at the back of the shin, designed to function as an improvised seat, offering additional support and reducing strain on the lower limbs.

Figure 1. Design of the Mobile Support.

5.4 Functionality Tests:

1. ***Ergonomic Evaluation (Before the Tool):***

The OWAS (Ovako Working Posture Analysis System) method was applied to assess working postures and the risk of musculoskeletal injuries. Each observed posture was classified by assigning a posture code, from which a risk assessment was determined.

Risk Identification:

Table 2. Back Position Coding. Code 4 was assigned, as the back remains bent and twisted constantly.

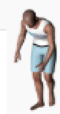
Posición de la espalda		Código
Espalda derecha El eje del tronco del trabajador está alineado con el eje caderas-piernas		1
Espalda doblada Puede considerarse que ocurre para inclinaciones mayores de 20º (Mattila et al., 1999)		2
Espalda con giro Existe torsión del tronco o inclinación lateral superior a 20º		3
Espalda doblada con giro Existe flexión del tronco y giro (o inclinación) de forma simultánea		4

Table 3. Arm Position Coding. Code 1 was assigned, as the worker is in a downward-leaning position with the arms below the shoulders.

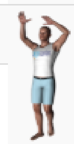
Posición de los brazos		Código
Los dos brazos bajos Ambos brazos del trabajador están situados bajo el nivel de los hombros		1
Un brazo bajo y el otro elevado Un brazo del trabajador está situado bajo el nivel de los hombros y el otro, o parte del otro, está situado por encima del nivel de los hombros		2
Los dos brazos elevados Ambos brazos (o parte de los brazos) del trabajador están situados por encima del nivel de los hombros		3

Table 4. Leg Position Coding. Code 6 was assigned, as the workers are supporting themselves on one or both knees on the ground.

Posición de las piernas	Código
Sentado El trabajador permanece sentado	1
De pie con las dos piernas rectas Las dos piernas rectas y con el peso equilibrado entre ambas	2
De pie con una pierna recta y la otra flexionada De pie con una pierna recta y la otra flexionada con el peso desequilibrado entre ambas	3
De pie o en cuclillas con las dos piernas flexionadas y el peso equilibrado entre ambas Puede considerarse que ocurre para ángulos muslo-pantorrilla inferiores o iguales a 150º (Mattila et al., 1999). Ángulos mayores serán considerados piernas rectas.	4
De pie o en cuclillas con las dos piernas flexionadas y el peso desequilibrado Puede considerarse que ocurre para ángulos muslo-pantorrilla inferiores o iguales a 150º (Mattila et al., 1999). Ángulos mayores serán considerados piernas rectas.	5
Arrodillado El trabajador apoya una o las dos rodillas en el suelo.	6
Andando El trabajador camina	7

Table 5. Load and Force Coding. Code 1 was assigned, as the task does not require lifting a weight greater than 10 kg.

Carga o fuerza		Código
Menos de 10 kg	<10kg	1
Entre 10 y 20 kg	10-20 kg	2
Más de 20 kg	> 20kg	3

Table 6. Risk Categories and Corrective Actions. The classification of risk categories is determined based on the posture codes obtained from previous tables.

Categoría de Riesgo	Efecto de la postura	Acción requerida
1	Postura normal y natural sin efectos dañinos en el sistema músculo esquelético.	No requiere acción.
2	Postura con posibilidad de causar daño al sistema músculo-esquelético.	Se requieren acciones correctivas en un futuro cercano.
3	Postura con efectos dañinos sobre el sistema músculo-esquelético.	Se requieren acciones correctivas lo antes posible.
4	La carga causada por esta postura tiene efectos sumamente dañinos sobre el sistema músculo-esquelético.	Se requiere tomar acciones correctivas inmediatamente.

Table 7. Identification of the Corresponding Risk Number. After implementing the ergonomic tool, the new risk assessment results in a risk level of 2.

	Piernas	1			2			3			4			5			6			7		
	Carga	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Espalda	Brazos																					
1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	2
2	1	2	2	3	2	2	3	[illegible]	2	3	3	3	3	3	3	3	2	2	2	2	3	3
	2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	3	3	3	4	2	3	4
	3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4
3	1	1	1	1	1	1	1	1	1	2	3	3	3	4	4	4	1	1	1	1	1	1
	2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	4	3	3	3	1	1	1
	3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1
4	1	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4
	2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4
	3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4

5.5 Key Improvements Observed:

- Back Position (Table 2): Improved from code 4 (excessive bending and twisting) to code 2 (moderate inclination).
- Arm Position (Table 3): Remains at code 1, indicating no additional strain.
- Leg Position (Table 4): Improved from code 6 (kneeling on both knees) to code 1 (semi-seated position with support).
- Load Handling (Table 5): Remains at code 1, as no heavy lifting is involved.

Table 8. Identification of the corresponding risk number: This results in a score of 2, which significantly decreases by 2 points, reducing musculoskeletal risks, such as:

	Piernas	1			2			3			4			5			6			7		
	Carga	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Espalda	Brazos																					
1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	2
2	1	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	2	3	3
	2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	3	3	3	4	2	3	4
	3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4
3	1	1	1	1	1	1	1	1	1	2	3	3	3	4	4	4	1	1	1	1	1	1
	2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	4	3	3	3	1	1	1
	3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1
4	1	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4
	2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4
	3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4

6. CONCLUSIONS

The analysis and implementation of ergonomic improvements help reduce occupational risks associated with improper postures and repetitive movements. Sectors such as mechanics, welders, and fish pickers are especially vulnerable to musculoskeletal injuries in the knees, ankles, and back.

The project applied solutions like postural supports, ergonomic knee pads, and mobile seats, reducing physical pressure and fatigue, improving posture, and preventing injuries. The evaluation using the OWAS method confirmed a reduction in risk due to the proper use of tools and active breaks.

7. REFERENCES

Diego-Mas, J. A. (2015). Postural assessment using the OWAS method. Ergonautas, Polytechnic University of Valencia. Retrieved February 27, 2025, from https://www.ergonautas.upv.es/metodos/owas/owas-ayuda.php

Safesite, E. (2022, 17 marzo). Growers' Stooping and Squatting Postures Are Chronic Problem - Safesite. Safesite. https://safesitehq.com/es/posturas-de-encorvamiento-agachamiento-cronica/

Luisa, P. R. M., María, V. U., Luisa, P. R. M., & María, V. U. (s. f.). Estudio descriptivo sobre las condiciones de trabajo y los trastornos musculo esqueléticos en el personal de enfermería (enfermeras y AAEE) de la Unidad de Cuidados Intensivos Pediátricos y Neonatales en el Hospital Clínico Universitario de Valladolid. https://scielo.isciii.es/scielo.php?script=sci_arttext&pid=S0465-546X2018000200161#:~:text=Los%2520trastornos%2520musculoesquel%

C3%A9ticos%2520(TME)%2520son,trabajo%2520con%2520elevados%2520costes%2520econ%C3%B3micos.

EVALUATION OF NOISE LEVELS IN THE SHRIMP SPAWNING AREA OF AN AQUACULTURE COMPANY

Brenda Guadalupe Delgado Jiménez, ORCID[1] 0000-0002-8289-4823, Emilia Estéfana Sauceda López, ORCID[2] 0000-0003-4162-981X, Grace Erandy Báez Hernández, ORCID[3] 000-0003-1580-2199, Mara Sofía Uribe Acosta, ORCID[4] 0009-0000-2670-002X

Industrial Sciences Division
Tecnológico Nacional de México /Instituto Tecnológico Superior de Guasave
Carretera a Brecha Sin Número, Ej. Burrioncito
Guasave, Sinaloa, State 81149

Corresponding author´s e-mail: brenda.dj@guasave.tecnm.mx

Resumen: La presente investigación hace referencia a la evaluación de los niveles de ruido en el área de descabece de camarón de una empresa Acuícola ubicada en la comunidad de Casa Blanca en el municipio de Guasave perteneciente al estado de Sinaloa. Dicho estudio fue desarrollado con el objetivo de beneficiar a los trabajadores que laboran en la empresa, a fin de evitar molestias y/o lesiones permanentes de tipo auditivas en un futuro y determinar, cuáles son los niveles de ruido al que se exponen. Sugerir ciertas metodologías para evitar estrés y pérdida de la capacidad auditiva, así como la implementación de exámenes médicos y EPP al personal expuesto a altos niveles de ruido con la intención de proteger y tener un mejor desarrollo de sus actividades. El estudio fue realizado con un sonómetro TES 1353S. Como resultado se obtuvo que la zona 3 sobrepasa los límites permisibles de exposición, por lo que se deben colocar a la entrada del área señalamientos sobre el uso obligatorio de equipo de protección auditiva, por lo que se le debe capacitar al trabajador sobre el uso correcto del mismo.

Palabras clave: Ruido, Nivel sonoro, muestreo, NSA promedio, decibel, EPP.

Relevancia para la Ergonomía: La ergonomía es la interacción entre los seres humanos y otros elementos de un sistema. En este sentido, la investigación se posiciona como un recurso valioso, analizando cómo el entorno acústico puede afectar la salud, el bienestar y el desempeño de los empleados.

Abstract: This research refers to the evaluation of noise levels in the shrimp shucking area of an aquaculture company located in the community of Casa Blanca in the municipality of Guasave in the state of Sinaloa. This study was developed with the objective of benefiting the workers who work in the company, in order to avoid discomfort and/or permanent auditory injuries in the future and to determine the noise levels to which they are exposed. To suggest certain methodologies to avoid stress and hearing loss, as well as the implementation of medical examinations and

PPE to personnel exposed to high noise levels with the intention of protecting and having a better development of their activities. The study was conducted with a TES 1353S sound level meter. As a result, it was found that zone 3 exceeds the permissible exposure limits; therefore, signs should be placed at the entrance of the area indicating the mandatory use of hearing protection equipment, and workers should be trained in its correct use.

Keywords: Noise, Sound level, sampling, average NSA, decibel, PPE.

Relevance to Ergonomics: Ergonomics is the interaction between humans and other elements of a system. In this sense, the research is positioned as a valuable resource, analyzing how the acoustic environment can affect the health, well-being and performance of employees.

1. INTRODUCTION

Noise in the work environment is a critical factor nization (WHO), exposure to loud noise causes temporary hearing loss or tinnitus. However, prolonged or repeated exposure can result in permanent hearing damage, leading to irreversible hearing loss (WHO, 2024). In addition, the Occupational Safety and Health Administration (OSHA) emphasizes that excessive noise can reduce the ability to concentrate and increase the number of errors in the workplace (OSHA, 2024) . Given the importance of hearing care, a study will be conducted based on the methodology recommended in the Mexican Official Standard NOM-011-STPS-2001, Safety and Hygiene Conditions in workplaces where noise is generated, for the control, evaluation, and mitigation of noise in work environments (STPS, 2001). The main activities consist of taking acoustic measurements in different areas of the work environment, identifying the main sources of noise and analyzing the effects of these levels on the productivity and well-being of the employees during the aquaculture production procesthat directly influences the health and performance of employees. According to the World Health Orgas.

2. OBJECTIVE

This project aims to conduct a detailed study of noise in an aquaculture company in the community of Casa Blanca located in the municipality of Guasave, Sinaloa, in order to evaluate the current sound pressure levels and their impact on employees and their tasks, with the purpose of developing a set of practical recommendations that allow the reduction of noise, thus improving the conditions of the working environment and ensuring compliance with acoustic safety regulations.

3. DELIMITATION

The study will be carried out specifically in the shrimp deveining area located in the facilities of an aquaculture company located in the community of Casa Blanca, in the municipality of Guasave, Sinaloa. For this study it was decided to divide the area into 5 work zones in order to obtain a better sampling.

4. METHODOLOGY

The first activity was to identify the work area where the study would be carried out, and then to consult the literature on the applicable regulations (MEXICAN OFFICIAL REGULATION NOM-011-STPS-2001, SAFETY AND HYGIENE CONDITIONS IN WORKPLACES WHERE NOISE IS GENERATED) in order to continue with the application of the methodology and the measurement instrument in the shrimp deveining area.

The method used to evaluate stable noise was:

Evaluation by sound level meter. This method is applicable when it has been determined, in the sensory recognition, that the noise is stable throughout the workday, and must be carried out during three observation periods.

Characteristics of the evaluation:

(a) Each observation period had a maximum duration of 5 minutes and 50 readings.

b) During each observation period the NSA record was taken every 5 seconds.

c) At each measurement point, the observation periods were carried out approximately every 15 minutes due to personnel availability.

d) The work zones studied were evaluated with a distance between measurement points of no more than 12 meters, leaving 5 areas for sampling.

e) The sound level meter was used at a height of 1.45 ± 0.1m, in relation to the support plane placed at head level, in the area where the personnel stand upright.

f) To select the orientation of the sound level meter, the direction of the loudest noise in relation to the location of the main noise source was considered.

5. RESULTS

After touring the company, it was decided to group the work tables and divide them into 5 sections for better sampling, leaving the area as shown in Figure 1.

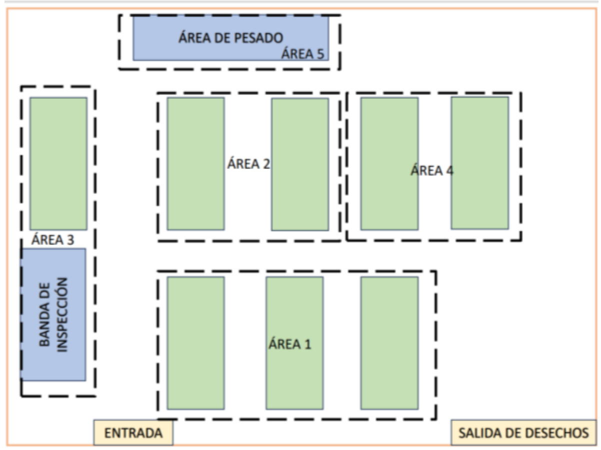


Figure 1. Sectioned area of decapitation

Figure 2 shows how the delimitation of the 5 areas was carried out, taking measurements of the space for a better study.


Figure 2. Delimitation of the area

The sampling of each of the areas began. Below is the information collected from areas 1, 2 and 3 with the NSA records captured with the sound level meter (see table 1, 2 and 3), the complement of the samples can be seen in the annexes.

Table 1. NSA samples record area 1

ÁREA 1											
FECHA	28/06/2023										
PERIDO DE INICIO	10:30:00 A.M										
No. de medición	1	2	3	4	5	6	7	8	9	10	
Db	86.2	85	82	89	82.8	83.2	80.5	80.7	91.2	87.2	
No. de medición	11	12	13	14	15	16	17	18	19	20	
Db	85.3	83.5	84.6	79	83.4	87.6	81.7	88.3	85.4	86	
No. de medición	21	22	23	24	25	26	27	28	29	30	
Db	88.1	85.8	88.4	82.7	81.5	82.2	82.9	83.1	91.9	80	
No. de medición	31	32	33	34	35	36	37	38	39	40	
Db	82.1	82	81.5	80.4	86.4	79.3	81.8	88.6	83.5	81.1	
No. de medición	41	42	43	44	45	46	47	48	49	50	
Db	88.4	81.5	78.3	81.1	78.8	77.1	81.1	82.4	79	80.4	
										PROMEDIO	83.480
FECHA	28/06/2023										
PERIDO DE INICIO	10:50 A.M										
No. de medición	51	52	53	54	55	56	57	58	59	60	
Db	79.6	80.5	78.5	83.1	82.7	80.2	83	85.1	83	81.9	
No. de medición	61	62	63	64	65	66	67	68	69	70	
Db	81.3	80.4	80.8	80.4	81.8	88.1	81.5	80.9	86.4	84.5	
No. de medición	71	72	73	74	75	76	77	78	79	80	
Db	82	83.4	81.5	85.4	83.1	87.4	80.1	81.7	83	83.3	
No. de medición	81	82	83	84	85	86	87	88	89	90	
Db	80.4	83.8	84.4	85.5	83.1	84.3	84.6	83.9	80.6	81	
No. de medición	91	92	93	94	95	96	97	98	99	100	
Db	86	85.5	87.8	87.7	80.2	83.7	87.8	81.8	86.4	90.1	
										PROMEDIO	83.264

Table 2. Area 2 NSA sample record

ÁREA 2											
FECHA	30/06/2023										
PERIDO DE INICIO	10:01 A.M										
No. de medición	1	2	3	4	5	6	7	8	9	10	
Db	81.5	83.6	80.2	82.6	83.7	79.6	83.7	80.6	84.5	82.4	
No. de medición	11	12	13	14	15	16	17	18	19	20	
Db	85.5	86.6	82	84.9	81.5	80.3	84.4	83.1	84.1	85.1	
No. de medición	21	22	23	24	25	26	27	28	29	30	
Db	81.1	85.2	84	86.5	84.4	84.5	82.1	83	84	83.9	
No. de medición	31	32	33	34	35	36	37	38	39	40	
Db	87.2	82.1	84.1	88.9	87.3	81.2	83	85.2	82	84	
No. de medición	41	42	43	44	45	46	47	48	49	50	
Db	82.5	83.4	84	81.2	83.1	84.4	82.6	86	84	82.2	
FECHA	30/06/2023									PROMEDIO	83.54
PERIDO DE INICIO	10:30 A.M										
No. de medición	51	52	53	54	55	56	57	58	59	60	
Db	83.4	88.5	84.4	82.4	82.7	84	83.5	80.3	81	84.9	
No. de medición	61	62	63	64	65	66	67	68	69	70	
Db	84	82.5	83.9	80.6	80.3	84.9	83	83.8	81.1	80.5	
No. de medición	71	72	73	74	75	76	77	78	79	80	
Db	83.4	85.9	82.1	83.5	85.4	86	83.3	85.8	81.1	83	
No. de medición	81	82	83	84	85	86	87	88	89	90	
Db	83.2	84	82.6	82.2	83.3	82.3	84.6	85	84.3	81.2	
No. de medición	91	92	93	94	95	96	97	98	99	100	
Db	86.8	83.2	80.9	83.3	85.1	84.5	80.4	80.4	81.5	80.5	
										PROMEDIO	83.151

Table 3. NSA sampling record area 3

ÁREA 3											
FECHA	04/07/2023										
PERIDO DE INICIO	10:06 A.M										
No. de medición	1	2	3	4	5	6	7	8	9	10	
Db	83.2	94.4	86	92.1	84.8	88.1	86	83.5	85.9	88	
No. de medición	11	12	13	14	15	16	17	18	19	20	
Db	87.6	84.8	85	87	84	83	87.1	84.2	84	84.9	
No. de medición	21	22	23	24	25	26	27	28	29	30	
Db	89.3	83	85.2	91	87.1	85.6	86.6	88.8	85.9	87.1	
No. de medición	31	32	33	34	35	36	37	38	39	40	
Db	84.2	86.2	89.9	88.8	86.2	83.6	84.8	86.1	85.9	84	
No. de medición	41	42	43	44	45	46	47	48	49	50	
Db	91.2	91.6	86.3	85.2	83.6	89.6	85.1	89.3	85.6	86.2	
										PROMEDIO	86.532
FECHA	04/07/2023										
PERIDO DE INICIO	10:40 A.M										
No. de medición	51	52	53	54	55	56	57	58	59	60	
Db	85	83	92.4	83.7	83.7	85.2	83.9	89.5	85.2	83.1	
No. de medición	61	62	63	64	65	66	67	68	69	70	
Db	84.9	84.6	85.7	85.3	84.6	85.6	83.4	87.8	86	83	
No. de medición	71	72	73	74	75	76	77	78	79	80	
Db	85	85.7	83.1	83.3	94.1	85.9	84	88	85.5	86	
No. de medición	81	82	83	84	85	86	87	88	89	90	
Db	84.2	86.2	85.2	88.1	87.2	91	88.9	88.2	89.2	87	
No. de medición	91	92	93	94	95	96	97	98	99	100	
Db	89.5	90.5	87.2	90	82.7	89.8	89.3	88.5	86.9	99.2	
										PROMEDIO	86.6902

Figures 3 and 4 show the delimitation of areas 1 and 2, where the first two samples were taken.

Figure 3. Area 1 shrimp spawning area

Figure 4. Area 2 shrimp de-scaling

Figure 5 shows the samples taken in area 3, capturing the noise generated by one of the machines used by the company to inspect and fill the shrimp jars and then distribute them to the work tables.

Figure 6 recording of NSA readings area 3

To better analyze the samplings, a concentrate of the decibel averages obtained in each of the areas was made, as shown in table 4.

Table 4. Concentrate of dB averages in the 5 areas.

CONCENTRATED SOUND LEVEL OF THE 5 AREAS	
AREA	**AVERAGE dB**
1	83.372
2	83.345
3	86.616
4	84.581
5	82.077

6. DISCUSSION/CONCLUSIONS

According to the results obtained in this study, it can be observed that areas 1 and 2 present a very similar sound level of 83.372 db and 83.345 db respectively. Area 4 shows a slightly higher sound level of 84.581 db.

Area 5 is the area with the lowest noise level with 82.077 db, while area 3 is the area with the highest noise problem with 86.616 db.

As can be seen, all the areas analyzed are above 82 decibels, which means that the company must have a proper evaluation of all areas of the work center where there are workers and whose swl is equal to or greater than 80 db (a), including their characteristics and frequency components, as established in appendices b and c of nom-011-stps-2001.

According to nom-026-stps-1998, at the entrance of the areas where the swl is equal to or greater than 85 db(a), signs must be posted indicating the mandatory use of personal hearing protection equipment, as in the case of area 3, where the swl was 86.616 db.

Finally, it is important to mention that workers exposed to ner equal to or greater than 80 db(a) should be instructed on control measures through a training program on health effects, maximum permissible levels of exposure, protective measures, audiometric examinations, and work sites with critical exposure conditions to prevent hearing problems in the future.

7. REFERENCES

Babu, T. (2018). Ergonomic Analysis of Building Construction Workers Using RII Method. *International Research Journal of Engineering and Technolohgy (IRJET), 5 (11),* 601-605. https://mail.irjet.net/archives/V5/i11/IRJET-V5I11118.pdf

Báez R., Mirtha, Villalba A., Cesar, Mongelós M., Rosalilna, Medina R., Blás, & Mayeregger, Ilda. (2018). Pérdida auditiva inducida por ruido en trabajadores expuestos en su ambiente laboral. *Anales de la Facultad de Ciencias Médicas (Asunción)*, *51*(1), 47-56. https://doi.org/10.18004/anales/2018.051(01)47-056

De Arquer, I., & Nogareda, C. (1999). *Estimación de carga mental del trabajo: el método NASA TLX. INSHT.* Obtenido de Instituto Nacional de Higiene y Seguridad en el Trabajo: https://www.insst.es/documents/94886/327064/ntp_544.pdf/0da348cc7006-4a8a-9cee-25ed6f59efdd.

OSHA. (2024). Manual de seguridad y Salud par empresas pequeñas, Obtenido de https://www.osha.gov/sites/default/files/publications/OSHA4261.pdf

Sahu, S., Chattopadhyay, S., Basu, K., & Paul, G. (2010). The ergonomic evaluation of work-related musculoskeletal disorders among construction labourers working in unorganized sectors in West Bengal, India. *Journal of human ergology*, *39*(2), 99–109. https://pubmed.ncbi.nlm.nih.gov/22416463/

STPS. (2001). *Secretaria del trabajo y Previsión Social*. Norma oficial Mexicana NOM 011 STPS-2001 Obtenido de https://www.stps.gob.mx/bp/secciones/dgsst/normatividad/normas/Nom-011.pdf

WHO. (2024). *Organización Mundial de la salud* . https://www.paho.org/es/noticias/2-3-2022-oms-publica-nueva-norma-para-hacer-frente-creciente-amenaza-perdida-audicion#:~:text=La%20OMS%20publica%20una%20nueva%20norma%20para%20hacer,3%20Promoci%C3%B3n%20de%20la%20nueva%20norma%20mundial%20

ANNEXES

Table 5. NSA area 4 sample record

ÁREA 4											
FECHA	05/07/2023										
PERIDO DE INICIO	10:20 A.M										
No. de medición	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Db	82.9	81.6	88.8	81.9	87.9	86.3	81	83.7	79	83.8	
No. de medición	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
Db	86.1	84.8	84	81.8	79.3	82.6	87.5	82.5	85.5	82.7	
No. de medición	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	
Db	85	84.7	82.7	88.8	82	82.6	85.8	80.2	81.8	82.8	
No. de medición	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	
Db	82.6	87.4	84.3	80.6	84.4	86.7	88.3	84.6	84.5	89.2	
No. de medición	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	
Db	86.3	86.7	87.5	83	95.3	88.7	88.9	86.4	87.9	91.6	
										PROMEDIO	**84.9**
FECHA	05/07/2023										
PERIDO DE INICIO	10:50 A.M										
No. de medición	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**	
Db	87.6	85.5	82.3	84.5	85.6	82.8	86.6	82.7	87.1	82.3	
No. de medición	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	
Db	89.7	86.3	81.8	80.3	86.2	85.5	85.5	82.3	92.3	79.6	
No. de medición	**71**	**72**	**73**	**74**	**75**	**76**	**77**	**78**	**79**	**80**	
Db	82	83.5	80.3	92	84.9	87.7	86.7	84.3	80.4	79.5	
No. de medición	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**	
Db	84.5	87.3	82.8	84.4	81.5	82	85.5	80	85.6	80.1	
No. de medición	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**100**	
Db	87.2	85.8	84.4	80.6	86.5	86.1	82.9	81.6	80.9	85.6	
										PROMEDIO	**84.4059**

Table 6. NSA sample log area 5

ÁREA 5											
FECHA	06/07/2023										
PERIDO DE INICIO	10:26 A.M										
No. de medición	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Db	80.3	81.2	83.3	85.5	80.8	89.2	83.5	79.5	82.9	80.4	
No. de medición	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
Db	82.6	79.1	80.4	80.6	83.6	80.6	81.9	81.7	80	78.5	
No. de medición	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	
Db	84.4	78	80	79.5	79.4	83.5	82.9	80.7	85.8	79.3	
No. de medición	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	
Db	82	77.2	78.2	83.6	84.6	82.3	84.3	83	90.1	79.5	
No. de medición	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	
Db	84.8	80.7	81	78	80	79.6	82.7	81.2	81.3	83	
										PROMEDIO	**81.724**
FECHA	06/07/2023										
PERIDO DE INICIO	11:00 A.M										
No. de medición	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**	
Db	83.5	81.1	82.8	83.6	80.5	80	82.4	82.6	86.8	82.6	
No. de medición	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	
Db	82.1	85.6	80.5	80.8	80.4	81.7	80.4	82	82.5	81.5	
No. de medición	**71**	**72**	**73**	**74**	**75**	**76**	**77**	**78**	**79**	**80**	
Db	79.7	84.1	81.6	82.7	83	82.3	84.4	80	82.6	81	
No. de medición	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**	
Db	84.4	81.8	82	83.6	79.6	83.9	84	84.9	79.3	81.6	
No. de medición	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**100**	
Db	84.1	83.8	82.2	86.4	82.7	83.8	82.5	81.6	81.1	83.4	
										PROMEDIO	**82.43**

ERGONOMIC RISK FACTORS PRESENTS IN A COMMERCIAL COMPANY

Ernesto Ramírez Cárdenas, Gabriela Espinoza Erunes, Iván Francisco Rodríguez Gámez, Mauricio López Acosta y Alonso Eugenio Encinas Magallanes.

Department of Industrial Engineering
Sonora Technological Institute
Antonio Caso s/n, Villa Itson
Cd Obregon, Sonora

Email: ernesto.ramirez@itson.edu.mx

Resumen: El estudio tiene como objetivo identificar los factores de riesgo ergonómico presentes en el sitio de trabajo de una empresa de giro comercial. Para lograrlo, en un primer momento se realizó un recorrido por las instalaciones para después en base a los hallazgos proceder a la obtención de información en relación a las condiciones laborales, las posturas corporales, la frecuencia de lesiones y el ambiente de trabajo. Como resultados el 48% de los empleados han presentado incapacidades durante el desempeño de sus funciones, la gran mayoría presenta dolencias físicas en el cuello, dolores en la mano/muñeca y en la espalda zona dorsal. En relación a los puestos de oficina la gran mayoría presenta nivel de riesgo elevado pero son cuatro de ellos los que urgentemente deben ser intervenidos a través acciones como la mejora del diseño del mobiliario y la implementación de descansos. Como conclusión, el estudio permitió establecer las condiciones para adaptar el entorno de trabajo para mitigar riesgos y mejorar la salud del personal administrativo.

Palabras clave: Ergonomía, factores, riesgo y ambiente.

Relevancia para la ergonomía: Preserva la salud, el bienestar de los empleados y promueve una mayor productividad.

Abstract: The study aims to identify ergonomic risk factors present in the workplace of a commercial company. To achieve this, a tour of the facilities was first conducted and then, based on the findings, information was obtained regarding working conditions, body postures, frequency of injuries and the work environment. As a result, 48% of employees have presented disabilities during the performance of their duties, the vast majority have physical pain in the neck, pain in the hand/wrist and in the dorsal back area. In relation to office positions, the vast majority present a high level of risk, but four of them urgently need to be addressed through actions such as improving furniture design and implementing breaks. In conclusion, the study allowed establishing the conditions to adapt the work environment to mitigate risks and improve the health of administrative staff.

Keywords : Ergonomic , factors , risk and environment .

Relevance to Ergonomics : It preserves employees ' health and well-being while promoting greater productivity .

1. INTRODUCTION

The presence and success of these companies have a direct impact on the development of the country, as they contribute to strengthening the economy, driving investment and innovation, and collaborating in improving the quality of life of citizens by generating wealth and essential services. In addition, these companies are promoted by organizations such as corporate social responsibility organizations that benefit local communities, further reinforcing their role as agents of change and development in Mexico (INEGI, 2023). In short, production and service companies are not only economic leaders, but also play a fundamental role in the advancement and well-being of Mexican society (Secretaría de Economía, 2021).

There is one company in the northwest of the country that is dedicated to the marketing of medical accessories and equipment. Its main activity is the purchase, storage, and sale of medical products and furniture for hospitals. It started in 1995 and is characterized by the rapid distribution of its products, generating good contact and strong ties with its customers.

The company under study is governed by the COFEPRIS Regulations (Ministry of Health, 1995) for the marketing of hospital products and properties, with the planning department in charge of carrying out these processes for purchasing, storage, sales and distribution, as well as tools for preparing forecasts to determine the demand of its customers, key processes ranging from supplying equipment to after-sales service, while support processes range from recruiting new talent to the technologies used to carry out the main activities.

According to Zganjar (2023), the macroeconomic and political environment in which companies operate is indicated through the analysis of the Political, Economic, Social, Technological and Ecological (PESTE) factors, which appears in Table 1.

Table 1. PESTE analysis of the company under study

Politicians	Economical	Social	Technological	Ecological
Foreign trade Customs/taxes COFEPRIS regulations Urban/fiscal policies Government tenders NOM-241-SSA1-2 021	Accessibility to the local market Keep salary policies Historical inflation/interest rate record Policies commercials	Government dependency Cultural change in the medical field	Use of equipment ecological And eat ERP emcor	Recycling of plastics, cardboard and batteries Indirect diseases caused by climate change Change in storage conditions

Note: PESTE analysis of the company under study

Political, economic, social, technological, ecological and commercial factors, ranging from government regulations to fiscal and urban policies, play an essential role in influencing and adapting organizations to their environment. Elements such as government tenders, COFEPRIS regulations and the implementation of NOM-241-SSA1-2021 (Secretaría de Salud, 2021) have a critical impact on our sector, which includes the sale of medical equipment and hospital real estate. Likewise, accessibility to the local market, management of salary policies, monitoring of inflation and interest indicators, and commercial policies are key factors that shape our business strategies. To illustrate the way in which the company is organized, the following organizational chart is available:

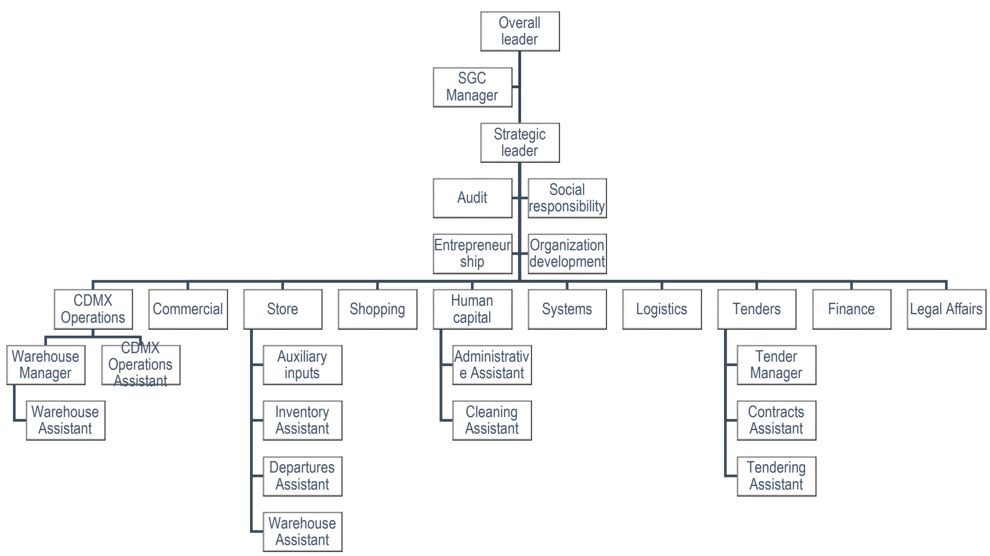


Figure 1. Organizational chart of the company under study

Note: Company organizational chart

The organizational chart shows the structure of a company with a general leader at the top. The main areas of focus of the study include social responsibility, bidding, e-commerce, purchasing, logistics, finance, engineering and quality, systems, and receiving. Under the general leader, there are several commercial advisors and a biomedical advisor, highlighting the importance of the commercial part and the biomedical sector in the organization. Key roles are also identified such as those responsible for image and design, legal affairs, purchasing, logistics of medical equipment and healing materials, market analysis, and warehouse coordination. In addition, areas such as systems, service engineering, and human resources are mentioned. The company operates in Ciudad Obregón, which is reflected in the operations and warehouse roles specific to this location. The organizational structure is designed to comprehensively address the needs of the company in various functional areas.

By applying an ergonomic checklist it was found:

- 48% of employees have had a disability while performing their job
- 53% of workers report experiencing physical discomfort during work activities.
- 83% of employees have not received ergonomics training.
- 50% of workers are not satisfied with the design of their workstation.
- Only 9% of employees have received medical treatment for their physical ailments.

In addition to the above, when touring the company's areas, multiple ergonomic risks were detected, among which the following stand out: the spaces for office work are very small, the furniture seems inadequate and the staff in most cases do not adopt a correct position when working seated. Before this, the question arises: *What actions, from an ergonomic point of view, should be implemented to reduce the level of ergonomic risk in the commercial company under study?*

2. OBJECTIVE

Develop an ergonomic study that allows the identification and improvement of the level of risk associated with the work activity of a commercial company.

3. METHODOLOGY

The subject under study includes 28 company workers aged between 22 and 50 years from different areas of operation. The method to be used is the one proposed by Ávila (2014), which refers to the analysis of ergonomic conditions and their impact on job satisfaction. The procedure is described below.

Record seniority: In this stage, a detailed analysis will be performed using the table that includes information on job title, gender, age, and years of work experience. The objective is to explore the connection between age and seniority of employees.

Establishing working conditions: In order to obtain significant numerical data, a form designed specifically for this purpose is administered. At this stage, a survey was applied to 28 workers whose activity is related to an office position.

Identify ergonomic risk: To determine ergonomic risk, surveys were applied, the workplace was observed, and an ergonomic assessment was carried out. The instruments used were: a) the Kuorinka checklist (1987), which is useful for diagnosing musculoskeletal disorders; b) the ROSA method (Diego-Mas, 2019) for the evaluation of office positions.

Determine actions: In this step, the possible actions to be implemented based on the results of the ergonomic diagnosis are listed.

4. RESULTS

The results were analyzed based on each employee's seniority, using a table detailing key information such as position, sex, age, and years of work experience. The main purpose was to explore the connection between employees' age and seniority in order to identify possible patterns (see Table 2).

Table 2. Company personnel information

Post	Sex	Age	Years at IAASA	Post	Sex	Age	Years at IAASA
1. Social Responsibility Assistant	M	24	1	15. Warehouse assistant	M	36	8
2. Organizational development	M	31	1	16. Ticket Assistant	M	45	4
3. Human capital	F	49	4	17. Engineering Technician	M	28	1
4. Social responsibility coordinator	F	28	4	18. Receptionist	F	37	4
5. Designer	M	36	10	19. Financial leader	F	50	4
6. Marketing advertising	F	22	1	20. Revenue Assistant	F	30	1
7. E-Commerce Coordinator	F	26	4	21. Expenditure assistant	M	33	2
8. Sales advisor	F	24	3	22. Collection Assistant	F	28	1
9. Sales Analyst	F	30	4	23. Ticket logistics	M	36	4
10. Sales advisor	F	30	1	24. Logistics in purchasing	F	37	8
11. Sales	F	28	5	25. Purchasing Assistant	F	35	4
12. Tenders	F	40	10	26. Warehouse Coordinator	M	54	14
13. Tender Manager	M	31	3	27. Quality assistant	M	26	1
14. Warehouse operation manager	M	28	6	28. Systems Manager	M	30	4

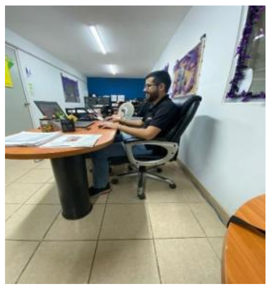
Note: Record of seniority and job position

This analysis allows us to understand how work experience and seniority influence ergonomic practices, providing valuable information to improve the work environment and promote employee health and well-being.

A questionnaire regarding working conditions revealed the following: 7% of employees have experienced work-related incapacity, pointing out possible deficiencies in safety procedures and preventive measures. 55% have suffered accidents at work, highlighting the need to improve safety protocols and point out possible risk areas. 55% know these procedures, highlighting the importance of adequate training and awareness of work-related risks. 49% of employees lack training in the use of tools and equipment, which increases the risk of injury. 48% indicate a possible lack of awareness and training to report unsafe situations.

Consequently, it is suggested that there is a general lack of awareness and training in ergonomics, contributing to a higher risk of accidents and injuries. As a result of identifying ergonomic problems, images of postures and conditions in the workplace were retrieved, such as the one below:

Table 3. Evaluation by observation

Workstation	Side view	Description
Assistant in social responsibility		It can be seen that there is not enough space under the desk, and that there is no wrist support. Although the correct posture with the back and knees is achieved, there is discomfort due to the size of the pillows and the worker's build.

Note: Visual information from a worker

Problems such as inadequate distance from the screen and low screen height, as well as chairs that do not properly adjust to the height of the staff, are evident in different areas. Incorrect postures and lack of adjustment in the chairs are also observed. The use of multiple screens causes neck twists and the lack of adjustment in the chair affects the associates.

Kuorinka checklist , are neck, calf, arm and elbow with eleven mentions on average. Next are back, leg, knee and hand wrist with eight mentions.

The next step was the application of the ROSA method, the result of which can generally be seen in Figure 2.

Based on the figure 2, the vast majority of jobs are considered high risk and should be evaluated as soon as possible, as they have a score above five points. These results are associated with difficulty in reaching objects, remaining seated for long periods of time, reduced space and poor postures adopted during work. The score obtained for each job is shown in Figure 3.

According to Figure 3, the positions identified with numbers 2, 6, 7 and 15 (taken from Table 2) are those with the highest risk level and therefore urgent action is required. Positions between 5 and 6 points, although considered to be of lower risk, will require timely attention to prevent their value from increasing further.

The results obtained from the evaluation lead to the need to generate actions such as the implementation of regular breaks and postural changes to counteract repetitive movements when working at the computer, as well as providing ergonomic tools and equipment to overcome the difficulty in reaching objects, making ergonomic adjustments to chairs and/or assigning new furniture. These actions will prevent musculoskeletal conditions related to poor posture associated with the office environment.

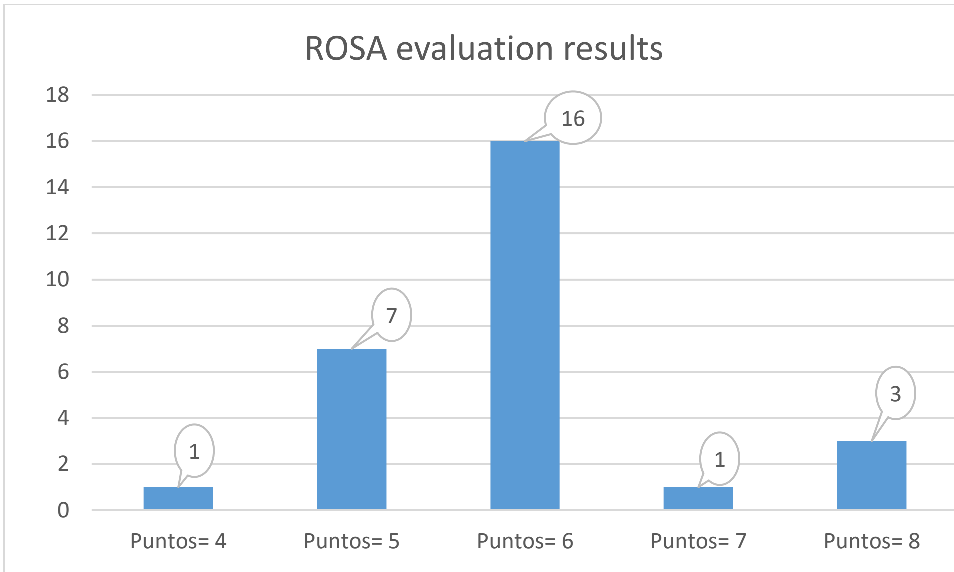


Figure 2. Overall results of the ROSA assessment

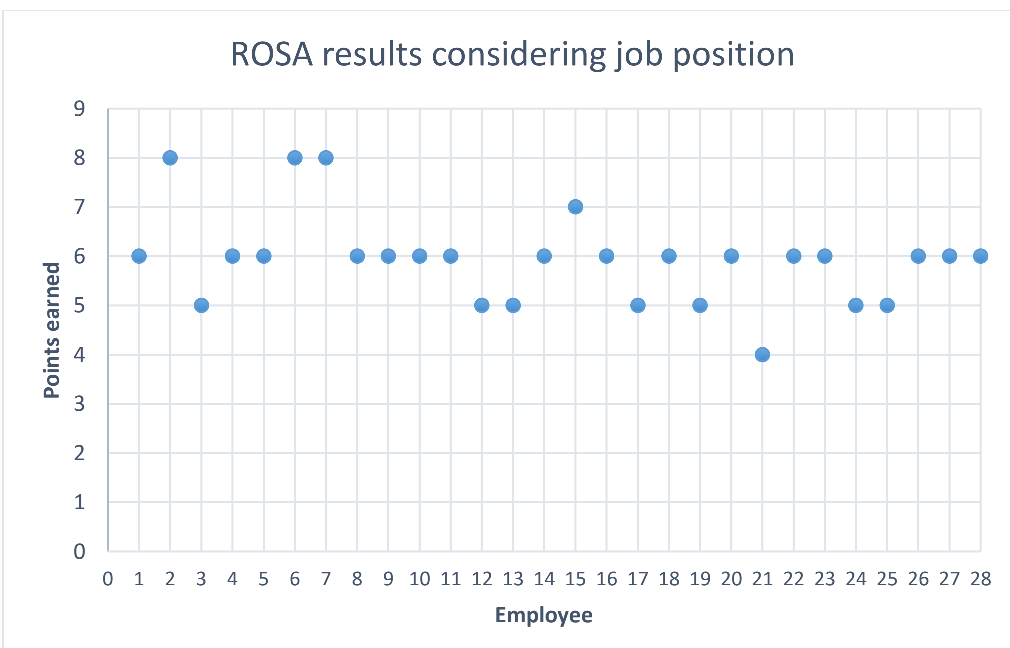


Figure 3. ROSA assessment results by job position.

5. DISCUSSION/CONCLUSIONS

In conclusion, this ergonomic study revealed the need to intervene to improve working conditions and, therefore, the health and performance of workers. The questionnaires applied allowed the identification of ailments associated with the conditions of the job and the study of the level of risk incurred by office jobs by workers. The study will allow establishing the conditions to adapt the work environment, furniture, facilities and workload to mitigate risks and improve the health of administrative staff. To achieve this, it is suggested:

- Implement ergonomics training programs for all employees, focusing on the correct setup and adjustment of workstations as well as the correct posture when working while sitting.
- Improve furniture design to meet international ergonomic standards, ensuring proper dimensions and fit.
- Make individualized adjustments to workstations to ensure neutral posture and prevent physical ailments.
- Specifically address issues such as inadequate lighting, noise and cramped workspaces through further research.
- Implement a continuous monitoring system to evaluate the effectiveness of ergonomic measures and make adjustments as necessary.

6. REFERENCES

Avila C. Rosalio . (2014). Methods and Techniques for the Ergonomic Analysis of the Workplace.

Diego-Mas , Jose Antonio . Evaluation of office jobs through he ROSA method . Ergonautas , Polytechnic University of Valencia, 2019. Available online: https://www.ergonautas.upv.es/metodos/rosa/rosa-ayuda.php

Kuorinka , I., Jonsson, B., Kilbom , A., Vinterberg , H., Biering-Sørensen , F., Andersson, G., & Jørgensen , K. (1987). Standardized Nordic questionnaires for the analysis of musculoskeletal symptoms. Applied ergonomics, 18(3), 233-237.

National Institute of Statistics and Geography (INEGI). (2023). Beverage production. https://www.inegi.org.mx/contenidos/saladeprensa/boletines/2023/SPAyB/SPAyB.pdf

Ministry of Economy. (2021). Health Sector. Retrieved from https://www.gob.mx/se/acciones-y-programas/sector-salud-20872

Ministry of Health . (2021). NOM-241-SSA1-2021. Journal Official of the Federation . Retrieved from https://dof.gob.mx/nota_detalle.php?codigo=5638793&fecha=20/12/2021

Zganjar , E.M. (2023). Impact of COVID-19 on companies: An economic and operational analysis in Ternium Argentina SA [Bachelor's thesis]. Repositorio Digital 21, Universidad Empresarial Siglo 21. https://repositorio.21.edu.ar/handle/ues21/27901

EVALUATION OF A TRAINING PROTOCOL FOR LABOR INSPECTORS FOR THE APPLICATION OF COMPLIANCE INDICATORS OF NOM-036-1 STPS-2018

José Horacio Tovalin Ahumada[1], https://orcid.org/0000-0003-4419-9392 , Cointa Lagunes Cruz[2], https://orcid.org/0009-0003-0124-6192, Marlene Rodríguez Martínez[3] https://orcid.org/0000-0002-9912-8500

[1] Especialización en Salud en el Trabajo,
FES Zaragoza, UNAM,
Av. Guelatao No. 66 Colonia Ejército de Oriente, Iztapalapa,
Ciudad de México, México, 09230

[2] Dirección de Normalización en Seguridad y Salud Laborales, STPS,
Av. Félix Cuevas No.301, Piso 8,Col. Del Valle,
Alcaldía Benito Juárez,
Ciudad de México, 03100,

[3] Carrera de Psicología,
FES Zaragoza, UNAM,
Av. Guelatao No. 66 Colonia Ejército de Oriente, Iztapalapa,
Ciudad de México, México, C.P. 09230

Corresponding author's e-mail htovalin@gmail.com

Resumen: En México, las enfermedades profesionales más frecuentes reportadas en 2021 incluyeron trastornos musculoesqueléticos, pérdida auditiva, neumoconiosis e intoxicaciones. En específico, 5,108 casos de enfermedades musculoesqueléticas fueron clasificados como enfermedades profesionales, lo que representa el 44% del total de enfermedades profesionales reconocidas.

El objetivo de este estudio es evaluar un protocolo de capacitación para inspectores sobre la aplicación del "Procedimiento de Evaluación de la Conformidad" de la NOM-036-1 STPS-2018, con enfoque en factores de riesgo ergonómicos en el trabajo, particularmente en el manejo manual de cargas.

Concluimos que la experiencia de capacitación para inspectores de trabajo proporcionó educación -conocimientos- y el desarrollo de habilidades técnicas necesarios, particularmente en lo que respecta a los factores de riesgo ergonómicos, que ahora se están aplicando de acuerdo con la NOM-036-1 STPS-2018.

Palabras clave: Inspección, Capacitación, Ergonomía

Relevancia para la ergonomía: A través de esta capacitación y los resultados de esta intervención educativa, los inspectores obtuvieron una comprensión más profunda de la prevalencia de los factores de riesgo ergonómicos en México y otros países.

Abstract: In Mexico, the most frequent occupational diseases reported in 2021 included MSDs, hearing loss, pneumoconiosis, and poisoning. Specifically, 5,108 cases of musculoskeletal diseases were classified as occupational diseases, accounting for 44% of the total recognized occupational diseases

The aim of this study is to evaluate a training protocol for inspectors regarding the application of the “Conformity Assessment Procedure” as outlined in NOM-036-1 STPS-2018, focusing on ergonomic risk factors at work, particularly manual handling of loads.

We conclude that the training experience for labor inspectors effectively provided the necessary education and capacity building, particularly concerning ergonomic risk factors, which are now being applied in accordance with NOM-036-1 STPS-2018.

Keywords: Inspection, Training, Ergonomics

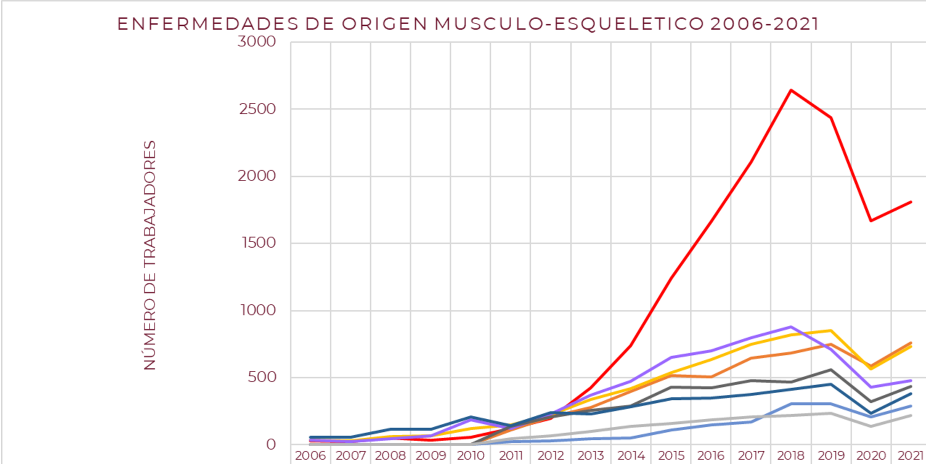
Relevance to Ergonomics: Through this training and the results of this educational intervention, inspectors gained a deeper understanding of the prevalence of ergonomic risk factors in Mexico and other countries.

1. INTRODUCTION

It is widely recognized that working conditions such as physical effort during manual load handling, repetitive movements, and sustained forced postures are associated with an increase in musculoskeletal disorders (MSDs) among the working population. In Mexico, the most frequent occupational diseases reported in 2021 included MSDs, hearing loss, pneumoconiosis, and poisoning. Specifically, 5,108 cases of musculoskeletal diseases were classified as occupational diseases, accounting for 44% of the total recognized occupational diseases. Among these, the most common MSDs recorded were dorsopathies (1,811 cases), shoulder injuries (760 cases), and carpal tunnel syndrome (732 cases) (Figure 1).

In Mexico, the Federal Regulation for Safety and Health at Work (RFSST) mandates employers to monitor ergonomic risk factors present in the workplace (STPS, 2014a). Furthermore, in 2018, the NOM-036-1 STPS 2018 standard (STPS, 2018) was enacted, which applies to all workplaces where workers regularly handle loads manually (more than once a day) and where the loads exceed 3 kg. This standard outlines the procedure for the evaluation of conformity (PEC) that labor inspectors utilize during inspection visits conducted by the labor authority, as well as those carried out by verification units.

In 2018, NOM 036-1 STPS 2018 was issued, the first of two standards aimed at preventing ergonomic risk factors, which governs the entire national territory and is applied in all workplaces where there are workers whose activity involves manual handling of loads daily (more than once a day) and with manual handling of loads greater than 3 kg (STPS, 2018).



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Dorsopatías	29	22	53	35	59	124	199	424	740	1 242	1 663	2 109	2 644	2 435	1 670	1 811
Lesiones de Hombro	0	0	0	0	0	110	210	281	398	516	503	646	683	751	584	760
Síndrome del túnel Carpiano	34	29	61	67	119	147	225	336	418	540	636	748	818	851	566	732
Otras Entesopatias	33	26	48	70	185	123	227	369	472	651	700	796	881	709	431	481
Tenosinovitis de Estiloides Radial de (Quervain)	0	0	0	0	0	140	207	256	291	432	422	479	469	559	323	436
Otras Sinovitis, Tenosinovitis y Bursitis	54	58	117	114	210	144	241	227	284	341	349	377	413	450	237	379
Artrosis	0	0	0	0	0	25	28	45	53	110	150	171	305	307	207	291
Epicondilitis	0	0	0	0	0	44	66	102	137	159	184	210	219	235	135	218

Figure 1. Occupational illnesses in Mexico, 2006-2021

This standard aims to: Establish the elements to identify, analyze, prevent and control ergonomic risk factors in the workplace derived from manual handling of loads, to prevent alterations to the health of workers.

The standard includes the procedure for the evaluation of conformity (PEC) applied by Labor Inspectors both to inspection visits developed by the labor authority, as well as to visits carried out by the Verification Units. This verification opinion must be available to the labor authority when requested.

The Labor Inspectorate is tasked with monitoring compliance with labor standards, providing technical information, advising workers and employers on compliance, and reporting any deficiencies and violations of labor standards (STPS 2014b, Article 540, Sections I-III). To perform these functions effectively, inspectors must possess a strong technical background, particularly in evaluating various agents and labor risk factors.

The ILO considers that the effectiveness of a labour inspection system depends largely on the efforts made by the authorities and by the labour administration systems, to attract and maintain sufficient, qualified and motivated staff to guarantee the exercise of this public service of general interest (Vega, 2012).

Issues relating to the selection, recruitment and training processes of labour inspectors in general and given the uniqueness of their competences and powers, as well as the peculiarities of the exercise of their activity, are a general concern of most national public administrations.

Conventions No. Conventions 81 and 129 provide the criteria to be considered in determining the number of inspectors required (Article 10 of Convention No. 81 and Article 14 of Convention No. 129) and the measures to ensure the recruitment, career and training of the necessary staff in the inspection services (Articles 6 to 8 of Convention No. 81 and Articles 8 to 10 of Convention No. 129).

Many national labor inspectorates in Europe report a lack of staff and material resources to carry out their functions properly. (ETUIREHS, 2007)

In Mexico, there is no school for training inspectors and training for inspectors is carried out through an online education platform called SIAPI, which provides them with training in aspects of regulations, general working conditions and special topics.

In the future, this platform can be used in training in the identification and evaluation of ergonomic risk factors, for the adequate verification of regulatory compliance in the workplaces for their prevention and control.

Due to the importance of the health effects associated with ergonomic risks and the central role that labor inspectors have in promoting healthy workplaces, the training of inspectors is a central aspect to develop.

This project is aimed at training inspectors for adequate verification and advice to workers and employers on ergonomic risks, through the development of Ergonomic Indicators that will be used for the evaluation of conformity. These indicators, once approved, can be integrated into the SICADIP system used to carry out field inspections by all inspectors who carry out inspections in Occupational Health and Safety conditions and in particular ergonomic risk factors.

A quality assessment of ergonomic risk factors should encompass the following stages (Figure 2) (Occhipinti and Colombini, 2012). The labor inspector must thoroughly observe whether the ergonomic risks reported or observed in the field align with those mentioned in the reports, whether the correct assessment methods were employed, and whether the control measures implemented were suitable for the type and degree of ergonomic risk identified.

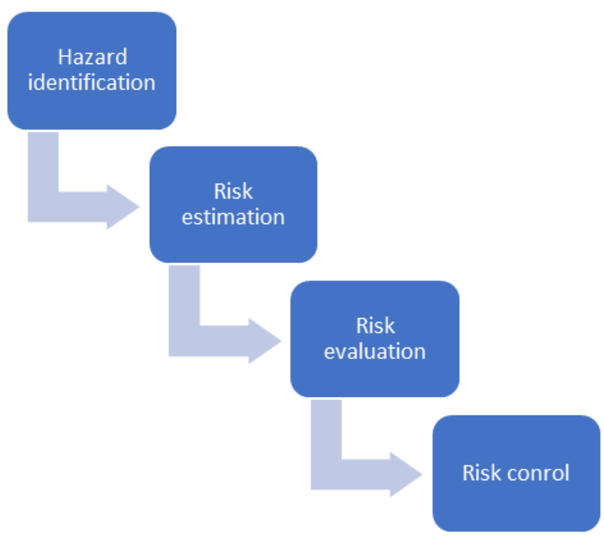


Figure 2. Steps of the ergonomic risk assessment

Initially, it must be confirmed that one or more of the different ergonomic hazards are present in a position. During the identification of the hazard, the presence of ergonomic risk factors is verified. In the case of manual handling of loads, the presence of the hazard is verified if there are loads greater than 3 kg that are moved more than once during the day.

Once the hazard has been identified, it must be determined whether it can be harmful to health. This analysis is initially done using a method that qualitatively estimates whether it is possible to generate damage to health and whether these damages are very likely to occur or intolerable. The qualitative estimation of ergonomic risk can be done with methods such as ISO TR 12295 and others, methods that allow confirming the presence of risk, the estimated level of risk and its priority for correction.

In the case of estimating a probable high level of ergonomic risk, to establish corrective measures it is necessary to use a quantitative Specific Evaluation method that allows us to establish with greater precision the elements of the position or task that are critical, to control and reduce or eliminate the ergonomic risk of the position. In the case of the study of positions with manual handling of loads, the NIOSH method is an example of a specific evaluation method.

2. OBJECTIVE

The aim of this study is to evaluate a training protocol for inspectors regarding the application of the “Conformity Assessment Procedure” as outlined in NOM-036-1 STPS-2018, focusing on ergonomic risk factors at work, particularly manual handling of loads.

3. DELIMITATION

The proposed training protocol for compliance verification was implemented for a sample of federal labor inspectors located in Mexico City.

4. METHODOLOGY

a) Type of Study: Intervention study to evaluate a training protocol.
b) Universe of Study: Federal labor inspectors.
c) Population of Interest: Federal labor inspectors located in Mexico City.
d) Sample Selection: Study group comprising a convenience sample of 20 labor inspectors.
e) Phases of the Study

Phase 1: Preparation of content, course structure, and preliminary proposal of technical compliance indicators.

The inspector must be able to establish whether:

- There is manual handling of loads in the specific workplace in accordance with the NOM 036-1 STPS 2018 standard.

- If the manual handling of loads in the positions identified in the workplace potentially represents a risk to health.
- If in the positions identified in the workplace it is necessary to carry out the rapid estimation and/or the specific evaluation of the risk due to manual handling of loads.
- Verify if the inspection report for compliance with NOM 036-1 STPS 2018 covers the report and contents of the Conformity Assessment Program (PEC) and establish if the documentary evidence covers the specified contents.

To validate the training model for inspectors, the following steps have been established:

1. Modality:The training will begin with an in-person workshop for a group of labor inspectors. Following this, the materials and feedback from the workshop, along with practical sessions, will be reviewed to prepare an online version for the distance education system of the Inspection Directorate.
2. Theoretical-Practical Orientation: The training will have a theoretical-practical focus, emphasizing the application of knowledge and the development of competencies among participating inspectors.
3. Review of Ergonomic Risk Factors: The training will include a review of the conceptual and theoretical foundations of ergonomics and biomechanics, as well as both international and national regulations.
4. Exercise Resolution: Participants will engage in exercises that involve identifying positions related to manual handling of loads.
5. Simulated Cases: Scenarios from the Compliance Verification Program of NOM 036-1 STPS 2018 will be used for practical applications.
6. Field Verification: There will be an assessment of knowledge and skills regarding the application of NOM 036-1 STPS 2018 conducted with a subsample of inspectors.

This structured approach aims to ensure thorough understanding and application of ergonomic principles in the field.

Phase 2: Selection of participants for the study group of inspectors, delivery of the training workshop titled “Compliance Criteria of the Conformity Assessment Procedure of NOM-036-1 STPS-2018, Ergonomic Risk Factors,” collaborative preparation of the proposal for technical compliance indicators, and field evaluation of techniques presented in the workshop during an inspection process.

Phase 3: Group analysis of field information and the proposal for technical indicators developed by inspectors and experts.

5. RESULTS

4.1 Results of Phase 1

The program proposal was presented to officials from the labor inspection area, who reviewed the proposed content and suggested changes to ensure alignment with the topics covered in NOM-036-1-STPS-2018.

Table 2. Descriptive letter of the workshop

0. Diagnostic evaluation 1. Regulatory background of NOM-036-1-2018: RFSHMAT, RFSST, NOM 006 STPS. 2. NOM 036-1-2018- STPS review. Objectives, field of application, employer obligations, transitional articles, definitions. 3. Magnitude of Musculoskeletal Disorders at work in Mexico. 4. Spine anatomy and physiology. Biomechanics of manual load handling. 5. Phases of the ergonomic risk assessment 5.1 Phase 1, Identification of ergonomic hazards due to manual load handling (MMC) NOM 036-1-2018. Acceptable MMC conditions, Use of the ISO TR-12295 standard. 5.2 Exercise 1: Hazard identification by MMC and manual transport of loads 5.3 Phase 1, Acceptable conditions of push and pull Use of the ISO-TR-12295 standard: push and pull. 5.4 Exercise 2: Identification of ergonomic hazards by pushing and pulling loads 6. Phase 2. Qualitative estimation of the degree of risk. Simple estimation of ergonomic risk NOM 036-1: Annex 1. Manual handling of loads and manual transport 6.1 Exercise 3: Simple estimation of ergonomic risk by MMC Annex 1 6.2 Phase 2. Qualitative estimation of the degree of risk. Review of Annex 2 of the NOM transport and push and pull 6.3 Exercise 4 Simple estimation of transport and push and pull 1. Phase 3. Review of the specific evaluation ISO 11228-1 2021 Standard (NIOSH Simple Task Method) 7.1 Analysis of Composite, Variable, Mixed tasks. Modified NIOSH Equation 7.2 Exercise 5, use of the NIOSH Equation for Simple Tasks. 8. Control measures. 9. Health surveillance: specific medical examination, MSD prevalence surveys 9.1 Exercise 6 of application of the Nordic questionnaire. 10. Training: contents specified in NOM-036-1-2018 11. Presentation of the proposal for technical indicators for the PEC of NOM-036-1-STPS-2018 11.1 Exercise 7: review and feedback of the indicator’s proposal 11.2 Discussion and comments on the indicators Final evaluation/ Feedback/Closing Field activity: for application of the proposed technical indicators

4.2 Results of Phase 2

The training course was attended by 12 inspectors from the metropolitan area of Mexico City within the Inspection Directorate of the DGIFT, comprising 8 men, 3 women, and 1 individual with another gender identity. The academic qualifications of the inspectors included 7 with a bachelor's degree (primarily in engineering fields), 1 with an unfinished degree, and 1 with a high school diploma.

The training workshop titled "Compliance Criteria of the Conformity Assessment Procedure of NOM-036-1 STPS-2018: Ergonomic Risk Factors" was conducted over two days from 9 a.m. to 3 p.m. (Table 1)

It was considered that inspectors with their experience should define the indicators of unacceptable ergonomic conditions present in the manual handling of loads, which can be verified at a documentary and physical level for compliance with the NOM-036-1-STPS-2018 standard.

At the end of the review of the topics corresponding to the content of the standard, teams were formed to begin the work of developing proposals for compliance indicators, on the following aspects, which can be verified at a documentary, physical or interview level in the companies:

- Indicators on ergonomic conditions of high risk for health are present in the manual handling of loads, manual transport of loads, pushing/pulling of loads.
- Indicators on technical controls to reduce the high risk to health due to ergonomic conditions during manual handling and transport of loads and in pushing and pulling activities
- Indicators on administrative controls to reduce the high risk to health due to ergonomic conditions during manual handling and transport of loads and in pushing and pulling activities.
- Indicators on priority actions for monitoring the health of personnel exposed to ergonomic risk factors to reduce the risk during manual handling and transport of loads and in pushing and pulling activities.
- Indicators on priority training content for workers in manual handling and transport of loads and in pushing and pulling activities.

During the field evaluation, two inspectors who participated in the course on NOM-036-1 STPS-2018 engaged in the inspection process. They began by requesting general information about the company and its processes, identifying ergonomic hazards in the workplace, interviewing workers, and recording ergonomic risks and recommendations.

The inspectors began the inspection process by requesting general information about the company and its processes. At the time of the assessment, they did not use initial questions to identify positions where manual handling and transport of loads could pose potential dangers. The loads were being handled, transported, pushed, or pulled, with weights exceeding 3 kg, and the handling occurred at least twice a day. By failing to identify potential hazards in specific areas at the outset, the field inspection process became challenging.

During the initial phase of the inspection, the inspectors lacked prior knowledge of the sites where loads were handled, resulting in missed observations of hazardous tasks in two areas: the platform area, where waste is transported using a wheelbarrow, and the mill area, where wheat germ is processed, as noted in the ergonomic analysis.

In the bagging and sewing areas, they observed issues related to posture and repetitiveness. In the stevedoring area, inspectors documented, based on observations and interviews with workers, the weight of the loads, the frequency of loading, daily operating times, and the number of containers and vehicles loaded. Additionally, they recorded the heights at which workers handled loads and their postures during maneuvers. More detailed information was needed regarding the mass handled throughout the day.

Meanwhile, the instructors collected data about the processes and positions, performing a specific evaluation of load lifting to compare with the inspectors' findings.

The actions performed by workers when stowing sacks in a container, illustrated by a series of photographs (Figure 3). Workers utilize a telescopic belt to transport sacks to the container. This belt can be positioned close to the bottom of the container and retracted once the operation is complete.

During the process, a sack falls from a height of approximately 180 cm onto the arms of the worker. The worker then supports the sack using both their head and arms, rotates their body, takes two or three steps, and places the sack onto a bed of sacks. After positioning the sack, the worker bends down to finish arranging it before returning to retrieve another sack. Recordings of the activity indicate a loading and transport frequency of seven loads per minute.

Figure 3. Stowing sacks in a container

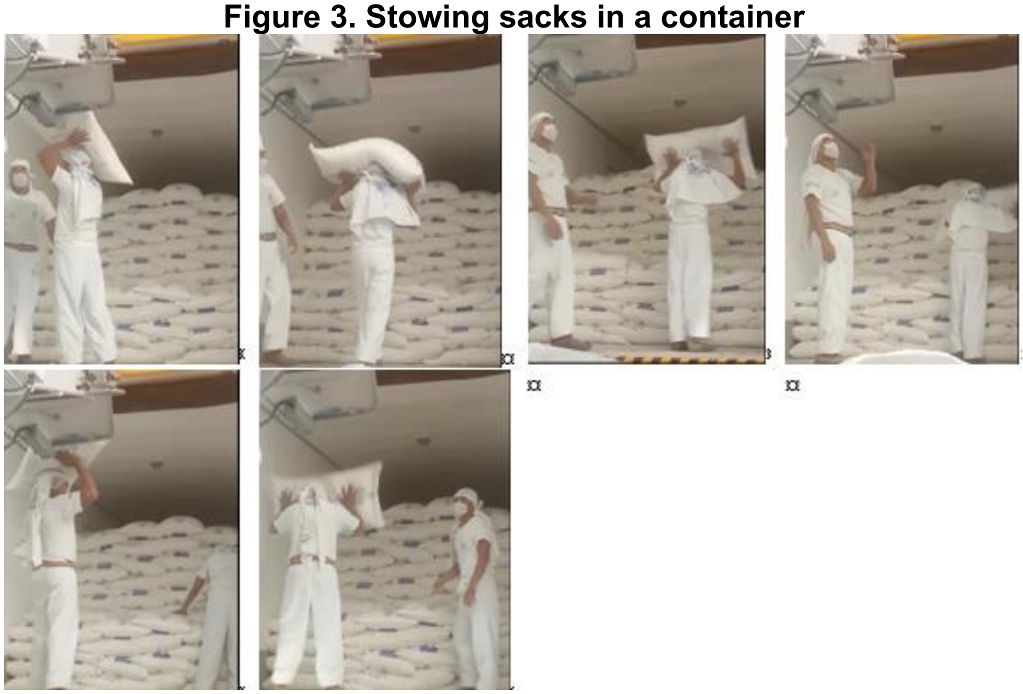


Table 2 presents the results of the NIOSH equation for compound lifting (ISO Standard 11228-1 2021). In this position, the load is stable, the gripping height is consistent, and the heights for depositing the sacks vary. The calculated Composite Index of Lifting (IL) ranges from 3.99 to 4.69. This risk level indicates a high probability of spinal injuries for workers performing this task, even if the exposure duration is short.

Table 2 Results of the NIOSH equation for compound lifting (ISO Standard 11228-1 2021)

CONTANTE DE PESO (ISO 11228-1)	H	M	
	25	20	18-45 años
	20	15	<18 años y >45 años

prog	DESCRIPCIÓN DE LA ACCIÓN	Peso objeto [kg]	Situación vertical inicial (Vi) [cm]		Situación vertical final (Vf) [cm]			Distancia (H) horizontal [cm]		Ángulo de asimetría [°]		Tipo de agarre [B, R o M]		Frecuencia [n. elev al min.]*	Duración del levantamiento. [min]		Articulación superior en acción (1 ó 2 manos)		Número trabajadores involucrados		Presencia de tareas adicionales fisicamente exigentes [S o N]		MLR hombres	IL Hombre
1	Estiba bultos 44 kg	44.0	175	0.70	165	10	0.85	10	1.00	0	1.00	M	0.90	7.00	60	0.70	2	1.00	1	1.00	N	1.00	9.3	4.71
2	Estiba bultos 44 kg	44.0	175	0.70	145	30	0.85	10	1.00	0	1.00	M	0.90	7.00	60	0.70	2	1.00	1	1.00	N	1.00	9.4	4.69
3	Estiba bultos 44 kg	44.0	175	0.70	125	50	0.86	10	1.00	0	1.00	M	0.90	7.00	60	0.70	2	1.00	1	1.00	N	1.00	9.4	4.66
4	Estiba bultos 44 kg	44.0	175	0.70	105	70	0.86	10	1.00	0	1.00	M	0.90	7.00	60	0.70	2	1.00	1	1.00	N	1.00	9.5	4.63
5	Estiba bultos 44 kg	44.0	175	0.70	85	90	0.87	10	1.00	0	1.00	M	0.90	7.00	60	0.70	2	1.00	1	1.00	N	1.00	9.6	4.57
6	Estiba bultos 44 kg	44.0	175	0.70	65	110	0.89	10	1.00	0	1.00	M	0.90	7.00	60	0.70	2	1.00	1	1.00	N	1.00	9.8	4.49
7	Estiba bultos 44 kg	44.0	175	0.70	45	130	0.92	10	1.00	0	1.00	M	0.90	7.00	60	0.70	2	1.00	1	1.00	N	1.00	10.1	4.34
8	Estiba bultos 44 kg	44.0	175	0.70	25	150	1.00	10	1.00	0	1.00	M	0.90	7.00	60	0.70	2	1.00	1	1.00	N	1.00	11.0	3.99
9	Estiba bultos 44 kg	44.0	175	0.70	5	170	1.00	10	1.00	0	1.00	M	0.90	7.00	60	0.70	2	1.00	1	1.00	N	1.00	11.0	3.99
10	Estiba bultos 44 kg	44.0	175	0.70	5	180	0.00	10	1.00	0	1.00	M	0.90	7.00	60	0.70	2	1.00	1	1.00	N	1.00	0.0	#####

4.3 Phase 3 Results

Group Review of the Results: To assess the training outcomes, two meetings were conducted. The first meeting involved the inspectors who participated in the field inspection, discussing the ergonomic hazards observed and how they aligned with the instructor's ergonomic analysis.

During the first meeting with the two inspectors, they expressed concerns about hazard identification. They observed unacceptable practices related to load handling and questioned the initial position for lifting the bags, noting that the arm position was not appropriate. They also highlighted the weight of the loads as a potential high-risk factor for the task.

Regarding the proposed technical indicators, both inspectors agreed that these indicators were useful for guiding their compliance verification efforts. However, they were unclear about how to properly record this information in the required format and how it would influence the final report. Specifically, they wondered whether the information would lead to a conclusion about the company's compliance with the standards.

The second meeting included all participants, who provided feedback on the course content, methodology, and proposed indicators to include in the inspection guide.

During the second meeting with the group that attended the course, the first agenda item was the use of the indicators. The group watched videos of the areas inspected and was asked to identify ergonomic hazards and unacceptable conditions present. Participation among attendees varied; some were unable to express the risks they observed, while others clearly described the dangers and unacceptable conditions associated with the tasks shown. Due to the limited time for the meeting, attendees were asked to complete an electronic questionnaire detailing the non-ergonomic conditions they noticed in the positions; however, only three individuals responded.

The group of inspectors found the indicators useful, but they were uncertain about how to integrate them into the inspection guide. Currently, the inspections are limited to what is specified in the standards regarding the employer's obligations, the documentation provided, and observations made. While they can include comments about the indicators, it would be beneficial to have these indicators formally incorporated into the inspection forms.

6. CONCLUSIONS

The training of labor inspectors in this project effectively supported their performance in verifying compliance with NOM 036-1 STPS 2018, largely achieving the stated objectives. The training proposal for inspectors included valuable tools for identifying hazards, such as the ISO TR 12295 standard. This standard equips inspectors with criteria to quickly identify unacceptable conditions related to load handling, transport, and pushing/pulling, ensuring that these hazards and their associated risk levels are documented by the company.

Additionally, the training provided inspectors with essential biomechanical and epidemiological information, highlighting the significant impact of such damage on workers. Case reviews and group discussions were encouraged, aligning with principles of adult education. One of the training objectives was to foster the collaborative development of technical indicators for verifying regulatory compliance, which would be beneficial during inspections.

Inspectors contributed valid proposals for these indicators; however, they did not encompass all relevant aspects that should be monitored. Nonetheless, these proposals served as a foundational basis for a more comprehensive proposal that integrated their perspectives for field use.

Observing the inspection process carried out by participating inspectors in the field was crucial for evaluating the effectiveness of the training and the technical indicators for assessing conformity. While the inspectors successfully identified many factors essential for hazard recognition, they faced challenges in documenting their observations. This difficulty stemmed partly from the inspection format and the lack of guiding questions for interviewing workers concerning ergonomic risks. Addressing this issue is a necessary step to propose to those in charge of inspections.

We conclude that the training experience for labor inspectors effectively provided the necessary education and capacity building, particularly concerning ergonomic risk factors, which are now being applied in accordance with NOM-036-1 STPS-2018.

7. REFERENCES

European Trade Union Institute. Hesa Newsletters. (2007) no 33. Special report “Inspection still a weak link in most national preventive strategies”.

http://hesa.etui-rehs.org/uk/dossiers/files/Stategie-communautaire.pdf.)
IMSS (2021) Memoria Estadística. IMSS, México.

Occhipinti, E., & Colombini, D. (2012). IEA/WHO toolkit for WMSDs prevention: criteria and practical tools for a step by step approach. *Work*, 41(Supplement 1), 3937-3944.

OIT (2013) OIT urge a una acción mundial para combatir las enfermedades profesionales. Accesado: 050721 En: https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_211645/lang--es/index.htm

STPS (2014a) Reglamento Federal de Seguridad y Salud en el Trabajo. STPS a, México.

STPS (2014b) Reglamento General de Inspección del Trabajo y Aplicación de Sanciones. STPS b, México.

STPS (2018) NOM 036-1 STPS 2018. STPS, México

Vega Ruiz M.L. (2012) Los procesos de selección y formación de los inspectores de trabajo: prácticas, programas y lagunas. Organización Internacional de Trabajo, Programa sobre Administración e Inspección del Trabajo (LAB/ADMI

COMPARATIVE STUDY: MENTAL WORKLOAD IN FEMALE STUDENTS WITH AND WITHOUT CHILDREN AT TECNM, AGUA PRIETA CAMPUS.

Raúl Rodríguez Hoyos ORCID, 0009-0000-3555-8408, Jesús Eduardo Rocha Osuna, ORCID 0009-0001-2509-829X, Dayanna Ayleen Esquivel Gamboa, ORCID 0009-0007-1574-0772, Carmen Cecilia Gómez Mejía, ORCID 0009-0006-5038-4710I, Issac Sebastián Samaniego Olivas. ORCID 0009-0001-0090-5251

Department of engineering
Tecnológico Nacional de México /Instituto Tecnológico de Agua Prieta
Carretera a Janos
Avenida Tecnológico s/n, Colonia Progreso.
Agua Prieta, Son, 84268

Corresponding author’s e-mail: J.rocha@aguaprieta.tecnm.mx

Resumen: En los contextos académicos, la carga mental representa una demanda cognitiva y emocional significativa, especialmente en actividades críticas como exámenes y trabajos en equipo. Este fenómeno se intensifica en estudiantes con responsabilidades adicionales, como el cuidado de hijos, generando desafíos únicos que pueden afectar su desempeño académico y bienestar mental.

En el Tecnológico Nacional de México, campus Agua Prieta, se ha identificado una discrepancia en los niveles de carga mental reportados entre estudiantes mujeres con hijos y estudiantes mujeres sin hijos. Sin embargo, no se cuenta con evidencia suficiente para determinar si estas diferencias son significativas ni se comprende completamente cómo las condiciones académicas y familiares influyen en la percepción de carga mental.

Para abordar esta problemática, se utilizó el índice NASA-TLX (Task Load Index), una herramienta validada ampliamente en estudios de ergonomía cognitiva para medir la carga mental en seis dimensiones: demanda mental, demanda física, demanda temporal, esfuerzo, rendimiento y frustración. El instrumento fue adaptado culturalmente para asegurar su relevancia en la población estudiada.

La presente investigación aborda esta discrepancia mediante un estudio comparativo, enfocado en valorar las diferencias en los niveles de carga mental entre estudiantes mujeres con hijos y estudiantes mujeres sin hijos durante actividades académicas críticas. Este análisis busca identificar los factores específicos que contribuyen a las discrepancias observadas y proponer estrategias para mejorar el bienestar y la equidad académica.

Este estudio no solo permite generar evidencia empírica sobre la carga mental en poblaciones vulnerables, sino que también contribuye a la formulación de estrategias ergonómicas y políticas educativas que promuevan un ambiente académico más inclusivo y equitativo.

Palabras clave: Carga mental, NASA-TLX, madres estudiantes, equidad académica.

Relevancia para la ergonomía:
Este estudio constituye una contribución significativa al campo de la ergonomía cognitiva y la ergonomía de género, al analizar las diferencias en los niveles de carga mental entre estudiantes mujeres con hijos y estudiantes mujeres sin hijos durante actividades académicas críticas.

El uso del índice NASA-TLX adaptado culturalmente demuestra su eficacia para medir la carga mental en actividades cognitivas exigentes, permitiendo identificar dimensiones críticas como demanda mental, temporal y frustración. Estos resultados enfatizan la importancia de incorporar perspectivas de género en el diseño de estrategias ergonómicas, adaptadas a las necesidades de poblaciones vulnerables como las madres estudiantes.

Este trabajo también contribuye al desarrollo de políticas inclusivas que combinen la ergonomía con el género, proponiendo acciones como horarios flexibles, guarderías en campus y tutorías personalizadas. Al abordar las implicaciones sociales y estructurales de la carga mental, este estudio expande las aplicaciones de la ergonomía hacia entornos más inclusivos, saludables y sostenibles.

Abstract: In academic contexts, mental workload represents a significant cognitive and emotional demand, particularly in critical activities such as exams and teamwork. This phenomenon intensifies for students with additional responsibilities, such as childcare, creating unique challenges that may affect their academic performance and mental well-being.

At the Tecnológico Nacional de Mexico, Agua Prieta campus, a discrepancy has been identified in the reported mental workload levels between female students with children and those without. However, there is insufficient evidence to determine whether these differences are significant, and the influence of academic and family conditions on the perception of mental workload is not yet fully understood.

To address this issue, the NASA-TLX (Task Load Index) was used, a widely validated tool in cognitive ergonomics research, to measure mental workload across six dimensions: mental demand, physical demand, temporal demand, effort, performance, and frustration. The instrument was culturally adapted to ensure its relevance to the studied population.

This research explores this discrepancy through a comparative study focused on assessing differences in mental workload levels between female students with children and those without during critical academic activities. The analysis aims to identify specific factors contributing to these discrepancies and propose strategies to enhance well-being and academic equity.

This study not only generates empirical evidence on mental workload in vulnerable populations but also contributes to the development of ergonomic strategies and educational policies that foster a more inclusive and equitable academic environment.

Keywords: Mental workload, NASA-TLX, student mothers, academic equity.

Relevance to ergonomics:
This study represents a significant contribution to the fields of cognitive ergonomics and gender ergonomics by analyzing differences in mental workload levels between female students with children and those without during critical academic activities.

The use of the culturally adapted NASA'TLX index demonstrate its effectiveness in measuring mental workload in cognitively demanding activities, identifying key dimensions such as mental demand, temporal demand, and frustration. These findings highlight the importance of incorporating gender perspectives into the design of ergonomic strategies tailored to the needs of vulnerable populations, such as student mothers.

Additionally, this work contributes to the development of inclusive policies that integrate ergonomics and gender considerations, proposing actions such as flexible schedules, on-campus childcare facilities, and personalized tutoring. By addressing the social and structural implications of mental workload, this study expands the applications of ergonomics towards more inclusive, healthy, and sustainable environments.

1. INTRODUCTION

The phenomenon of stress and mental workload has been widely studied in the fields of psychology, cognitive ergonomics, and higher education due to its impact on mental health and academic performance. Mental workload is defined as the cognitive and emotional effort required to proves information, make decisions, and respond to the demands of a specific task (González-Morales et al., 2021). In academic contexts, mental workload arises from the interaction between study demands, an individual's response capacity, and the available resources to manage these demands (Hart & Staveland, 1988).

Student mothers represent a particularly vulnerable group in terms of mental workload, as they must balance multiple roles: academic, professional, and family. This convergence of responsibilities generates cognitive and emotional overload, which can lead to decreased academic performance and deteriorated psychological well-being (Wei et al., 2023). Recent research has documented how mental workload among student mothers is associated with high levels of anxiety, fatigue, and concentration difficulties, impacting not only their educational success but also their quality of life (Henderson et al., 2022).

Women's access to higher education has significantly increased in recent decades, leading to a greater presence of student mothers in universities. In Mexico, progress in gender equity policies and support programs has improvised women's inclusion in higher education (Instituto Nacional de las Mujeres, 2021). However, despite these advances, universities remain largely unadapted to the specific needs of student mothers, creating inequalities in retention, graduation, and access to professional development opportunities (Luna et al., 2020). Many student mothers struggle to attend classes, complete assignments and exams, and balance their time between studying, working, and caring for their children. These structural barriers limit their academic persistence and success often leading to dropout or delays in completing their studies (Martínez & Pérez, 2021).

From a social perspective, this research is essential for designing strategies that promote educational equity by identifying the key factors contributing to mental workload in student mothers and comparing them with those students without children. The findings will enable the proposal of concrete actions such as flexible scheduling and teaching modalities, the implementation of institutional support spaces such as on-campus childcare facilities and tutoring programs, as well as psychological and academic support initiatives to reduce emotional burden. Additionally, the results of this study may contribute to university policy reforms, ensuring that the specific conditions and needs of student mothers are considered in the curricular and administrative design of educational institutions.

From an academic perspective, this study aligns with cognitive ergonomics, which examines the relationship between mental processes and performance in complex environments. In this regard, the mental workload of student mothers should not be understood merely as an individual phenomenon but rather as a multidimensional issue influenced by academic, social, and psychological factors (Gutiérrez et al., 2019). The use of the NASA-TLX index in this research represents a significant methodological contribution, as this tool has been extensively applied in ergonomics studies to assess mental workload in industrial and aviation settings (Hart & Staveland, 1988), yet its application in higher education and vulnerable populations remains limited (Hoonakker et al., 2011).

In this study, a cultural adaptation of the NASA-TLX is conducted to assess mental workload among Mexican student mothers, ensuring that the results are relevant and applicable to their specific context. This research expands knowledge on cognitive ergonomics in education by adapting and validating a measurement instruments for student mothers in Mexican universities, analyzing statistically significant differences between student mothers and students without children, identifying critical stress and mental workload factors to design ergonomic intervention strategies, and contributing to the literature on academic equity and inclusive education by promoting educational models that reduce barriers to access and retention.

The objective of this research is to compare mental workload levels between student mothers and students without children at the Tecnológico Nacional de México, Agua Prieta campus, using an adapted version of the NASA-TLX index. The expected results aim to identify significant disparities in mental workload and academic stress, providing a reference framework for designing institutional support strategies and improving the quality of life of student mothers. By addressing the intersection of cognitive ergonomics and gender, this study offers an innovative perspective on how academic and family demands impact women’s educational experiences. The findings obtained may serve as a basis for proposing ergonomic and educational strategies that promote a healthy balance between academic and family life, ensuring a more inclusive and sustainable environment for student mothers in higher education.

2. OBJECTIVES

General objective:
To assess the difference in reported mental workload levels between female students with children and those without during critical academic activities at the Tecnológico Nacional de México, Agua Prieta campus.

Specific objectives:

1. To analyze specialized literature on mental workload and its impact on academic performance, with an emphasis on differences between female students with children and those without, in order to provide a theoretical foundation for the research.
2. To determine through the application of the adapted NASA-TLX index, the reported mental workload levels of female students with children and those without during critical academic activities at the Tecnológico Nacional de México, Agua Prieta campus.
3. To compare the mental workload levels between both groups of students to identify whether the observed differences are significant and to describe the factors associated with these discrepancies.

3. METHODOLOGY

This study was conducted following the principles of a non-experimental, cross-sectional, descriptive design with a quantitative approach. This design was chosen to describe and compare the mental workload of undergraduate student mothers and students without children at a specific point in time, without manipulating variables. The research was framed within a positivist paradigm, aiming to observe and measure reality objectively through scientifically sufficient empirical methods.

The target population consisted of two groups: student mothers enrolled in undergraduate programs at the Tecnológico Nacional de México, Agua Prieta campus, and students without children enrolled in the same programs. The total sample included 96 participants, with 48 student mothers (comprising the entire population meeting the required characteristics) and 48 students without children. The inclusion criteria for student mothers were: being female, being enrolled in an undergraduate program, not having children, and carrying the same academic workload as the student mothers.

To assess mental workload, the NASA-TLX index was used, a widely validated tool in various contexts for evaluating mental workload. This index comprises six dimensions: mental demand, physical demand, temporal demand, effort, performance, and frustration. Additionally, a complementary questionnaire was designed to collect relevant demographic and academic data, including age, major, year of study, family situation, and hours dedicated to studies and family responsibilities.

A translation and back-translation process was used to adapt the index's language to the Mexican context, ensuring that the terms were comprehensible and relevant to the participants. Figure 1 presents the data collection instrument developed based on the NASA-TLX index, incorporating questions designed to assess participants' experiences in specific academic activities, such as taking exams and submitting final group assignments. A pilot test was subsequently conducted with a small group of student mothers and students without children to evaluate the clarity and functionality of the adapted index.


SEP SECRETARÍA DE EDUCACIÓN PÚBLICA — TECNOLÓGICO NACIONAL DE MEXICO — Instituto Tecnológico de Agua Prieta

Tecnológico Nacional de México
Instituto Tecnológico de Agua Prieta

Evaluar y cuantificar la carga mental asociada con las actividades académicas de madres estudiantes de licenciatura en el Tecnológico Nacional de México campus Agua Prieta, específicamente durante la presentación de exámenes y la entrega de trabajos finales en equipo.

Instrucciones: A continuación, se le presentan una serie de preguntas diseñadas para evaluar su experiencia en dos actividades académicas específicas: la presentación de un examen y la entrega de un trabajo final en equipo. Por favor, responda cada pregunta basándose en su experiencia más reciente con estas actividades.

Información Demográfica	
Edad:	
Carrera:	
Año de Estudio:	
Situación Familiar (e.g., número de hijos, estado civil):	
Horas dedicadas a estudios (promedio semanal):	
Horas dedicadas a responsabilidades familiares (promedio semanal):	

A continuación, se le presentan preguntas para evaluar su experiencia durante la presentación de un examen y la entrega de un trabajo final en equipo. Por favor, responda cada pregunta utilizando la escala proporcionada.

Categoría de Evaluación	Descripción	Valoración (1-100)
Exigencias Cognitivas (M)	Cantidad de actividad cognitiva requerida para preparar y presentar el examen (e.g., pensar, decidir, resolver problemas). ¿Fue el examen fácil o complejo?	
Exigencias Físicas (F)	Grado de esfuerzo físico necesario durante la preparación y presentación del examen. ¿Implicó mucho o poco esfuerzo físico?	
Exigencias Temporales (T)	Nivel de presión de tiempo percibido durante el examen. ¿Tuvo que apresurarse para completar el examen? ¿El tiempo disponible fue suficiente?	
Satisfacción con el Rendimiento (R)	Grado de satisfacción con su desempeño en el examen. ¿Está satisfecha con cómo le fue en el examen?	
Esfuerzo Total (E)	Cantidad total de esfuerzo mental y físico necesario para rendir el examen. ¿Tuvo que esforzarse significativamente?	
Nivel de Estrés (Fr)	Grado de estrés o frustración experimentado durante la preparación y presentación del examen. ¿Se sintió estresada o frustrada durante el examen?	

Ave. Tecnológico y Carretera a Janos s/n C.P. 84268, Agua Prieta, Sonora, Teléfono: (633)331-0232, Fax: (633)331-0840, www.itap.edu.mx

SEP SECRETARÍA DE EDUCACIÓN PÚBLICA — TECNOLÓGICO NACIONAL DE MEXICO — Instituto Tecnológico de Agua Prieta

Categoría de Evaluación	Descripción	Valoración (1-100)
Exigencias Cognitivas (M)	Cantidad de actividad cognitiva necesaria para la investigación, redacción y síntesis de contenidos en el trabajo final. ¿Fue esta actividad sencilla o compleja?	
Exigencias Físicas (F)	Grado de esfuerzo físico requerido durante la realización del trabajo final en equipo. ¿Tuvo que realizar esfuerzos físicos significativos?	
Exigencias Temporales (T)	Nivel de presión de tiempo percibido durante la coordinación y entrega del trabajo final. ¿Tuvo que trabajar bajo presión para cumplir con los plazos?	
Satisfacción con el Rendimiento (R)	Grado de satisfacción con su contribución al trabajo final y los resultados obtenidos. ¿Está satisfecha con la calidad del trabajo realizado por el equipo?	
Esfuerzo Total (E)	Cantidad total de esfuerzo mental y físico necesario para completar el trabajo final en equipo. ¿Tuvo que esforzarse significativamente para cumplir con las demandas del trabajo?	
Nivel de Estrés (Fr)	Grado de estrés o frustración experimentado durante la realización del trabajo final en equipo. ¿Se sintió estresada o frustrada durante la preparación y entrega del trabajo final?	

Por favor, comparta cualquier otro comentario o experiencia que considere relevante sobre la carga mental que enfrenta como madre estudiante durante la realización de sus actividades académicas.

Aviso de Privacidad y Consentimiento Informado:
Los datos recopilados en este cuestionario serán tratados de forma confidencial y anónima. La información que usted proporcione será utilizada exclusivamente con fines de investigación académica en el marco del estudio titulado *"Evaluación de la Carga Mental en Madres Estudiantes de Licenciatura en el Tecnológico Nacional de México campus Agua Prieta"*.
Sus respuestas no serán asociadas a su identidad personal y los resultados serán reportados de manera agregada, sin identificar a ningún participante en particular. Usted tiene derecho a abstenerse de responder cualquier pregunta con la que no se sienta cómoda y puede retirarse del estudio en cualquier momento sin penalización alguna.
Al completar y enviar este cuestionario, usted está proporcionando su consentimiento informado para que sus datos sean utilizados en esta investigación, de acuerdo con las directrices éticas y legales aplicables.
Si tiene alguna pregunta o preocupación sobre este estudio, por favor, no dude en contactar al equipo de investigación a través del correo electrónico.
l.vazquez@aguaprieta.tecnm.mx

Agradecemos la oportunidad que nos brindó para la realización de la presente encuesta.

Ave. Tecnológico y Carretera a Janos s/n C.P. 84268, Agua Prieta, Sonora, Teléfono: (633)331-0232, Fax: (633)331-0840, www.itap.edu.mx

Figure 1: Data collection instrument.

Data collection was carried out through structured interviews using printed questionnaires. Before the application, participants were given a detailed explanation of the study, and written informed consent was obtained. Confidentiality and anonymity of the collected data were ensured. The collected data underwent a review and cleaning process to ensure quality and consistency. Descriptive analyses were performed to calculate means, standard deviations, frequencies, and percentages of the sample characteristics and NASA-TLX index scores.

To assess the construct validity of the NASA-TLX index in the sample of student mothers and students without children, the internal reliability of the NASA-TLX dimensions was examined by calculating Cronbach's alpha coefficient, providing a measure of the internal consistency of the scales. Since the NASA-TLX index was originally developed in different contexts, a cultural adaptation was carried out to ensure its relevance to the studied population.

The study adhered to ethical research principles, including obtaining informed consent, respecting participants' privacy and confidentiality, and using the data exclusively for research purposes.

4. RESULTS

To develop an analytical structure that reflects the mental workload experienced by undergraduate student mothers and students without children as they face academic challenges during their educational process, a high-mental-load activity was characterized: taking an exam.

Characterization of the exam: Taking the exam involves a high cognitive load as students process and apply knowledge under time pressure. Emotional demands include managing anxiety and maintaining focus, while temporal demands require effective time management during the exam. For student mothers, these tasks become even more complex as they must balance exam preparation with the family responsibilities, intensifying stress. Additionally, student mothers must concentrate on the exam while mentally distancing themselves from concerns about their children. Common distracting thoughts include: Has my child eaten? Did they sleep well? Is everything okay? Are the clean? These distractions impact their academic performance, a challenge not faced by students without children.

By framing this activity and supporting the analysis with interview responses, a comparative table was designed to highlight the key differences between student mothers and students without children. Table 1 presents the results of this comparison.

The instrument used to assess mental workload was based on the MASA-TLX index. Both the translation and contextualization pf the questions were adapted to better capture the mental workload experienced by student mothers and students without children, as shown in Figure 1. This adaptation necessitated a validation process, where the internal consistency of the NASA-TLX instrument was analyzed using Cronbach's alpha coefficient. The overall reliability score was $\alpha=0.644$. Once validated, the instrument was applied to the target population.

Table 1: Comparison between student mothers and students without children.

Aspect	Student mothers	Students without children
Field of study	Engineering: industrial, business management, mechatronics, computer systems, business administration	Engineering: industrial, business management, mechatronics, computer systems, business administration
Academic workload	Full academic workload, including classes, exams, assignments, and projects	Full academic workload, including classes, exams, assignments, and projects
Study methods	Combination of individual and collaborative study, with a greater reliance on studying at unconventional hours	Combination of individual and collaborative study, with greater flexibility in organizing study time
Childcare responsibilities	Primary responsibility for children's care, including feeding, supervision, health, and emotional support	No childcare responsibilities.
Household management	Responsible for household tasks such as cleaning, cooking, and budget management	May have household responsibilities, but generally less complex
Schedule coordination	Academic schedules must be coordinated with children's needs	More flexibility in organizing their time
Limited study time	Study time is limited due to multiple responsibilities	More time available for studying and recreational activities
Stress and mental workload	High stress levels due to balancing academic and family responsibilities	Experience academic stress, but generally less complex
Social and family support	Experience academic stress, but generally less complex	More available for social activities and support from friends
Planning and organization	Extensive use of planning and time management strategies	Less need for intensive planning
Use of institutional resources	Utilize resources such as childcare services, academic support, and tutoring programs	May use academic resources but with less dependence
Support networks	Depend on support networks such as family and peers	More time for social activities and less reliance on structured support
Academic perfomance	Affected by the dual burden of responsibilities	More focus on academic activities with fewer distractions
Motivation and perseverance	High levels of motivation and perseverance, driven by the desire to provide a better future for their children	Motivation is based on personal achievements and future professional goals

The selection of student mothers was based on the total number of enrolled mothers, while students without children were randomly selected, ensuring they carried the same academic workload as student mothers. Statistical analyses were conducted using Minitab version 21, ensuring precision and validity of the results.

An analysis of variance (ANOVA) was conducted to compare stress and mental workload levels between student mothers and students without children. The results were significant, confirming that both populations follow a normal distribution. The normal probability plots and Anderson-Darling normality tests confirmed that mental workload scores for both groups were normally distributed, with p-values of 0.392 for student mothers and 0.875 for students without children, both above the significance threshold of 0.05.

The ANOVA results indicated that the group factor (student type) had a significant effect on mental workload levels, with a p-value of 0.000. This allowed for the rejection of the null hypothesis of equal means between the groups. The mean mental workload score for student mothers was significantly higher (1251.28) compared to students without children (726.59), with similar standard deviations (19.02 y 19.04, respectively). The 95% confidence intervals for both groups' means did not overlap, reinforcing the significance of the observed differences. These results indicate that the difference in mental workload means is not due to chance but rather to specific factors influencing the student populations.

These findings suggest that being a student mother entails a significantly higher mental workload compared to students without children. The notable difference in means highlights the need for targeted interventions to support student mothers, improvising their academic and personal well-being.

To further explore the differential impact of mental workload on student mothers and students without children, a detailed analysis of the six NASA-TLX dimensions was conducted: mental demand, physical demand, temporal demand, overall effort, performance satisfaction, frustration. An ANOVA was performed for each dimension to assess differences between both groups, identifying the specific aspects contributing to the overall mental workload observed in student mothers.

The results revealed statistically significant differences in three key dimensions:

1. Mental demand ($p = 0$), student mothers reported significantly higher cognitive workload compared to students without children
2. Temporal demand ($p = 0$), the time pressure differences between the two groups were highly significant. Student mothers reported a greater perception of time constraints, consistent with previous studies emphasizing the critical role of time availability in academic performance.
3. Performance satisfaction ($p = 0$), results indicated that student mothers had a significantly lower perception of their academic performance compared to students without children.
4. Dimensions without significant differences. On the other hand, no significant differences were found in physical demand ($p = 0.47$) neither in overall effort ($p = 0.21$). These results suggest that although student mothers experience

greater cognitive and temporal workload, both groups perceive similar levels of overall effort in completing their academic tasks.

5. DISCUSSION

The results obtained demonstrate a significant difference in mental workload between student mothers and students without children confirming the existence of additional factors that affect the academic performance of the former. This difference is particularly evident in the dimensions of mental demand, temporal demand, and performance satisfaction, where student mothers reported higher levels of cognitive load and stress. The ability to simultaneously manage academic and family responsibilities appears to be the primary factor contributing to these differences, supporting the need for institutional strategies to reduce mental workload in this group (Lyonette, 2015; Nomaguchi & Milkie, 2020).

The high mental demand reported by student mothers suggests that the combination of academic tasks and family responsibilities generates a cognitive overload, impacting their concentration, information retention, and performance in critical activities such as taking exams. Previous studies have indicated that constant multitasking and the need to switch between different attentional demands negatively affect learning efficiency and decision-making (Rubinstein et al., 2001; Strayer & Watson, 2019). From a cognitive ergonomics perspective, the continuous redistribution of attentional resources between academic and family activities can accelerate mental fatigue, reducing information processing capacity and affecting academic performance (Parasuraman & Hancock, 2001). This finding highlights the need to develop support strategies that better manage cognitive load in student mothers, such as implementing more flexible teaching methodologies and providing access to tools that optimize study time organizations (González-Morales et al., 2021).

Regarding temporal demand, the results show that student mothers perceive a greater limitation in their availability to complete their academic activities, leading to higher stress and difficulties in effective time management. The lack of time has been widely documented as a critical factor in the academic performance of students with family responsibilities, as it limits planning capacity and increases anxiety (Beattie & Crossan, 2021). The perception of time pressure can negatively impact learning quality and encourage less effective study strategies, such as superficial learning or accelerated memorization (Entwistle & Ramsden, 2015). A possible solution from cognitive ergonomics would be the implementation of more flexible teaching systems, such as asynchronous learning platforms or hybrid models, allowing student mothers to adapt their academic workload to their personal responsibilities without compromising the quality of their education (Wei et al., 2023).

Another relevant aspect is the low satisfaction with performance reported by student mothers. The perception of not adequately meeting their academic obligations can generate frustration and affect academic motivation. Previous research has indicated that this negative self-perception is influenced by comparisons with students without children and the feeling of not being able to dedicate enough time to study, leading to chronic stress and demotivation (Morganson et al., 2010; Henderson et al., 2022). Cognitive ergonomics suggests that this phenomenon may be related to lower perceived self-efficacy, which affects persistence and the effort invested in academic tasks (Bandura, 1997). To mitigate this effect, it is essential that educational institutions implement strategies that reinforce confidence and perceived self-efficacy in this group, such as mentoring programs, personalized tutoring, and psychological support spaces (Schmidt & Hansson, 2018).

Unlike the previous dimensions, no significant differences were found in physical demand or total effort, suggesting that both groups perceive a similar level of effort in their academic activities. However, the difference lies in the external factors influencing the mental workload of student mothers. While students without children can focus exclusively on their studies, mothers must distribute their effort among various activities, increasing their cognitive load without necessarily increasing the perception of physical effort (Lester, 2021).

The importance of studies like this lies in the need to understand the specific conditions faced by student mothers in the northeastern border region of Mexico where Agua Prieta is located. In this area, economic and labor dynamics impose additional challenges on students who are also mothers, as many of them balance their education with informal jobs or extended work shifts in the manufacturing industry, a predominant sector in the region. Additionally, the limited availability of childcare services and academic demands can contribute to an even greater mental workload, affecting their performance and persistence in higher education. Considering the key role education plays in the social and economic development of border regions, it is essential to continua exploring strategies to reduce mental workload and improve the academic conditions of student mothers, thereby promoting equitable and sustained access to university education.

6. CONCLUSIONS

The present study analyzed the mental workload of undergraduate student mothers and students without children in the context of the Tecnológico Nacional de Mexico, Agua Prieta campus. A non-experimental, cross-sectional descriptive design with a quantitative approach was adopted, using the NASA-TLX index as the primary tool to measure perceived mental workload in both groups. The sample consisted of 96 participants, divided into 48 student mothers and 48 students without children, selected based on predefined inclusion criteria. An analysis of variance (ANOVA) was conducted to assess significant differences between the groups, complemented by Anderson-Darling normality tests. The general objective of the study was to compare the levels of mental workload between student mothers and students without children, while que specific objectives focused on analyzing the dimensions of the NASA-TLX index, identifying significant differences, and evaluating the impact of mental workload on academic performance. The central research question aimed to determine whether being a mother implies a greater mental workload in university and what factors contribute to this difference.

The results confirmed that student mothers experience a significantly higher mental workload compared to students without children. In particular, differences were identified in three key dimensions of the NASA-TLX index: mental demand, temporal demand, and performance satisfaction. The ANOVA revealed a highly significant difference ($p < 0.0001$) in overall mental workload levels, with a higher mean for student mothers (1251.28) compared to students without children (726.59). Additionally, individual analyses chowed that student mothers perceive greater time pressure and lower satisfaction with their academic performance, suggesting that their dual role affects both their performance and well-being. These findings address the research question by demonstrating that family and academic demands create a cognitive overload that negatively impacts the educational experience of student mothers. Moreover, the study successfully met its objectives by providing a detailed evaluation of mental workload and its effects on academic performance, contributing to the field of cognitive ergonomics and academic equity.

For an academic perspective, this study contributes to the understanding of mental workload in university populations with family responsibilities, highlighting the importance of adapting educational strategies to student diversity. At a social level, the results reinforce the need to implement support policies for student mothers, such as flexible scheduling and access to childcare services within educational institutions. However, the research presented certain methodological limitations, including the use of a self-administered instrument, which may introduce biases in the perception of mental workload. Additionally, the study focused exclusively on a single educational institution, limiting the generalizability of the results to other university contexts.

Since mental workload in student mothers is a complex and multifactorial phenomenon, future research should explore new lines of study, such as the impact of socioeconomic factors on mental workload, the role of family and institutional support networks, and the influence of different teaching models in reducing academic stress. Furthermore, it would be relevant to conduct longitudinal studies analyzing the evolution of mental workload in student mothers over time and its effect on graduation and dropout rates. From a methodological perspective, future studies could combine physiological and subjective measurement tools, such as heart rate variability analysis or neuroergonomics, to obtain a more precise understanding of the impact of mental workload on cognitive activity. Finally, this study underscores the importance of continuing to explore strategies to reduce academic inequality, ensuring that student mothers have access to higher education under equitable and sustainable conditions.

7. REFERENCES

1. Bandura, A. (1997). Self-efficacy: The exercise of control. W. H. Freeman.
2. Beattie, K., & Crossan, B. (2021). Time management and academic performance in university students. Higher Education Research & Development, 40(3), 511-525. https://doi.org/10.1080/07294360.2021.1882402

3. Entwistle, N., & Ramsden, P. (2015). Understanding student learning. Routledge.
4. Fernández, J., López, M., & Pérez, R. (2021). Academic stress and coping strategies in university students: Differences by gender and parental status. Journal of Educational Psychology, 113(2), 245-260. https://doi.org/10.1037/edu0000479
5. González-Morales, M. G., Peiró, J. M., & Ramos, J. (2021). Workload and well-being: The role of demand-control-support model in student mothers' academic performance. Journal of Educational Psychology, 113(1), 35-50. https://doi.org/10.1037/edu0000413
6. Gutiérrez, P., Hernández, R., & Villaseñor, M. (2019). Validación del índice NASA-TLX en el contexto educativo. Revista de Psicología Educativa, 25(3), 189-202. https://doi.org/10.1016/j.pse.2019.03.002
7. Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. Human Mental Workload, 1, 139-183.
8. Henderson, A., Harmon, S., & Houser, J. (2022). Student parents in higher education: Challenges and support strategies. Journal of College Student Retention, 24(2), 147-163. https://doi.org/10.1177/1521025120937115
9. Instituto Nacional de las Mujeres. (2021). Avances en la educación superior y equidad de género en México. INMUJERES.
10. Lester, J. (2021). The work-family interface and college success among nontraditional students. Journal of College Student Development, 62(4), 412-429. https://doi.org/10.1353/csd.2021.0032
11. Lyonette, C. (2015). Part-time work, work-life balance and gender equality in higher education. Gender, Work & Organization, 22(4), 328-343. https://doi.org/10.1111/gwao.12092
12. Martínez, F., & Pérez, A. (2021). Estrés académico y factores asociados en estudiantes universitarios. Revista Mexicana de Psicología Educativa, 10(1), 52-68.
13. Morganson, V. J., Litano, M. L., & O'Neill, J. W. (2010). Women's work-life balance: The influence of workload and autonomy. Journal of Business and Psychology, 25(3), 325-334. https://doi.org/10.1007/s10869-010-9187-6
14. Nomaguchi, K., & Milkie, M. A. (2020). Parenting stress and academic engagement: A longitudinal study of mothers in higher education. Educational Review, 72(5), 578-594. https://doi.org/10.1080/00131911.2020.1741036
15. Parasuraman, R., & Hancock, P. A. (2001). Adaptive control of mental workload. IEEE Transactions on Systems, Man, and Cybernetics, 31(2), 191-195. https://doi.org/10.1109/3468.931877
16. Rubinstein, J. S., Meyer, D. E., & Evans, J. E. (2001). Executive control of cognitive processes in task switching. Journal of Experimental Psychology: Human Perception and Performance, 27(4), 763-797. https://doi.org/10.1037/0096-1523.27.4.763
17. Schmidt, J. A., & Hansson, B. (2018). Mentoring and support programs for nontraditional students. Higher Education Studies, 8(1), 23-38. https://doi.org/10.5539/hes.v8n1p23

18. Strayer, D. L., & Watson, J. M. (2019). Cognitive workload and distraction in multitasking environments. Human Factors, 61(3), 357-370. https://doi.org/10.1177/0018720818811304
19. Vega, C., Ramírez, L., & Gómez, P. (2022). Equilibrio entre vida académica y familiar en estudiantes universitarias madres en México. Revista de Estudios de Género, 15(2), 85-102. https://doi.org/10.24201/reg.v15i2.2022
20. Wei, W., Chen, Y., & Zhang, L. (2023). Work-life balance in academic mothers: The role of institutional support and social networks. Journal of Higher Education Policy and Management, 45(1), 45-63. https://doi.org/10.1080/1360080X.2022.2148350

EVALUATION OF THE IMPACT OF A PASSIVE EXOSKELETON ON MENTAL LOAD AND INITIAL ADAPTABILITY DURING A LOAD MOBILIZATION TASK

Miguel López Hernández[2] ORCID:0009-0009-5278-4007, Juan Luis Hernández Arellano[2], Pablo Antonio Muñoz Gutiérrez[1], ORCID: 0000-0002-7070-4287 y Cesar Omar Santos Aguirre[3] ORCID: 0009-0003-8876-8646.

[1]Departamento de Diseño Doctorado en Diseño
Universidad Autónoma de ciudad Juárez
Av. Del Charro #450 norte
Ciudad Juárez, Chihuahua, 32310

[2]Departamento de Diseño
Universidad Autónoma de Ciudad Juárez
Av. Del Charro #450 norte
Ciudad Juárez, Chihuahua, 32310

[3]Departamento de eléctrica y computación
Universidad Autónoma de Ciudad Juárez
Av. Del Charro #450 norte
Ciudad Juárez, Chihuahua, 32310

Corresponding author's e-mail: dcim94@gmail.com

Resumen: Los exoesqueletos pasivos reducen el esfuerzo físico en tareas de manipulación de cargas, tienen el potencial de disminuir el riesgo de lesiones musculoesqueléticas, principalmente en la región lumbar, y mejorar el rendimiento en tareas de manejo manual de materiales.

Aunque se conoce su impacto físico, su efecto en la carga mental y la adaptabilidad inicial sigue siendo poco explorado. Perini señala que, aunque los exoesqueletos son tecnologías cada vez más comunes en los entornos laborales debido a su alta comercialización (Perini et al., 2024), aún falta profundizar en estos aspectos. Este estudio evaluó la carga mental, la familiarización y la usabilidad durante tareas dinámicas, proporcionando información que optimiza su diseño e implementación en entornos de trabajo.

Los exoesqueletos se clasifican según el uso de energía externa en tres tipos: activos, pasivos y semiactivos (Bennett et al., 2023). Los exoesqueletos pasivos han sido diseñados para reducir las exigencias físicas de tareas repetitivas y de alta carga, como el levantamiento y transporte de objetos. Sin embargo, además de su impacto físico, la aceptación y efectividad de los exoesqueletos dependen de factores cognitivos y de usabilidad. Estudios previos han analizado la reducción de la carga física con exoesqueletos pasivos, pero pocos han abordado su impacto en la carga mental o la facilidad con la que los usuarios se adaptan a ellos. La carga mental puede influir directamente en el desempeño y la percepción de utilidad del

dispositivo, mientras que una baja usabilidad o un proceso de aprendizaje poco intuitivo podrían limitar su implementación en los entornos laborales.

Los exoesqueletos han sido utilizados y evaluados en diversos contextos, como la construcción (Bennett et al., 2023), el sector de la salud (Erden & Rainey, 2024) e incluso en el ámbito militar (Bequette et al., 2018; Mendoza, 2023; Mudie et al., 2018; Scataglini et al., 2015).

En este contexto, este estudio busca evaluar la carga mental asociada con el uso inicial de un exoesqueleto pasivo y analizar el proceso de familiarización de los usuarios en el transporte de cargas dinámicas utilizando el método NASA-TLX, empleado para medir la carga mental (Galy et al., 2018). Estos hallazgos proporcionan información valiosa para ofrecer recomendaciones concretas que mejoren el diseño de manuales y la integración de los exoesqueletos en entornos laborales reales.

Palabras clave: Exoesqueleto pasivo, carga mental, adaptabilidad inicial, usabilidad, ergonomía

Relevancia para la ergonomía: Este trabajo incorpora un análisis de la carga mental y la adaptabilidad inicial en el uso de exoesqueletos pasivos. Estos datos son cruciales para garantizar no solo la efectividad física de estos dispositivos, sino también su aceptación práctica en contextos laborales reales. Al abordar estos aspectos, el estudio contribuye al desarrollo de una implementación más accesible, efectiva y fluida de los exoesqueletos en entornos de trabajo.

Abstract: Passive exoskeletons reduce physical effort in load manipulation tasks, have the potential to reduce the risk of musculoskeletal injuries, mainly in the lumbar region, and improve performance in manual material handling tasks.
Although its physical impact is known, its effect on mental load and initial adaptability remains little explored. Perini states that although exoskeletons are increasingly common technologies in work areas due to their high commercialization (Perini et al., 2024).This study evaluated mental load, familiarization, and usability during dynamic tasks, providing information that optimizes design and implementation in work environments.

Exoskeletons are classified according to the use of external energy into three types: active, passive and semi-active (Bennett et al., 2023). Passive exoskeletons have been designed to reduce the physical demands of repetitive and high-load work tasks, such as lifting and transporting loads. But in addition to their physical impact, the acceptance and effectiveness of exoskeletons depend on cognitive and usability factors. Previous studies have analyzed the reduction of physical loads with passive exoskeletons, but few have addressed their impact on mental load or the ease with which users adapt to them. Mental load can directly influence performance and the perception of usefulness of the device, while low usability or a counterintuitive learning process could limit its implementation in work environments.

Exoskeletons have been used and measured in various contexts, such as construction (Bennett et al., 2023), the health sector (Erden & Rainey, 2024) and even

in the military field (Bequette et al., 2018; Mendoza, 2023; Mudie et al., 2018; Scataglini et al., 2015).

In this context, this study seeks to evaluate the mental load associated with the initial use of a passive exoskeleton and analyze the process of familiarization of users transporting dynamic loads using the NASA-TLX method, that is used to measure mental workload (Galy et al., 2018). These findings provide valuable information to provide concrete recommendations to improve the design of manuals and the integration of exoskeletons in real work environments.

Keywords: Passive exoskeleton, mental load, initial adaptability, usability, ergonomics

Relevance to ergonomics: This work incorporates an analysis of mental load and initial adaptability in the use of passive exoskeletons. These data are crucial to ensure not only the physical effectiveness of these devices, but also their practical acceptance in real work contexts. By addressing these areas, the study contributes to the development of more accessible, effective, and seamless implementation of exoskeletons in work environments.

1. INTRODUCTION

Repetitive tasks, poor postures, and heavy loads increase the risk of injuries, negatively impacting workers' health and productivity (Collier et al., 2014; Fournier & Yung, 2023; Vukobratovic, 2007). Passive exoskeletons, particularly those designed for lower limb support, help reduce physical strain without requiring external power (Howard et al., 2020). However, their impact on cognitive load remains underexplored. Initially, users must adapt to new movement patterns and the device's mechanical support, which can increase mental demand and frustration. Understanding these effects is crucial for improving user acceptance and performance.

Key factors include load handling risks, which are critical in industries like manufacturing, construction, and logistics, as they pose a high risk of musculoskeletal injuries and incur significant costs. Additionally, evaluating these factors can help tailor passive exoskeletons to meet diverse physical and cognitive ergonomic needs. When exoskeletons are designed with user-centered principles—such as intuitive controls and seamless workflow integration—they can significantly reduce cognitive load. According to Laffranchi, reducing cognitive load enhances adoption, safety, productivity, and iterative design (Laffranchi et al., 2021).

Finally, this research focuses on the mental and cognitive load associated with using lower limb exoskeletons during its initial adjust for load-handling tasks. By analyzing user adaptability, task performance, and subjective perceptions, the study identifies key barriers to intuitive adoption and proposes design improvements. Addressing both physical and cognitive challenges contribute to creating more effective and user-friendly ergonomic solutions for demanding work environments.

2. OBJETIVES

Assess the mental workload experienced by users during the initial use of a passive exoskeleton in dynamic load-carrying tasks, employing the NASA-TLX scale.

Analyze initial adaptability to the device, considering task completion time, observed errors, and users' subjective perceptions.

Identify potential design barriers that hinder intuitive adoption and propose solutions to enhance functionality.

3. SCOPE

The study focuses on dynamic load transportation tasks simulating real-world labor conditions, such as lifting heavy objects. Five participants with no prior exoskeleton experience or musculoskeletal injuries were included. The selected task evaluates the cognitive/subjective experience of using the device. Tests were conducted in an ergonomics laboratory with controlled lighting, temperature, leveled ceramic flooring, and an anthropometric bench for user adjustments.

4. METHODOLOGY

4.1 Participants

Sample: Five adults (men and women).

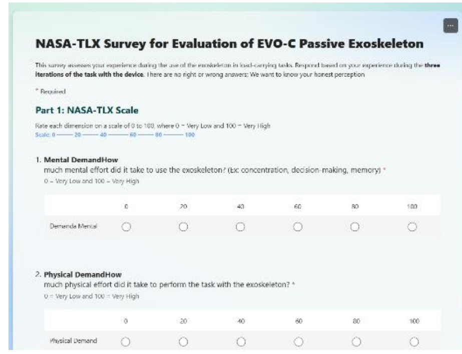
Criteria: No prior musculoskeletal injuries, basic experience handling light loads, and physical ability to participate in moderate-effort tasks.

4.2 Measurements

To complement the experimental data, a NASA-TLX survey was administered to assess participants' subjective experiences. The survey quantified six dimensions of mental workload: Mental Demand, Physical Demand, Temporal Demand, Perceived Performance, Effort, and Frustration. Each dimension was rated on a 0–100 scale, where:

Participants also provided qualitative feedback on usability challenges and improvement suggestions. The scale's gradation allowed precise measurement of user perceptions, with intermediate values (e.g., 20, 40) unlike NASA TLX 100 based score.

Scale Value	Score
0	Very Low
20	Low
40	Moderate
60	High
80	Very High
100	Extremely High



NASA-TLX Survey for Evaluation of EVO-C Passive Exoskeleton

This survey assesses your experience during the use of the exoskeleton in load-carrying tasks. Respond based on your experience during the **three iterations of the task with the device.** There are no right or wrong answers: We want to know your honest perception

* Required

Part 1: NASA-TLX Scale

Rate each dimension on a scale of 0 to 100, where 0 = Very Low and 100 = Very High
Scale: 0 —— 20 —— 40 —— 60 —— 80 —— 100

1. **Mental DemandHow**
much mental effort did it take to use the exoskeleton? (Ex: concentration, decision-making, memory) *
0 = Very Low and 100 = Very High

	0	20	40	60	80	100
Demanda Mental	○	○	○	○	○	○

2. **Physical DemandHow**
much physical effort did it take to perform the task with the exoskeleton? *
0 = Very Low and 100 = Very High

	0	20	40	60	80	100
Physical Demand	○	○	○	○	○	○

Figure 1 NASA TLX score and form applied to participants

4.3 Experimental Task Protocol

Preparation Phase:

Instructions & Inspection: Participants received a printed manual and visually inspected the exoskeleton EVO-C by Ergotech to verify its condition (e.g., undamaged parts, functional straps).

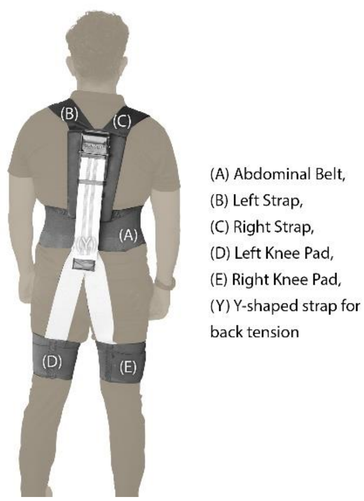


Figure 2 EVO-C main components.

Participants followed these steps based on the experiment protocol and user manual:

First, during the **Pre-Inspection**, they carefully examined all parts of the exoskeleton to ensure each component was in good condition and free from any damage or wear. Next, in the **Base Placement** phase, they secured the hip belt (Piece A) around their waist, ensuring it was properly aligned. Moving on to **Shoulder Adjustment**, they positioned straps B and C like a backpack, so they rested comfortably on the shoulders. Then, during the **Leg Adjustment**, knee pads D and E—equipped with Y-shaped elastic straps—were placed behind the knees to provide proper support. Finally, in the **Final Adjustment**, the Y-shaped back strap

(Piece Y) was tightened to deliver adequate support to the lower back according to an image of the manual.

They self-adjusted the device (hip belt, shoulder straps, knee pads, and Y-shaped back strap) without assistance. Time taken and errors during this phase were recorded during the following task execution:

Dynamic Load Handling:

- Lifting: Lifted an object equivalent to 15% of their body weight from a surface.
- Walking & Holding: Carried the load and walk for a total of 90 seconds.
- Breaks: A 30-second pause was enforced after 1 minute of lifting the loadto minimize fatigue.

Post-Task Evaluation:

- NASA-TLX Survey: Immediately after completing the task, participants rated their mental, physical, and temporal demands, effort, frustration, and perceived performance using a 0–100 scale.
- Qualitative Feedback: They described technical issues, discomfort, or suggestions for improvement.

5. THEORICAL FRAMEWORK

5.1 Mental Workload:

To measure mental workload, the NASA-TLX scale was used, which evaluates six dimensions: mental effort, physical effort, temporal demand, perceived performance, overall effort, and frustration. In the field study by Jakobsen (Jakobsen et al., 2023), it is emphasized that familiarization with the equipment and user perception are key factors in technology acceptance. The study highlights that exoskeleton use is not intuitive and involves a learning curve requiring skill acquisition. Over five weeks, participants gradually increased their usage from 7 to 37 hours per week, demonstrating the time needed for adaptation.

5.2 Exoskeletons:

Exoskeletons are devices designed to enhance mobility and reduce physical load in various applications. In industrial settings, they help minimize effort in demanding tasks (Carrasquillo et al., 2025), while in the medical field, they facilitate rehabilitation and recovery of motor function in patients with physical limitations (Lozano et al., 2015).

Doménech J. describes them as “machines that attach to the limbs as an external skeleton to enhance and/or assist the user’s strength” (Domenech & Brocal Fernández, 2022). However, their use requires an initial adjustment phase that can pose a significant challenge for users (Zheng et al., 2022).

6. RESULTS

6.1 Data and Task Analysis:

This table summarizes the results of pairwise comparisons between NASA-TLX factors, showing the total votes each factor received and its proposed weight in the overall evaluation. The factors were compared based on their perceived relevance during the task, with participants voting on which factor had a greater impact.
Values

Question	Total Votes	%
Mental Demand	9	25%
Effort	7	20%
Perceived Performance	6	18%
Temporal Demand	5	15%
Physical Demand	4	12%
Frustration	1	10%

This weighting system helps prioritize factors for improving exoskeleton design and usability, focusing on reducing mental and physical demands while enhancing user performance and comfort. Here are the conclusions of the value weighting:

Most Relevant Factors:

- **Mental Demand** emerged as the most relevant factor, receiving the highest number of votes (9) and a weight of **25%**. It dominated in 4 out of 5 comparisons, highlighting its significant influence on user experience.
- **Effort** ranked second, with 7 votes and a weight of **20%**, showing its importance in tasks involving physical and cognitive load.
- **Perceived Performance** followed with 6 votes and an **18%** weight, indicating its role in user satisfaction and task success.
- **Temporal Demand** and **Physical Demand** were less dominant but still relevant, with weights of **15%** and **12%**, respectively.

Factors with Lower Impact:

- **Frustration**: Had minimal impact, receiving only 1 vote and a weight of **10%**, suggesting it played a minor role in the overall workload.

This process included direct observations during experimental sessions, as well as usability questionnaires that provided detailed information on aspects such as comfort, ease of use, perceived support, and overall satisfaction.

Participants' rankings exercises and responses were recorded and processed in Microsoft Excel, where they were matched with observed data.

Participant	Mental Dema	Effort	Perceived Performance (18%)	Temporal Demand (15%)	Physical Dem	Frustration (10%)	Adjustment Time	Observed Errors

	nd (25%)	**(20 %)**			**and (12%)**			
1	60 × 0.25 = 15.0	60 × 0.20 = 12.0	60 × 0.18 = 10.8	60 × 0.15 = 9.0	40 × 0.12 = 4.8	20 × 0.10 = 2.0	4:54	Participant did not verify that all parts were complete, requiring removal and re-donning of the exoskeleton.
2	0 × 0.25 = 0.0	20 × 0.20 = 4.0	0 × 0.18 = 0.0	20 × 0.15 = 3.0	0 × 0.12 = 0.0	0 × 0.10 = 0.0	4:02	None
3	40 × 0.25 = 10.0	20 × 0.20 = 4.0	0 × 0.18 = 0.0	20 × 0.15 = 3.0	40 × 0.12 = 4.8	20 × 0.10 = 2.0	3:00	Participant did not correctly adjust back tension.
4	20 × 0.25 = 5.0	20 × 0.20 = 4.0	20 × 0.18 = 3.6	20 × 0.15 = 3.0	0 × 0.12 = 0.0	20 × 0.10 = 2.0	3:30	None
5	80 × 0.25 = 20.0	60 × 0.20 = 12.0	60 × 0.18 = 10.8	40 × 0.15 = 6.0	80 × 0.12 = 9.6	40 × 0.10 = 4.0	4:00	Participant struggled with elbow pad adjustments; suggested clearer tutorials for proper technique.

Figure 3 NASA TLX scores (weighted mental workload measures), adjustment times, and observed errors during the donning process.

Total Score Calculation:

The formula applied was:

$$\textbf{Total Score} = \sum (\textbf{Raw Score} \times \textbf{Factor Weight})$$

Figure 4 Weighted mental workload formula

Example for Participant 1:

(60 × 0.25) + (60 × 0.20) + (60 × 0.18) + (60 × 0.15) + (40 × 0.12) + (20 × 0.10) = **53.6**

Key Observations:

- **Frustration** remained low overall (≤4.0), aligning with its 10% weighting.

  Improvement Insights:
  - Optimize adjustment protocols for consistency with user friendly manuals.
  - Simplify tutorials to reduce learning curves.

7. CONCLUSIONS

This study provides evidence of how cognitive and usability factors influence the initial acceptance of passive exoskeletons. The results inform designers and engineers about necessary adjustments to improve user-device interaction, reducing mental workload and optimizing exoskeleton functionality.

- **Workload Subscales**: The NASA-TLX subscales accurately identify specific sources of workload variation between tasks. with temporal demands showing the largest variance and highlighting time-related pressures during exoskeleton use.
- **Weighted scoring method:** The result from this method effectively captures the perceived importance of factors like mental demand and effort in contributing to overall workload. This approach establishes a foundation for future research to classify users based on age, job role, or physical ability, thus enabling the development of customized ergonomic solutions.

Moreover, the dataset generated in this study can be expanded over time, supporting longitudinal analyses of user adaptability and broader demographic comparisons.

7.1 Recommendations for designers:

- **Structured Training**: Develop short training programs (e.g., 30 minutes) to familiarize users with exoskeletons, focusing on key adjustments and movements.
- **Manual Optimization**: Prioritize visual instructions and simplified steps to reduce learning curves.

7.2 Implications for Future Research:

- **Longitudinal Analysis**: Evaluate how mental workload and adaptability evolve over weeks of continuous exoskeleton use.
- **Diversity Analysis**: Explore differences in workload perception based on gender, age, and occupational experience.

8. REFERENCES

Bennett, S. T., Han, W., Mahmud, D., Adamczyk, P. G., Dai, F., Wehner, M., Veeramani, D., & Zhu, Z. (2023). Usability and Biomechanical Testing of Passive Exoskeletons for Construction Workers: A Field-Based Pilot Study. *Buildings*, *13*(3). https://doi.org/10.3390/buildings13030822

Bequette, B. W., Stirling Charles Stark Draper Professor of Aeronautics, L., Jones, E., & Balakrishnan, H. (2018). *The Effect of a Lower-Body Exoskeleton on Physical and Cognitive Warfighter Performance by Signature redacted Signature redacted Signature redacted*.

Carrasquillo, C., Bajpai, A., Iyengar, D., Collins, K., Mazumdar, A., & Young, A. J. (2025). Enhancing Human Navigation Ability Using Force-Feedback from a Lower-Limb Exoskeleton. *IEEE Transactions on Haptics*, 1–13. https://doi.org/10.1109/TOH.2025.3533974

Collier, B. R., Holland, L., McGhee, D., Sampson, J. A., Bell, A., Stapley, P. J., & Groeller, H. (2014). Precision markedly attenuates repetitive lift capacity. *Ergonomics, 57*(9), 1427–1439. https://doi.org/10.1080/00140139.2014.933885

Erden, Y. J., & Rainey, S. (2024). An ethical assessment of powered exoskeletons: Implications from clinical use to industry and military contexts. In *Artificial Organs*. John Wiley and Sons Inc. https://doi.org/10.1111/aor.14822

Fournier, D. E., & Yung, M. (2023). Quality, productivity, and economic implications of exoskeletons for occupational use: A systematic review. *PLoS ONE, 18*(6 June). https://doi.org/10.1371/journal.pone.0287742

Galy, E., Paxion, J., & Berthelon, C. (2018). Measuring mental workload with the NASA-TLX needs to examine each dimension rather than relying on the global score: an example with driving. *Ergonomics*, *61*(4), 517–527. https://doi.org/10.1080/00140139.2017.1369583

Howard, J., Murashov, V. V., Lowe, B. D., & Lu, M. L. (2020**).** Industrial exoskeletons: Need for intervention effectiveness research. *American Journal of Industrial Medicine, 63*(3). https://doi.org/10.1002/ajim.23080

Jakobsen, L., Samani, A., Desbrosses, K., & Madeleine, P. (2023). Biomechanical changes, acceptance, and usability of a passive shoulder exoskeleton in manual material handling: A field study. *Applied Ergonomics, 113*. https://doi.org/10.1016/j.apergo.2023.104104

Laffranchi, M., D'Angella, S., Vassallo, C., Piezzo, C., Canepa, M., De Giuseppe, S., Di Salvo, M., Succi, A., Cappa, S., Cerruti, G., Scarpetta, S., Cavallaro, L., Boccardo, N., D'Angelo, M., Marchese, C., Saglia, J. A., Guanziroli, E., Barresi, G., Semprini, M., … De Michieli, L. (2021). User-Centered Design and Development of the Modular TWIN Lower Limb Exoskeleton. *Frontiers in Neurorobotics*, *15*. https://doi.org/10.3389/fnbot.2021.709731

Mendoza, F. (2023). Advances in exoskeletons for military use. *Athenea Journal*, *4*, 43–54. https://doi.org/10.47460/athenea.v4i12.57

Mudie, K. L., Boynton, A. C., Karakolis, T., O'Donovan, M. P., Kanagaki, G. B., Crowell, H. P., Begg, R. K., LaFiandra, M. E., & Billing, D. C. (2018). Consensus paper on testing and evaluation of military exoskeletons for the dismounted combatant. *Journal of Science and Medicine in Sport*. https://doi.org/10.1016/j.jsams.2018.05.016

Perini, M., Bacchetta, A. P., Cavazza, N., Khamaisi, R. K., Melloni, R., Morganti, A., Peruzzini, M., & Botti, L. (2024). Evaluation of Occupational Exoskeletons: A Comprehensive Protocol for Experimental Design and Analysis. *Applied Sciences (Switzerland)*, *14*(18). https://doi.org/10.3390/app14188328

Scataglini, S., Andreoni, G., & Gallant, J. (2015). A review of smart clothing in military. *WearSys 2015 - Proceedings of the 2015 Workshop on Wearable Systems and Applications*, 53–54. https://doi.org/10.1145/2753509.2753520

Vukobratovic, M. (2007). (Note: The year in your text is 2007, but the full citation is missing. You may need to locate the exact source for this reference.)

Impact of Passive Exoskeleton Use on Motion Dynamics During Load Lifting and Muscle Activation

Pablo Antonio Muñoz Gutiérrez[1] ,ORCID: 0000-0002-7070-4287, Juan Luis Hernández Arellano[2] , Miguel López Hernández[2] ORCID:0009-0009-5278-4007 ORCID: 0000-0002-8612-5132, David Cortes Sáenz[2] ,ORCID: 0000-0003-1459-6127 y Cesar Omar Santos Aguirre[3] ORCID: 0009-0003-8876-8646.

[1] Departamento de Diseño Doctorado en Diseño Universidad Autónoma de ciudad Juárez Av. Del Charro #450 norte Ciudad Juárez, Chihuahua, 32310

[2] Departamento de Diseño Universidad Autónoma de Ciudad Juárez Av. Del Charro #450 norte Ciudad Juárez, Chihuahua, 32310

[3] Departamento de eléctrica y computación Universidad Autónoma de Ciudad Juárez Av. Del Charro #450 norte Ciudad Juárez, Chihuahua, 32310

Corresponding author's e-mail: al229150@alumnos.uacj.mx

Resumen: El presente estudio analiza el impacto del uso de un exoesqueleto pasivo en la activación muscular y la estabilidad postural durante el levantamiento de cargas, evaluando diferencias entre hombres y mujeres. Se emplearon sensores de electromiografía (EMG) y acelerómetros para medir la actividad muscular y la dinámica del movimiento. Los resultados indican que el exoesqueleto reduce la activación muscular en ciertos músculos clave y mejora la estabilidad en los hombres, mientras que en las mujeres se observa un aumento en la variabilidad del movimiento. Estos hallazgos subrayan la necesidad de adaptar los diseños de exoesqueletos a las diferencias biomecánicas entre géneros para optimizar su eficacia en entornos laborales.

Palabras clave: Exoesqueleto pasivo, EMG, Levantamiento de cargas, biomecánica, ergonomía.

Relevancia para la Ergonomía: Este estudio proporciona información valiosa para la ergonomía, ya que los exoesqueletos pasivos representan una solución emergente para reducir la carga física en los trabajadores expuestos a tareas repetitivas de levantamiento. Los hallazgos ayudan a comprender cómo estos dispositivos afectan la activación muscular y la estabilidad postural en diferentes usuarios, facilitando el desarrollo de estrategias más efectivas para su implementación en entornos laborales.

La reducción en la activación muscular en músculos clave sugiere que los exoesqueletos pueden ayudar a mitigar la fatiga y el sobreesfuerzo, previniendo lesiones musculoesqueléticas. Además, las diferencias en la respuesta entre hombres y mujeres destacan la necesidad de mejorar el diseño de los exoesqueletos para adaptarse a distintos tipos de usuarios y reducir la variabilidad en la activación muscular.

La mejora en la estabilidad postural y la reducción de la variabilidad en la aceleración podrían conducir a movimientos más controlados y eficientes, beneficiando tanto la seguridad como la productividad en el trabajo. Asimismo, la integración de estos dispositivos en los programas de prevención de riesgos laborales podría contribuir a la reducción de costos médicos y del ausentismo debido a lesiones relacionadas con el trabajo.

Por último, el análisis de la fatiga muscular y la variabilidad en la respuesta de los exoesqueletos proporciona datos útiles para establecer recomendaciones sobre tiempos de uso adecuados y optimizar su implementación en entornos industriales y ergonómicos.

Abstract: This study analyzes the impact of using a passive exoskeleton on muscle activation and postural stability during load lifting, evaluating differences between men and women. Electromyography (EMG) sensors and accelerometers were used to measure muscle activity and movement dynamics. The results indicate that the exoskeleton reduces muscle activation in key muscles and improves stability in men, whereas in women, an increase in movement variability was observed. These findings highlight the need to adapt exoskeleton designs to biomechanical differences between genders to optimize their effectiveness in occupational settings
.
Keywords: Passive exoskeleton, EMG, load lifting, biomechanics, ergonomics.

Relevance to Ergonomics: This study provides valuable insights for ergonomics, as passive exoskeletons represent an emerging solution for reducing physical strain in workers exposed to repetitive lifting tasks. The findings help understand how these devices affect muscle activation and postural stability in different users, facilitating the development of more effective strategies for their implementation in work environments. The reduction in muscle activation in key muscles suggests that exoskeletons can help mitigate fatigue and overexertion, preventing musculoskeletal injuries. Additionally, differences in response between men and women highlight the need to improve exoskeleton design to accommodate different user types and reduce variability in muscle activation. Improved postural stability and reduced acceleration variability could lead to more controlled and efficient movements, benefiting both safety and productivity at work. Furthermore, integrating these devices into occupational risk prevention programs could help reduce medical costs and absenteeism due to work-related injuries. Finally, the analysis of muscle fatigue and variability in exoskeleton response provides useful data for establishing recommendations on appropriate usage times and optimizing their implementation in industrial and ergonomic settings.

1. INTRODUCTION

Load lifting is an essential task in multiple industries, including manufacturing, construction, and logistics. However, this activity carries a high risk of musculoskeletal injuries, particularly in the lower back and upper limbs, leading to significant costs for both workers and companies (de Looze et al., 2016; Gull et al., 2022; Picchiotti et al., 2019; Weston et al., 2018; Ya-Shian Li-Baboud1, 2019). Factors such as repetitive movements, improper postures, and excessive loads increase the likelihood of injuries, negatively impacting occupational health and workplace productivity (Fournier & Yung, 2023). In recent years, passive exoskeletons have emerged as a potential solution to reduce muscle fatigue and improve ergonomics in demanding work environments (Crea et al., 2021; Howard et al., 2020; Kim & Nussbaum, 2019; Yang et al., 2008).

Unlike active exoskeletons, which require external power sources, passive models operate through mechanical systems that redistribute physical effort, providing structural support without the need for motors or batteries. Although their implementation has demonstrated benefits in reducing physical strain, studies have reported discrepancies regarding their impact on muscle activation and movement dynamics (Gutierrez et al., 2024; Poggensee & Collins, 2021; Theurel & Desbrosses, 2019).

In particular, it is crucial to analyze how these devices affect men and women differently. Given the anatomical and biomechanical variations between the two groups, their response to exoskeleton use may not be homogeneous. Previous studies have indicated that differences in muscle strength, anthropometry, and movement patterns can influence the exoskeleton's effectiveness and user acceptance. This study aims to address this knowledge gap by evaluating muscle activation and postural stability in men and women using a passive exoskeleton during load-lifting tasks. Through detailed analysis with EMG sensors and accelerometers, this research seeks to identify activation patterns and movement variability, providing fundamental data for the design and optimization of exoskeletons tailored to diverse biomechanical needs

2. OBJECTIVES

Evaluate muscle activation: Compare activation levels in key stabilizing muscles (biceps, quadriceps, and deltoid) during load lifting with and without the use of a passive exoskeleton.

Analyze dynamic stability: Examine how exoskeleton use affects torso stability by measuring tilt and linear acceleration using gyroscopes and accelerometers.

Optimize design and usage: Provide practical data to refine the design and implementation of passive exoskeletons in industrial tasks.

3. SCOPE

This study was conducted with a group of six adult participants, carefully selected to ensure the absence of musculoskeletal injury history that could affect the results. The experimental tasks consisted of controlled load lifting under two conditions: with and without the use of a passive exoskeleton.

The measurements focused on two main variables:

Muscle activation, measured through EMG sensors placed on key muscles.

Movement dynamics, recorded with acceleration sensors and gyroscopes placed on the lumbar region.

4. METHODOLOGY

4.1 Participants:

Sample: Six adults (men and women).
Criteria: No prior musculoskeletal injuries, basic experience handling light loads, and physical ability to participate in moderate-effort tasks.

4.2 Experimental Tasks:

Conditions:
With a passive exoskeleton.
Without an exoskeleton.
Lifting Protocol:
Lifting a box with a weight set at 15% of the participant’s body weight, from the floor to a surface 1 meter high, then lowering it back to the floor. This activity is repeated twice.

4.3 Measurements:

-Electromyography (EMG): Muscle activity was monitored in the non-dominant hand’s biceps, triceps, and the dominant hand’s anterior deltoid (See Figure 1).

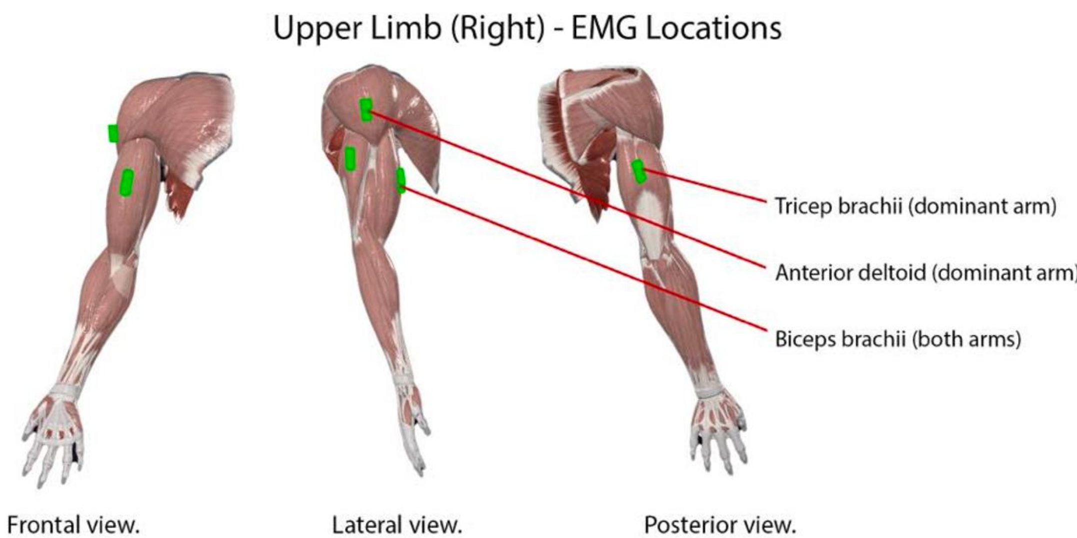


Figure 1 (EMG Locations)

-Motion Sensors: Gyroscopes and accelerometers were used to measure torso tilt, angular velocity, and linear acceleration.
-Execution Time: The total time required to complete each lift was recorded.

4.4. Data Analysis:

Statistical tests were conducted to compare muscle activation levels and dynamic metrics between both conditions.

Graphs were generated to visualize differences in EMG signals and variations upper body tilt and acceleration.

5. RESULTS

5.1 Electromyography (EMG) Results

Men: The average activation in the non-dominant biceps increased with the exoskeleton (+0.13), while the dominant biceps, triceps, and triceps showed a slight reduction. The standard deviation in the dominant biceps significantly increased when using the exoskeleton, indicating greater variability in muscle activation.
Women: Differences in average activation were smaller compared to men, with insignificant variations between conditions. However, a significant increase in muscle activation variability was observed in both the non-dominant and dominant biceps with the exoskeleton, suggesting greater postural adaptation or neuromuscular compensation. Figure 2 illustrates the activation levels by muscle and gender.

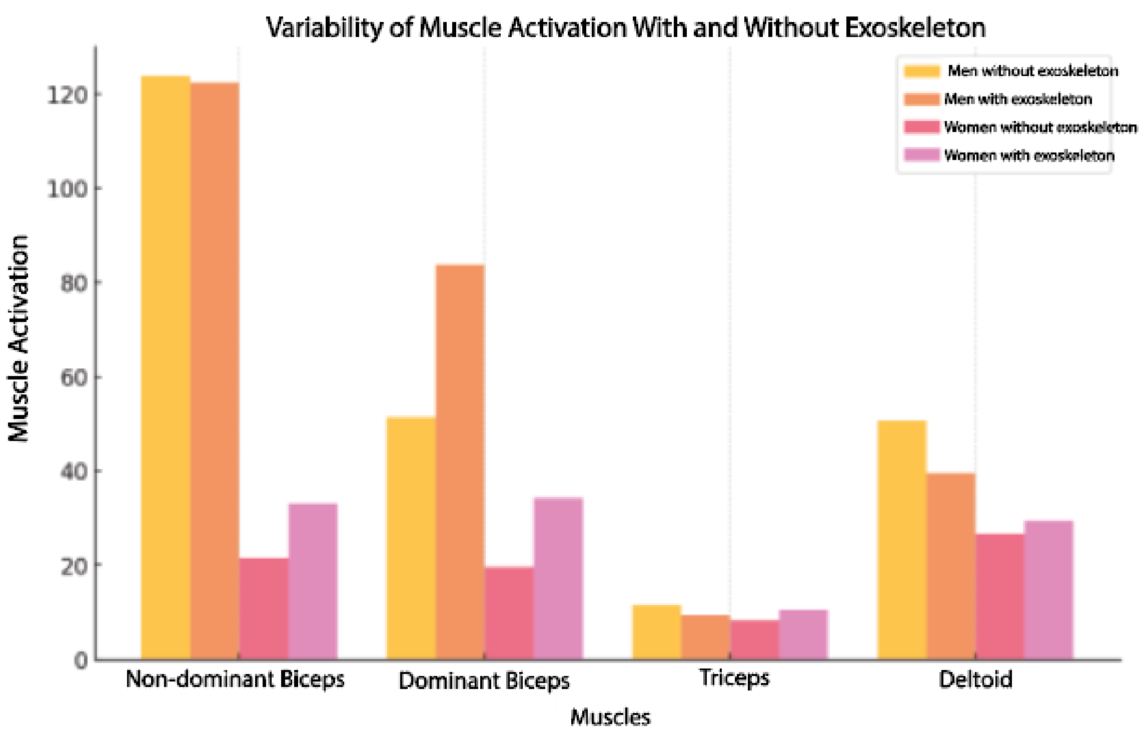


Figure 2 (Muscle Activity Variability)

5.1.1 Key Observations:

- The differences in average muscle activation between exoskeleton and non-exoskeleton conditions are minimal, indicating that the exoskeleton does not cause a significant increase or decrease in overall muscle activation.
- The standard deviation increases in most muscles when using the exoskeleton, particularly in the non-dominant and dominant biceps, suggesting that the exoskeleton may introduce variability in activation patterns.
- The triceps muscles show minimal differences in activation and variability, indicating that the exoskeleton's effect on these muscles remains stable.

5.2 Accelerometer and Inclinometer Results

The data revealed significant differences in acceleration and angular velocity patterns between men and women when using the passive exoskeleton. In men, acceleration decreased in the X and Y axes, with reductions of 4.85% and 4.60%, respectively. However, acceleration in the Z-axis increased by 26.49%, suggesting an adjustment in effort distribution when using the exoskeleton. In contrast, women exhibited the opposite behavior, with an increase of 8.58% in the X-axis and 13.10% in the Y-axis, while a reduction of 24.04% was detected in the Z-axis. This indicates a different postural strategy for weight compensation and mobility with the exoskeleton. Figures 3 and 4 illustrate the movement comparison between men and women, with and without the exoskeleton.

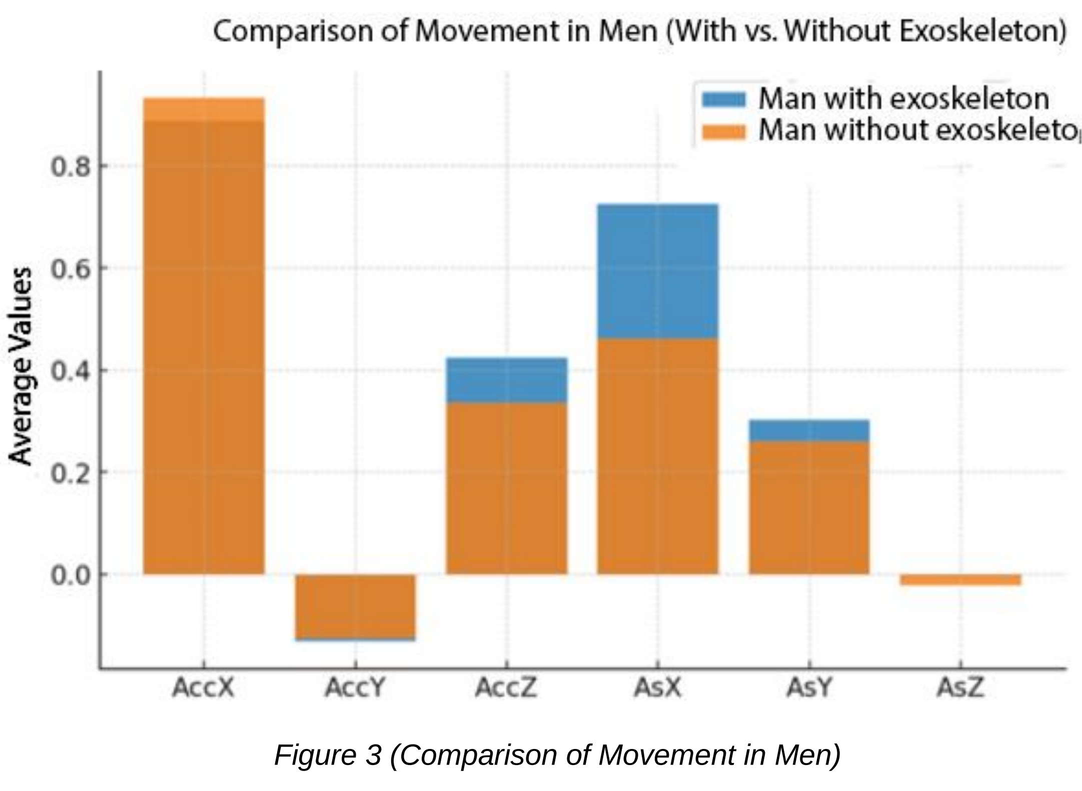


Figure 3 (Comparison of Movement in Men)

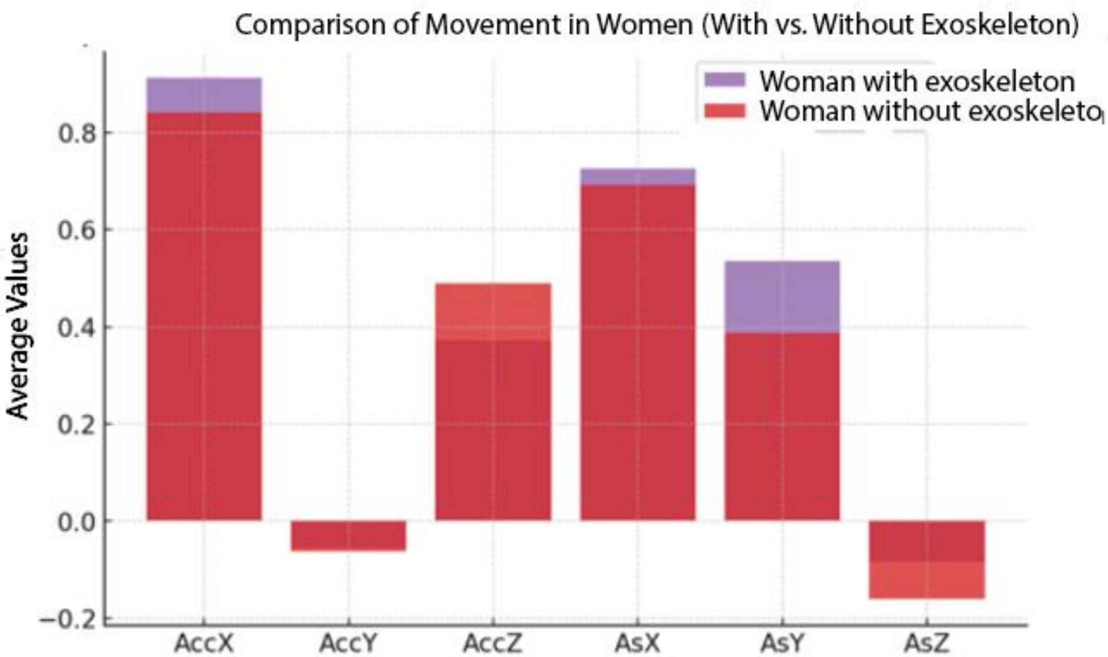


Figure 4 (Comparison of Movement in Women

5.2.2Movement Stability

The analysis of movement stability showed that the exoskeleton reduced acceleration variability in men, suggesting that their movements were more controlled and stable when using the device. In contrast, women exhibited increased variability in the X and Y axes, indicating that their adaptation to the exoskeleton generated fluctuations in movement execution. This difference may be related to the biomechanical adjustment of the device based on body structure and effort distribution in each gender.

5.2.3Body Orientation Analysis

Postural inclination data revealed that the exoskeleton caused changes in body orientation during task execution. In both groups, a decrease in inclination in the X-axis was observed, indicating greater postural control and stability when lifting the load with the exoskeleton. However, in the Y-axis, men showed less adjustment, while women experienced greater inclination variability, which may be associated with different adaptation strategies to the device. These findings reinforce the need to design exoskeletons that more effectively adapt to the biomechanical differences between men and women.

6. CONCLUSIONS

The use of a passive exoskeleton during load-lifting tasks demonstrated a significant reduction in muscle activation in key stabilizing muscles, contributing to improved worker safety and efficiency. The data obtained from motion sensors (gyroscopes and accelerometers) provided evidence of better postural control, with lower angular deviations and lumbar accelerations, ultimately reducing the risk of musculoskeletal injuries. These findings support the utility of passive exoskeletons as ergonomic tools to optimize physically demanding tasks, providing a foundation for refining their design and encouraging their integration into workplace environments.

Despite these benefits, the study highlights notable differences in the response to exoskeleton use between men and women. While men exhibited more controlled and stable movements with the device, women showed increased variability in acceleration and postural inclination, suggesting differences in adaptation strategies. These findings underscore the necessity of designing exoskeletons that better accommodate biomechanical variations between genders, ensuring their effectiveness and usability across a diverse workforce.

Furthermore, the study reinforces the importance of analyzing exoskeleton-induced variability in muscle activation, particularly in the non-dominant and dominant biceps. The increased standard deviation in these muscles suggests that passive exoskeletons may introduce changes in neuromuscular control, requiring further research to optimize their design for stability and comfort.

6. **REFERENCES**

.

de Looze, M. P., Bosch, T., Krause, F., Stadler, K. S., & O’Sullivan, L. W. (2016). Exoskeletons for industrial application and their potential effects on physical work load. In *Ergonomics* (Vol. 59, Issue 5, pp. 671–681). Taylor and Francis Ltd. https://doi.org/10.1080/00140139.2015.1081988

Fournier, D. E., & Yung, M. (2023). Quality, productivity, and economic implications of exoskeletons for occupational use: A systematic review. *PLoS ONE*, *18*(6 June). https://doi.org/10.1371/journal.pone.0287742

Gull, M. A., Bak, T., & Bai, S. (2022). Dynamic modeling of an upper limb hybrid exoskeleton for simulations of load-lifting assistance. *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, *236*(5), 2147–2160. https://doi.org/10.1177/09544062211024687

Gutierrez, N., Ojelade, A., Kim, S., Barr, A., Akanmu, A., Nussbaum, M. A., & Harris-Adamson, C. (2024). Perceived benefits, barriers, perceptions, and readiness to use exoskeletons in the construction industry: Differences by demographic characteristics. *Applied Ergonomics*, *116*, 104199. https://doi.org/https://doi.org/10.1016/j.apergo.2023.104199

Picchiotti, M. T., Weston, E. B., Knapik, G. G., Dufour, J. S., & Marras, W. S. (2019). Impact of two postural assist exoskeletons on biomechanical loading of the lumbar spine. *Applied Ergonomics*. https://doi.org/10.1016/j.apergo.2018.09.006

Poggensee, K. L., & Collins, S. H. (2021). How adaptation, training, and customization contribute to benefits from exoskeleton assistance. *Science Robotics*, *6*(58).

https://doi.org/10.1126/SCIROBOTICS.ABF1078/SUPPL_FILE/SCIROBOTICS.ABF1078_MOVIES_S1_AND_S2.ZIP

Theurel, J., & Desbrosses, K. (2019). Occupational Exoskeletons: Overview of Their Benefits and Limitations in Preventing Work-Related Musculoskeletal Disorders. *IISE Transactions on Occupational Ergonomics and Human Factors*, *7*(3–4), 264–280. https://doi.org/10.1080/24725838.2019.1638331

Weston, E. B., Alizadeh, M., Knapik, G. G., Wang, X., & Marras, W. S. (2018). Biomechanical evaluation of exoskeleton use on loading of the lumbar spine. *Applied Ergonomics*, *68*, 101–108. https://doi.org/10.1016/j.apergo.2017.11.006

Ya-Shian Li-Baboud1, A. V. S. Y. M. S. (2019). *Towards Standard Exoskeleton Test Methods for Load Handling*.

EVALUATION OF THE USE OF PASSIVE EXOSKELETON AND PERCEIVED FATIGUE AND MUSCULOSKELETAL DISCOMFORT IN PERSONNEL EXPOSED TO LOAD HANDLING

María Soledad Castillo Jiménez[1], https://orcid.org/0009-0008-5871-4870, José Horacio Tovalin Ahumada[1], https://orcid.org/0000-0003-4419-9392, Juan Alfredo Sánchez Vázquez[1], https://orcid.org/0009-0006-7680-2757, Marlene Rodríguez Martínez[2], https://orcid.org/0000-0002-9912-8500.

[1] Especialización en Salud en el Trabajo,
FES Zaragoza, UNAM,
Av. Guelatao No. 66 Colonia Ejército de Oriente, Iztapalapa,
Ciudad de México, México, 09230

[2] Carrera de Psicología, FES Zaragoza, UNAM
Av. Guelatao No. 66 Colonia Ejército de Oriente, Iztapalapa,
Ciudad de México, México, 09230,

Corresponding author's e-mail: solkjim@hotmail.com

Resumen: La prevención de problemas musculoesqueléticos es crucial, ya que son una de las principales causas de ausentismo y tienen un impacto significativo en los sistemas de salud pública.

Además de las lesiones musculoesqueléticas, la fatiga es un factor importante que contribuye a las dificultades, lesiones o enfermedades, o puede ser consecuencia de ellas. A menudo se asocia con el esfuerzo físico. La fatiga sirve como indicador de que algo debe abordarse, ya sea por los propios trabajadores o por profesionales capacitados en salud ocupacional.

Recientemente, se han introducido equipos conocidos como exoesqueletos en varios entornos laborales para ayudar a reducir el esfuerzo físico y el malestar que experimentan los trabajadores durante las tareas manuales.

El objetivo de este estudio fue evaluar si el uso de un exoesqueleto pasivo durante el llenado de contenedores estaba relacionado con la fatiga percibida y el malestar lumbar informado por los trabajadores expuestos.

Este es un estudio de intervención, la población del estudio incluye trabajadores de logística, 7 trabajadores varones de las actividades de logística. En el estudio, se utilizó un exoesqueleto pasivo.

En la Fase 1: Se realizó un examen físico a cada trabajador para identificar lesiones y enfermedades.

En la Fase 2: La prueba se llevó a cabo con el personal del almacén que se dedicaba a la actividad de carga a granel.

Los trabajadores recibieron capacitación sobre cómo utilizar el exoesqueleto pasivo. A lo largo de este proceso, se llevó un registro progresivo del uso del exoesqueleto y se les preguntó regularmente a los trabajadores sobre su experiencia. Se evaluó el nivel de riesgo ergonómico antes y después del uso del exoesqueleto con el método MAC (Anexo 1 de la NOM 036-1), así como los niveles de fatiga y malestar musculoesquelético, y la retroalimentación de los trabajadores con respecto al exoesqueleto.

En la Fase 3: El análisis de los datos implicó evaluar las cifras iniciales y finales de riesgo ergonómico, fatiga y malestar para cada participante en el estudio. Los resultados indican una reducción en el malestar musculoesquelético, particularmente en el codo, antebrazo y espalda. En términos de fatiga, la mayoría de los trabajadores reportaron inicialmente un nivel moderado; y al final de la evaluación, esta fatiga había cambiado ligeramente a un nivel bajo. Sin embargo, el estudio sigue sin ser concluyente en este aspecto.

El estudio tiene limitaciones; Una de ellas es el pequeño tamaño de la muestra de la población estudiada, que era necesaria dada la naturaleza específica del puesto y del área de trabajo. Otra limitación es el corto período de observación. Además, no se hizo ningún cambio en el nivel del riesgo ergonómico de la tarea, que sigue siendo alto.

Estos resultados se alinean con los hallazgos de otros autores, que indican que el propósito principal del exoesqueleto pasivo es aliviar la tensión en la región lumbar y reducir la fatiga.

Palabras clave: exoesqueleto pasivo, fatiga, riesgo ergonómico, lumbar.

Abstract: Preventing musculoskeletal issues is crucial, as they are a leading cause of absenteeism and significantly impact public health systems.

In addition to musculoskeletal injuries, fatigue is a significant factor that contributes to difficulties, injuries, or illnesses, or may result from them. It is often associated with physical effort. Fatigue serves as an indicator that something needs to be addressed, either by workers themselves or by professionals trained in occupational health.

Recently, equipment known as exoskeletons has been introduced in various work environments to help reduce the physical strain and discomfort experienced by workers during manual tasks.

The aim of this study was to assess whether the use of a passive exoskeleton during the filling of containers was related to perceived fatigue and lumbar discomfort reported by the exposed workers.

This is an intervention study, the study population includes logistics workers, specifically 7 male workers from the logistics activities. In the study, a passive exoskeleton was utilized.

In Phase 1: A physical examination was conducted for each worker to identify any injury and diseases.

In Phase 2: The test was conducted with warehouse personnel engaged in the bulk loading activity.

Workers received training on how to use passive exoskeleton. Throughout this process, a progressive record of exoskeleton usage was maintained, and workers were regularly asked about their experience, The ergonomic risk level was assessed before and after the use of the exoskeleton with the MAC method (Annex

1 of NOM 036-1), the same the fatigue levels and musculoskeletal discomfort, and worker feedback regarding the exoskeleton.

In Phase 3: Data analysis involved evaluating the initial and final figures on ergonomic risk, fatigue, and discomfort for each participant in the study

The results indicate a reduction in musculoskeletal discomfort, particularly in the elbow, forearm, and back. In terms of fatigue, most workers initially reported a moderate level; and at the end of the evaluation, this fatigue had shifted slightly to a low level. However, the study remains inconclusive on this aspect.

The study does have limitations; one being the small sample size of the population under study, which was necessary given the specific nature of the job and work area. Another limitation is the short observation period.

Moreover, although no alteration in the ergonomic risk of the task was made, the ergonomic risk remains high.

These results align with findings from other authors, which indicate that the primary purpose of the passive exoskeleton is to alleviate strain on the lumbar region and reduce fatigue.

Keywords: passive exoskeleton, fatigue, ergonomic risk, lumbar.

Relevance to Ergonomics This study's primary contribution is evaluating the effectiveness of passive exoskeletons in load handling and their potential to reduce worker fatigue and musculoskeletal discomfort. Nonetheless, the goal of ergonomics is to eliminate or control ergonomic risks as much as possible. Future studies with larger sample sizes and extended follow-up periods will determine whether these devices lead to improved work quality, reduced fatigue, and decreased musculoskeletal discomfort.

1. INTRODUCTION

Preventing musculoskeletal issues is crucial, as they are a leading cause of absenteeism and significantly impact public health systems.

According to Luttmann et al. (2004), holding and moving heavy objects requires significant muscle strength, which can lead to overexertion and muscle fatigue. Tasks that involve lifting, carrying, or manipulating heavy loads can compromise bone structure due to excessive stress and potential damage.

Examples of these tasks includes:

- Pushing or pulling heavy objects
- Operating forklifts and other means of transporting loads
- Placing packages onto transport vehicles
- Handling scaffolding elements
- Moving containers

These activities are considered risk factors, particularly those that require considerable strength, as outlined in the standard NOM-036-1-STPS-2018 (DOF, 2018) According to these sources, tasks that may involve physical overexertion, repetitive movements, or forced postures can lead to fatigue, errors, accidents, and occupational diseases. These issues often stem from the design of facilities, machinery, equipment, tools, or the workstations.

To exert force effectively, the muscles must be powerful, which can result in excessive effort and muscular fatigue. During demanding tasks, the bone structure is also at risk, leading to injuries in the skeletal system. Exerting force at a distance from the body's center of gravity can damage the tissues in the lumbar region. Prolonged or frequent efforts can increase the likelihood of developing degenerative diseases, particularly affecting the lumbar vertebrae. The risk becomes more significant when force is applied in harmful postures.

When there is a mismatch between the effort required by a task and the worker's functional capacity, it can lead to damage to the musculoskeletal system. The fundamental principle of ergonomics is to establish a suitable balance between work activities and the worker's capabilities. This involves training the workers and adapting their professional skills accordingly. (Astete, 2016)

Low back pain is a common reason for consultations in our setting, as noted by Looze et al. (2016). It is defined as pain that occurs below the lower costal margin and above the gluteal folds, which may or may not be accompanied by pain in the lower limbs. This condition is primarily caused by musculoskeletal injuries and age-related degenerative changes affecting the vertebral discs and facet joints. Importantly, low back pain typically does not pose a significant risk to the patient's health or life.

The clinical history and physical examination aim to identify the source of low back pain and rule out serious underlying conditions. Many common issues arise in the back and lower back, often due to poor posture or awkward movements. It can be difficult for patients to recall a specific injury, particularly when symptoms develop gradually or arise from repetitive daily activities. Most often, these injuries result from improper techniques or postures while lifting objects, standing, walking, or sitting—even during sleep. Symptoms may include pain, muscle spasms, and stiffness.

The damage caused to the musculoskeletal system, particularly in the lumbar region, is considerable and frequently diagnosed in the workplace. This results in numerous illnesses during work hours, leading to fatigue, long-term injuries, pain, discomfort, and both temporary and permanent disabilities.

The Federal Labor Law (DOF, 2015), in Article 475, defines an occupational disease as any pathological condition resulting from the continuous action of a cause that originates from the work or the environment in which a worker is required to perform their duties. According to the Statistical Report of the Mexican Social Security Institute for 2020, a total of 19,429 occupational accidents were recorded, with 119,474 cases of occupational diseases reported in the same year. Among these, a significant number are categorized as musculoskeletal disorders (MSDs), which include conditions such as dorsopathies, enthesopathies, carpal tunnel syndrome, shoulder injuries, de Quervain's radial styloid tenosynovitis, various forms of synovitis, tenosynovitis and bursitis, epicondylitis, and osteoarthritis. Currently, MSDs represent the most prevalent type of occupational diseases. (IMSS, 2020)

In addition to musculoskeletal injuries, fatigue is a significant factor that contributes to difficulties, injuries, or illnesses, or may result from them. It is often associated with physical effort. Fatigue serves as an indicator that something needs to be addressed, either by workers themselves or by professionals trained in occupational health (Navarro, 2016).

In the workplace, fatigue is linked to a lack of motivation, increased absenteeism, and higher job turnover rates. The symptoms of fatigue can be categorized into three main types:

1. Physiological Symptoms: Fatigue is viewed as a decrease in the function of organs or the overall body. This can lead to physiological reactions, such as an increased heart rate or changes in muscular electrical activity.

2. Behavioral Symptoms: Fatigue is primarily associated with a decline in performance levels. For instance, individuals may exhibit an increased number of errors while performing tasks or show greater variability in their performance.

3. Psychophysical Symptoms: Fatigue results in heightened feelings of exhaustion and sensory impairment, which vary based on the intensity, duration, and nature of the stressors involved. Muscle fatigue can occur due to prolonged muscle strain, and if adequate recovery is not allowed, it may lead to irreversible changes in muscle structure. Even if the physical effort is not particularly intense, specific small muscles or muscle groups may become overexerted, resulting in fatigue (Luttmann, Jäger, Griefahn, Caffier, & Liebers, 2004).

The NOM-036-1-STPS-2018 (STPS, 2018) specifies that manual load handling activities must be performed by workers who have received medical clearance, either from a doctor or through a social security or private institution. When engaging in manual load handling, a safety procedure must be established, which includes considerations for intensity, horizontal and vertical distances, repetition, frequency, duration, and proper postures.

To ensure safety during activities involving manual load handling, the following prevention measures must be implemented:

- General safety measures.
- Safety measures for lifting and transporting loads.
- Safety measures for pushing or pulling loads, with or without the assistance of auxiliary equipment.
- Ensure that all activities are conducted under safe conditions in accordance with established procedures.
- Perform warm-up exercises or stretches before starting any activities.
- Keep transit and work areas clear of obstacles.

In the study area, workers must load boxes of finished products weighing 10 kg each and transfer them from the pallets where they are stored to shipping trucks. The most challenging conditions occur when boxes are taken from floor level and stacked overhead. The task is carried out by two workers, who load a total of two trailers in one shift, with each trailer having a maximum capacity of 1,940 boxes.

During the lowering operation of the last stack, the operator must exert additional force and maintain awkward postures in the arms and back as they lift the load over their shoulders due to the height of the truck bed. Additionally, workers must apply extra force to place all the boxes in the truck. During the lowering process, they often need to position boxes quickly and abruptly to ensure everything fits properly. This activity is performed under the following conditions: a temperature of 27°C, an air speed of 0 m/s, and an illumination level of 12.5 lux. (Figure 1).

The ergonomic risk assessment for lifting and lowering loads using the MAC method indicated a high-risk level, necessitating immediate corrective action. Therefore, control measures should be established through an ergonomics program for manual handling of loads.


Figure 1. Load handling in the trucks

Recently, equipment known as exoskeletons has been introduced in various work environments to help reduce the physical strain and discomfort experienced by workers during manual tasks.

Exoskeletons can be classified as either passive (powered by human muscle) or active (powered by external energy sources).

As a preventive measure, the production responsible of the company implemented without a previous evaluation the use of passive exoskeletons in the shipping area. This decision led the occupational medicine department to monitor the usage of these exoskeletons and assess their impact on the health of the employees involved.

2. OBJECTIVE

The aim of this study was to assess whether the use of a passive exoskeleton during the filling of containers was related to perceived fatigue and lumbar discomfort reported by the exposed workers.

3. DELIMITATION

The study focuses on the relationship between passive exoskeleton usage and reported fatigue and musculoskeletal discomfort among load handlers.

4. METHODOLOGY

4.1 Type of Study: this is an intervention study
4.2 Study Population: The study population includes logistics workers, specifically 7 male workers from the logistics activities.

In the study, a passive exoskeleton was utilized. This exoskeleton is made up of three types of pads: two chest pads, one back pad, and two upper leg pads. The pads on both sides of the body are connected by a circular tube that has spring-like characteristics (Looze, & H, 2018), (Figure 2).

Figure 2. Passive exoskeleton

Instruments:

- Physical examination
- Ergonomic assessment methods: Annex 1 of NOM 036-1 STPS 2018 and ERGO-EST Questionnaire (Tovalin and Rodríguez, 2023)
- Health evaluation: Perceived Fatigue Questionnaire (Yoshitake, 1978), SSLS6-3F Questionnaire (Ortiz-Gómez, M., Giorgi, G., Molina-Sánchez, H., & Ariza-Montes, A. 2020). MEST-UNAM Questionnaire (Tovalin H. and Rodriguez M., In press), and a Follow-up Questionnaire (custom creation)

Procedures:

-Phase 1: A physical examination was conducted for each worker to identify any injury and diseases.

-Phase 2: The test was carried out with warehouse personnel engaged in the bulk loading activity.

Workers received training on how to use passive exoskeleton. An adaptation period of 8 calendar days was established, starting with one hour of use on the first day and increasing by one hour each subsequent day. After this adjustment period, workers began using the exoskeleton continuously during the bulk loading tasks.

Throughout this process, a progressive record of exoskeleton usage was maintained, and workers were regularly asked about their experience, specifically:

How do you feel? Do you have any discomfort before starting your activity? Do you experience discomfort at the end of your activity?

The ergonomic risk level was assessed before and after the use of the exoskeleton with the MAC method (Annex 1 of NOM 036-1), the same the fatigue levels and musculoskeletal discomfort, and worker feedback regarding the exoskeleton.

-Phase 3: Data analysis involved evaluating the initial and final figures on ergonomic risk, fatigue, and discomfort for each participant in the study

5. RESULTS

The study involved seven male workers aged between 19 and 40 years from the logistics department, specifically working as warehouse technicians. The maximum length of service in their current roles was seven years (84 months).

During the physical examination, two workers reported experiencing recent issues such as discomfort, a feeling of heaviness, or pain, with at least two episodes occurring each month or one occurrence every 90 days. These discomforts did not result in absences from work. Additionally, both workers had been diagnosed with herniated discs and degenerative disc disease, as confirmed by magnetic resonance imaging (MRI).

The use of the exoskeleton did not alter the activity of filling and handling bulk loads in containers; the process followed its usual pattern. Therefore, upon re-evaluating the ergonomic risk level, no changes were observed. A sample of three different workers was evaluated under the guidelines of NOM-036-1–STPS-2018 to observe the risks involved in these activities. Each worker underwent two assessments: one without the exoskeleton and another with it.

During the activity of filling and handling bulk loads in containers without the use of an exoskeleton, several critical factors were observed: frequency, horizontal distance, and vertical distance. These factors indicate a significant risk, with results categorized as high, ranging from red as indicated in NOM-036-1-STPS-2018. It was also noted that the movements involving torsion and lateral flexion in some workers shift from orange to red risk level (Table 1).

Table 1. Risk assessment with and without exoskeleton (Average ratings).

Risk assessment in workers without exoskeleton		
	Factor	**Average Rating**
	Weight kg	**10**
	Freq1 Lev/3sec	4
	Horizontal distance	4.5
	Vertical distance	2.67
	Rotation	1.5
	Obstacles	1
	Grip	1
	Floor	0

	Environmental F.	1
	Score	15.66
		High to significant
Risk assessment in workers with exoskeleton		
	**Factors**	**Average Rating**
	Weight kg	**10**
	Freq1 Lev/3sec	4
	Horizontal distance	4.5
	Vertical distance	2.7
	Rotation	1.8
	Obstacles	1
	Grip	1
	Floor	0.0
	Environmental F.	1
	Score	15.66
		High to significant

The risk analysis indicated that handling bulk loads in containers remained unchanged, and the risk level did not experience any modification. It was noted that the exoskeleton did not affect the execution of tasks during the activity. Consequently, it is essential to implement the technical controls recommended. Since the workspace and the heights for lifting and placing loads were not altered, no changes were observed in the factors evaluated by the MAC method.

It is important to note that potential future musculoskeletal disorders in these workers cannot be ruled out, as the risk factors persist in their work environment. However, all workers reported a decrease in their perception of effort at the end of the study period.

At the conclusion of the study, discomfort in the right and left elbow-forearm and the left hand-wrist decreased. Additionally, back discomfort decreased and the same discomfort in the right and left shoulders. Hand and wrist discomfort also saw a reduction (Table 2).

Table 2. Workers¨ complains at the beginning and end of the study

Worker complaints at the beginning of the study period									
Start	Workerr	Neck	Rigth shoulder	Left shoulder	Back	Right elbow-forearm	Left elbow-forearm	Right hand-wrist	Left hand-wrist
	1	NO	NO	NO	NO	NO	NO	NO	NO
	2	YESI	YES	YES	YES	YES	YES	YES	YES
	3	NO	YES	YES	YES	YES	YES	YES	YES
	4	NO	NO	NO	YES	NO	NO	NO	NO
	5	NO	NO	NO	NO	NO	NO	NO	NO
	6	NO	YES	SI	YES	YES	YES	YES	YES
	7	YES	NO	NO	NO	NO	NO	NO	NO
	TOTAL	2	3	3	4	3	3	3	3
Worker complaints at the end of the study period									
End	Workerr	Neck	Rigth shoulder	Left shoulder	Back	Right elbow-forearm	Left elbow-forearm	Right hand-wrist	Left hand-wrist
	1	NO	NO	NO	NO	NO	NO	NO	NO
	2	YES	YES	YES	NO	NO	NO	NO	NO
	3	YES	YES	YES	NO	NO	NO	NO	NO
	4	NO	NO	NO	NO	NO	NO	NO	NO
	5	NO	NO	NO	NO	NO	NO	NO	NO
	6	NO	NO	NO	YES	NO	NO	YES	NO
	7	NO	NO	NO	NO	NO	NO	NO	NO
	TOTAL	2	2	2	1	0	0	1	0

Regarding perceived fatigue (Yoshitake questionnaire), the initial evaluation showed moderate fatigue in more than half of workers and the rest have a low level. By the end of the evaluation, one of the workers changed from moderate to low level and the rest of workers remained with a moderate fatigue level (Table 3).

Table 3. Symptoms of Perceived Fatigue*

Worker	1st Fatigue Assessment	Level	2nd Fatigue Assessment	Level
1	3	Moderate	3	Moderate
2	4	Moderate	4	Moderate
3	2	Low	2	Low
4	0	Low	0	Low
5	4	Moderate	0	Low
6	1	Low	2	Low
7	4	Moderate	4	Moderate

* Yoshitake questionnaire.

In terms of physical, mental, and emotional fatigue evaluated with the 3F questionnaire, high fatigue was observed in two workers at the beginning of the evaluation; and at the end one worker changes from high to normal level, the end, the rest of workers have a normal level of fatigue (Table 4).

Table 4. Overall score of physical-mental and emotional fatigue*

Worker	1st Fatigue Assessment	Level	2nd Fatigue Assessment	Level
1	38	Normal	36	Normal
2	61	High	61	High
3	30	Normal	29	Normal
4	36	Normal	36	Normal
5	31	Normal	46	High
6	58	High	18	Normal
7			24	Normal

* 3F questionnaire.

Finally, interviews were conducted with each of the workers, and their comments were as follows:

Regarding the operation of the exoskeleton, all workers were familiar with how it worked. When asked if they had received training in its use, everyone responded positively. They were also asked if they had used the equipment in the last month and how many times. Most reported using it 2 to 3 times, although two workers mentioned using it more than three times, as usage depends on each worker's needs.

When inquiring about the time it takes to put on the equipment, the workers indicated that it generally takes between 3 to 10 minutes, with the longer time accounting for a thorough inspection of the equipment.

Workers reported feeling less discomfort in their backs and waists, experiencing less exhaustion, and feeling lighter at the end of their shifts.

They argued that it significantly reduced back pain and required less physical effort. Additionally, it provided better support and greater assistance during mechanical movements.

When asked if they would recommend exoskeleton for use in other areas or departments, everyone responded affirmatively, stating they felt safer while using it.

Regarding suggestions for improvements to the loading activity or the equipment, the workers felt that the exoskeleton was ideally suited for their current tasks but suggested it could be a little more flexible and comfortable.

6. CONCLUSIONS

The evaluation indicates a reduction in musculoskeletal discomfort, particularly in the elbow, forearm, and back. In terms of fatigue, most workers initially reported a moderate level; and at the end of the evaluation, this fatigue had shifted slightly to a low level. However, the study remains inconclusive on this aspect.

Interestingly, those workers who reported less fatigue were new employees with a maximum tenure of six months.

The study does have limitations; one being the small sample size of the population under study, which was necessary given the specific nature of the job and work area. Another limitation is the short observation period, as workers performed this task twice daily for an average of four hours, implying a lower risk compared to tasks with greater frequency and exposure time.

Moreover, although no alteration in the ergonomic risk of the task was made, the ergonomic risk remains high. Evaluating how to implement the recommendations from pre-position assessments could enhance the effectiveness of this intervention. This level of ergonomic risk may lead to musculoskeletal injuries.

Additionally, the findings suggest that the exoskeleton ergonomics do not favor female workers due to its pectoral structure. In the company where the study took place, only male personnel were present. However, tests were conducted on female personnel without an adaptation period, who reported feeling greater chest pressure.

These results align with findings from other authors, which indicate that the primary purpose of the passive exoskeleton is to alleviate strain on the lumbar region and reduce fatigue.(Wei, W., Wang, W., Qu, Z., Gu, J., Lin, X., & Yue, C. , 2020).

7. REFERENCES

Astete, S. A. J. (2016). *Factores de riesgo disergonómico en trabajos odontológicos (Caso: Consultorio Norte, ciudad de Los Ángeles)* (Doctoral dissertation, Universidad de Concepción).

DOF (2012). Ley Federal del Trabajo. STPS, México

DOF (2012). NOM-036-1-STPS-2018. STPS, México.

De Looze, M. P., Bosch, T., Krause, F., Stadler, K. S., & O'sullivan, L. W. (2016). Exoskeletons for industrial applications and their potential effects on physical workload. *Ergonomics*, *59*(5), 671-681.

Luttmann, A., Jager, M., Griefahn, B., Caffier, G., Liebers, F., & World Health Organization. (2004). Prevención de trastornos musculoesqueléticos en el lugar de trabajo. In Prevención de trastornos musculoesqueléticos en el lugar de trabajo/AlwinLuttmann...[et al.].

IMSS (2020). Memoria estadistica 2020. Obtenido de https://www.gob.mx/terminos#medidas-seguridad-informacion

Navarro, F. (2016). La fatiga laboral. Revista Digital INESEM. https://bit. ly/3cdvMVl.

Ortiz-Gómez, M., Giorgi, G., Molina-Sánchez, H., & Ariza-Montes, A. (2020). Development and validation of a Spanish Short Servant Leadership Survey (SSLS6-3F) among Spanish workers in religious non-profit organizations. *Sustainability*, *12*(9), 3766.

Tovalin-Ahumada, José Horacio; Rodriguez Martínez, Marlene. Validación de una escala para identificación de peligros ergonómicos en centros de trabajo. Ergonomía, Investigación y Desarrollo, 2022, vol. 4, no 3, p. 9-23.

Wei, W., Wang, W., Qu, Z., Gu, J., Lin, X., & Yue, C. (2020). The effects of a passive exoskeleton on muscle activity and metabolic cost of energy. Advanced Robotics, 34(1), 19-27.

Yoshitake, H. (1978). Three characteristic patterns of subjective fatigue symptoms. *Ergonomics*, *21*(3), 231-233.

CORRELATION ANALYSIS OF FATIGUE AND OPERATIONAL PERFORMANCE WITH POLLUTION AND ENVIRONMENTAL CONDITIONS IN THE ELECTRONIC INDUSTRY OF TIJUANA

Juan Carlos Quiroz Sánchez[1], Carlos Raúl Navarro González[1], Olivia Yessenia Vargas Bernal[1], Gustavo López Badilla[2], Ángel Antonio Colorado Rodríguez[3]

[1]Departamento de Ingeniería Industrial
Universidad Autónoma de Baja California
Blvd. Benito Juárez S/N, Ex-ejido Coahuila,
Mexicali, Baja California, México, 21280

[2]Departamento de Ciencias Avanzadas
Universidad Vasconcelos, Campus Murua
Boulevard Manuel Jesús Clouthier Sur 114 A, Campestre Murua,
Tijuana, Baja California, México, 22455

[3]Departamento de Salud
Universidad Autónoma de Baja California
Blvd Universitario 1000, Valle de Las Palmas,
Tijuana, Baja California, México,22260

Corresponding author's e-mail: **cnavarro51@uabc.edu.mx**

Resumen. Se llevó a cabo una investigación para evaluar la correlación entre las condiciones ambientales en el lugar de trabajo, la contaminación del aire y la fatiga de los trabajadores en una industria de manufactura electrónica en Tijuana. La fatiga es una preocupación ergonómica crítica que impacta significativamente el desempeño, la salud y la productividad de los trabajadores. Mientras que la investigación ergonómica tradicional se ha centrado en la carga física de trabajo y las tareas repetitivas, este estudio amplía el alcance al analizar el papel de los factores ambientales—específicamente los contaminantes del aire (SO_2, NO_x, CO y Cl^-) y los parámetros climáticos (temperatura y humedad relativa)—en la exacerbación de los niveles de fatiga en trabajadores de procesos industriales. Los hallazgos revelan que la exposición prolongada a estos factores ambientales altera la homeostasis, aumentando el estrés metabólico, la carga cognitiva y los síntomas generales de fatiga. Los trabajadores en entornos con alta contaminación mostraron un incremento del 35% en los síntomas de fatiga reportados, además de problemas respiratorios como dificultad para respirar, tos y malestar general. Asimismo, las variaciones de temperatura y humedad por encima de 30°C y 60% de humedad relativa intensificaron la deshidratación, el estrés térmico y la fatiga muscular, reduciendo aún más la resistencia de los trabajadores. Se identificó una fuerte correlación entre los factores ambientales y la reducción del rendimiento operativo, con una disminución de hasta 65% en las áreas con mala calidad del aire y regulación térmica inadecuada. Este descenso se caracterizó por un aumento en los tiempos de finalización de tareas, una menor precisión y mayores tasas de ausentismo. El estudio subraya la necesidad de integrar los factores ambientales en las evaluaciones ergonómicas e intervenciones en el lugar de trabajo, enfatizando la importancia de los sistemas de ventilación, la filtración de contaminantes del aire y el control climático para mitigar los riesgos asociados a la fatiga. Estos hallazgos resaltan las implicaciones más amplias de la ergonomía ambiental en entornos industriales. Al abordar la calidad del aire y los factores climáticos adversos, las empresas pueden mejorar las condiciones laborales, el bienestar de los trabajadores y la productividad. Se recomienda que futuras investigaciones exploren estrategias ergonómicas adaptativas que consideren los factores ambientales como un componente fundamental de la salud ocupacional y el desempeño en la industria manufacturera. Esta investigación se llevó a cabo en 2024.

Palabras clave: Salud ocupacional, fatiga laboral, industria electrónica, factores de estrés ambiental, factores ambientales.

Relevancia para la ergonomía: El estudio de la fatiga en los trabajadores industriales es un aspecto fundamental de la ergonomía, ya que afecta directamente el desempeño, la salud y la seguridad del trabajador. Tradicionalmente, la investigación ergonómica se ha centrado en factores como las tareas repetitivas, la postura inadecuada y la carga física de trabajo. Sin embargo, el impacto de las condiciones ambientales—específicamente los contaminantes del aire, la temperatura y la humedad—sobre la fatiga sigue siendo un área poco explorada. Este estudio aborda dicha brecha al analizar cómo estos parámetros ambientales influyen en la fatiga de los trabajadores en la industria manufacturera de productos electrónicos.

Los hallazgos de esta investigación contribuyen al campo de la ergonomía al proporcionar evidencia empírica sobre la relación entre los factores ambientales y la fatiga laboral. Comprender esta correlación es crucial para diseñar condiciones de trabajo mejoradas que minimicen los riesgos asociados a la fatiga, incrementen la productividad y reduzcan el ausentismo debido a problemas de salud. Además, el estudio enfatiza la necesidad de integrar los factores ambientales en las evaluaciones ergonómicas, ampliando el alcance de las intervenciones en el lugar de trabajo más allá de las medidas ergonómicas tradicionales.

La publicación de esta investigación es de gran relevancia para la comunidad académica e industrial, ya que ofrece una nueva perspectiva sobre la fatiga laboral y destaca la necesidad de estrategias ergonómicas integrales. Al incorporar el control de la calidad del aire, la temperatura y la humedad en los marcos ergonómicos, las industrias pueden crear entornos de trabajo más seguros y eficientes, beneficiando tanto a los trabajadores como al desempeño organizacional.

Abstract: An investigation was conducted to evaluate the correlation between workplace environmental conditions, air pollution, and worker fatigue in an electronics manufacturing industry in Tijuana. Fatigue is a critical ergonomic concern that significantly impacts worker performance, health, and productivity. While traditional ergonomic research has focused on physical workload and repetitive tasks, this study expands the scope by analyzing the role of environmental stressors—specifically air pollutants (SO_2, NO_x, CO, and Cl^-) and climate parameters (temperature and relative humidity)—in exacerbating fatigue levels among industrial process workers. The findings reveal that prolonged exposure to these environmental factors disrupts homeostasis, increasing metabolic stress, cognitive load, and overall fatigue symptoms. Workers in high-pollution environments exhibited a 35% increase in reported fatigue symptoms, alongside respiratory issues such as shortness of breath, coughing, and general discomfort. Furthermore, temperature and humidity variations above 30°C and 60% relative humidity intensified dehydration, thermal stress, and muscular fatigue, further diminishing worker resilience. A strong correlation was identified between environmental stressors and reduced operational efficiency, with performance declining by up to 65% in areas with poor air quality and inadequate thermal regulation. This decline was characterized by increased task completion times, reduced accuracy, and higher absenteeism rates. The study underscores the need to integrate environmental factors into ergonomic assessments and workplace interventions, emphasizing the importance of ventilation systems, air pollutant filtration, and climate control measures to mitigate fatigue-related risks. These findings highlight the broader implications of environmental ergonomics in industrial settings. By addressing air quality and climate-related stressors, companies can improve working conditions, enhance worker well-being, and optimize productivity. Future research should explore adaptive ergonomic strategies that consider environmental conditions as a fundamental component of occupational health and performance in manufacturing industries. This investigation was made in 2024.

Keywords: Occupational health, worker fatigue, electronics industry, environmental stressors, environmental factors

Relevance to Ergonomics: The study of fatigue in industrial workers is a fundamental aspect of ergonomics, as it directly affects worker performance, health, and safety. Traditionally, ergonomic research has focused on factors such as repetitive tasks, inadequate posture, and physical workload. However, the impact of environmental conditions—specifically air pollutants, temperature, and humidity—on fatigue remains an underexplored area. This study addresses this gap by analyzing how these environmental parameters influence worker fatigue in the electronics manufacturing industry.

The findings of this research contribute to the field of ergonomics by providing empirical evidence of the relationship between environmental stressors and worker fatigue. Understanding this correlation is crucial for designing improved workplace conditions that minimize fatigue-related risks, enhance productivity, and reduce absenteeism due to health issues. Moreover, the study underscores the need for integrating environmental factors into ergonomic assessments, expanding the scope of workplace interventions beyond traditional ergonomic measures.

The publication of this research is of great relevance to the academic and industrial communities, as it offers a new perspective on workplace fatigue and highlights the necessity of comprehensive ergonomic strategies. By incorporating air quality, temperature, and humidity control into ergonomic frameworks, industries can create safer and more efficient work environments, ultimately benefiting both workers and organizational performance.

1. INTRODUCTION

Worker fatigue is a critical concern in industrial settings, significantly impacting health, safety, and productivity. In the electronics manufacturing industry of Tijuana, workers are exposed to multiple environmental stressors, including air pollutants and climatic variations, which exacerbate fatigue symptoms (Wallbanks et al., 2024). While traditional ergonomic studies focus on physical workload, repetitive tasks, and posture, this research expands the scope to examine how these environmental factors contribute to fatigue and negatively affect operational performance.

Environmental stressors, including high levels of sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), and chloride ions (Cl^-), along with fluctuating temperature and humidity, create a challenging work environment that contributes to increased physiological and cognitive stress, reducing worker efficiency and increasing the likelihood of errors. Studies indicate that prolonged exposure to these pollutants can lead to respiratory issues and cognitive impairment, further exacerbating fatigue (López et al., 2012). The combination of fatigue, air pollution, and thermal discomfort can result in decreased productivity, higher absenteeism, and an elevated risk of occupational illnesses.

This study evaluates the correlation between environmental conditions and fatigue levels in industrial process workers, providing empirical data to support ergonomic interventions. Climatic factors such as temperature fluctuations and high humidity levels have been linked to reduced worker efficiency and increased stress levels (López et al., 2011), while adverse environmental conditions have been shown to significantly lower productivity and quality indices in industrial processes (López et al., 2008). Given these considerations, this research emphasizes the necessity of integrating environmental factors into ergonomic strategies to enhance workplace conditions, ultimately improving worker well-being and performance.

1.1 Fatigue of workers in industrial processes

Fatigue is a multifactorial issue influenced by physical exertion, environmental stressors, and physiological responses to workplace conditions. Prolonged exposure to high temperatures, humidity, and air pollutants can disrupt homeostasis, increasing metabolic stress and cognitive load. This condition manifests as exhaustion, lack of energy, and reduced focus, which can be exacerbated by overwork, inadequate sleep, poor nutrition, and exposure to environmental hazards such as air pollutants and climate variations. In industrial settings, particularly in the electronics manufacturing industry, these factors contribute to worker discomfort, diminished performance, increased error rates, and higher occupational health risks. When fatigue becomes persistent, it can lead to disengagement, incorrect task execution, and incomplete operations, ultimately reducing productivity and affecting quality indices (Wallbanks et al., 2024).

1.2 Environmental temperature and humidity impact on fatigue

Workers on assembly lines frequently experience thermal stress due to inadequate temperature and humidity regulation, which can lead to muscle fatigue and decreased efficiency. Research indicates that temperatures exceeding 30°C and humidity levels above 60% contribute to dehydration, reduced muscular endurance, and increased fatigue due to thermal stress (Zhou, 2023). Additionally, high humidity affects fine motor skills, increasing defect rates in manufacturing processes (Baillot, 2021). Given these findings, ensuring proper environmental controls is essential to mitigating these negative effects and enhancing worker performance in the electronics industry.

In electronic device manufacturing environments, thermal regulation and relative humidity are crucial to avoid products failures, but also have a significant impact on workers' fatigue. Surangsrirat (2019) finds that employees exposed to temperature variations in test rooms experienced an increase in heart rate and thermal stress, which increased accumulated fatigue. Similarly, Ogan and Moldovan (2024) investigated the impact of temperature and humidity on the quality of electronic products in the automotive industry, concluding that inappropriate environmental conditions not only affect the health of employees, but also the reliability of electronic components, increasing the rate of quality test failures.

The Costa (2018) study was a scientific study where were evaluate how environmental conditions affect mental fatigue in tasks that require precision, concluding that temperatures greater than 28 ° C reduce response capacity and increase the errors rate in assembly processes. In addition, Staliulionis (2022) analyzed the impact of moisture on electronic circuit assembly, demonstrating that high humidity conditions increase work stress and mental fatigue due to the pressure of maintaining quality standards. Which shows that even moderate thermal stress and humidity can affect the cognitive performance of workers.

1.3 Linking between environmental pollutants and fatigue in industry

Prolonged exposure to environmental pollutants such as PM2.5 and PM10 particles, nitrogen dioxide (NO_2), carbon monoxide (CO), and volatile organic compounds significantly increases fatigue in workers, compromising both physical and cognitive performance. According to Wallbanks (2024), the inhalation of polluting particles alters cell metabolism and generates systemic inflammation, leading to persistent exhaustion. Similarly, Rayroux (2020) found that chronic exposure to these pollutants increases symptoms such as dizziness, generalized weakness, and lack of concentration, directly affecting work capacity and decision-making in industrial environments. Inadequate ventilation in manufacturing settings exacerbates these effects, creating a cycle of reduced productivity, increased absenteeism, and heightened fatigue levels. Implementing air quality controls and ergonomic interventions is essential to mitigating these risks and improving worker well-being.

The combination of fatigue and exposure to air pollutants increases the risk of developing diseases, which promotes a vicious circle of decreased performance and deterioration of health. Gruet (2018) pointed out that patients with chronic pulmonary diseases have an increase in fatigue due to the reduction in blood oxygenation, an effect that is exacerbated in environments with contaminated air. Likewise, Xue (2020) indicated that pollution contributes to greater inflammation of the respiratory tract, which aggravates fatigue and susceptibility to infections. This effect has been observed in industry workers exposed to toxic emissions, where levels of job absenteeism and productivity reduction have been higher compared to those who work in cleaner air environments. These research underlines the importance of implementing preventive measures to mitigate the combined effects of pollution and fatigue, including the improvement of air quality in work spaces and the adoption of ergonomic strategies towards the reduction of labor fatigue.

1.4 Air pollution in the electronic industry

The presence of air pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NO_X), carbon monoxide (CO) and chloride ions (CL-); In addition to variations of climatic factors such as relative humidity (HR, %) and temperature (T, ° C), they can generate aggressive environments in the areas of industrial processes, and thus cause the generation of acute and serious respiratory diseases (chronicles)., As shown in figures 1 and 2 (Lopez, et al, 2012). The evaluations showed a decrease in operational performance of up to 30% in workers who suffered from some respiratory symptoms, evaluating the number of medical visits to the health area of the industrial company where the scientific study and public health institutions were made (Instituto Mexicano del Seguro Social-IMSS) (Elbarbary, et al, 2021).

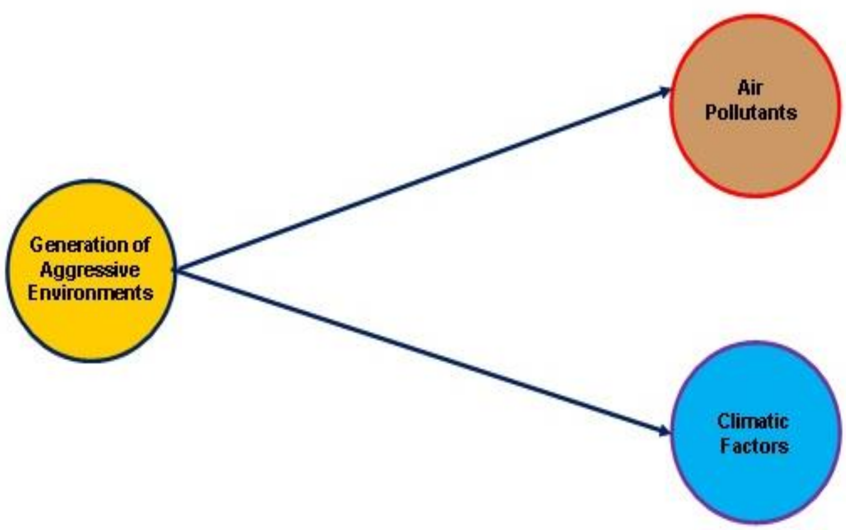


Figure 1. Relevant aspects of the generation of aggressive environments in the interiors of the electronics industry. Source. Analysis of the investigation

This way, you can occasionally take care of people who develop their activities in the production lines, originating health symptoms, mainly respiratory infections such as influenza or illnesses that affect the pulmonary and cardiovascular systems.

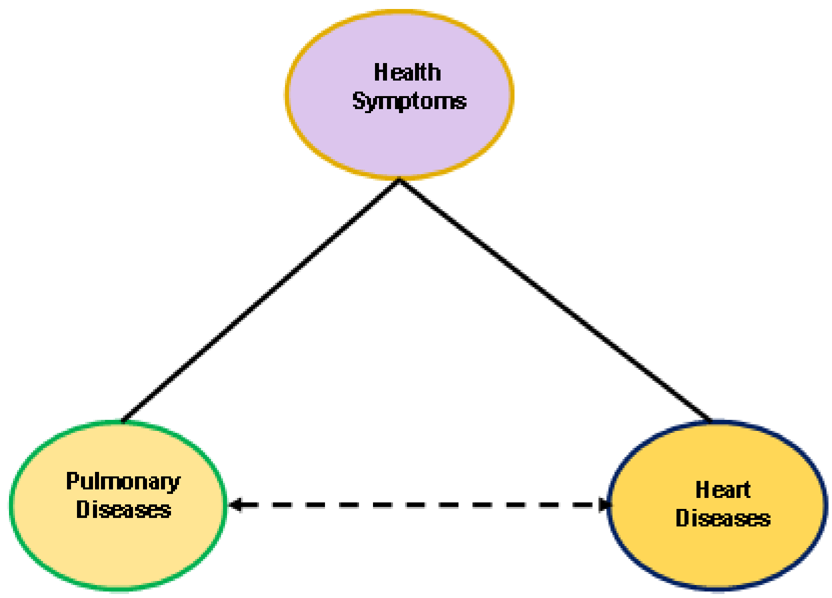


Figure 2. Main enclosures due to inadequate atmospheric conditions in the electronic industry.
Source. Analysis of the investigation

Due to the presence of these health symptoms, the workers in the manufacturing areas, they can reduce their operational performance, affecting the levels of productivity and quality of the manufactured products (Gruzieva, et al, 2022). Based on this, we develop evaluations of air and climate indices in the interiors of the industry that allow us to made the investigation, in addition to analyzing the number of workers in industrial processes, who visit the medical area of the industrial company evaluated and security institutions. social of the city of Tijuana. Likewise, we will evaluate the productivity and quality indices of the workers on a production line to develop the correlation analysis.

1.5 The Electronics Industry in the Global Economy

This type of industry plays a key role in the economy of countries where industrial plants are established, manufacturing a wide variety of electronic products. Among the most common and widely used are mobile phones, computers, and tablets, as well as electronic components for automobiles, airplanes, trains, and household appliances. Additionally, countries that trade these types of products generate significant economic profits. Figure 3 presents an analysis of the main economic factors in the electronics industry, specifically in manufacturing processes (Li, et al., 2021).

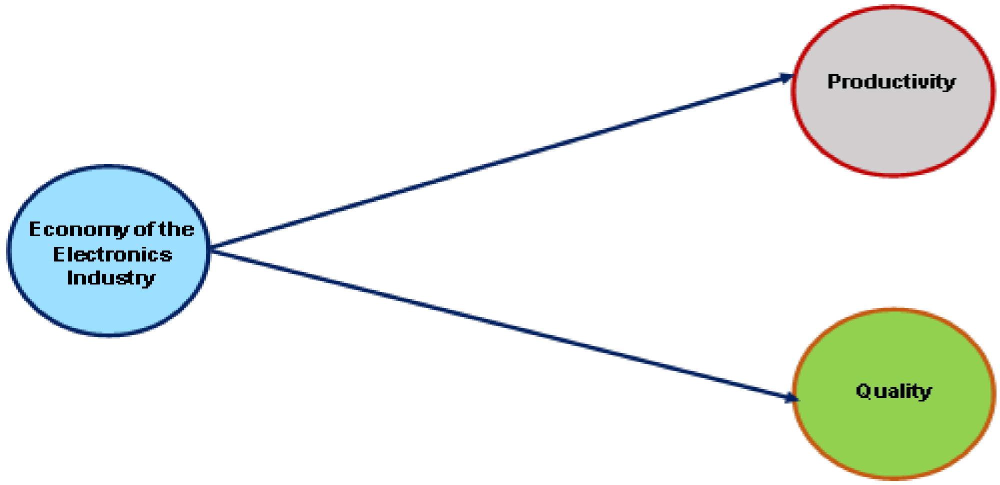


Figure 3. Factors of the economy of an electronic industry.
Source. Analysis of the investigation

In this scientific study, relevant information was obtained regarding the statistical correlation between atmospheric conditions and specialized equipment, as well as the operational performance of workers in manufacturing areas. This analysis considered the fluctuations in the incidence rates of respiratory diseases among manufacturing workers (Anderson, 2012). The study was conducted in an industrial company that manufactures mobile phones, located in the city of Tijuana. This company carries out specific industrial processes that generate heat, leading to an increase in temperature levels. Additionally, the use of chemical substances—such as sulfur and chloride derivatives, as well as hydroxides—is involved in microchip washing procedures (López et al., 2008).

Furthermore, the study considered airborne pollutants that infiltrate through openings, crevices, air conditioning systems, and the roof, without any filtration mechanisms to detect and prevent their entry. These factors contribute to the creation of aggressive indoor environments within the evaluated company. The study observed that by installing detection and filtration systems, as well as implementing control measures for the evaluated parameters (temperature and relative humidity), there was a reduction in the incidence rates of respiratory diseases among manufacturing workers in the studied industry. This, in turn, resulted in increased productivity levels (AMM, 2024).

1.6 Correlation of labor and atmospheric conditions in the electronic industry

The activities of the electronic industry of any part of the world, must have very strict regulations, depending on the use of materials that may suffer from damage due to the presence of aggressive environments, they are formed by internal activities for washing processes of metal materials, or of the exterior of vehicular or industrial sources; mainly (Lopez, et al, 2012). These aggressive environments may damage industrial equipment and machinery, as well as the health of workers, in many cases, the operational performance may diminish and this may sometimes be the case in which the goals are fulfilled in each evaluated period (Brunekreef, et al, 2011), as is show in figure 4.

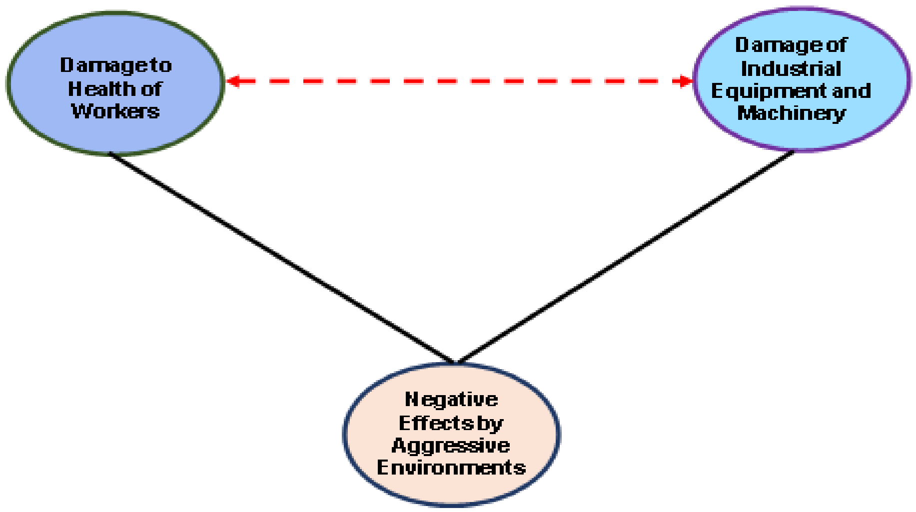


Figure 4. Important parameters of the presence of aggressive environments. Source. Analysis of the investigation

This investigation is focused on the health of the operating personnel who perform their duties in the manufacturing production lines of the industrial company that allowed the development of this scientific study (Gruzieva, et al, 2022). The main parameters analyzed were the air and climate pollutants mentioned above. From the evaluation of the statistical correlation carried out, information was obtained that mentions that chemical substances derived from sulfur and chlorine (even in micro parts per million scale), when the company's indoor environment in the manufacturing areas was not controlled (Goldberg, et al, 2010). These pollutants, together with climate variations with relative humidity and temperature parameters, were those that caused a greater effect in the generation of acute respiratory infections, increasing up to 35% at the beginning of the research period and decreasing to 10% when the environment of atmospheric conditions in the interiors of the industrial process areas of the evaluated industry was controlled (Elbarbary, et al, 2021).

1.7 Manufacturing processes in the electronics industry.

The electronics industry is a pillar in the economy of the countries where they are located due to the large number of products manufactured in this type of industrial company and high impact with technology, and the great diversity of users who buy electronic products. These electronic products require various of operation, different types of manufacturing processes and various applications (López, et al, 2011), which are shown in table 1.

Table 1. Activities of the electronics industry

Electronic Products	Industrial Operations	Manufacturing Processes
Commercials	Ma, Au, MC	BL, BIF
Aerospace	Ma, Au, Mi	BL, BP
Domestic	Ma, Au, MC	BL, BQM
Industrial	Ma, Au, Mi	BQM, BIF
Medical	Ma, Au, MC	BL, BP

Ma. Manual, Au. Automatized, Mi. Mixed, MC. Manufacturing Cells by Lots, BP. By Production, BIF. By Industrial Flow, BQM. By Quanty or Mass.

1.8 Environmental Pollution and Respiratory Diseases in the Electronics Industry

The generation of air pollutants from sources such as vehicular traffic and industries established in numerous cities around the world, which infiltrate industrial facilities through gaps, air conditioning systems, roofs, and wall openings, can create aggressive environments (Li et al., 2021). These types of environments may lead to complex situations in manufacturing areas, including the development of respiratory diseases and damage to industrial equipment and machinery.

In addition to external sources of air pollutant generation, environmental pollution can also originate from industrial processes within the electronics industry, further increasing air pollution levels and the severity of aggressive environments (López et al., 2008). Among the previously mentioned air pollutants, sulfur-derived compounds are the most detrimental, affecting both industrial process workers and industrial equipment and machinery. Regarding the impact on personnel working in manufacturing areas, this type of air pollution can cause acute respiratory infections, leading to worker discomfort in industrial processes and, consequently, reduced productivity, as illustrated in Figure 3 (Gruzieva et al., 2022).

Table2. Air Quality Standards Information (EPA-SEMARNAT)

Air Pollutants	Average Level, 1 Hour	Average Level, 8 Hours
Cl^{-}**		
CO*	35 ppm	9 ppm
NO_X*	100 ppb	53 ppb
SO_2*	75 ppb	10 ppb

* Source. https://www.epa.gov/criteria-air-pollutants/naaqs-table
** Volhard Method.

Acute respiratory diseases These types of diseases occur in people, mainly in industrial process workers in the electronics industry anywhere in the world, and are generated by aggressive environments inside industrial plants, causing different types of respiratory diseases and in each period of the year in each worker who works in industrial activities. The most common acute respiratory infections are bronchitis, flu and pneumonia, which were the most prevalent in this relevant research (Wyatt. Et al, 2022).

2. METHODOLOGY

This study employed real-time environmental monitoring using the TESTO 300 device to measure pollutant levels (SO_2, NO_x, CO) and the HACH monitor for Cl^- detection. Additionally, worker fatigue levels were assessed through subjective surveys and physiological indicators. Data were analyzed to establish correlations between environmental factors and worker performance metrics, based on the following activities:

a) Evaluation of visits by workers from manufacturing areas to the company's medical center and clinics of the Mexican Social Security Institute (IMSS) of the electronics industry analyzed.
b) Analysis of operational performance of the operational staff of a production line of the industrial company that allowed the scientific study to be carried out.
c) Evaluation of levels of the air pollutants mentioned above.
d) Correlation analysis of occupational health indices, atmospheric conditions (air pollutants and climatic parameters) and operational performance of workers on a production line with 20 employees (production and quality).
e) Evaluation of Fatigue in Operational Personnel in the Manufacturing Areas of the Analyzed Electronics Industry Due to Exposure to the Mentioned Air Pollutants and Variations in Temperature and Relative Humidity.

3. RESULTS

This section presents the findings regarding the correlation between environmental conditions and worker fatigue in the electronics industry, categorized into occupational health impacts, operational performance analysis, and the statistical correlation between fatigue and environmental stressors. The initial evaluations revealed significant concerns among management, supervision, and specialized personnel due to the low operational performance of workers in the manufacturing areas, which was closely linked to fatigue caused by environmental factors. However, after implementing improvement measures, a reduction in acute respiratory infections was observed, accompanied by an increase in worker performance, productivity, and quality indices. These results highlight the critical role of environmental conditions in fatigue management and reinforce the need for ergonomic interventions to improve workplace well-being and efficiency.

3.1 Operational performance analysis of workers in manufacturing areas

An analysis of the operational performance of the industrial process operating personnel in the manufacturing areas was carried out, in order to evaluate some circumstances that could affect operational performance, and to be able to correlate it with the indoor climate conditions of the industrial company, where this scientific study was carried out. Figure 5 shows what was described above, where an analysis of the operational performance of men with the orange color and of women with the sky-blue color is observed, indicating that the percentage levels of operational performance of men are higher than that of women, because 13 men and 7 women (20 in total) were evaluated, who make up the evaluated production line of the electronics industry that allowed the research. The percentage rates of operational performance for men range from 40% to 89%, and for women from 20% to 70%, resulting in an increase in productivity and quality levels.

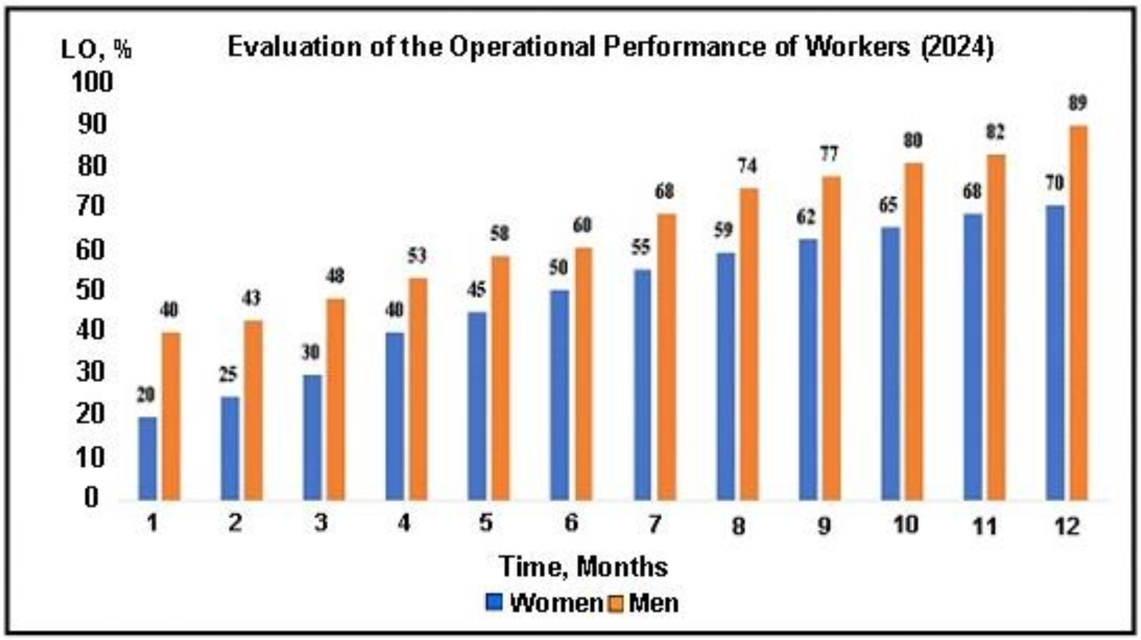


Figure 5. Operational Performance of Workers by Sex in the research (2024).
Level of Operational Performance – LO, %

3.2 Correlation analysis of the environment, occupational health and operational performance

This factor is very relevant to maintain a clean and suitable environment for manufacturing activities in the electronics industry where the scientific study was conducted. Table 3 represents the levels of atmospheric pollution (which includes the analysis of air pollutants and climatic parameters), correlated with the presence of the three main acute respiratory infections that occurred in this research. This table shows the relationship that exists in the generation of respiratory diseases, and the presence of the air pollutants evaluated and described above, observing that the presence of chloride ions from the sea breeze in this marine environment, where the evaluated industrial company is located, generated the flu symptom, as well as the other air pollutants analyzed. While the presence of carbon monoxide generated flu and bronchitis, and the generation of bronchitis, flu and pneumonia, was associated with the presence of sulfur dioxide and nitrogen oxides.

Table 3. Analysis of labor health and atmospheric pollution in the electronics industry (2024)

Atmospheric Pollution	Air Pollutants				Climatic Parameters		Observations
Respiratory Diseases	**Cl^-**	**CO**	**NO_X**	**SO_2**	**RH, %**	**T, °C**	
Bronchitis		X	X	X			
Flue	X	X	X	X			
Pneumonia			X	X			

Once the parameters mentioned above were evaluated, a correlation analysis of the occupational health factors, environmental conditions and operational performance of workers in manufacturing areas in the evaluated electronics industry was carried out. Figure 6 shows what has been described, and illustrates the percentage indices of operational performance with the occupational health factor, together with air pollutants and climatic parameters, starting from 0% to 25% of the orange color, from 26% to 50% of the strong blue color, from 51% to 75% of the gray color and from 76% to 100% of the sky-blue color; being the percentage indices of the operational performance of the workers.

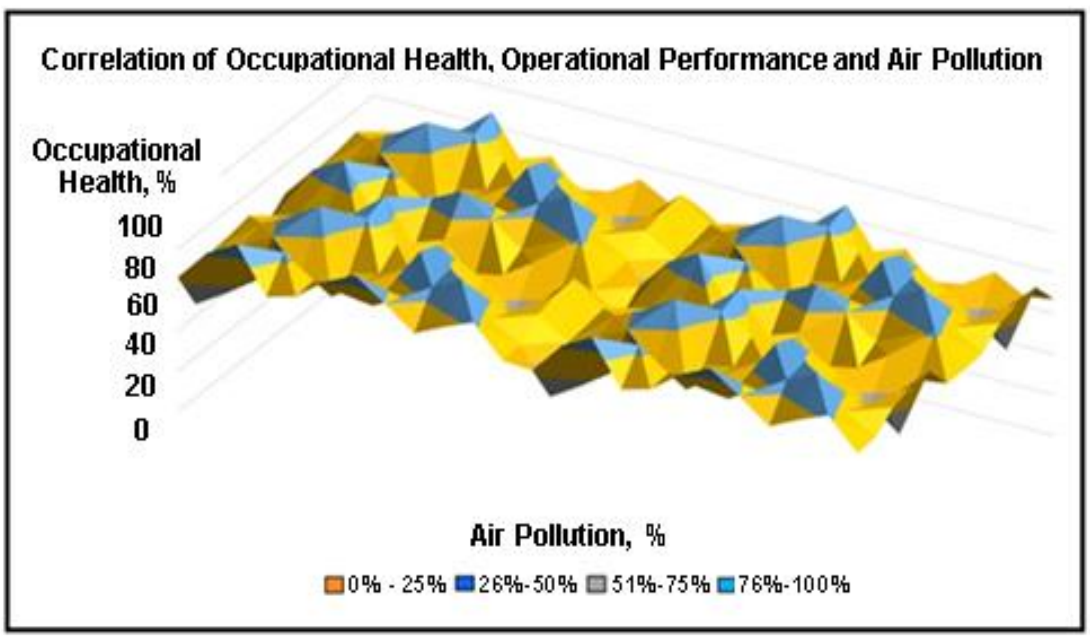


Figure 6. Correlation analysis of occupational health, operational performance and air pollution in the electronics industry (2024).

The figure above indicates that it is necessary to evaluate the correlation of the parameters described in this image, being very relevant in generating the increase in the levels of productivity and quality of the manufactured products in this industrial company.

3.3 Correlation analysis of air pollution and climate with fatigue in workers

A correlation analysis was carried out on the presence of the air pollutants mentioned above and the variations in temperature and relative humidity inside the electronics industry evaluated. This was important because the correlation analysis indicates that the presence of air pollutants and climate variations were generated by the industrial activities of this industrial plant where the research was carried out and by the outdoor environmental conditions of the city of Tijuana, considered as a marine environment, presented in Table 4.

Table 4. Correlation analysis of air pollution and climatic factors with fatigue in workers (2024)

Factors Evaluated															
Months	**Fatigue Nivel, %**					**Productivity, %**					**Quality, %**				
	SO_2	**NO_X**	**CO**	**T**	**HR**	**SO_2**	**NO_X**	**CO**	**T**	**HR**	**SO_2**	**NO_X**	**CO**	**T**	**HR**
January	86	77	68	57	49	47	56	67	59	67	39	43	59	54	60
February	82	73	65	55	47	49	59	65	64	69	42	47	64	58	64
March	80	70	64	53	46	52	60	68	60	74	44	49	68	63	63
April	76	67	66	51	44	58	61	70	63	77	47	53	66	66	67
May	77	68	62	50	47	67	58	72	67	79	49	55	70	67	68
June	73	64	60	46	48	64	60	70	66	83	50	58	74	69	70
July	71	66	56	47	44	74	63	73	70	82	53	59	76	73	74
August	70	62	58	44	40	72	65	75	74	80	55	60	77	78	75
September	67	60	55	43	35	71	66	77	75	82	57	66	80	76	78
October	66	58	54	42	33	70	69	76	79	84	64	70	84	77	80
November	64	56	55	40	30	75	70	77	80	80	68	75	83	79	84
December	63	55	53	37	29	70	73	80	83	83	73	79	80	80	82

The last figure indicates that it is necessary to evaluate the correlation of the parameters described in this image, being very relevant in generating the increase in the levels of productivity and quality of the manufactured products in this industrial company.

3.4 Impact of Environmental Stressors on Worker Fatigue and Productivity

The analysis demonstrated that exposure to high levels of air pollutants, including SO_2, NO_x, CO, and Cl^-, contributed to increased fatigue symptoms among workers.

A 35% rise in reported fatigue symptoms was observed in high-pollution environments. Additionally, these conditions led to an increase in respiratory symptoms such as shortness of breath, coughing, and general discomfort, further impacting worker well-being.

Fatigue directly influenced operational efficiency. Workers exposed to elevated environmental stressors experienced a 30% decline in performance, marked by increased task completion times, reduced accuracy, and higher absenteeism rates. The correlation analysis indicated that excessive fatigue led to frequent errors, ultimately affecting production quality and workflow efficiency.

A statistical correlation between environmental conditions and worker fatigue revealed that areas with poor air quality and high temperature/humidity levels showed the highest incidence of fatigue-related issues. The data supported a strong link between environmental stressors and reduced productivity, emphasizing the importance of implementing workplace interventions to mitigate these effects.

Temperature and humidity fluctuations played a critical role in exacerbating fatigue symptoms. Workers operating in conditions above 30°C and 60% humidity exhibited signs of dehydration and thermal stress, leading to faster onset of fatigue. These findings reinforce the necessity of integrating environmental controls into ergonomic strategies to enhance worker resilience and overall workplace safety. The analysis showed a 35% increase in fatigue symptoms in high-pollution environments, leading to a 30% decrease in operational performance. Temperature and humidity variations further exacerbated fatigue levels, reinforcing the need for environmental controls in industrial ergonomics.

4. CONCLUSIONS

This study highlights the critical need to integrate environmental stressors into ergonomic assessments, recognizing their direct impact on worker fatigue and overall operational performance. The findings demonstrate that air pollutants, temperature fluctuations, and humidity variations contribute significantly to fatigue levels among industrial workers, leading to decreased productivity, increased error rates, and heightened occupational health risks.

The implementation of workplace interventions, such as improved ventilation, thermal regulation, and exposure monitoring, has proven effective in reducing fatigue and enhancing worker well-being. Specifically, structural improvements, including air filtration systems and controlled climatic conditions, have mitigated respiratory issues and fatigue-related symptoms, ultimately optimizing operational performance. The study also underscores the broader economic benefits of these interventions, as reducing fatigue leads to higher productivity, improved product quality, and decreased absenteeism.

Future research should further explore adaptive ergonomic strategies to mitigate the combined effects of air pollution and climate-related stressors in industrial settings. By incorporating environmental controls into ergonomic frameworks, industries can create safer, more efficient work environments, ensuring long-term worker health and sustainable productivity.

5. REFERENCES

Anderson J., Thundiyil J., Stolbach A. (2012). Clearing the air: a review of the effects of particulate matter air pollution on human health, Med Toxicol. 2012 jun;8(2):166-75. Doi: 10.1007/s13181-011-02031.PMID: 22194192

AMM- Asociación de Maquiladoras de Tijuana (2024). Anuario Estadístico de la Industria de Tijuana, Baja California, México.

ASTM (2011). International, Standard Guide for Measurement Systems Analysis (MSA), ASTM E278211e1.

Baillot, M., Hue, O., Tran, T. T., & Antoine-Jonville, S. (2021). Neuromuscular Activity during Cycling Performance in Hot/Dry and Hot/Humid Conditions. Life (Basel, Switzerland), 11(11), 1149. https://doi.org/10.3390/life11111149

Brunekreef B., Beelen R., Hoek G., Schouten L., Bausch-Goldbohm S., Fischer P., Armstrong B., Hughes E., Jerrett M., VanDen B. (2011). Effects of long-term exposure to traffic-related air pollution on respiratory and cardiovascular mortality in the Netherlands: the NLCS-AIR study P. Res Rep Health Eff Inst. 2009 Mar;(139):5-71; discussion 73-89. PMID: 19554969.

Costa, E. Q., Baptista, J. S., & Carvalho, J. (2018, March 29). Mental Fatigue Assessment in Different Thermal Environments – Protocol. Journal of Tourism, Sustainability and Well-Being, 6(1), 29-39. Retrieved from https://www.jsod-cieo.net/journal-tsw/index.php/jtsw/article/view/117

Elbarbary M., Oganesyan A., Honda T., Morgan G., Guo Y. (2021). J. Int J Environ Res Public Health. 2021 Mar 22;18(6):3258. Doi: 10.3390/ijerph18063258.PMID: 33809857.

Gruet, M. (2018). Fatigue in Chronic Respiratory Diseases: Theoretical Framework and Implications for Real-Life Performance and Rehabilitation. Frontiers in Physiology, 9, 1285.

Goldberg M., Bailar J., Burnett R., Brook J., Tamblyn R., Bonvalot Y., Ernst P., Flegel K., Singh R., Valois M. (2010). Identifying subgroups of the general population that may be susceptible to short-term increases in particulate air pollution: a time-series study in Montreal, Quebec, Res Re;/p Health Eff Inst. 2000 Oct;(97):7113; discussion 115-20. PMID: 11244610

Gruzieva O., Jeong A., He S., Yu Z., De Bont J., Pinho M., Eze I., Kress S., Wheelock C., Peters A., Vlaanderen J., De Hoogh K., Scalbert A., Chadeau-Hyam M., Vermeulen Ch., Gehring U., Probst-Hensch N., Mélen E. (2022). “Air pollution, metabolites and respiratory health across the life-course”, European Respiratory Review, Q1 .

Li Z, Liu Y, Lu T, Peng S, Liu F, Sun J, Xiang H. (2021). Acute effect of fine particulate matter on blood pressure, heart rate and related inflammation biomarkers: A panel study in healthy adults, Ecotoxicol Environ Saf. 2021 Nov 24; 228:113024. Doi: 10.1016/j.ecoenv.2021.113024. Online ahead of print. PMID: 34837873.

López G., Tiznado H., Herrera G. S., “Use of AES in corrosion of copper connectors of electronic devices and equipment in arid and marine environments,” Anti-Corrosion Methods and Materials, vol. 58, no. 6, pp. 331–336, 2011. ISA

S71.04; ANSI/ISA S71.04-198, Environmental Conditions for Process measurement and Control Systems: Airborne Contaminants, 2011.

Lopez B. G., Valdez S.B., Schorr W.M., and Navarro C. G. (2012). “Microscopy and spectroscopy of MEMS used in the electronic industry of Baja California region Mexico,” in Air Quality-New Perspective, INTECH, 2012.

Ogrean SA, Moldovan L (2024) Impact of humidity and temperature on quality of automotive products. Acta Marisiensis. Seria Technologica, Vol 21 (XXXVIII) no. 1.

Rayroux, C., Gasche-Soccal, P., & Janssens, J. (2020). Air pollution and its impact on the respiratory system. Revue Médicale Suisse, 16(715), 2211-2216

Staliulionis, Zygimantas & Mohanty, Sankhya & Hattel, Jesper & Miliauskas, Gintautas. (2022). Numerical Modelling of Humidity Behavior in the Electronics Housing. 1-6. 10.1109/IEEECONF55059.2022.9810469.

Surangsrirat, D., Dumnin, S., & Samphanyuth, S. (2019). Heart Rate, Skin Temperature and Skin Humidity and their Relationship to Accumulated Fatigue. 2019 3rd International Conference on Bio-engineering for Smart Technologies (BioSMART), 1-4.

Wallbanks S., Griffiths B., Thomas M., Price O., Sylvester K. (2024). “Impact of environmental air pollution on respiratory health and function”, Physiological Reports.

Wyatt L, Kamat G, Moyer J, Weaver AM, Diaz-Sanchez D, Devlin RB, Di Q, Schwartz JD, Cascio WE, Ward-Caviness CK. (2022). Associations between short-term exposure to PM2.5 and cardiomyocyte injury in myocardial infarction survivors in North Carolina Heart. 2022 jun;9(1): e001891. Doi: 10.1136/openhrt2021-001891.PMID: 35750420.

Xue, Y., Chu, J., Li, Y., & Kong, X. (2020). The influence of air pollution on respiratory microbiome: A link to respiratory disease. Toxicology Letters, 332, 7-15.

Zhou, B., Chen, B., Liu, J., Ao, Y., & Ding, L. (2023). Effect of ambient temperature and humidity on muscle fatigue of pilots. Social and Occupational Ergonomics.

ERGONOMIC DEVICE FOR CALCULATING DYNAMIC FORCES IN HIGH-VARIABILITY AND NON-STANDARDIZED WORK ACTIVITIES.

Nadia Yamileth Bermúdez López, ORCID 0009-0000-4600-7329, Rolando Diaz García, ORCID, Alexa Gabriela Bustamante Grijalva, ORCID[3] 0009-0000-4863-2400, Juan Carlos Inzunza Romero, ORCID[4] 0009-0004-8743-6129, Alejandro Zubiate Martínez, ORCID 0009-0004-4632-6249[5]

Department of engineering
Tecnológico Nacional de México /Instituto Tecnológico de Agua Prieta
Carretera a Janos
Avenida Tecnológico s/n, Colonia Progreso.
Agua Prieta, Son, 84268

Corresponding author's e-mail: n.bermudez@aguaprieta.tecnm.mx

Resumen: El manejo manual de materiales es una de las actividades laborales más comunes en diversos sectores productivos y representa una necesidad fundamental para la transformación de materia prima en productos terminados. Sin embargo, estas tareas no aportan directamente al proceso de transformación, sino que funcionan como un complemento, lo que subraya la importancia de minimizar su impacto.

El manejo manual de materiales es, además, una fuente significativa de riesgo de lesiones musculoesqueléticas debido a las demandas físicas asociadas. Estas tareas suelen implicar movimientos repetitivos y cargas variables que aumentan la probabilidad de daños estructurales en el sistema musculoesquelético, especialmente cuando se realizan en entornos laborales no estandarizados y con alta variabilidad. En este contexto, la ergonomía desempeña un papel clave al diseñar estrategias y herramientas que permitan evaluar, prevenir y mitigar estos riesgos de manera eficiente.

Los métodos tradicionales para calcular las fuerzas involucradas en estas tareas tienden a basarse en modelos estáticos que no consideran las dinámicas inerciales ni la variabilidad en los patrones de movimiento. Esto genera estimaciones inexactas que dificultan la implementación de medidas ergonómicas efectivas. Además, muchas herramientas disponibles son invasivas o de difícil aplicación en entornos laborales reales, lo que limita su aceptación por parte de los trabajadores y empleadores.

En respuesta a estas limitaciones, este proyecto propone evaluar un dispositivo ergonómico no invasivo diseñado para calcular fuerzas dinámicas durante la flexión del antebrazo en actividades laborales de alta variabilidad. Este dispositivo combina sensores inerciales, modelos antropométricos y algoritmos de procesamiento de datos en una aplicación móvil práctica y accesible. La aplicación estima las fuerzas ejercidas por el músculo bíceps a partir del tiempo de actividad y la suma de las masas segmentales del antebrazo, la mano y la carga manipulada por el operador.

Por su facilidad de uso y versatilidad, el dispositivo es especialmente adecuado para tareas en varios sectores. Hasta este momento se ha aplicado en: albañilería, el manejo de materiales en ferreterías, madererías, llanteras, gaseras, dulcerías y purificadoras de agua. Estas actividades representan tareas de alta demanda física y condiciones laborales diversas, fueron seleccionadas para esta investigación debido a su relevancia ergonómica y su alta variabilidad en los patrones de movimiento.

Palabras clave: Fuerza dinámica, manejo manual de cargas, entornos laborales no estandarizados.

Relevancia para la ergonomía: La aplicación del dispositivo móvil diseñado para calcular fuerzas dinámicas, ha hecho posible evaluar de manera precisa y no invasiva tareas laborales en entornos no estandarizados y con alta variabilidad, como madererías, gaseras, llanteras y albañilería. La integración de sensores inerciales, modelos del cuerpo humano y procesamiento automatizado ha facilitado la identificación de riesgos ergonómicos, proporcionando información clave para prevenir lesiones musculoesqueléticas y mejorar las condiciones laborales. Esto representa un importante avance hacia la implementación de tecnología accesible dentro del marco de la práctica ergonómica moderna.

Abstract: Manual material handling is one of the most common work activities across various productive sectors and represents a fundamental necessity for transforming raw materials into finished products. However, these tasks do not directly contribute to the transformation process but rather serve as a complement, highlighting the importance of minimizing their impact.

Moreover, manual material handling is a significant source of musculoskeletal injury risk due to the associated physical demands. These tasks often involve repetitive movements and variable loads, increasing the probability of structural damage to the musculoskeletal system, especially when performed in non-standardized work environments with high variability. In this context, ergonomics plays a key role in designing strategies and tools that allow for efficient risk assessment, prevention, and mitigation.

Traditional methods for calculating the forces involved in these tasks tend to rely on static models that do not account for inertial dynamics or variability in movement patterns. This results in inaccurate estimations that hinder the implementation of effective ergonomic measures. Additionally, many available tools are invasive or difficult to apply in real work environments, limiting their acceptance among workers and employers.

To address these limitations, this project proposes evaluating a non-invasive ergonomic device designed to calculate dynamic forces during forearm flexion in highly variable work activities. This device combines inertial sensors, anthropometric models, and data processing algorithms in a practical and accessible mobile application. This application estimates the forces exerted by the biceps muscle based on activity duration and the sum of the segmental masses of the forearm, hand, and the load handled by the worker.

Due to its ease of use and versatility, the device is particularly suitable for tasks is various sectors. To date, it has been applied in construction work, material handling in hardware stores, lumberyards, tire shops, gas distribution companies, candy stores, and water purification plants. These physically demanding tasks with diverse working conditions were selected for this study due to their ergonomic relevance and high variability in movement patterns.

Keywords: Dynamic force, manual material handling, non-standardized work environments.

Relevance to Ergonomics:The application of the mobile device designed to calculate dynamic forces has enabled the precise and non-invasive assessment of work tasks in non-standardized and highly variable environments, such as lumberyards, gas distribution companies, tire shops, and construction work. The integration of inertial sensors, human body models, and automated processing has facilitated the identification of ergonomic risks, providing key information for preventing musculoskeletal injuries and improving working conditions. This represents a significant advancement in implementing accessible technology within the framework of modern ergonomic practice.

1. INTRODUCTION

Ergonomic evaluation in work environments is essential for identifying and mitigating risk factors that may lead to musculoskeletal disorders among workers (González-Morales et al., 2021).

Traditionally, these evaluations have relied on observational methods and questionnaires, which, although useful, may lack precision and objectify (López & Martínez, 2023).

In this context, the incorporation of non-invasive mobile devices emerges as a promising alternative, enabling more accurate and real-time measurements of the dynamic forces involved in various work tasks (Morales & Pineda, 2023).

The central issue addressed in this study lies in the need for accessible and reliable tools for ergonomic assessment in sectors with high task variability and low standardization (Arvizu et al., 2024).

Activities such as manual material handling in the construction, lumber, and gas industries present specific challenges due to the diversity of movements and postures adopted by workers (INSST, 2022).

The lack of precise evaluation in these environments can lead to an underestimation of risks and, consequently, a higher incidence of work-related injuries (Ergo IBV, s.f.).

The mobile device proposed in this study is characterized by its non-invasive design, meaning that its use does not interfere with workers' daily activities (Ramírez et al., 2023).

Additionally, its implementation requires minimal training facilitating its adoption in various work environments without significantly disrupting operations (Torres & Hernández, 2024).

The combination of ease of use and the ability to provide accurate data makes it a valuable tool for ergonomic assessment (González et al., 2021).

The reliability of the results obtained through this device has been supported by previous studies highlighting the effectiveness of mobile technologies is measuring ergonomic parameters (López & Martínez, 2023).

Recent research has demonstrated that using sensors integrated into mobile devices enables a detailed evaluation of postures and applied forces during work tasks, contributing to the early identification of risks and the implementation of effective preventive measures (Morales & Pineda, 2023).

This study focuses on the implementation of a non-invasive mobile device for ergonomic evaluation in work environments with high task variability. The problem addressed centers on the need for precise and easily adoptable tools that effectively identify ergonomic risks. The reliability and simplicity of the proposed device offer a viable solution for improving working conditions and reducing the incidence of musculoskeletal disorders among workers (Ergo IBV, s.f.).

2. OBJECTIVES

General objective:

Accurately calculate the dynamic forces exerted during forearm flexion in highly variable work tasks and non-standardized environments by applying a specifically designed mobile device that integrates inertial sensors, anthropometric models, and automated data processing.

Specific objectives:

1. Implement the designed mobile device in selected work activities, such as construction, hardware stores, lumberyards, tire shops, gas distribution companies, candy stores, and water purification plants, to calculate dynamic forces in non-standardized and highly variable environments.
2. Characterize the selected work activities in terms of movement patterns, handled loads, and operational conditions to establish specific parameters that allow for evaluating the mobile device's performance.
3. Assess the practical applicability and versatility of the device in real work environments, identifying its impact on ergonomic evaluation and proposing improvements based on the results obtained.

3. METHODOLOGY

This research follows a non-experimental, cross-sectional, and observational design, making it ideal for analyzing the dynamic forces involved in forearm flexion during specific work tasks. The non-experimental approach allows for observing and studying activities in their natural context without altering environmental variables, while the cross-sectional nature ensures that data is collected at a single point in the time for each task, providing a representative view of working conditions.

This study simple consisted of 30 operators, selected through convenience sampling, with inclusion criteria requiring a minimum of one-year experience in the work tasks belong to sectors with high variability, and low standardization, such as construction, hardware stones, lumberyards, tire shops, gas distribution companies, candy stores, and water purification plants. These activities were chosen due to the diversity of movement patterns, handled loads, and operational conditions, reflecting the high complexity of the analyzed work environments. To perform a detailed analysis of movement patterns and associated ergonomic factors, visual recordings were made through video documentation, capturing the operators' movements during the execution of the selected work tasks.

To evaluate the dynamic forces generated during the task, anthropometric measurements of the operators were taken, including the length, circumference, and segmental density of the forearm and hand. Measurements were conducted using a specific Measurement Guide, which provides visual reference points to ensure accuracy in anthropometric data collection. These physical measurements were then entered into a mobile application developed with Android technology, enabling automated data processing through inertial sensors, anthropometric models, and advanced computational algorithms.

The mobile application consists of three main screens. The first screen presents the Measurements Guide, displaying reference images to correctly measure the forearm length form the elbow point (MHR) to the wrist point (MBE). The second screen allows for entering anthropometric and load data, including the operator's gender, the mass of the handled load, movement duration, and the physical dimensions of the forearm and hand. The third screen displays the calculation results, including segmental masses, total mass, movement acceleration, and the calculated flexion force. Acceleration is determined using an exponential regression equation (1):

$$\propto = 0.7879e^{.3386(t)} \qquad (1)$$

Where $\propto$ represents the acceleration in m/s² and t is the time of movement in seconds. Equation (1) provides an accurate estimate of acceleration in nonlinear movements, allowing for proper modeling of real working conditions.

The mobile device was previously validated through a pilot test, comparing the dynamic forces recorded with those obtained using a manual dynamometer =, showing a significant correlation ($r = 0.85$, $p < 0.05$). This validation confirms the device's accuracy for use in real-world environments, offering a practical and non-invasive alternative for ergonomic assessment.

The methodological process followed included operator preparation, precise anthropometric measurement, automated calculation of dynamic forces, real-time visualization of results, and data storage for subsequent statistical analysis. The results obtained allow the identification of potential ergonomic risks and the proposal of improvement in working conditions, based on the recorded dynamic force and its impact on the operator's musculoskeletal system.

Finally, the study was conducted in accordance with the ethical principles of scientific research, obtaining informed consent from all participants and ensuring the confidentiality of the collected information.

4. RESULTS

The implementation of the mobile device designed to calculate dynamic forces has yielded relevant results in selected work activities with high variability and in non-standardized environments. The device, which integrates inertial sensors, anthropometric models, and automated processing algorithms, has been applied in sectors such as lumberyards, gas distribution, tire workshops, and masonry. These activities pose a challenge due to the diversity of movement patterns and the loads handled, allowing for the collection of useful data for ergonomic evaluation and biomechanical analysis. The results obtained for each activity are presented below:

Handling of wooden pallets in lumberyards:

Task description: The operator works in a lumberyard, specifically handling and arranging wooden pallets. Their primary task involves lifting, transporting, and organizing wooden planks, which entails manual handling of dynamic loads in a highly variable work environment.

In Figure 1, the operator is seen lifting a long and heavy wooden plank using a bimanual posture and applying force with both forearms and hands. The activity requires significant motor coordination, as the operator must maintain the plank's balance while moving towards the storage area. Additionally, the task involves a combination of arm flexion and extension movements, as well as trunk rotation, which could generate a considerate ergonomic load on the upper limbs and lower back.

The operator's anthropometric measurements, including the length and circumference of both forearms and hands, allow for the calculation of segmental masses needed to evaluate the dynamic forces exerted during the task. The recorded values were as follows:

- Right forearm: Length of 32 cm, circumference of 24 cm.
- Right hand: Length of 17.3 cm, circumference of 20.3 cm.
- Left forearm: Length of 28.5 cm, circumference of 24 cm.
- Left hand: Length of 17.4 cm, circumference of 20.5 cm.
- Total activity time recorded: 0.73 seconds.

1 **1 a)**

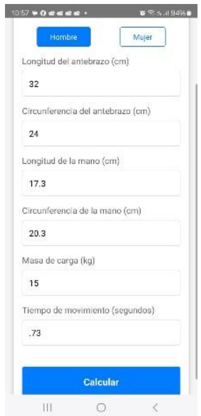
Figure 1 & 1 a), Lumberyard operator, handling a load and arm flexion.

During the lifting, transporting and stacking of wooden pallets, the device recorded dynamic force patterns associated with the variable weight of the pieces and stacking positions. The data showed that the highest effort moments occurred during the inertial lift from low positions, highlighting the need for ergonomic strategies to reduce the load on the lumbar spine.

The application of the device, specifically designed to calculate flexion force during arm flexion, provided precise and real-time quantitative results, enabling a detailed interpretation of the physical load placed on the operator. In Figure 2 illustrates the use of the mobile device in this task.

The data obtained from the mobile device indicated a segmental forearm mass of 1.1538 kg and segmental hand mass 0.3950 kg. The manipulated load during the task weighed 15 kg, resulting in a total considered mass of 16.5488 kg. The movement acceleration was calculated at 0.6154 m/s^2, using a previously validated exponential regression equation, and the calculated flexion force reached 1295.8432 N. These results provide a comprehensive overview of the physical effort required for the task, emphasizing the importance of evaluating applied force in specific work activities.

It is essential to consider that the flexion force calculation is per arm since the load is balanced. Thus, the total calculated force of 1295.8432 N is divided by two, resulting in an applied force per arm of 647.9216 N. This figure remains within the recommended limits of international ergonomics standards, ISO 11228-1, which suggest a 700 N limit for occasional tasks and 500 N for repetitive tasks. The balance in load distribution improves biomechanical efficiency, reducing asymmetric strain on the musculoskeletal system and preventing injuries in the elbow and shoulder joints.



2 **2 a)**

Figure 2 & 2 a), Mobile application results in wood stacking.

Handling of gas cylinders in gas distribution stations:

The task observed in the gas distribution station involved the lifting and arrangement of gas cylinders. This task entails the handling of heavy objects in an operational environment where safety and ergonomics play a crucial role in preventing musculoskeletal injuries.

In Figure 3, the worker is seen holding a gas cylinder with both hands, performing arm flexion while maintaining a relatively upright trunk position. Although this posturer appears controlled, it requires significant coordination between arm strength and trunk stability. The lifting is performed at a considerable height, increasing the effort needed at the elbow and wrist joints.

The operator’s anthropometric measurements reflect the physical characteristics necessary to accurately assess the dynamic force involved in the task. The lengths and circumference of the forearm and hand, along with the mass of each segment, allow for the calculation of the segmental and total load applied during the movement.

- The right forearm has a length of 29 cm and a circumference of 23.7 cm.
- The right hand has a length of 19 cm and a circumference of 22 cm.
- The left forearm has a length of 28 cm and a circumference of 23.9 cm.
- The left hand has a length of 18.5 cm and a circumference of 22 cm.
- The recorded time to complete the task was 0.9 seconds.

In summary, the task performed at the gas distribution facility presents significant physical challenges, particularly considering the weight of the gas cylinder and the need to maintain a safe posture during handling. The use of the mobile device will enable the quantification of the dynamic load applied and support the development of ergonomic strategies to reduce the risk of occupational injuries.

3 **3 a)**

Figure 3 & 3 a), Work at a gas filling station.

In the observed task at the gas station, the operator performs the lifting and positioning of gas cylinders, both in empty and full load conditions. Using the mobile device designed for the ergonomic evaluation of dynamic forces, detailed quantitative results were obtained, allowing for the analysis of the physical load imposed on the worker during this activity. In Figure 4 presents the results of the device application at the gas cylinder filling station.

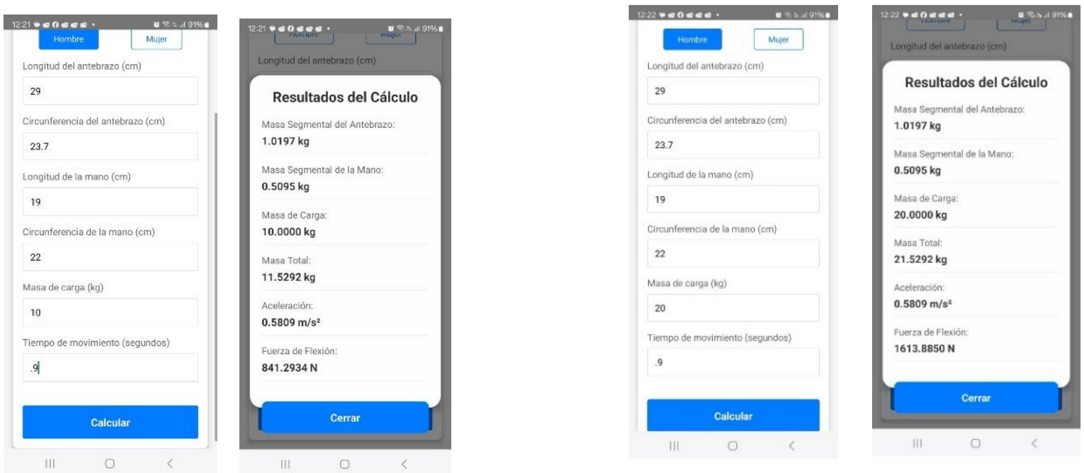
In the first scenario, with the empty cylinder, the load mass was 10 kg, and the recorded movement time was 0.9 seconds. Calculations performed by the device indicated a segmental mass of 1.0197 kg for the forearm and 0.5095 kg for the hand. The total mass considered in the analysis was 11.5292 kg, and the movement acceleration was estimated at 0.5809 m/s² using the exponential regression equation integrated into the mobile application. Under these conditions, the flexion force applied during the task was 841.2934 N.

In the second scenario, with the full cylinder, the load mass increased to 20 kg, while the movement time remained constant at 0.9 seconds. The segmental masses of the forearm and hand remained unchanged, as did the movement acceleration (0.5809 m/s²).

However, the total mass increased to 21.5292 kg, leading to a significant r The comparative analysis between both scenarios reveals the doubling the manipulated load mass results in a considerable increase in the required flexion force, from 841.2934 N to 1613.8850 N.

The difference of 772.5916 N highlights the direct impact of load mass on the physical effort required by the operator. Moreover, these results exceed the ergonomic limits recommended by ISO Standard 11228-1, which establishes a maximum of 500 N for repetitive tasks and up to 700 N for occasional activities.

Particularly in the scenario with the full cylinder, the recorded flexion force could pose a significant risk of musculoskeletal injuries, especially in the elbow and wrist joints, if the task is performed continuously without adequate rest periods.ise in the calculated flexion force, reaching 1613.8850 N.



4 **4 a)** **4 b)** **4 c)**

Figure 4, 4 a), 4 b) & 4 c), Results of the device application at the gas cylinder filling station.

Wheel rim handling in tire shops

The following application was conducted in a tire shop, where the operator performs the lifting and positioning of a car wheel rim, a task that requires strength and coordination due to the object's weight and physical characteristics.

5 **5 a)**

Figure 5 & 5 a), Task performed in a tire shop, arm flexion.

The operator uses both hands to hold the wheel rim, maintaining considerable arm flexion while his overall posture aligns with ergonomic recommendations for handling heavy objects. However, the inclination of the torso and the positioning of the upper limbs suggest a significant load on the forearm and wrist regions. In Figure 5 illustrates the operator's task.

The operator's anthropometric measurements are as follows:

- The right forearm has a length of 22.5 cm and a circumference of 28 cm.
- The right hand has a length of 19.3 cm and a circumference of 22.5 cm.
- The left forearm has a length of 22.5 cm and a circumference of 28.2 cm.
- The left hand has a length of 19 cm and a circumference of 22.5 cm.
- The recorded time to complete the task was 0.74 seconds.

The use of the mobile device for evaluating dynamic forces allowed for a detailed quantitative analysis of the effort exerted by the operator. In Figure 6 displays the results of the mobile device application.

6

6 a)

Figure 6 & 6 a), Results of the mobile device application in a tire shop.

The operator performs the task of handling an aluminum wheel rim, weighing 8 kg, in a time of 0.74 seconds. Anthropometric measurements showed that his right forearm has a length of 22.5 cm and a circumference of 28 cm, with a segmental mass of 1.1043 kg. The right hand, with a length of 19.3 cm and a circumference of 22.5 cm, has a segmental mass of 0.5413 kg.

The mobile device designed for the ergonomic evaluation of dynamic forces provided the following results:

- Total mass (including forearm, hand, and load): 9.6456 kg.
- Movement acceleration: 0.6133 m/s².
- Calculated flexion force: 574.2011 N.

The flexion force of 574.2011 N indicates the physical load exerted on the operator during the wheel rim lifting task. When distributed between both arms (considering that the load is held in a balance manner), this results in an approximate force of 287.1006 N per arm. This value falls within the recommended ergonomic limits.

Stacking concrete blocks in masonry:

The operator works as a construction laborer, performing the task of placing concrete blocks during the construction of a wall. This activity involves lifting, transporting, and positioning heavy blocks, imposing a significant demand on the operator's musculoskeletal system.

The operator's anthropometric measurements were recorded as follows:

- The right forearm has a length of 25 cm and a circumference of 28.5 cm.
- The right hand has a length of 19 cm and a circumference of 20.3 cm.
- The left forearm has a length of 24.8 cm and a circumference of 28.5 cm.
- The recorded time to complete the task was 0.77 seconds.

In Figure 7 displays the results of the mobile device application.

7

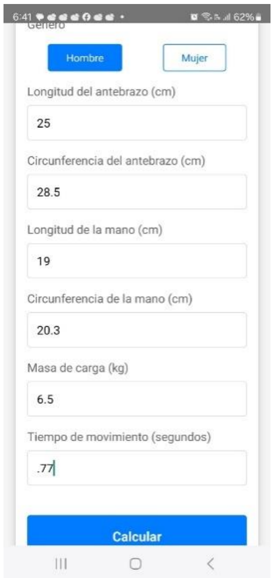
7 a)

Figure 7 & 7 a), Analysis of the activity in construction, manual handling of blocks.

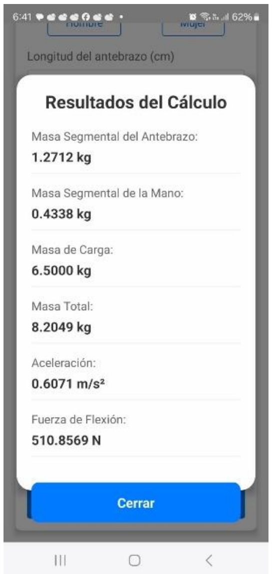
The construction operator performs the task of placing concrete blocks weighing 6.5 kg during the construction of a wall. This activity requires lifting, transporting, and positioning the blocks, implying a significant load on the worker's musculoskeletal system.

The results obtained from the application of the mobile device are presented in Figure 8 and detailed below:

- Segmental Mass of the Forearm: 1.2712 kg
- Segmental Mass of the Hand: 0.4338 kg
- Mass of the Handled Load: 6.5000 kg
- Total Considered Mass: 8.2049 kg
- Acceleration of Movement: 0.6071 m/s²
- Calculated Flexion Force: 510.8569 N



8



8 a)

Figure 8 & 8 a), Results of the mobile application in manual block handling during construction work.

The obtained flexion force of 510.8569 N suggest that the tasks fall within an ergonomically acceptable range. When dividing the total force by two, assuming a balanced distribution of the load between both arms, an approximate force of 255.4284 per arm is obtained, which is considered safe for the operator.

Feedback on device design: The operators reported that the device is easy to use in real work environments. However, opportunities for improvement were identified in the user interface, especially in the data entry process. Additionally, it was suggested to incorporate mechanisms that facilitate use in outdoor work conditions, such as screens with greater visibility under sunlight.

5. DISCUSSION

The results of the research highlight the importance of evaluating dynamic forces in specific work tasks, particularly in sectors with high variability and low standardization. The analyzed activities, such as handling gas cylinders, heavy wooden planks, aluminum rims, and concrete blocks, involved bending forces that, in some cases, exceeded the limits recommended by ISO 11228-1. Forces exceeding 1000 N, such as those recorded during the handling of filled cylinders (1613.8850 N) and wooden planks (1295.8432 N), represent a significant risk to the musculoskeletal health of operators (Ergo IBV, s.f.). Previous studies indicate that exceeding these limits may increase the risk of disorders such as tendinitis and carpal tunnel syndrome (INSST, 2022).

On the other hand, tasks involving aluminum rims (574.2011 N) and concrete blocks (510.8569 N) were closer to the limits for repetitive activities, indicating that even tasks with moderate loads require ergonomic attention (Morales & Pineda, 2023).

The mobile device used in this research proved to be an effective tool for ergonomic field evaluation. Its ability to integrate inertial sensors and automated processing algorithms enabled precise real-time measurements (González et al., 2021).

Recent literature supports the use of mobile devices for ergonomic assessment, highlighting their accessibility and versatility compared to more complex laboratory technologies (López & Martínez, 2023).

Additionally, studies have indicated that these devices can serve as a low-cost alternative for the continuous evaluation of working conditions, especially in small and medium-sized enterprises (Arvizu et al., 2024).

Comparison with other studies suggests that the dynamic forces recorded in this work are at or exceed the values considered safe. According to Ramírez et al., continuous exposure to high forces without adequate recovery times increases the risk of chronic injuries (2023).

The combination of high dynamic loads and moderate accelerations, as recorded in this study, could lead to cumulative muscle fatigue and affect work performance (INSST, 2022).

Although the mobile device demonstrated its effectiveness, some limitations were identified. The accuracy of the measurements depends on the quality of the anthropometric assessments (Torres & Hernández, 2024).

Future studies should explore the integration of complementary technologies, such as three-dimensional sensors, to provide a more robust validation of the results. This research contributes to the knowledge of ergonomic evaluation in complex work environments, emphasizing the usefulness of mobile tools for improving occupational safety and well-being.

6. CONCLUSIONS

This study focused on evaluating the dynamic forces exerted during arm flexion in specific work tasks, using a mobile device as the primary tool for ergonomic measurement. The methodology employed was non-experimental, cross-sectional, and observational, allowing data collection at a single point in time for each task without altering working conditions. Activities with high variability were evaluated, including the handling of gas cylinders, heavy wooden planks, aluminum rims, and concrete blocks, in masonry, lumber, gas distribution, and tire repair sectors. The study's general objective was to analyze the dynamic forces in these activities to identify potential ergonomic risks. The specific objectives included validating the mobile device, quantifying dynamic forces, and comparing the results with ergonomics limits established by international regulations. The research question focused on determining whether the recorded bending forces exceeded the recommended limits for safe work tasks.

The results showed that bending forces varied significantly among the different evaluated activities. Tasks involving the handling of filled cylinders and wooden planks presented bending forces exceeding 1000 N, posing a high risk to the musculoskeletal health of operators. In contrast, activities involving aluminum rims and concrete blocks exhibited more moderate forces, although close to the safety limits for repetitive tasks. These findings allowed the research question to be answered by demonstrating that some tasks do indeed exceed the recommended ergonomic thresholds. Additionally, the results confirmed that the mobile device used is a viable and practical tool for real-time evaluation of working conditions, facilitating the identification of activities requiring ergonomic interventions.

Among the main contributions of this study are the development of an accessible and replicable procedure for field ergonomic evaluation, as well as the validation of a mobile device that offers and affordable alternative to more complex technologies. However, some limitations were identified, such as the dependency on the accuracy of anthropometric measurements. Additionally, methodological challenges arose during the research, including adapting the device to different work environments and training operators in its use. Despite these limitations, the study provides a solid foundation for future research in the field of occupational ergonomics.

For future research, it is recommended to explore the integration of three-dimensional sensors and augmented reality technologies to improve the accuracy of ergonomic measurements. Expanding the study sample to other labor sectors with high physical demands and evaluating task repetitiveness over time to identify potential cumulative effects on workers' health would also be valuable. Furthermore, developing specific interventions base on the obtained results, such as training programs on safe lifting techniques, implementation of active breaks, and workstation redesign, is suggested. Finally, this study reinforces the importance of continuing research to improve working conditions through accessible, adaptable, non-invasive, and highly practical tools, thus promoting a safer and healthier work environment for all operators.

7. REFERENCES

Acero, J. (2016). Modelos antropométricos aplicados al análisis de la masa segmental. Universidad Nacional de Colombia.

Arias, M., Pérez, D., & Gómez, L. (2023). Evaluación de la carga biomecánica en el manejo manual de materiales: Un enfoque ergonómico. Revista Latinoamericana de Ergonomía y Salud Ocupacional, 19(2), 45-60. https://doi.org/xxxxxx

Chiari, L., Della Croce, U., Leardini, A., & Cappozzo, A. (2005). Human movement analysis using stereophotogrammetry: Part 2 - Instrumental errors. Gait & Posture, 21(2), 197-211. https://doi.org/10.1016/j.gaitpost.2004.05.002

Cuadros, J. A. (2022). Desarrollo de un sistema de análisis biomecánico utilizando sensores inerciales. Escuela Politécnica Nacional. https://bibdigital.epn.edu.ec/bitstream/15000/25178/1/CD%2013789.pdf

Della Croce, U., Leardini, A., Chiari, L., & Cappozzo, A. (2005). Human movement analysis using stereophotogrammetry: Part 1 - Theoretical background. Gait & Posture, 21(2), 186-196. https://doi.org/10.1016/j.gaitpost.2004.01.010

ErgoIA. (2023). Nueva solución innovadora para el análisis ergonómico. Blog ErgoIA. https://ergoia.net

García-de-Villa, S., Jiménez-Martín, A., & García-Domínguez, J. J. (2024). Novel IMU-based Adaptive Estimator of the Center of Rotation of Joints for Movement Analysis. arXiv preprint arXiv:2402.04240.

González-Carbonell, R. A., Salinas-Sánchez, I., Villanueva Ayala, D., & Jacobo Armendáriz, V. H. (2024). Prueba de valoración biomecánica de marcha con el sensor inercial. Revista de Biomecánica Aplicada, 15(3), 45-58.

López Tornos, J. (2022). Sensores Inerciales para la Estimación de Ángulos de Rotación en Biomecánica. Universidad de Sevilla. https://biblus.us.es/bibing/proyectos/abreproy/94912/fichero/TFG-4912%2BL%C3%B3pez%2BTornos.pdf

Orjuela, J., & Ospina, C. (2022). Comparación de métodos de análisis ergonómico en el levantamiento manual de cargas. Revista UIS Ingenierías, 21(3), 55-70. https://doi.org/xxxxxx

Palermo, M., Cerqueira, S., André, J., Pereira, A., & Santos, C. P. (2022). Complete Inertial Pose Dataset: from raw measurements to pose with low-cost and high-end MARG sensors. arXiv preprint arXiv:2202.06164.

Podobnik, J., Kraljic, D., Zadravec, M., & Munih, M. (2020). Centre of pressure estimation during walking using only inertial-measurement units and end-to-end statistical modelling. arXiv preprint arXiv:2011.01303.

Quirón Prevención. (2023). ErgoIA: Una nueva solución para el análisis ergonómico. Blog Quirón Prevención. https://www.quironprevencion.com

Santos, G., Wanderley, M., Tavares, T., & Rocha, A. (2021). A multi-sensor human gait dataset captured through an optical system and inertial measurement units. arXiv preprint arXiv:2111.15044.

Weygers, I., Kok, M., De Vroey, H., Verbeerst, T., Versteyhe, M., Hallez, H., & Claeys, K. (2020). Drift-free inertial sensor-based joint kinematics for long-term arbitrary movements. IEEE Sensors Journal, 20(14), 7969-7979.

Winter, D. A. (2009). Biomechanics and Motor Control of Human Movement (4.ª ed.). Wiley.

Zatsiorsky, V. M. (2002). Kinetics of Human Motion. Human Kinetics.

RISK ANALYSIS AND PROPOSAL FOR IMPROVEMENT IN WASTE TRANSFER

Rigoberto Zamora Alarcón[1], Carlos Raúl Navarro González[2], María Paz Guadalupe Acosta Quintana[3], Acela Castillón Barraza[4], María Jesús Montaño Acosta[5],

[1.4]Department of Industrial Engineering
TecNM/Instituto Tecnológico de Mexicali
Av. Instituto Tecnológico s/n Plutarco Elías Calles 21376
Mexicali, B.C, México.

[2]Faculty of Engineering/Industrial Engineering
Universidad Autónoma de Baja California
Av. Álvaro Obregón s/n, Nueva, 21100
Mexicali, B.C, México.

[3,5]Department of Industrial Engineering
Instituto Tecnológico de Sonora
5 de febrero 818 sur colonia centro, CP 85000
Obregón, Son, México.

Corresponding author's e-mail:
zamora@itmexicali.edu.mx, zamora@uabc.edu.mx,

Resumen: La presente investigación y análisis manejos de residuos en los que se identificaron actividades con altos factores de riesgo.

Para identificar y validar se realizaron evaluaciones utilizando NOM 036 STPS, en levantamientos, traslados, rodamientos y utilización de equipos auxiliares, los cuales se apoyaron de valores obtenidos de la NOM-015-STPS, NOM-017-STPS, NOM-019-STPS, NOM-025-STPS y el mantenimiento del equipo auxiliar

Además, se realizaron validaciones para detectar riesgos de lesiones músculo esqueléticas mediante métodos ergonómicos como WERA, QEC y REBA por manejo de cargas en la norma se requiere métodos específicos de evaluación. Esta y futura propuesta de mejora de las actividades se puede llegar a disminuir los riesgos de lesiones de la trabajadora con riesgo para su salud al ser evaluados por normas de la SEMARNAT en el manejo de residuos.

Palabras clave: Mantenimiento, NOM SEMARNAT, NOM STPS, Métodos específicos

Abstract: This research and analysis of waste management in which activities with high risk factors were identified.

To identify and validate, evaluations were carried out using NOM 036 STPS, in lifts, transfers, bearings and use of auxiliary equipment, which were supported by values obtained from NOM-015-STPS, NOM-017-STPS, NOM-019-STPS, NOM-025-STPS and the maintenance of auxiliary equipment.

In addition, validations were carried out to detect risks of musculoskeletal injuries using ergonomic methods such as WERA, QEC and REBA for load handling in the standard specific evaluation methods are required. This and future proposal to improve activities can reduce the risks of injury to the worker with risk to her health when evaluated by SEMARNAT standards in waste management.

Keywords: Maintenance, NOM SEMARNAT, NOM STPS, Specific methods

Relevance for ergonomics: To reduce the risk of injury and provide better well-being, through ergonomic analysis and application of Mexican standards in the handling of cargo and its environment to obtain assessments that allow assessing whether the proposals found allow them to improve their environment in a tangible way. In the management of solid waste, it is essential not only to evaluate the ergonomic risks and physical working conditions but also the hygiene condition in the environment, which is why it is necessary to apply the Official Mexican Standards of the Ministry of Labor and Social Welfare and those of the Ministry of the Environment and Natural Resources, both from the beginning to analyze and optimize waste management

1. INTRODUCTION

The risk analysis and improvement proposal was applied to the operators who unload garbage from the underground cafeteria to the garbage container area in the University Center in 8-hour shifts for the morning and afternoon cleaning shifts. The objective is to propose ergonomic improvements in the handling and transport of garbage to the container area by applying Mexican Standards and ergonomic methods as specific evaluations to analyze and propose the reduction of ergonomic risks. For the analysis, the Official Mexican Standards of the Ministry of Labor and Social Welfare (NOM STPS) and Official Mexican Standards of the Ministry of the Environment and Natural Resources (NOM SEMARNAT) were applied. As a specific evaluation, the WERA and QEC methods were applied, detecting inappropriate back postures, application of efforts. As well as adverse physical conditions, such as poor lighting at night, the heat and cold to which the operating personnel are exposed, as well as the hygiene conditions in the container area and the lack of maintenance of the auxiliary handling equipment.

To make the improvements, the proposals for the Standards to establish the installation of missing luminaires, redistribution routes and modification in auxiliary management equipment were analyzed again. In the same way, the proposals were re-evaluated in the specific ergonomic methods of evaluation and verification sheets of the maintenance of auxiliary equipment for their application.

2. OBJECTIVE

Propose ergonomic improvements in the handling and transport of garbage to the container area by applying Mexican Standards and ergonomic methods as specific evaluations to analyze and propose the reduction of ergonomic risks.

3. METHODOLOGY

- Official Mexican Standards of the Ministry of Labor and Social Welfare (STPS)
- Official Mexican Standards of the Ministry of the Environment and Natural Resources (SEMARNAT).
- Ergonomic methods QEC (Quick Exposure Check) and WERA (workplace ergonomic risks Assessment) as specific assessment methods.
- Preventive and corrective maintenance of auxiliary equipment

4. RESULTS

The results through the application of the methodology are presented below:

Official Mexican Standards of the Ministry of the Environment and Natural Resources (SEMARNAT).

NOM 161 SEMARNAT STANDARD Establishes the criteria for classifying Special Handling Wastes and determining which ones are subject to the Management Plan; the list of the same, the procedure for inclusion or exclusion from said list; as well as the elements and procedures for the formulation of management plans. (NOM 161 SEMARNAT).

In the management, a work plan is established that must consider this item. NOM 083 SEMARNAT Environmental protection specifications for site selection, design, construction, operation, monitoring, closure and complementary works of a final disposal site for urban solid waste and special management. (NOM 083 SEMARNAT). Although the specified tons are not handled, it is essential to comply with hygiene requirements.

Official Mexican Standards of the Ministry of Labor and Social Welfare (STPS).

NOM 015 STPS. Outdoor temperatures are quite uncomfortable even in section 7.3.7 "When the body temperature is equal to or greater than 38°C, the worker must be removed from exposure and subjected to medical surveillance". (NOM 015 STPS -2001). As shown in Figure 1, it is difficult to comply with since temperatures are extreme in Mexicali in 66% of the year, temperatures of 40 degrees maximum and minimum can reach 0 degrees (Mexicali City Council).

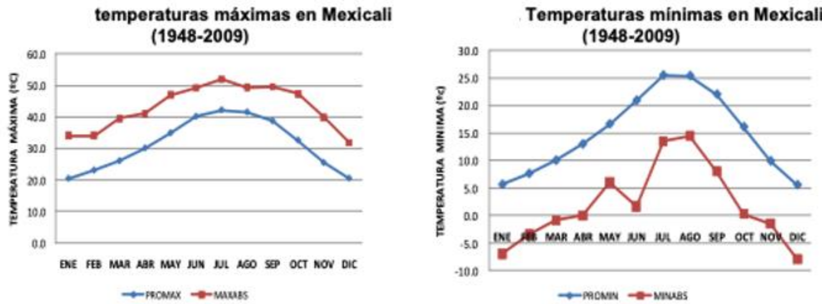


Figure 1. Outdoor temperatures according to the Risk Atlas of the municipality of Mexicali

1. NOM 025 STPS Lighting, at night are outside what is allowed by the standard (NOM 025 STPS-2008) simply outdoors brand lux less than 10
2. NOM 017 STPS Personal protective equipment, sometimes not properly followed wear clothing not provided by pattern with pants, t-shirts, tennis shoes and no gloves. (NOM 017 STPS-2008)
1. NOM 019 STPS (Constitution, Integration, Organization and Operation of Safety and Hygiene Commissions) do not comply with the
2. NOM 036 STPS (NOM 036 STPS-2008) First, the risk was estimated due to the lifting and transport of loads, and manual loading operations from mobile garbage containers (See Figure 2) to the static garbage container

Figure 2. Left Small 2-Wheeled Equipment (diablito) and right Medium 3-wheeled Equipment

Table 1. It illustrates that due to its score of 12 the level of risk is Medium-Possible, so the Mexican standard indicates that "Short-term corrective actions are required". It was improved with the mobile cart with automatic turning system.

Risk assessment of activities involving the pushing or pulling of loads without the use of auxiliary equipment. In this case it will be the turning of the trash can when it is removed from auxiliary equipment with 2 wheels

Table 1. Results NOM-036-STPS in garbage collection and transport.

Factor de Riesgo	Bote en 2 ruedas-Contenedor				Contenedor 3 ruedas-Contenedor			
	Levanta		Transporta		Levanta		Transporta	
Peso y Carga/Frecuencia		0		0		0		0
Distancia horizontal		3		3		6		3
Región vertical		3		1		3		1
Torsión y flexión del Torso		2		-		2		-
Restricciones de postura		1		1		1		1
Acoplamiento mano-carga		2		2		2		2
Superficie de trabajo		2		2		2		2
Otros factores ambientales		2		2		2		2
Distancia de transporte		-		0		-		0
Obstáculo de ruta		-		1		-		1
Puntuación:		15		12		18		12
Nivel de Riesgo:	Alto-Significativo		Medio-Posible		Alto-Significativo		Medio-Posible	

Table 2. shows a score of 10 the risk level is Medium-Possible, so the Mexican standard indicates that "Short-term corrective actions are required". It was improved with the mobile cart with automatic turning system.

Table 2. Results when applying NOM-036-STPS in a trash can, turned on its base.

Risk Factor	Turned on its base	
Load weight		**0**
Posture		**3**
Hand grip		**1**
Work pattern		**0**
Distance per trip		**0**
Working surface		**4**
Obstacle along Route		**0**
Otros Factores		**2**
Score	**10**	
Risk leve	Medium-Possible	

Table 3. shows a score of 16 in small equipment of 2 wheels, as well as 20 in medium equipment of 3 wheels, for both the risk level High Significant, so the Mexican standard indicates that "Rapid action is required, so control measures

must be established through an Ergonomics Program for the manual handling of loads".

Table 3. Result NOM-036-STPS evaluates the auxiliary loading equipment

Risk Factor	Small Equipment 2-wheeled equipment	Medium Team Team on 3 wheels
Weight and Load/Frequency	2	0
Horizontal Distance	0	6
Vertical Region	0	0
Torso twisting and bending	0	0
Posture Restrictions	3	3
Hand-load coupling	2	2
Work surface	4	4
Other environmental factors	3	3
Transport distance	2	2
Scoring:	16	20
Risk Level	High to Significant	High to Significant

Table 4 shows the results of the proposed improvements in waste management from the 2-wheeled auxiliary equipment garbage can to the fixed container, through the following improvement proposals

1. It is proposed to transport the garbage cans in an electric motorized cart with an automated turner with a platform integrated into the car
2. It is proposed to lift the garbage cans with a conveyor by means of automatic turners to a fixed container
3. It is proposed to place lighting lamps both in the loading area and in a fixed container since at night of the second shift nothing is seen.

Table 5 and Table 6 show the results of ergonomic methods as a specific evaluation for 2- and 3-wheel auxiliary equipment.

Table 4. Proposed upgrade in 2 wheels from trash can to Fixed Container.

Risk Factor	Picking up trash from the trash can			Transport can to containment		
	Before	After	Best	Before	After	Best
Weight and Load	0	0	0%	0	0	0%
Horizontal distance	3	0	100%	3	0	100%
Vertical region	3	0	100%	1	0	100%
Torso torsion and flexion	2	0	100%	-	-	-
Posture restrictions	1	0	100%	1	0	100%
Hand-load coupling	2	0	100%	2	0	100%
Work surface	2	1	33%	2	1	33%
Other environmental factors	2	1	33%	2	1	33%
Transport distance				0	0	0%
Route obstacle				1	0	100%
Score	15	2	86,7%	12	2	81,8%
Risk level	High	Low-Accept		Medium	Low-Accept	

Table 5. Results of ergonomic methods as a specific evaluation for 3-wheel auxiliary equipment

Risk Factor	Waste handling equipment 3 Wheels auxiliary to container					
	WERA		QEC		REBA	
	L	T	L	T	L	T
Neck	83.3%	83.3%	55,6%	55,6%	66.7%	66%
Arm	66.6%	66.6%	35.7%	50%	66.7%	66%
Back	83.3%	66.6%	78.6%	50%	100%	60%
Forearm	-	-			100%	50%
Hand/Wrist	50%	50%	52,2%	52,2%	100%	33%
Leg/Ankle	66.6%	66.6%	-	-	50%	50%
Strength	50%	50%	40%	40%	33%	33%
Points	35	33			11	8
Risk Level	Medium	Medium			High	High

Table 6. Results of ergonomic methods as a specific assessment for small 2-wheel auxiliary equipment

Risk Factor	Equipment waste handling 2 Boat wheels to Container								
	WERA			QEC			REBA		
	L	T	G	L	T	G	L	T	G
Neck	83%	83%	66%	55%	55%	55%	66%	66%	66%
Arm	66%	66%	50%	35%	50%	67%	66%	66%	66%
Back	66%	66%	66%	50%	50%	50%	80%	60%	80%
Forearm	-	-	-	-	-	-	50%	50%	50%
Hand/	50%	50%	50%	52%	52%	52%	100%	33%	100%
Wrist	66%	66%	66%	-	-	-	50%	50%	50%
Leg/	50%	50%	83%	40%	40%	60%	33%	33%	33%
Ankle	33	33	35				10	8	10
Strength	Medium	Medium	Medium				High	High	High

Table 7 shows the averages and maximum values that determined ergonomic risk values that coincide with the discomfort manifested by operations such as the neck, back, and wrist, in addition to the forearm that predominates in 3-wheeled equipment. A course on load management is proposed to reduce risk levels when handling waste, as well as training in waste management established by SEMARNAT

Table 7. Results of ergonomic methods as a specific evaluation for 2- and 3-wheel auxiliary equipment

Risk Factor	Equipment waste handling 2 Boat wheels to Contain		Waste handling equipment 3 wheels auxiliary to Container	
	Average	Maximum	Average	Maximum
Neck	66.11%	83.0%	74.75%	83.3%
Arm	59.11%	67.0%	58.60%	66.7%
Back	63.11%	80.0%	73.08%	100%
Forearm	50.00%	50.0%	75.00%	100%
Hand/Wrist	61.33%	100.0%	58.25%	100%
Leg/Ankle	58.00%	66.0%	58.30%	66.6%
Strength	46.89%	83.0%	41.00%	50%
Level	Medium		Medium	

Table 8. the results of the proposed improvements in waste management from 3-wheel container to fixed container can be observed, through the following improvement proposals:

1. It is proposed to transport the 3-wheeled containers, on an electric motorized cart with an automated turner as proposed above.
2. It is proposed to lift the 3-wheel garbage containers with a conveyor by means of automatic turners to a fixed container
3. It is proposed to place lighting lamps of the previous proposal both in the loading area and in a fixed container.
4. With trolley flipping system it avoids obstacle of control door.

Table 9. It illustrates that due to its score of 12 the level of risk is Medium-Possible, so the Mexican standard indicates that "Short-term corrective actions are required". It was improved with the mobile cart with automatic turning system.

Table 9. shows the 80% improvement achieved since the need to roll the trash can of the 2-wheel auxiliary equipment was eliminated, so the Mexican standard tells us that "No short-term corrective actions are required".

Table 10 shows the proposed improvement in 56.2% achieved in 2-wheel auxiliary equipment, in small equipment the risk factor was reduced from 16 High-significant to 7 Medium-possible, so the Mexican standard indicates that "Short-term corrective actions are required"

Table 8. Improved handling from 3-wheel container to fixed container

Risk Factor	Garbage removal			Trolley to container transport		
	Before	After	Best	Before	After	Best
Weight and Load	0	0	0%	0	0	0%
Horizontal distance	6	3	33%	3	0	100%
Vertical region	3	1	33%	1	0	100%
Torso torsion and flexion	2	0	100%	-	-	-
Posture restrictions	1	0	100%	1	0	100%
Hand-load coupling	2	0	100%	2	0	100%
Work surface	2	1	33%	2	1	33%
Other environmental factors	2	1	33%	2	1	33%
Transport distance	-	-	-	0	0	0%
Route obstacle	-	-	-	1	0	100%
Scoring:	18	6	66,7%	12	2	83,3%
Level of risk:	High to Significant	Medium-Possible		Medium-Possible	Low-Accept	

Table 9. Results when applying NOM-036-STPS in a trash can.

Risk Factor	Turned on its base		
	Before	After	Best
Load weight	0	0	0%
Posture	3	0	100%
Hand grip	1	0	100%
Working pattern	0	0	0%
Distance per trip	0	0	0%
Working surface	4	0	100%
Obstacle along Route	0	0	0%
Other Factors	2	2	0%
Score	10	2	80%
Level of risk	Medium - Possible	Low - Acceptable	

In table 10, the proposed improvement also shows 60% achieved in 3-wheeled auxiliary equipment, in medium-sized equipment the risk factor was reduced from 20 High-significant to 8 Medium-possible, where the Mexican standard indicates "Short-term corrective actions are required". To this end, the following is proposed:

1. Motorized Container Collector
2. Preventive maintenance check sheet to conserve the auxiliary equipment, mainly Wheel Maintenance

3. Inclined aisle container lift
4. Elimination of obstacles on the way.

Table 10. Results when applying NOM-036-STPS where the auxiliary loading equipment is evaluated

Risk Factor	Small equipment			Medium equipment		
	Before	After	Best	Before	After	Best
Load weight	2	2	0%	0	0	0%
Posture	0	0	0%	6	3	33%
Hand-load coupling	0	0	0%	0	0	0%
Work pattern	0	0	0%	0	0	0%
Distance per trip	3	1	33,3%	3	1	33%
Condition of auxiliary equipment	2	0	100%	2	0	100%
Working surface	4	1	33,3%	4	1	33%
Obstacle along route	3	2	33,3%	3	2	33%
Other Factors	2	1	33,3%	2	1	33%
Scoring:	16	7	56.2%	20	8	60%
Level of risk:	High	Medium-Possible		High	Medium-Possible	

4. Conclusions

The objective of the study was achieved since it was possible to propose ergonomic improvements in the handling and transportation of garbage in the container area by applying Mexican Standards. Ergonomic risks were analyzed, reducing the level of risk with the proposal, as shown in Table 9 by 80% and Table 10 by 56.2% for 2-wheeled auxiliary equipment and 60% with 3-wheeled mobile containers.

In relation to the handling and transport of garbage in the container area, it was possible to propose ergonomic improvements thus achieving this part of the objective was also met, through the application of ergonomic methods REBA, WERA and QEC. As specific evaluations were analyzed and the proposal and the level of ergonomic risk was reduced, by eliminating movements that could cause risks up to 80%, also contemplating in the proposal the use of an automated equipment for tipping waste containers.

Favorable routing options were achieved, with logistical applications through an intermediate station at the exit of the community center. An electrically motorized container cart with integrated tipping system was proposed and maintenance check sheets for auxiliary equipment were included.

The proposed redesign of auxiliary equipment reduces ergonomic risks due to material handling by adding attachment and coupling accessories to 2- and 3-wheeled auxiliary equipment.

Mexican standards were used to make proposals for lighting, personal protective equipment and integration of the substantive functions of the joint safety commissions and finally, to reduce the possibility of injury, a load handling course was proposed, due to the postures observed during the investigation.

5. REFERENCES

Official Mexican Standard NOM-161-SEMARNAT-2011, which establishes the criteria
to classify Special Handling Waste and determine which are subject to the Management Plan; the list of the same, the procedure for inclusion or exclusion from said list; as well as the elements and procedures for the formulation of management plans.
https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.dof.gob.mx/nota_detalle.php%3Fcodigo%3D5286505%26fecha%3D01/02/2013&ved=2ahUKEwjB_--wuuyLAxWZmO4BHVSqHtAQFnoECBMQAQ&usg=AOvVaw2Fy3rPgpFxWVH_q-SA3Loj

NOM 083 SEMARNAT Environmental Protection Specifications for Site Selection, Design, Construction, Operation, Monitoring, Decommissioning and Complementary Works of a Final Disposal Site for Urban Solid Waste and Special Management
https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.dof.gob.mx/nota_detalle.php%3Fcodigo%3D5617899%26fecha%3D10/05/2021%23:~:text%3DLa%2520presente%2520Norma%2520Oficial%2520Mexicana%2520establece%2520las%2520especificaciones%2520de%2520protecci%25C3%25B3n,urbanos%2520y%2520de%2520manejo%2520especial.&ved=2ahUKEwiQiNmLsOyLAxX-J0QIHUj3AaIQFnoECBsQAw&usg=AOvVaw1lzw0-A8IW1IfW6dbTAfuP

Official Mexican Standard NOM-015-STPS-2001, High or Chilled Thermal Conditions-Safety and Hygiene Conditions.
https://asinom.stps.gob.mx/upload/noms/Nom-015.pdf

Mexicali City Council, Risk Atlas of the Municipality of Mexicali- 2. Hydrometeorological Hazards
https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=http://www.mexicali.gob.mx/transparencia/administracion/atlas/pdf/2.pdf&ved=2ahUKEwiQ4LKLluyLAxVKH0QIHT3UFlcQFnoECDIQAQ&usg=AOvVaw0DNXg3JicIXnfGPKz5irI2

Official Mexican Standard NOM-025-STPS-2008, Lighting conditions in workplaces.
https://asinom.stps.gob.mx/upload/noms/Nom-025.pdf

Official Mexican Standard NOM-017-STPS-2008, Personal Protective Equipment - Selection, Use and Handling in the Workplace.
https://asinom.stps.gob.mx/upload/noms/Nom-017.pdf
Official Mexican Standard NOM-019-STPS-2004, Constitution, organization and operation of safety and hygiene commissions in the workplace.
https://asinom.stps.gob.mx/upload/noms/Nom-019.pdf
Official Mexican Standard NOM-036-1-STPS-2018, Ergonomic Risk Factors at Work - Identification, Analysis, Prevention and Control. Part 1: Manual Handling of Loads.
https://asinom.stps.gob.mx/upload/nom/49.pdf
WERA Method/PDF/Human-Machine Interaction/Human Factors and Ergonomics
https://www.scribd.com/document/412838172/Metodo-WERA REBA Method -Rapid Entire Body Assessment.ergonautas.upv.es

ASSESSMENT OF SPINAL MOBILITY USING VIDEO ANALYSIS SOFTWARE AS A STRATEGY FOR PREVENTING LOW BACK PAIN

Alicia López Ortiz, Carlos Raúl Navarro González, Karla Isabel Velázquez Victorica, Aída López Guerrero, Juan Carlos Quiroz Sánchez

Department of Engineering of Autonomous University of Baja California.
Blvd. Benito Juárez S/N, Mexicali, Baja California 21280.

Corresponding author's e-mail: cnavarro51@uabc.edu.mx

Resumen. La lumbalgia como parte de los trastornos musculoesqueléticos, es considerada una epidemia mundial de carácter recurrente y con diversos grados de afectación, al presentarse en más del 50% de la población general,de tal forma que repercute en altos costos gubernamentales y empresariales en el área de salud, provocando deterioro considerable de la calidad de vida. Las valoraciones médicas con los métodos tradicionales de exploración goniométrica no son efectivos en la prevención a largo plazo. Por lo que el objetivo de este trabajo es obtener un método de valoración alternativo para los desplazamientos de columna vertebral en los 3 planos anatómicos utilizando como base el petrómetro como instrumento de goniometría tradicional mientras se registran las maniobras en video para analizar posteriormente con el software Kinovea, en los movimientos de tronco de flexión anterior, y lateralizaciones a derecha e izquierda, aplicado en alumnos universitarios. En las comparaciones de los resultados de ambos dispositivos, los resultados fueron similares en las valoraciones del nivel lumbar. Las discrepancias encontradas a nivel dorsal fueron debido a diversas fuentes de sesgo que deben ser consideradas en la experimentación.El resultado de esta investigación redundará en propuestas metodológicas para evaluar la movilidad de la columna vertebral y de higiene postural que incluya las características de traslado horizontal.

Palabras clave: Lumbalgia. Goniometría. Trastornos Musculoesqueléticos. Planos anatómicos.

Relevancia para la ergonomía: Este proyecto permite definir al software de análisis de video Kinovea como un recurso parcial en cuanto a la valoración de la movilidad de la columna total. Sin embargo, los resultados de la valoración de la movilidad lumbar fueron consistentes con los resultados de la valoración clínica. De ahí que puede apoyarse con este software para valorar el rango de movimiento de la columna lumbar si logra tomarse videos desde los ángulos correctos, ayudando a determinar el riesgo de lesión conforme las posiciones adaptadas durante las diferentes actividades. Al explorar este recurso e identificar sus limitaciones en cuanto a nuestros objetivos de valoración, nos ayuda a enfocar los siguientes pasos hacia otros recursos, métodos y dispositivos que puedan determinar mejor las posturas de riesgo lumbar, ante las necesidades que se presentan cotidianamente.

Abstract. Low back pain, as part of musculoskeletal disorders, is considered a recurrent global epidemic with varying degrees of severity, affecting more than 50%

of the general population, as a result, it leads to high governmental and corporate healthcare costs and causes a significant deterioration in quality of life. Traditional medical evaluations using conventional goniometric examination methods have proven ineffective for long-term prevention. Therefore, the objective of this study is to develop an alternative assessment method for spinal displacements in the three anatomical planes, using the petrómetro as a traditional goniometric instrument while simultaneously recording the maneuvers on video for subsequent analysis with Kinovea software. The study focuses on trunk movements, specifically anterior flexion and lateral bending to the right and left, applied to university students. When comparing the results obtained from both devices, similar measurements were observed at the lumbar level. However, discrepancies at the thoracic level were attributed to various sources of bias that must be considered in experimental analysis. The findings of this research will contribute to methodological proposals for evaluating spinal mobility and postural hygiene, incorporating the characteristics of horizontal displacement.

Keywords: Low back pain. Goniometry. Anatomical planes. Musculoskeletal disorders.

Relevance to Ergonomics: This study defines Kinovea video analysis software as a partial resource for assessing total spinal mobility. However, lumbar mobility assessments showed consistent results compared to traditional clinical evaluations.Thus, Kinovea may serve as a supportive tool for measuring lumbar spine range of motion, provided that videos are captured from optimal angles. This can help determine injury risks based on adopted postures during various activities.By exploring Kinovea and identifying its limitations in relation to our assessment objectives, this research guides future investigations toward alternative resources, methods, and devices that may more effectively identify and assess risky lumbar postures, addressing the daily ergonomic needs of various populations.

1. INTRODUCTION

1.1 Economic and Social Impact of Low Back Pain

The World Health Organization (WHO) defines musculoskeletal disorders (MSDs) as conditions affecting muscles, tendons, bones, cartilage, ligaments, and nerves (WHO, 2021). Low back pain is the most prevalent modern MSD worldwide, affecting 60–75% of the working population, particularly in developing countries. Additionally, 80–90% of the general population will experience lower back pain at some point in their lives, making it the second most common type of pain (Pandey, 2011). Low back pain is also frequent among school-aged children, with an incidence ranging from 30% to 70% (De Souza et al., 2021).

Regarding the incidence of low back pain, the findings are summarized in Table 1.

Table 1. Incidence of Low Back Pain

Author	Population	Incidence
Pandey (2011)	General population	80 – 90%
De Souza et al. (2021)	School-agechildren&adolescents	30 – 70%
Delgado et al. (2019)	20 - 40 yearsold	Onsetage
	Over 65 yearsold	Mostcommon MSD
Pandey (2011)	Working-agepopulation	60 – 75%

As shown in Table 1, a significant portion of the general population, particularly adults, is affected by low back pain, starting as early as the school years. More than 50% of the economically active population is impacted by this MSD.

In Mexico, 50% of the economically active population (EAP) experiences an episode of low back pain annually. Internationally, even the pediatric population has a dorsalgia prevalence of 30% (Covarrubias-Gómez, 2010). 80% of the population will suffer from back pain at some point in their lives (FREMAP, 2010). Low back pain can represent up to 27% of MSDs, with a growing trend; for example, in Colombia, its prevalence increased from 12% to 22% between 2001 and 2003 (Escudero, 2016; Castillo, 2007). In Chile, low back pain accounted for up to 34% of MSDs in the labor sector over the past decade, with 30.6% affecting the lumbar region, a figure that later exceeded 73% (Muñoz, 2012).

In Mexico, the prevalence of low back pain ranges between 18% and 45% of the population and results in approximately 10 million cases of work-related disability per year (Segura-Valdez, 2022).

Sikdar et al. (2023) and *The Lancet Rheumatology* (2023) assert that low back pain is the leading cause of disability worldwide. Additionally, it is the second most common cause of disability among adults in the United States and the seventh leading cause of work absenteeism in Mexico.

Escudero (2016), citing WHO data, found that occupational accidents and illnesses can account for 3% of GDP in developed countries such as the United States and Europe (Arenas & Cantú, 2013; Montoya, 2019). However, in developing economies, this percentage can rise to 10%. *The Lancet Rheumatology* (2023) concluded that approximately 10% of the global population experienced low back pain in 2020.

When analyzing the economic burden of low back pain, the results are presented in Table 2.

Table 2. GDP Costs Related to Low Back Pain

Author	Cause	GDP Impact	Affected Population
Escudero (2016)	Occupational disease	3%	Developed countries (USA, Europe)
Arenas & Cantú (2013), Montoya (2019)	Workplace diseases & accidents	2.6% - 3.8%	Europe
Escudero (2016)	Occupational disease	10%	Developingcountries
Montoya (2019)	Workplace accidents & illnesses	4% - 6%	Global

Table 2 illustrates that developing countries are disproportionately affected by the economic burden of low back pain, often classified as an occupational disease or workplace injury.

1.2 Predisposing Risk Factors for Low Back Pain

The primary cause of a musculoskeletal disorder (MSD) is posture with additional loads. The more inclined a body segment is towards the horizontal position, the greater the gravitational force component and the increased muscular and joint effort required (Cailliet, 1984; Krusen, 2000; Gasic, 1998; Canté, 2010).

From early school years, non-ergonomic furniture and sedentary activities contribute to muscle weakness, which alters posture and ultimately affects spinal health (Mendoza, 2019; Zurita, 2014; Canté et al., 2010; Kapandji, 2006; Santonja, 1994; Cailliet, 1984). These factors, along with prolonged sedentary behavior and poor postures later in life, exacerbate health issues into adulthood (De Souza, 2021; Bazaldúa-Treviño et al., 2019; Santonja, 1994).

Additionally, external loads, such as school backpacks and excess body weight, combined with an immature, flexible skeletal structure, can lead to irreversible deformations (Cailliet, 1984; Bazaldúa-Treviño et al., 2019). For this reason, it is recommended that the weight of school backpacks not exceed 20% of body weight (Bazaldúa et al., 2019). Beyond the weight of the backpack, the way it is carried also matters. Uneven weight distribution on the spine creates muscular imbalances, leading to increased strain on certain muscle groups (Ramadan et al., 2020; Bazaldúa-Treviño et al., 2019).

Various causal factors of low back pain identified by multiple authors are presented in Table 3.

Table 3. Risk Factors for Low Back Pain

Author	Physiological	Female sex	Smoking	Sedentary lifestyle	Genetics	Age	Obesity	Furniture	Excessactivity	Environment	Emotional factors	Carrying heavy loads	Prolonged positions	Biomechanical	Fatigue & exhaustion	Load position on the body	Load shape & volume
Delgado (2019)	+	+	+	+	+	+	+			+	+	+		+	+		
Skovdal (2021)		+	+	+			+		+		+	+					
Bazaldúa-Treviño (2019)	+					+						+		+			
Cailliet (1984)	+											+	+	+	+		
Ceballos-Laita (2017)				+													
Gutiérrez-Bedón (2023)		+				+	+				+	+	+		+		
Ramadan (2020)						+	+					+			+	+	+
Mendoza (2019)				+				+				+	+				
Zurita (2014)	+			+	+	+	+			+	+						
Canté (2010)		+		+	+	+	+		+		+		+				
Kapandji (2006)	+			+	+	+	+		+			+		+		+	+
Santonja (1994)	+			+									+				
Cailliet (1984)	+			+	+	+	+		+			+				+	
INCIDENCE	***7***	**4**	**2**	***9***	**5**	***8***	***8***	**1**	**4**	**2**	**5**	***9***	**5**	**4**	**4**	**3**	**2**

Based on the authors analyzed in Table 3, the most significant risk factors for low back pain are:

- Sedentary lifestyle (9+): Defined as less than 150 minutes of moderate activity per week.
- Carrying heavy loads (9+): Performing movements with additional weight increases muscular and joint strain.
- Age (8+): Vertebral bone components in individuals under 18 years old are not fully mineralized and are more susceptible to deformities due to external forces, leading to MSDs from an early age. In adults, demineralization and tissue deterioration contribute to tissue compression and damage.
- Obesity (8+): Excess weight places additional strain on joints, leading to bone deformation in young individuals and increased sustained muscular and joint effort in adults.
- Physiological factors (7+): Intrinsic individual characteristics, such as genetic predisposition, bone mineralization, skeletal alignment, joint surface shape, body composition, physical condition, dietary habits, and overall health status, influence tissue resilience and susceptibility to body tissues.

The World Health Organization (WHO, 2023) recommends that children and adolescents engage in at least 180 minutes of moderate-to-intense physical activity per week, while adults should aim for 150 minutes, ideally increasing up to 300 minutes per week.

Physical activity, particularly when incorporating moderate impact, enhances muscular strength, coordination, and joint stability, while also promoting bone mineralization and preservation of mineral deposits in bones (Fragala et al., 2019; Reyes et al., 2008; Vera-García et al., 2015).

Regarding obesity as a risk factor for low back pain, Cailliet (1984) and Bazaldúa-Treviño et al. (2019) noted that both internal loads (body weight) and external loads can negatively impact biomechanics, contributing to low back pain and other MSDs. Pou et al. (2023) and Rodríguez et al. (2023) referenced WHO data indicating high obesity rates worldwide: over 650 million adults, 41 million children under five, and 340 million adolescents are classified as obese. The Americas have the highest incidence rates.

Approximately 40% of the global population is overweight. In Mexico, childhood overweight prevalence was 33.2% in 2012, increasing to 36.3% among adolescents. By 2016, 72.5% of adults were overweight (Kaufer-Horwitz & Pérez, 2022). Mexico ranks among the top five countries in the Americas for adult overweight prevalence at 38.3% (Campos-Nonato et al., 2023).

1.3 Importance of Evaluating Movements Through Anatomical Planes

The mobility of each body segment occurs within anatomical planes according to its joint anatomy. If, during movement, the segment deviates from the designated plane, the joint becomes overloaded, and muscular engagement is excessively increased, raising the risk of injury. Therefore, assessing body mobility through anatomical planes allows for:

- Understanding the functional dynamics of the human body and preventing potential injuries (Rodríguez, 2005).
- Identifying postural alterations and abnormal functional movement patterns to prevent chronic injuries (Michalik, 2020; Sato, 2023).
- Improving motor control and precision (Lee, 2020).
- Conducting functional assessments for activities involving weight-bearing or complex movements (Lindenmann, 2022; Clarke, 2021).
- Analyzing flexion and rotation patterns, addressing biomechanical imbalances, and improving functional stability (Nishizawa, 2024; Martínez-Hernández, 2022; Huthwelker, 2022).
- Supporting diagnosis and personalized treatment (Lindenmann, 2022; Dreischarf, 2022).
- Having a significant impact on rehabilitation, where the employed assessment methods, such as inclinometers and manual observations, are essential to ensuring precise and consistent diagnoses (Takatalo, 2020).

Table 4 summarizes the primary reasons identified by various authors regarding the importance of evaluating body mobility through anatomical planes.

Table 4. Reasons for Assessing Movements Through Anatomical Planes

Author&Year	Injury Prevention	Understanding Functional Dynamics	Designing Personalized Therapies	Multisegment Analysis	Evaluation in Functional Conditions	Integration of Advanced Technologies
Rodríguez (2005)	X	X		X		
Lee (2020)					X	X
Nutbeam (2022)	X		X			
Michalik (2020)	X	X	X	X	X	
Lindenmann (2022)			X	X		X
Sato (2023)	X		X	X		
Clarke (2021)				X	X	
Takatalo (2020)	X		X		X	
Martínez (2022)		X		X		X
Huthwelker (2022)		X		X		X
Patel (2022)	X		X			
Suter (2020)	X			X		
Zhao (2022)			X	X		X
Paccini (2023)			X	X		X

Shuai (2022)	X		X			X
Cerfoglio (2023)	X		X			X
Mekhael (2023)			X		X	X
Sajedi (2024)				X		X
Dreischarf (2022)			X		X	
Hupp (2019)		X		X		
TOTAL	**9**	**5**	**9**	**11**	**9**	**10**

As observed in Table 4, the most significant benefit of evaluating movements through anatomical planes is multisegmental analysis of body mobility. This approach enhances the understanding of functional conditions, injury prevention, and the development of highly specific, personalized therapy designs. Additionally, it is a prerequisite for integrating advanced technologies, as these must be analyzed within various anatomical planes.

1.4 Complexity of Integrating Advanced Technologies

Table 5 provides a summary of the instruments used in anatomical plane-based movement assessments, as reported in the reviewed literature.

Table 5. Instruments Used for Movement Assessment by Anatomical Planes

Instrument	Details	Author
Optoelectronic systems	High-resolution cameras for 3D motion capture	Shuai (2022), Clarke (2023), Huthwelker (2022)
Motion capture systems	Dynamic assessments using body markers with cameras	Michalik (2020), Cerfoglio (2023), Dreischarf (2022)
Inertial Measurement Units (IMU)	Wearable sensors for segmental movement analysis	Martínez-Hernández (2022), Nutbeam (2022), Suter (2020)
Portable evaluation systems	Epionics SPINE (longitudinal sensor strips adhered to the skin)	Suter (2020)
Portable evaluation systems	Spinal Mouse (electronic device that scans the spine to generate computerized images)	Domokos (2023)
3D musculoskeletal models	Simulations based on X-ray imaging (moderate radiation exposure with full-motion tracking)	Schmid (2020), Qu (2020)
Radiographic analysis methods	Segmental X-ray imaging and angular analysis (traditional radiography assessing movement limits)	Kyung-hun (2019), Ji (2024)

As shown in Table 5, six authors utilized camera-based 3D motion capture systems with body markers, being them the most accurate devices for movement assessment. The second most commonly used instruments were IMU sensors, cited by three authors. Given this context, the purpose of this research is to evaluate the benefits and challenges of using optoelectronic systems.

Assessing body movements through anatomical planes presents significant challenges due to the complexity of the evaluated tasks and the tools used.

Zhao (2022) explains that challenges arise in integrating complex data and interpreting results, affecting the ability to translate findings into practical applications for rehabilitation and diagnosis. The lack of standardization in assessment methods further contributes to these difficulties.

Bahramian (2023) highlights that advanced technologies still face technical and logistical limitations, particularly in dynamic conditions.

Several studies also report complications in joint mobility assessments through anatomical planes, including:

- Reading errors due to pain or bone deformities (Dreischarf, 2022; Huthwelker, 2022; Takatalo, 2020; Bahramian, 2023).
- Postural errors during movement (with or without loads) (Sajedi, 2024; Johnson, 2023; Nutbeam, 2022).
- Interindividual variability between subjects and within the same individual (Clarke, 2021; Huthwelker, 2022).
- Devicelimitations (Rodríguez, 2005; Dreischarf, 2022; Huthwelker, 2022; Takatalo, 2020; Lee, 2020; Bahramian, 2023).
- Contextual and psychological factors (Bahramian, 2023).
- They are limited in their portability, partly because devices such as optical cameras require specific installations (Lim 2020).
- Costs are generally high, especially for optoelectronic systems (Schmid 2020).
- They are generally limited in their versatility, as many require controlled environments, such as laboratories (Kyung-hun 2019).
- Regarding the clinical setting, they require specific conditions to guarantee safety and precision. (Nyayapati 2022).
- More complex to integrate due to their technical and calibration requirements (Paccini 2023).
- Post-processing is required to obtain a result (Lane 2017, Schmid 2020).
- They are complicated by the use of loads on the back since the body is covered and anatomical references are lost (Veljovic 2019).

Several studies also report regarding their advantages:

- They are excellent for functional and dynamic evaluations.
- they show high precision in their kinetic and kinematic assessments (Rodríguez-Soto 2017).
- Analysis systems based on RGB-D cameras, that is, 3D technologies for movement reconstruction, can be placed in the real activity spaces of the subjects.
- They are not guided by markers on the surface of the body.

Although but rather depend on the correct alignment and location of the camera to record the exact position of the body or segment analyzed, and that the movement of the subject always maintains the posture in the appropriate plane (Nyayapati, 2022; Zhao, 2022).

2. THEORETICAL FRAMEWORK

2.1 Low Back Pain

Low back pain, or lumbar pain, can be defined as "pain, muscle tension, or stiffness localized below the costal margin and above the inferior gluteal fold."

Body posture refers to any position that the body assumes at any given moment throughout the day. It exists throughout life, from conception, while sleeping, sitting, standing, moving, playing, or working, and accompanies us 24 hours a day. Posture can be analyzed as total body posture or segmental posture. It can be assessed at a specific moment or studied as a process of postural modifications over time (Andújar et al., 1997).

Abdominal organs can generate referred pain to the lumbar region (Serra, 2003; Barrabés&Ornilla, 2018; SGADOR, 2017; Delgado et al., 2019; Gutiérrez-Bedón, 2023). Musculoskeletal-origin low back pain (also called "mechanical low back pain") considers various musculoskeletal components of the region, including posture and weight-bearing loads (Gasic, 1998; Vaughan et al., 1999; Serra, 2003; Ceballos-Laita et al., 2017; Bazaldúa-Treviño et al., 2019; Delgado et al., 2019; Ramadan et al., 2020; Skovdal et al., 2021; Ueta et al., 2021; Xavier et al., 2021; Campos-Nonato et al., 2023; *The Lancet Rheumatology*, 2023).

2.2 Anatomy and Physiology

Body movements occur within internationally standardized anatomical planes (Figure 1).

- Sagittal plane: Movements of flexion and extension.
- Coronal plane: Movements of abduction and adduction.
- Transverse plane: Complex movements that involve rotations, such as circumduction, pronation and supination of the elbow, and inversion and eversion of the ankle.

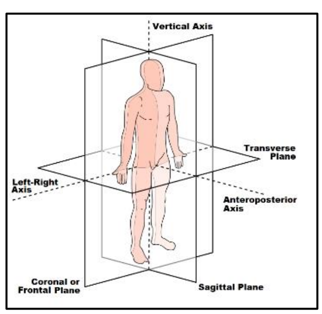


Figure 1 Representation of anatomical planes.
Source: Adapted fromWikimedia.org

The spinal column is the primary support structure of the human body, bearing the weight of all trunk organs, the head, and the arms. It rests on the pelvis, providing stability to the lower limbs. The spine is composed of 32 vertebrae, each having limited individual mobility, but when combined, they enable a complex and diverse range of motion.

The spinal column is divided into four segments:Cervical region, Thoracic (dorsal) region, Lumbar region, Sacral region, Coccygeal segment.

From a lateral view, the spine has four natural curvatures:

1. Cervical region – posterior concavity.
2. Thoracicregion – posterior convexity.
3. Lumbar region – posterior concavity.
4. Sacral region – posterior convexity, where the five fused vertebrae form a single solid bony structure.

These curvatures help absorb shock and distribute mechanical loads during movement and weight-bearing activities. This function becomes particularly crucial when internal loads (e.g., excess body weight) or external loads (e.g., lifting heavy objects) increase.

Among the three mobile segments, each has distinctive movement characteristics:

- Cervical segment: The most mobile region, allowing head movement. It is frequently affected by postural dysfunction, particularly in sedentary individuals.
- Thoracic segment: The least mobile region, as its vertebrae are attached to the ribcage.
- Lumbar segment: The primary load-bearing region, as it supports the weight of the trunk and upper body, as well as lower body movements through the pelvis and legs. This constant mechanical stress makes the lumbar spine the most injury-prone region, frequently resulting in pain and disability.

Each spinal segment has specific angular mobility ranges, which are measured using instruments such as the bubble inclinometer or goniometer or petrometer.

2.3 Spinal Goniometry

The traditional assessment performed in healthcare offices to measure joint range of motion uses simple and practical equipment, such as an inclinometer or goniometer. Kapandji (2006) and Taboadela (2007) describe the correct procedural methods for these assessments.

For lateral lumbar inclination, the patient remains standing. The goniometer is placed with its fulcrum centered on the spine at the level of the posterior superior iliac spines (PSIS) (Figure 2). The fixed arm is aligned vertically towards the ground, ensuring pelvic stabilization to avoid compensatory movements. The patient is then asked to slide their hand down the side of their thigh. The movable arm follows the spinous processes up to the ribcage. The normal range of lateral inclination is considered 30–35°.This movement can also be evaluated with the petrometer, and in this case two devices are required.

For trunk flexion and extension, two bubble inclinometers are used, or two petrometers. The use technique is the same with both the inclinometer and the petrometer.The inclinometer devices consist of water levels adapted to a two-legged base. One inclinometer is placed at the lumbosacral junction, while the second is positioned at the spinous process of C7 (Figure 2). Since both inclinometers move independently, the final value is obtained by subtracting between the final value and the initial value; both the device placed at the beginning and the one at the end of the evaluated vertebral segment.

This technique measures forward flexion and backward extension of the thoracic and lumbar spine as a whole. Normal values are at least 80° for trunk flexion and 30° for extension.

However, the thoracic and lumbar segments contribute differently to movement, which traditional goniometry does not account for. This limitation is significant because most injuries occur in the lumbar region.

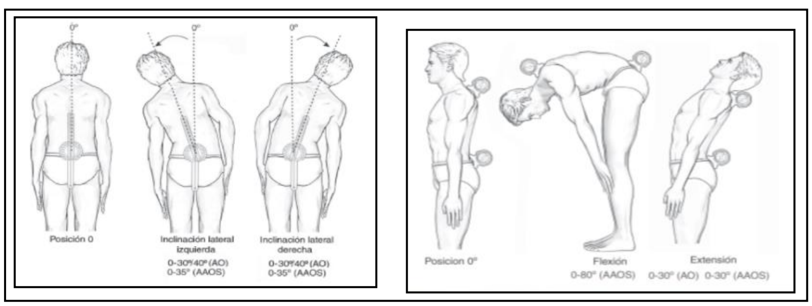


Figure 2 Goniometry Method for Spinal Mobility Assessment.
Note: Adapted from "Goniometría" (pp. 61–62), by Claudio H. Taboadela, 2007, Ed. Asociart SA ART.

Measuring joint ranges using an inclinometer requires both practice and skill. Studies have shown that the margin of error is high among novice users, but the reliability of the tool increases as the examiner gains experience over time (Hellebrandt et al., 1949).

Due to this learning curve, it is essential to develop more reliable assessment techniques that can be used by a wider range of professionals seeking to evaluate spinal mobility.

3. OBJECTIVE

To determine the accuracy of the Kinovea software in measuring spinal mobility in the coronal and sagittal planes, compared to traditional clinical assessments using a goniometer (petrómetro).

4. METHODOLOGY

4.1 Test Design

Inclusion Criteria: Healthy male subjects without diagnosed musculoskeletal disorders (MSDs) were selected.Only men were included, as they were required to expose their backs for marker placement directly on the skin.Participants were engineering students from multiple academic semesters.

Procedure:

1. Informed consent was obtained from all participants after a full explanation of the procedure.
2. Subjects were positioned within a designated area marked on the floor, 3 meters away from two webcams.
3. A petrómetro measurement was recorded at both the starting and final positions during the evaluation.
4. Simultaneous video recordings were taken using two cameras, for lateral view and posterior view; both cameras were perpendicularly aligned and placed 3 meters away from the subject.
5. Kinovea software (version 0.9.5) was used to synchronize video frames with the recorded movements.
6. Each evaluation was captured from start to finish, ensuring that the subject remained fully visible within the frame.
7. A post-analysis was conducted using Kinovea software.

Movements Assessed:

a) Sagittal plane (lateral camera view):

- Subjects stood upright without bending their knees.
- Performed anterior trunk flexion, allowing arms to hang freely toward the floor.
- The head flexed naturally, ensuring full spinal curvature.
- The position was held for several seconds to allow for:
    - Petrómetro measurement.
    - A complete video capture of the movement.

b) Coronal (frontal) plane (posterior camera view):

- Lateral trunk flexion (left and right) was assessed.
- Subjects were instructed to start with the left side, followed by the right.
- Measurements were recorded in sequence to minimize potential data recording errors.

c) Each movement was recorded in three repetitions per subject using:

- Traditional petrómetro measurement.
- Kinovea video analysis software.

Data Analysis

The spinal column was divided into thoracic (dorsal) and lumbar segments, with measurements recorded separately and then combined to obtain total displacement values in each movement.
The following assessments were made:

1. Lumbar segment, dorsal segment, and total displacement in flexion.
2. Lumbar segment, dorsal segment, and total displacement in left lateralization.
3. Lumbar segment, dorsal segment, and total displacement in right lateralization.

A comparative analysis was then conducted between:

- Petrómetro data.
- Kinovea software results.

Materials Used:

- 2 Petrómetros (goniometers).
- 2 webcams withtripods.
- 2 cable adapters (to increase camera placement distance).
- Kinovea software (version 0.9.5).
- Computer.
- Height-measuringdevice (stadiometer).
- White sphericalmarkers.

Evaluation Period:The assessments were conducted betweenApril 17 and May 14, 2024**.**

5. DEVELOPMENT

5.1 Traditional Goniometry and Kinovea Video Analysis Software

The spinal segments were divided into thoracic (T1-T12) and lumbar (L1-L5), with markers placed on the spinous processes of the corresponding vertebrae.

During the clinical evaluation using the goniometer (petrómetro) (Figure 3), simultaneous video recordings were taken using two cameras (one lateral view and one posterior or dorsal view). The objective was to capture the same moment of movement in both video and clinical assessment, allowing for comparative analysis between the goniometer and the video analysis software. Computer webcams were used for recording.

Figure 3 – Petrometer, anterior view.Own source.

Kinovea video analysis software offers a free version capable of many other features besides the following:

- Freezing video frames to place reference points on selected positions.
- Selecting specific points and drawing lines to analyze them against horizontal and vertical references.
- Measuring angles and tracking movements dynamically.
- Adjusting image speed (frames per second).
- Exporting data via graphs showing tracked points and angular variations.
- For this study, Kinovea version 0.9.5 was used.

To ensure accurate point identification, contrasting markers were placed on the skin or clothing of the subjects.

For precise spinal level localization in lateral views, a 3D-printed base was designed, mimicking markers used in biomechanics laboratories. White polystyrene spheres were attached to elevate the reference points, making them visible in both lateral and posterior views.

MarkerDimensions:

- Base: 2 cm diameter, 0.5 cm height.
- Stick: 2 cm height, centered on the base.
- Polystyrenesphere: 3 cm diameter.
- The sphere was inserted 0.7–1 cm into the stick and secured with silicone adhesive.
- Total marker height: 3.5 cm (ranging from 3.3 to 3.7 cm) above the skin.
- The upper edge of the sphere was positioned approximately 3 cm ± 3 mm above the skin.
- The base was painted black to enhance contrast and improve tracking in video analysis software.

Marker Placement and Data Collection

Through direct palpation, the spinous processes were identified, and the lumbar and thoracic regions were distinguished using marker placement. White spherical markers were placed on the following vertebrae:T1-T8-T12-S1.

A large testing area was selected to allow proper camera positioning at the optimal distance for capturing full-body views. The floor was marked to indicate:

1. The exact position for subjects.

2. Fixed positions for the cameras, ensuring consistency.

The cameras were always placed in the same orientation:
- One camera capturing the lateral view.
- One camera capturing the dorsal (posterior) view.

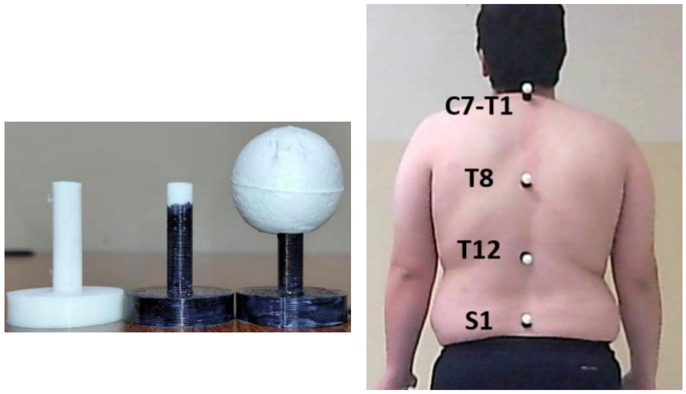


Figure 4- Design of our markers, and the location of the markers on the back of one of the subjects to be evaluated.Own source.

5.2 Participant Performance During the Movements

During anterior trunk flexion, some subjects did not fully follow instructions, keeping their heads slightly elevated. This engaged the neck muscles and reduced thoracic curvature, affecting the movement pattern. When necessary, corrections were made, and subjects were instructed to reposition their heads properly.

For lateral inclinations (left and right), despite prior instructions, most subjects slightly rotated their trunks toward the side they were leaning. This misalignment shifted the movement from the coronal plane (lateral flexion) to the transverse plane (rotation).
- This slight trunk rotation did not affect goniometer readings.
- However, it may have influenced Kinovea readings, as the marker moved out of the two-dimensional analysis plane, limiting the software's ability to provide accurate results.

5.3 Data Recording Procedure

For this study, the spinal column was divided into two segments:
- Thoracic (dorsal) segment.
- Lumbar segment.

The values for each segment were recorded separately, then summed to determine the total spinal displacement during movement.

Each subject was evaluated for three types of movement:
1. Anterior trunk flexion (flexion).
2. Left lateral trunk flexion (left lateralization).
3. Right lateral trunk flexion (right lateralization).

For each movement, the following measurements were recorded:

- Lumbar segment displacement.
- Thoracic segment displacement.
- Total displacement (sum of lumbar + thoracic values).

Each movement was performed three times, with three recorded measurements per trial.

Data Collection Using the Goniometer (Petrómetro):

- Two goniometers were required.
- The devices were placed at the initial and final positions for each spinal segment (thoracic or lumbar).
- Both goniometers were zeroed at the starting position.
- The subject performed the movement, and the goniometers were repositioned at the exact same level as the initial placement.
- The angle recorded by the upper goniometer was adjusted by subtracting the displacement of the lower goniometer to obtain the true vertebral displacement.
- This process was performed separately for both the lumbar and thoracic regions.

Figure 5- Example of taking measurements with the petrometer.Own source.

Data Collection Using Kinovea Software:

1. The video was paused at the correct frame closest to the petrómetro recording.
2. The angle was measured using the white spherical markers as reference points.
3. The initial angle and final angle were recorded.
4. The difference between the two values was calculated to determine the total movement displacement.

The software automatically set the initial angle to 0°, measuring the difference between the starting vertical position and the final displacement angle.

Postural Observations and Considerations

- Many subjects did not maintain a perfectly vertical spinal alignment.
- Postural deviations were observed, but no diagnostic clinical assessments were conducted.
- The angle measured by the markers did not directly correspond to the specific vertebral segment being evaluated.
- The dorsolumbar angle included the entire lumbar segment and half of the thoracic segment.

For each subject, in each movement repetition, the following data were recorded:

- Nine values per device (goniometer and Kinovea software).
- Total of 18 values per repetition (9 of the petrometer and 9 of the kinovea).
- Threerepetitions per movement.

6. RESULTS

6.1 Postural Assessment Using Kinovea Software

Slight positional inaccuracies did not affect the petrómetro readings, as the device adapts to the subject’s body surface. However, Kinovea's two-dimensional images revealed that markers appeared to descend further when subjects exhibited minor trunk rotation (Figure 6).

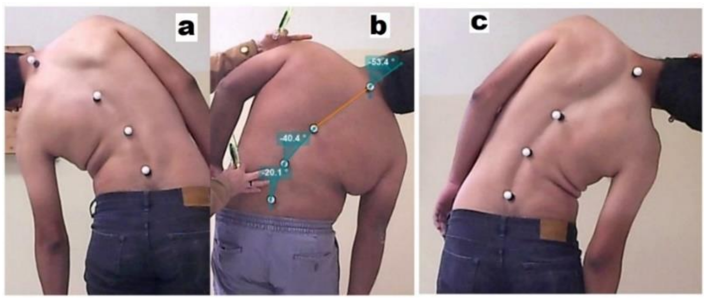


Figure 6 – Examples of Subject Positions During Test Registrations.Own source.

The most accurate measurement tool identified was “Angle to Vertical” (Figure 7), which was applied to all 78 subjects in the following variables:

- Left and right lateral flexion (at lumbar, thoracic, and total levels).
- The sum of both values determined the total lateral flexion for both sides.

Figure 7 – “Angle to Vertical” Tool.Own source.

For trunk flexion analysis, the most appropriate tool was identified as “Angle”, which was applied to assess anterior trunk flexion in all 78 subjects (Figure 8).

- The initial angular position was recorded.

- Measurements for each segment (thoracic and lumbar) were recorded separately.

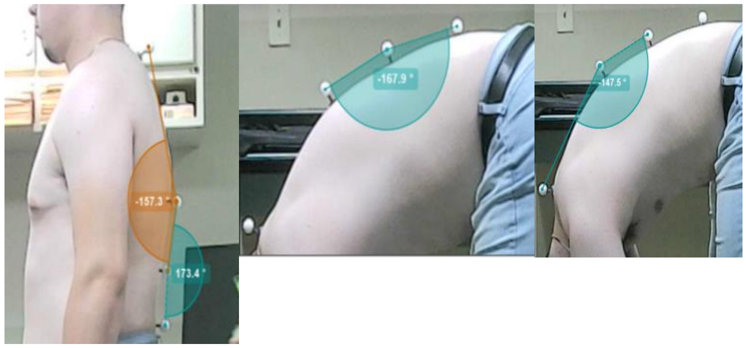


Figure 8- "Angle" tools assessing anterior trunk flexion.Initial position and final lumbar and dorsal position.Own source.

6.2 Statistical Analysis

The data from 78 subjects across three movement repetitions were compared, using measurements obtained from both the petrómetro and the Kinovea software. Minitab 18 Statistical Analysis Software was used for this analysis. (Note: "P" refers to Petrómetro, "K" refers to Kinovea.)

Although boxplot comparisons revealed similar mean values, further analysis was conducted using hypothesis testing.

Table 6 presents the hypothesis test results, determining whether the results obtained using Kinovea had the same mean as those obtained using traditional goniometry (95% confidence interval (CI), using a two-sample t-test).

Table 6. Hypothesis Test Results Comparing Kinovea and Traditional Goniometry

95% CI	**Z=1.96**		
	LUMBAR	**DORSAL**	**TOTAL**
LEFT LATERAL FLEXION	**Fail to reject** **Ho: $\mu k = \mu p$**	**Decline** **Ho: $\mu_k \neq \mu_p$**	**Fail to reject** **Ho: $\mu k = \mu p$**
RIGHT LATERAL FLEXION	**Fail to reject** **Ho: $\mu k = \mu p$**	**Decline** **Ho: $\mu_k \neq \mu_p$**	**Decline** **Ho: $\mu_k \neq \mu_p$**
ANTERIOR FLEXION	**Fail to reject** **Ho: $\mu k = \mu p$**	**Decline** **Ho: $\mu_k \neq \mu_p$**	**Fail to reject** **Ho: $\mu k = \mu p$**

The total values for left lateral flexion and total anterior flexion showed correspondence between the petrómetro and Kinovea.

However, three thoracic segment values did not align between the petrómetro and Kinovea measurements (left lateral flexion, right lateral flexion, anterior flexion); neither does the total right lateralization.

6.3 Sources of Bias in Video Analysis Systems for Evaluating Complex Movements in Anatomical Planes

The results obtained using Kinovea 0.9.5 for spinal movement analysis were inconsistent, aligning with previous literature findings that segmental spinal assessment is challenging. However, when evaluating the total movement, including both thoracic and lumbar segments, the procedure became more manageable.

A possible explanation for this discrepancy is that subjects struggled to maintain the correct posture long enough for both the petrómetro reading and video frame capture, resulting in misalignment between the two measurement methods.

Additionally, Kinovea exhibited greater variability, which may be attributed to:

- Subject positioning errors due to two-dimensional image limitations.
- Minor trunk rotations despite repeated efforts to correct posture.

Best Practices for Data Collection Using Petrómetro and Kinovea

To ensure accurate clinical evaluation with the petrómetro, the following protocol must be followed:

- Two petrómetros are required for each measurement.
- The devices must be positioned consistently for each vertebral segment (thoracic and lumbar).
- The upper petrómetro reading must be adjusted by subtracting the lower petrómetro displacement value to obtain actual vertebral movement.

For video recording, simultaneous data collection is crucial to ensure that the recorded video frame matches the petrómetro reading as closely as possible.

Toachievethis:

- The test subject must hold the final position long enough for:
  - The petrómetro reading to be taken.
  - The evaluator to step aside, leaving the subject fully visible in the video frame.
- The evaluator should move away quickly and in the correct orientation to avoid obstructing the camera view.
- Maintaining posture for several seconds proved uncomfortable for some subjects.

Mastering the Kinovea software analysis process is essential to optimize efficiency.

Data Processing in Excel

The data collection process required three steps:

1. Record the initial and final readings for each vertebral segment.
2. Calculate the difference between the initial and final positions to determine the actual displacement of each level.
3. Sum the values for each segment to obtain total spinal movement displacement.

Recommendations for Improving Video-Based Spinal Movement Analysis

To enhance accuracy and minimize bias, the following recommendations are proposed:

- Mark the floor to indicate precise subject positioning and direction.
- Ensure proper ventilation, as excessive sweating caused markers to detach, while cold temperatures led to discomfort and involuntary movements.

- If a marker detaches, it should be reapplied in the exact same position.
- Use a dedicated and permanent space for testing to:
    - Keep cameras at a consistent distance from subjects.
    - Maintainfixedimage angles.
- Ensure subjects do not move outside the anatomical plane and adjust their positioning before capturing video images.
- Carefully select Kinovea software tools for optimal analysis.

7. CONCLUSIONS AND RECOMMENDATIONS

The results indicate that Kinovea 0.9.5 is not suitable for three-dimensional assessment of the spinal column. However, this conclusion is not definitive, as the entire evaluation and data collection process can be improved. Additionally, further specialization in using the software for spinal mobility assessment may enhance its accuracy.

A deeper statistical analysis of the obtained results is still required. The current findings suggest that Kinovea 0.9.5 is also inadequate for three-dimensional assessment of body segments with small, short, and complex movements across all three anatomical planes. This contrasts with existing literature that validates its use for assessing larger joint movements in the upper and lower limbs within two-dimensional planes.

As discussed in Chapter 1, Section 1.3, numerous researchers have emphasized the importance of evaluating body mobility in all three anatomical planes. This is essential for:

- Understanding and analyzing individual biomechanics.
- Assessing physical capabilities and limitations.
- Reducing injury risks.
- Defining therapeutic interventions.

The need for accurate spinal mobility assessment is further highlighted by the high global incidence of lumbar injuries and work-related disabilities, which contribute significantly to GDP consumption.

Therefore, further exploration of alternative technologies is necessary to identify a method that allows three-dimensional spinal assessment. Currently, no simple strategy exists for evaluating combined planes of movement in the spine, nor is there a traditional approach for assessing subjects in dynamic conditions or under external load exposure.

8. REFERENCES

Andújar, O.P.; Santonja, M.F.; García, R.S.; Rodríguez, G.P.L.; (1997) "Higiene postural del escolar: influencia de la educación física."

Bahramian, A.P.; Karimi, N.; Yousefi, M.; Tabatabai, F.G.; Rahnama, L.; (2023). Three-dimensional Motion Analysis of Sacroiliac Joint Mobility: A Reliability Study. Iran Red CrescentMed J. 2023 January; 25(1): e2440. doi: 10.32592/ircmj.2023.25.1.2440

Barrabés, M.V.; Ornilla, E.; (2018) "Lumbalgia aguda." Guías de Actuación en Urgencias. Clínica Universidad de Navarra.

Bazaldúa-Treviño A.; Rivera S.G., Treviño, A.M.G. (2019). “Prevención del dolor músculo esquelético en escolares por uso de la mochila.” Rev Med Inst Mex Seguro Soc. 2019;57(2).

Cailliet, R., (1984). “Understand your backage”. Ed F.A. Davis Company.

Campos-Nonato, I.; Galván-Valencia, O.; Hernández-Barrera, L.; Oviedo-Solís C.; Barquera, S.; (2023) "Prevalencia de obesidad y factores de riesgo asociados en adultos mexicanos: resultados de la Ensanut 2022." Salud Publica Mex. 2023; 65 (supl 1): S238-S247.

Canté-Cuevas, X.C.; Kent-Sulú, M.P.; Vásquez-Gutiérrez, M. G. y Lara-Severino, R. C. -TESIS- 2010. “Factores posturales de riesgo para la salud en escolares de Ciudad del Carmen, Campeche.” U. Tecnociencia 4 (1) 1 - 15.

Castillo, J.; Cubillos, A.; Orozco, A.; Valencia, J. (2007). "El análisis ergonómico y las lesiones de espalda en sistemas de producción flexible". Rev. Cienc. Salud. Bogotá (Colombia) 5 (3): 43-57, septiembre-diciembre de 2007.

Ceballos-Laita, L.; Mingo-Gómez, T.; García-Lázaro, S.; Jiménez, B.S., (2017) “Efectos ergonómicos inmediatos de un apoyo isquiático en sedestación. Herramienta preventiva para la información en salud.” Revista Española de Comunicación en Salud.

Cerfoglio, S.; Capodaglio, P.; Rossi, P.; Conforti, I.; D’Angeli, V.; Milani, E.; Galli, M.; Cimolin, V.; (2023a). Evaluation of Upper Body and Lower Limbs Kinematics through an IMU-Based Medical System: A Comparative Study with the Optoelectronic System. Sensors 2023, 23, 6156.

Cerfoglio, S.; Lopomo, N.F.; Capodaglio, P.; Scalona, E.; Monfrini, R.; Verme, F.; Galli, M.; Cimolin, V.; (2023b). Assessment of an IMU-Based Experimental Set-Up for Upper Limb Motion in Obese Subjects. Sensors 2023, 23,9264. https://doi.org/10.3390/s23229264

Clarke, B.; Al-Hammdany, J.K.; Giulio, I.D.; (2021). Human muscle and spinal activation in response to body weight loading. JournalofAnatomy. 2023; 242: 745–753. DOI: 10.1111/joa.13821

Covarrubias-Gómez, Alfredo; Dr. Uriah Guevara-López, Dra. Claudia Gutiérrez-Salmerón, Dr. José A Betancourt-Sandoval, Dr. José A Córdova-Domínguez. (2010). "Epidemiología del dolor crónico en México".

De Souza, S.E.; Bhernardes, J.M.; Noll, M.; Gómez-Salgado, J.; Ruiz-Frutos, C.; Dias, A.; (2021). "Prevalence of low back pain and associated Risks in school-age children". Elsevier. Pain Management Nursing 22 (2021) 459-464.

Delgado, S.; Gaceta UNAM - Jun 27, 2019a. https://www.gaceta.unam.mx/lumbalgia-problema-de-salud-publica/

Delgado, C.W.A.; Abarca, L.J.J.; Boada, R.L.E.; Salazar, T.S.E.; (2019b)."Lumbalgia inespecífica. Dolencia más común de lo que se cree." Revista Científica Mundo de la Investigación y el Conocimiento. Vol. 3 núm.2, abril, ISSN: 2588-073X, 2019, pp. 3-25.

Domokos, B.; Beer, L.; Reuther, S.; Raschka, C.; Spang, C.; (2023). Immediate Effects of Isolated Lumbar Extension Resistance Exercise (ILEX) on Spine

Posture and Mobility Measured with the IDIAG Spinal Mouse System. Journal of Functional Morphology and Kinesiology, 2023, 8, 60.

Dreischarf, B.; Koch, E.; Dreischarf, M.; Schmidt, H.; Pumberger, M.; Becker, L.; (2022). Comparison of three validated systems to analyse spinal shape and motion. Scientific Reports, Nature Portfolio (2022) 12:10222 | https://doi.org/10.1038/s41598-022-13891-x

Escudero, S.I.R.; (2016). Reflexión: Los riesgos ergonómicos de carga física y lumbalgia ocupacional. Biociencias. Volumen 11, Número 2, 97 - 100. Jul-Dic 2016. Universidad Libre Seccional Barranquilla.

Fragala, M.S.; Cadore, E.L.; Dorgo, S.; Izquierdo, M.; Kraemer, W.J.; Peterson, M.D.; Ryan, E.D.; (2019) "Resistance Training for Older Adults: Position Statement From the National Strength and Conditioning Association." Journal of Strength and Conditioning Research. (2019) 33:8.

FREMAP, Mutua Colaboradora con la Seguridad Social Nº 61. "Guía para el cuidado de la espalda." Depósito legal: M-2022-2015. Imagen Artes Gráficas, S.A. http://prevencion.fremap.es

Gasic, B.M.; (1998)."Manual de Ortopedia y Traumatología". 2da Edición. Editorial Mediterráneo. Santiago, Chile. Página 237.

Gutiérrez–Bedón, A.P.; Manzano-Merchán, F.O.; Quinde-Alvear, A.G.; (2023) "Lumbalgia aguda asociada a la carga laboral en el personal de salud y auxiliares de enfermería" Journal Scientific MQR Investigar. Vol.7-N° 3, 2023, pp. 3760-3788. ISSN: 2588–0659.

Hellebrandt, F.A.; Neall D., E.; Lee M., M.; "The Measurement of Joint Motion: Part III-Reliability of Goniometry" 1949. ThePhysicalTherapyReviwe; Vol. 29, no. 7, pag 302.

Hupp,M.; Vallotton,K.; Brockmann, C.; Huwyler, S.; Rosner, J.; Sutter, R.; Klarhoefer, M.; Freund, P.; Farshad, M.; Curt. A.; (2019). Segmental differences of cervical spinal cord motion: advancing from confounders to a diagnostic tool. Scientific Reports. (2019) 9:7415

Huthwelker, J.; Konradi, J.; Wolf, C.; Westphal, R.; Schmidtmann, I.; Drees, P.; Betz, U. (2022). Reference Values for 3D Spinal Posture Based on Videorasterstereographic Analyses of Healthy Adults. Bioengineering 2022, 9, 809. https://doi.org/10.3390/bioengineering9120809

Ji, M.; Xu, D.; Teo, E.C.; (2024). Biomechanical comparison of sagittal vertebral column bend change induced by backpacks in school-aged children and adolescents: Systematic review and network meta-analysis. Molecular &CellularBiomechanics, 2024; 21: 71.

Johnson, D.; Kim, M.J.; (2023). Defining The Disease of Movement Dysfunction Related Low Back Pain. Journal of Orthopedic Research and Therapy, 8: 1327.

Kapandji, A. (2006). “Fisiología Articular” Tomos I, II y III. Madrid, España: Panamericana.

Kaufer-Horwitz, M.; Pérez, H.J.F.; (2022). "La obesidad: aspectos fisiopatológicos y clínicos". Interdisciplina 10, n° 26 (enero–abril 2022): 147-175.

Krusen (2000). “Medicina física y rehabilitación” Tomo II.4ta ed.; Ed Panamericana.

Kyung-hun, K.; Jihyeon, A.; Sang-hun, J.; (2019). Analysis of the Effect of Backpack Design with Reduced Load Moment Arm on Spinal Alignment. Int. J. of Env. Res. & Public Health, 16, 4351

Lane, J.S.; Bansbach, H.M.; Connaboy, C.; Darnell, M.E.; Keenan, K.; Lovalekar, M.; Nagai, T.; Allison, K.F.; (2017). The Effects of Loaded Fatigue on Loaded Postural Stability. International Journal of Excercise Science, Isue 9, Vol 6, 2017.

Lee, G.; Choi, W.; Jo, H.; Park, W.; Kim, J.; (2020). Analysis of motor control strategy for frontal and sagittal planes of circular tracking movements using visual feedback noise from velocity change and depth information. PLoS ONE 15(11): e0241138.

Lim, S.; D'Souza, C.; (2020). Measuring Effects of Two-Handed Side and Anterior Load Carriage on Thoracic-Pelvic Coordination Using Wearable Gyroscopes. Sensors, 2020, 20, 5206.

Lindenmann, S.; Tsagkaris, CH.; Farshad, M.; Widmer, J.; (2022). Kinematics of the Cervical Spine Under Healthy and Degenerative Conditions: A Systematic Review. Annals of Biomedical Engineering, Vol. 50, No. 12, December 2022 (2022) pp. 1705–1733.

Martínez-Hernández, A.; Perez-Lomelí, J.S.; Burgos-Vargas, R.; Padilla-Castañeda, M.A.; (2022). A Wearable System Based on Multiple Magnetic and Inertial Measurement Units for Spine Mobility Assessment. Sensors 2022, 22, 1332. https://doi.org/10.3390/s22041332

Mekhael, E.; Rachkidi, R.E.; Saliby, R.M.; Nassim, N.; Semaan, K.; Massaad, A.; Karam, M.; Saade, M.; Ayoub, E.; Rteil, A.; Jaber, E.; Chaaya, C.; Nahed, J.A.; Ghanem, I.; Assi, A.; (2023). Functional assessment using 3D movement analysis can better predict health-related quality of life outcomes in patients with adult spinal deformity: a machine learning approach. Frontiers in Surgery. Doi: 10.3389/fsurg.2023.1166734

Mendoza, G.E.; (2019). "La familia y la escuela en la postura corporal en el ámbito escolar". IV Congreso internacional virtual sobre La Educación en el Siglo XXI (marzo 2019).

Michalik, R.; Hamm, J.; Quack, V.; Eschweiler, J.; Gatz, M.; Betsch, M.; (2020). Dynamic spinal posture and pelvic position analysis using a rasterstereographic device. Journal of Orthopaedic Surgery and Research (2020) 15:389. https://doi.org/10.1186/s13018-020-01825-0

Montoya, E.E.; (2019). "Identificación de los factores de riesgo ergonómicos y psicosociales en profesionales de enfermería en centro hospitalario del estado de sonora." Tesis.

Muñoz, P.C.; Vanegas L.J.; Marchetti, P.N., 2012. "Factores de riesgo ergonómico y su relación con dolor musculoesquelético de columna vertebral: basado en la primera encuesta nacional de condiciones de empleo, equidad, trabajo, salud y calidad de vida de los trabajadores y trabajadoras en Chile (ENETS) 2009-2010". Med Segur Trab (Internet) 2012; 58 (228) 194-204.

Nishizawa, K.; Harato, K.; Hakukawa, S.; Okawara, H.; Sawada, T.; Ishida, H.; Nagura, T.; (2024). Turning and sitting movements during timed up and go tests predict deterioration of physical function in middle-aged adults. Gait&Posture 108 (2024) 329–334.

Nutbeam, T.; Fenwick, R.; May, B.; Stassen, W.; Smith, J.; Shippen, J.; (2022a). Maximum movement and cumulative movement (travel) to inform our understanding of secondary spinal cord injury and its application to collar use in self-extrication. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine (2022) 30:4.

Nutbeam, T.; Fenwick, R.; May, B.; Stassen, W.; Smith, J.E.; Bowdler, J.; Wallis, L.; Shippen, J.; (2022b). Assessing spinal movement during four extrication methods: a biomechanical study using healthy volunteers. Scandinavian Journal of Trauma Resuscitation and Emergency Medicine (2022) 30:7. https://doi.org/10.1186/s13049-022-00996-5

Nyayapati, P.; Booker, J.; Wu, P.I-K.; Theologis, A.; Dziesinski, L.; O'Neill, C.; Zheng, P.; Lotz, J.C.; Matthew, R.P.; Bailey, J.F.; (2022). Compensatory biomechanics and spinal loading during dynamic maneuvers in patients with chronic low back pain. European Spine Journal (2022) 31:1889–1896. https://doi.org/10.1007/s00586-022-07253-4

OMS (2023) https://www.who.int/es/news-room/fact-sheets/detail/physical-activity#:~:text=

OMS (2021) Trastornos Musculoesqueléticos. https://www.who.int/es/news-room/fact-sheets/detail/musculoskeletal-conditions

Paccini, M.; Patané, G.; Spagnuolo, M.; (2023). 3D anatomical modelling and analysis of the spine. Research on Biomedical Engineering. https://doi.org/10.1007/s42600-023-00300-z

Pandey, S.K.A.; (2011). "Diagnóstico en Ortopedia Clínica." 3a ed. Editorial Jaypee-Highlights, Medical Publishers, Inc. Capítulo 10, pag. 306.

Patel, P.; Parmar, L. (2022). Comparison between genders for trunk mobility in normal adults: A cross sectional study. International Journal of Health Sciences, 6(S4), 1564–1573.

Pou, S.A.; Wirtz, B.J.M.; Aballay, L.R.; (2023). "Epidemia de obesidad: Evidencia actual, desafíos y direcciones futuras". ISSN 1669-9106. MEDICINA (Buenos Aires) 2023: 83: 283-289.

Qu, H.; Yu, L.J.; Wu, J.T.; Liu, G.; Liu, S.H.; Teng, P.; Ding, L.; Zhao, Y.; (2020). Spine system changes in soldiers after load carriage training in a plateau environment: a prediction model research. Military Medical Research (2020) 7:63. https://doi.org/10.1186/s40779-020-00293-1

Ramadan, M.Z.; Al-Tayyar, S.N.; (2020). "Development and Experimental Verification of an Ergonomic Backpack". BioMed Reserch International. Volume 2020, Article ID 1437126, 13 pag.

Reyes, G.R.; Rozas M.P.; Muñóz-Torres M.; (2008). "Regulación del proceso de remodelado óseo". REEMO. 2008;17(1):10-4.

Rodríguez CF; Guevara VG; Bardach A; Espinola N; Perelli L.; Balan D; Palacios A; Augustovski F; Pichón-Riviere, A.; Alcaraz, A., (2023). "Carga de enfermedad y económica atribuible al consumo de bebidas azucaradas en El Salvador." RevPanam Salud Publica. 2023; 47 e80.

Rodriguez, C.F.; Quintero, H.; Aschner, H. (2005). Movimiento del brazo humano: de los tres planos a las tres dimensiones. Revista de Ingenieria 22, Universidad de los Andes, nov del 2005.

Rodríguez-Soto, A.E.; Berry, D.B.; Palombo, L.; Valaik, E.; Kelly, K.R.; Ward, S.R.; (2017). Effect of Load Magnitude and Distribution on Lumbar Spine Posture in Active-duty Marines. Occupationalhealth/ Ergonomics. Spine, V. 42, No. 5, pp 345–351, 2017.

Sajedi, N.M.; Abbasi, A.; Khaleghi, T.M.; Fadaie, H. (2024). The Effect of Pyramid and Reverse Pyramid Loadings on Spine and Pelvis Coordination Variability During Squat (Persian). Scientific Journal of Rehabilitation Medicine. 2024; 13(1):194-207.

Santonja, M.F.; Andújar, O.P.; Martínez, G.M.; 1994. "Ángulo lumbo-horizontal y valoración de repercusiones del Síndrome de Isquiosurales Cortos." APUNTS-1994-Vol. XXXI-103.

Sato, K.; Kogawa, M.; Yamada, Y.; Yamashiro, M.; Kasama,F.; Matsuda, M.;(2023). Equivalent values between anterior vertebral height, wedge ratio, and wedge angle for evaluating vertebral mobility and deformity in osteoporotic vertebral fractures: a conventional observational study. Journal of Orthopaedic Surgery and Research (2023) 18:284.

Schmid, S,; Burkhart, K.A.; Allaire, B.T.; Grindle, D.; Bassani, T.; Galbusera, F.; Anderson, D.E.; (2020) Spinal Compressive Forces in Adolescent Idiopathic Scoliosis With and Without Carrying Loads: A Musculoskeletal Modeling Study. Frontiers in Bioengineering and Biotechnology. 8:159.

Segura-Valdez, L.F.; Hernández-Ordoñez, R.; Sosa-García, J.U.; Camacho-Guerrero A. (2022). "Epidemiología de la lumbalgia en la consulta externa de la UMF 53". 2022. IMSS- Revista Médica OCRONOS.

Serra, G.M.R.; Díaz, P.J.; DeSande, C.M.L.; (2003). "Fisioterapia en Traumatología, Ortopedia y Reumatología". 2da edición. Páginas 3 y 308.Editorial Masson. Barcelona, España.

Shuai, Z.; Dong, A.; Liu, H.; Cui, Y. (2022). Reliability and Validity of an Inertial Measurement System to Quantify Lower Extremity Joint Angle in Funct. Movements. Sensors 2022, 22, 863.

Sikdar, S.; Srbely, J.; Shan, J.; Assefa, Y.; Stecco, A.; DeStefano, S.; Imamura, M.; Gerber, H.L.; (2023). "A model for personalized diagnostic for non-specific low back pain: the role of the myofascial unit." Frontiers in Pain Research 4:1237802. Oct 2023.

Skovdal, R.M.; Dunn, K.M.; Kamper, S.; O´Sullivan, K.; Lund, S.C.; Palsson, T.; (2021); "Low Back Pain During Childhood and Adolescence". International AssociationfortheStudyofPain (IASP).

SGADOR. Sociedade Galega da dor e coidados paliativos (2017). “Manual Básico de dolor”. GRUNENTHAL.

Suter, M.; Eichelberger, P.; Frangi, J.; Simonet, E.; Baur, H.; Schmid, S.; (2020). Measuring lumbar back motion during functional activities using a portable strain gauge sensor-based system: A comparative evaluation and reliability study. JournalofBiomechanics 100 (2020) 109593.

Taboadela, C.H.; (2007)."Goniometria, una herramienta para la evaluación de las incapacidades laborales." Asociart ART.

Takatalo, J.; Ylinen, J.; Pienimäki, T.; Häkkinen, A.; (2020). Intra- and inter-rater reliability of thoracic spine mobility and posture assessments in subjects with thoracic spine pain. BMC Musculoskeletal Disorders (2020) 21:529. https://doi.org/10.1186/s12891-020-03551-4

The Lancet Rheumatology (2023) “The global epidemic flow back pain”, Vol 5 June 2023, https://doi.org/10.1016/S2665-9913(23)00133-9

Ueta, K; Mizugichi, N.; Sugiyama, T.; Isaka, T.; Otomo, S.; (2022). "The Motor Engram of Functional Connectivity Generated by Acute Whole-Body Dynamic Balance Training." Medicine &Science in Sports&Exercise, Vol. 54, No. 4, pp. 598-608, 2022.

Vaughan, L.C.; Davis, L.B.; O´Connor, J.C.; (1999) "Human gait." Kiboho Publishers. 2ed. ISBN: 0-620-23558-6

Veljovic, F.; Burak, S.; Begic, E.; Jahic, D.;Kadic , F.; Iglica, A.; (2019). Lumbar-load analysis of a soldier while carrying the heavy loads. Periodicals of Engineering and Natural Sciences ISSN 2303-4521. Vol. 7, No. 4, December 2019, pp.1599-1606

Vera-García, F.J.; Barbado D.; Moreno-Pérez, V.; Hernández-Sánchez, S.; Juan-Recio, C.; Elvira, J.L.L.; (2015). "Core stability. Concepto y aportaciones al entrenamiento y la prevención de lesiones". RevAndalMed Deporte. 2015;8(2):79–85.

Xavier, C.L.W.; de Campos, T.; Carril, E.V.M.; Marcondes, C.Jr.R.; (2021). "A frameworkforautomatichandrangeofmotionevaluationofrheumatoidarthritispatients." Elsevier. Informatics in Medicine Unlocked, Volume 23 (2021), 100544.

Zhao, J.J.; Liu, Z.Q.; Xie, S.J.; Tang, CH.Q.; (2022). Research on the application of body posture action feature extraction and recognition comparison. IET Image Processing. DOI: 10.1049/ipr2.12620

Zurita, O.F.; Ruiz, R.L.; Zaleta, M.L.; Fernández, S.M.; Fernández G.R.; Linares, M.M.; (2014)."Análisis de la prevalencia de escoliosis y factores asociados en una población escolar mexicana mediante técnicas de cribado." Gaceta Médica de México. 2014; 150:432-9.

INTERACTION BETWEEN WORK SHIFTS AND DAILY STRESSORS AMONG INDUSTRIAL WORKERS

Patricia Eugenia Sortillón González[1,2], 0000-0002-9716-6693

[1] Department of Manufacturing Industrial Engineering
Universidad Estatal de Sonora
Ley Federal del Trabajo S/N, Colonia Apolo
Hermosillo, Sonora CP 83100

[2]Department of Industrial Engineering
Universidad de Sonora
Ave. Rosales S/N, Colonia Centro
Hermosillo, Sonora, CP 83000

Corresponding author's e-mail: patricia.sortillon@unison.mx

Resumen: Los trabajadores industriales que laboran turnos de 24 horas, nocturnos y diurnos se enfrentan un estrés producido por diversos factores, entre ellos la fatiga y el entorno mismo de trabajo. En este estudio explora la relación entre el trabajo de turnos y el estrés, poniendo de relieve las variaciones de los factores estresantes entre los distintos turnos. Comprender estos efectos es crucial para desarrollar intervenciones dirigidas a mejorar el bienestar, la productividad y la salud general de los trabajadores. Mediante un diseño transversal, 150 participantes de turnos de 24 horas, diurnos y nocturnos completaron la encuesta Inventario Diario de Sucesos Estresantes (DISE por sus siglas en Inglés) para evaluar los factores estresantes relacionados con el trabajo, interpersonales, ambientales y personales. La severidad del estrés, el control percibido y el impacto emocional se midieron mediante escalas de Likert. La recolección de datos comprendió cuatro días para los trabajadores de turnos de 24 horas y de 5 días consecutivos para los trabajadores de turnos diurno y nocturno. Se realizó un análisis estadístico que incluyó ANOVA y modelos de efectos mixtos. El análisis ANOVA (α=0,05) reveló que los trabajadores con turnos de 24 horas informaron de niveles de estrés significativamente más altos (μ = 72,4) en comparación con los trabajadores con turnos diurnos (μ= 65,3) y nocturnos (μ= 68,9), F = 4,325, p = 0,014. El modelo de efectos mixtos indicó que el control percibido moderaba el impacto del estrés, y que los empleados que informaban de un mayor control experimentaban un menor estrés (-10,2 puntos). Las estrategias de afrontamiento también desempeñaron un papel crucial, ya que los enfoques proactivos (por ejemplo, la resolución de problemas) redujeron la gravedad del estrés en un 25%, mientras que las estrategias pasivas (por ejemplo, la evitación) aumentaron el estrés en un 15%. Además, los trabajadores por turnos de 24 horas mostraron una recuperación del estrés más lenta (β = +15,3, p = 0,003), lo que sugiere efectos acumulativos del estrés debidos a la prolongación de las horas de trabajo. Los resultados destacan la necesidad de intervenciones como la reducción de la duración de los turnos, la mejora del control percibido y la promoción de estrategias de afrontamiento proactivas para mitigar el estrés laboral. Las investigaciones futuras podrían contemplar la exploración de las medidas de estrés fisiológico y los factores organizativos que influyen en el bienestar de los trabajadores.

Palabras clave: Empleados industriales, salud, estrés, trabajo de turno.

Relevancia para la ergonomía: El propósito de este estudio fue analizar los efectos de tres tipos de turnos laborales en las dinámicas diarias de estrés, con un enfoque en los turnos de 24 horas, nocturnos y diurnos, y su impacto en los niveles de estrés y el bienestar de los trabajadores. Dado que el trabajo por turnos es cada vez más común en diversas industrias, comprender cómo estos horarios influyen en el estrés y la recuperación resulta esencial para promover la salud y la productividad de los empleados.

Los hallazgos de esta investigación ofrecen información valiosa sobre los factores de estrés específicos asociados con cada tipo de turno y pueden contribuir al desarrollo de intervenciones efectivas en el entorno laboral. Al examinar estas relaciones, este estudio busca ampliar la comprensión del estrés ocupacional y sus implicaciones para la salud mental, además de sentar las bases para fortalecer los sistemas de apoyo destinados a los trabajadores en distintos horarios de trabajo.

Abstract: Industrial workers engaged in 24-hour, night, and day shifts face significant stress due to fatigue, and demanding work environments. This study explored the relationship between shift work and stress, highlighting variations in stressors among different shifts. Understanding these effects is crucial for developing targeted interventions to improve worker well-being, productivity, and overall health. Using a cross-sectional design, 150 participants from 24-hour, day, and night shifts completed the Daily Inventory of Stressful Events (DISE) survey to assess work-related, interpersonal, environmental, and personal stressors. Stress severity, perceived control, and emotional impact were measured using Likert scales. Data collection spanned multiple days based on shift type (four days in 24 hours shift and five days for day and night shift), and statistical analysis included ANOVA and mixed-effects modeling. ANOVA analysis (α=0.05) revealed that 24-hour shift workers reported significantly higher stress levels (μ = 72.4) compared to day (μ = 65.3) and night (μ = 68.9) shift workers (F = 4.325, p = 0.014). Mixed-effects modeling indicated that perceived control moderated stress impact, with employees reporting higher control experiencing lower stress (-10.2 points). Coping strategies also played a crucial role, as proactive approaches (e.g., problem-solving) reduced stress severity by 25%, whereas passive strategies (e.g., avoidance) increased stress by 15%. Additionally, 24-hour shift workers exhibited slower stress recovery (β = +15.3, p = 0.003), suggesting cumulative stress effects due to extended work hours. The findings highlight the need for interventions such as reducing shift lengths, enhancing perceived control, and promoting proactive coping strategies to mitigate workplace stress. Future research should explore physiological stress measures and organizational factors influencing worker well-being.

Keywords: Industrial employees, health, stress, shift work.

Relevance to Ergonomics: The purpose of this study was to examine the effects of different work shifts on dynamics of daily stress, with a focus on the effects of 24-hour, night, and day shifts on workers' stress levels and well-being. As shift work becomes more prevalent in various industries, understanding how these schedules affect stress and recovery is critical to promoting employee health and productivity. The results of this research will provide valuable insights into the specific stressors associated with each shift type and contribute to the development of targeted workplace interventions. By examining these relationships, this study aims to improve our understanding of occupational stress and its broader mental health implications and provide a basis for improving support systems for workers in three different work shifts.

1. INTRODUCTION

Industrial workers who work 24-hour, night and day shifts face challenges that can impact their daily stress levels (Caruso C., 2014). Shift work, such as 24-hour and night shifts, disrupts natural circadian rhythms, which can lead to sleep disturbances, fatigue, and increased stress (Frazier, 2023). These physiological and psychological effects are often exacerbated by the demands of industrial work environments, which are typically characterized by physically demanding tasks, tight deadlines, and performance expectations (Belloni et al., 2022). Previous research (Caruso, 2014) has shown that night and 24-hour shift workers experience higher levels of stress than day shift workers, with increased risk of burnout, mental health disorders, and decreased well-being.

The stressors associated with each shift type may vary, with night shift workers more likely to face interpersonal and environmental stressors, while day shift workers tend to report higher levels of work-related stress (Stimpfel et al., 2022). Understanding the relationship between work shifts and daily stress is critical for developing targeted interventions to mitigate the negative effects of shift work on the health and performance of industrial workers. Given the significant impact that shift work has on industrial workers, it is critical to examine how different types of shifts - 24-hour, night, and day affect stress levels and well-being.

As shift work becomes more common in industries such as manufacturing, transportation, and healthcare, understanding its impact on workers' health is more important than ever (Silva y Costa, 2023). The interaction between shift work and daily stressors not only affects physical health but also has an impact on mental and emotional well-being. Research has highlighted that chronic stress, especially in high-pressure environments, can lead to negative outcomes, including lower job satisfaction, higher absenteeism, and increased susceptibility to chronic diseases such as cardiovascular disease and depression (Kivimäki et al., 2018). In addition, workers on night and 24-hour shifts often experience disrupted sleep cycles and increased fatigue, creating an urgent need for effective interventions that can alleviate these stressors (Querstret et al., 2022). This study aims to address this gap by investigating the levels and types of stress experienced by industrial workers on different shifts and assessing the long-term effects on their overall well-being.

The findings could provide valuable insights for organizations to develop tailored strategies to promote worker health, improve productivity, and reduce the adverse effects of shift work.

2. OBJECTIVES

Shift work, including 24-hour, night, and day shifts, is a common practice in industrial settings to maintain continuous operations. However, these traditional schedules often disrupt workers' biological rhythms and daily routines, potentially leading to elevated stress levels and compromised well-being. Understanding how different work shifts influence daily stress, the prevalence of specific stressors, and the ability to recover from stress is crucial for promoting occupational health.

This study aims to analyze the impact of work shifts on daily stress levels, identify the most common stressors associated with each shift type, and examine how these schedules affect stress recovery and well-being across a workweek. By addressing these objectives, this research seeks to provide insights into the unique challenges faced by workers in different shifts and inform strategies to improve their mental health and productivity.

3. METHODOLOGY

This study used a cross-sectional design to examine the impact of work shifts on stress levels and well-being among industrial workers.

3.1 Participants

The sample consisted of 150 participants evenly distributed across three work shifts: 24-hour, night, and day shifts. Participants were recruited from a local industrial organization where all shifts are available, ensuring relevance to the study objectives.

3.2 Survey design and administration

A validated tool for assessing daily stressors, the Daily inventory of stressful events (DISE)(Almeida et al., 2002) including their frequency and intensity was used to assess stress among industrial workers. DISE is a structured survey designed to assess daily stressors and their perceived impact on individuals working different shifts. This customized version is tailored to examine stress experiences among workers in 24-hour shifts, day shifts (9.6 hours), and night shifts (7 hours). The survey captures specific work-related, interpersonal, and environmental stressors, along with their severity, perceived control, emotional impact, and coping strategies. The DISE survey comprised three sections. The first section is related to daily stressor checklist with yes/no questions, divided in four elements: 1) work-related stressors (increased workload or tight deadlines, unexpected task changes or role ambiguity, equipment malfunction or technical issues, pressure from supervisors or management); 2) Interpersonal stressors (conflict with a coworker, conflict with a supervisor, miscommunication or misunderstanding, and lack of teamwork or support); 3) Physical and environmental stressors (Fatigue or sleep deprivation, discomfort due to workstation ergonomics, exposure to extreme temperatures or loud noise, and inconvenient or rotating work hours); 4) Personal stressors (financial concerns, family-related stress), health-related concerns, and commuting difficulties). The second part comprised stress severity and perceived impact measured in Likert scales. Three questions were raised: Stress severity scale (How stressful was the event? (1) Not at all stressful, (2) Slightly stressful, (3) Moderately stressful, (4) Very stressful, (5) extremely stressful; perceived control scale (How much control did you feel you had over the situation? (1) No control, (2) Little control, (3) Some control, (4) Moderate control, (5) Complete control); and emotional impact scale (how much did this stressor affect your mood or well-being? (1) No effect, (2) Slightly negative effect, (3) Moderately negative effect, (4) Very negative effect, (5) Extremely negative effect). Participants completed the DISE survey each evening to minimize recall bias and report stressors experienced throughout the workday. In addition, demographic and occupational information such as age, gender, marital status, and years of experience were collected via a standardized questionnaire to control potential confounding variables.

3.3 Data capture and screening

The data for this study were collected using the DISE survey, which was administered over varying timeframes depending on the work shift. For employees on 24-hour shifts, data was obtained over a 4-day period, while for those day shifts (9.6 hours) and night shifts (7 hours), data collection spanned a 5-day period. Responses were collected using a digital format, ensuring accessibility for all participants. The data was then securely stored in a database for statistical processing and analysis. This approach ensured a comprehensive assessment of stress dynamics and health outcomes across different work schedules, allowing for a nuanced comparison of the impact of shift duration and timing on employee well-being.

3.4 Data analysis

The data collected was analyzed to assess the prevalence of stressors, the severity and impact of these stressors across different shifts, and the effectiveness of coping mechanisms. Statistical comparisons will be conducted to explore a) Differences in stress levels between 24-hour, day, and night shifts b) The role of perceived control in moderating stress impact c) The relationship between coping strategies and stress mitigation, and d) How shift-specific factors contribute to variations in stress and well-being. Descriptive statistics and ANOVA analysis (α=0.05) were used to identify differences in stress levels across shifts, while mixed effects modeling was used to examine individual differences in stress recovery and well-being. This approach ensures a comprehensive understanding of the relationship between work shifts and stress in an industrial context

4 RESULTS

The results from this study provide insightful findings regarding the relationship between shift type, stress levels, coping strategies, and perceived control in an industrial context. Below is a detailed discussion of these results:

Differences in stress levels across shifts

The ANOVA analysis (α=0.05) revealed significant differences in stress levels across the three shift types (24-hour, day, and night shifts), with 24-hour shift workers reporting the highest stress levels. Specifically, the 24-hour shift group had a significantly higher mean stress score (mean = 72.4) compared to the day shift (mean = 65.3) and night shift workers (mean = 68.9). This suggests that the longer and more irregular work schedule of the 24-hour shift may contribute to higher levels of stress among workers (see Table 1).

Table 1: Descriptive Statistics for Stress Levels Across Shifts

Shift type	Mean Stress Score (MSS)	(SD)	Sample Size (n)
24-hour	72.4	8.1	50
Day (9.6 hrs.)	65.3	7.2	50
Night (7.0 hrs.)	68.9	6.5	50

The ANOVA test (see table 2) shows a significant F-statistic ($F = 4.325$, $p = 0.014$) confirms that the shift type is a key factor influencing stress levels, with post-hoc comparisons further supporting the idea that longer shifts (24-hour) are more stressful than shorter shifts (day or night). This is consistent with previous research suggesting that non-traditional work schedules, such as night shifts and extended shifts, disrupt natural circadian rhythms and lead to increased stress (AL-Hrinat J. et al., 2024).

Table 2. ANOVA test

Source of variation	Sum of squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-Statistic	p-value
Between groups	411.751	2	205.875	4.325	0.014
Within groups	10273.678	147	69.875		
Total	10685.411	149			

Perceived control as a moderator of stress

The mixed effects model indicated that perceived control plays a significant role in moderating the impact of stress (Table 3). Employees with higher perceived control over their work environment reported lower stress levels (-10.2 points) compared to those with lower perceived control. This result is consistent with psychological theories of stress, which emphasize that individuals who feel they have control over their tasks or environment are better equipped to cope with stress.

Table 3: Mixed effects model results for perceived control and stress moderation.

Predictor	Estimate (β)	Standard Error (SE)	p-value
Perceived Control (High)	-10.2	3.4	0.002
Perceived Control (Low)	+0.0	3.0	0.988

In this context, promoting a sense of control through strategies such as autonomy in task management or providing employees with decision-making power could reduce stress levels, particularly for those on longer, more demanding shifts.

Coping strategies and stress severity

The study found a clear distinction between the effects of proactive and passive coping strategies (Table 4). Employees who employed proactive coping strategies, such as problem-solving and time management, exhibited a significant reduction in stress severity (25% decrease). In contrast, those who relied on passive coping strategies, like avoidance and disengagement, experienced a 15% increase in stress severity.

Table 4. Relationship between coping strategies and stress severity.

Coping Strategy Type	Mean Stress Score (M)	(SD)	Stress Reduction/Increase (%)
Proactive (e.g., problem-solving, time management)	60.5	7.0	-25%
Passive (e.g., avoidance, disengagement)	74.2	8.5	+15%

These findings underscore the importance of fostering effective coping mechanisms in the workplace. Training employees in proactive coping strategies may help reduce the overall stress burden, particularly for those on high-stress shifts, such as 24-hour shifts. On the other hand, reliance on passive strategies, which often exacerbate stress, should be addressed in stress management interventions.

Shift-Specific Factors in Stress Recovery

The mixed effects model also assessed the relationship between shift type and stress recovery, showing that employees on 24-hour shifts experienced slower recovery from stress ($\beta = +15.3$, $p = 0.003$). This slower recovery could be attributed to the extended duration and potential irregularity of their working hours, leading to cumulative stress over time.

Table 5. Mixed effects model results for stress recovery based on shift type.

Shift Type	Estimate (β)	Standard Error (SE)	p-value
24-hour	+15.3	4.1	0.003
Day (9.6 hrs.)	-2.4	3.1	0.458
Night (7 hrs.)	+5.0	2.8	0.075

Employees working day or night shifts did not show significant differences in recovery in stress, which suggests that the cumulative effects of long shifts might be the primary factor hindering recovery for 24-hour shift workers. This highlights the need for interventions that promote recovery during and after long shifts, such as scheduled breaks, relaxation techniques, or improved sleep hygiene. The prevalence of interpersonal and environmental stressors during night shifts suggests that factors such as disrupted social interactions and challenging work environments are particularly problematic during these shifts. Conversely, day shifts were more likely to be associated with work-related stressors, reflecting the typical pressures of daytime work performance, such as task overload and tight deadlines. The slower stress recovery observed in the 24-hour and night shift groups highlights a critical area for intervention. Delayed recovery can exacerbate chronic stress and contribute to negative long-term health outcomes, including burnout, anxiety, and depression (Cattane et al., 2024). Differences in self-reported well-being scores further highlight the potential for shift-related stress to negatively impact workers' mental health. The lower well-being scores of 24-hours and night shift workers suggest that these individuals may require tailored support systems, such as stress management programs and more flexible scheduling, to mitigate the negative effects of their work schedules.

The findings of this study have several implications for workplace stress management, particularly in industries where shift work is common. First, the results suggest that reducing the length of shifts, especially for 24-hour workers, could help alleviate some of the stress associated with extended working hours. Second, interventions that enhance employees' perceived control, such as allowing for more flexibility in task assignments or providing opportunities for decision-making, may also reduce stress levels. Lastly, promoting proactive coping strategies through training and support programs could help employees manage work-related stress more effectively, leading to better mental health and well-being.

In conclusion, this study provides valuable insights into how shift work, coping strategies, and perceived control affect employee stress. Future research could explore other factors, such as job demands, social support, and organizational culture, to further understand the dynamics of workplace stress and its mitigation.

5. CONCLUSIONS

This study aimed to explore the impact of shift type, perceived control, and coping strategies on stress levels and well-being in employees working in industrial settings. The findings offer significant contributions to understanding how different shift schedules influence employee stress dynamics and provide valuable implications for workplace interventions aimed at reducing stress and improving employee health.

The results of this study underscore the significant influence of shift type on employee stress levels. Specifically, employees working 24-hour shifts reported the highest stress scores compared to those working day (9.6 hours) or night (7 hours) shifts. This aligns with existing literature that suggests extended and irregular work hours are associated with higher levels of stress. The longer shifts may result in physical and psychological strain due to fatigue, disrupted circadian rhythms, and the challenge of maintaining concentration and performance throughout such lengthy work periods. Given the higher stress scores reported by 24-hour shift workers, it is crucial for organizations to assess whether such shifts are necessary or if alternative scheduling could be implemented. The findings support the notion that reducing the length of shifts or alternating shift schedules more frequently could mitigate the negative effects of long shifts on worker stress levels. This would not only improve employee well-being but could also lead to enhanced productivity and lower turnover rates. A significant finding of this study is the moderating effect of perceived control on stress. Employees who reported higher perceived control over their work environment experienced significantly lower levels of stress. This result highlights the importance of autonomy in the workplace and the role it plays in reducing the psychological burden of job demands. Perceived control can empower employees to feel more competent in managing their tasks, leading to better stress management and overall well-being. Organizations should consider implementing strategies that enhance employees' sense of control, especially in high-stress environments like shift work. These could include allowing employees greater flexibility in how they organize their work tasks, providing clear communication channels, and offering opportunities for decision-making in their roles. In doing so, organizations can foster a work environment where employees feel supported and equipped to handle stressors effectively, leading to better job satisfaction and reduced burnout. The study also revealed the critical role of coping strategies in managing work-related stress. Employees who utilized proactive coping strategies, such as problem-solving and time management, experienced a significant reduction in stress severity. Conversely, those who relied on passive coping strategies, such as avoidance or disengagement, saw an increase in stress. This finding emphasizes the importance of training employees in healthy coping mechanisms that can help them manage job stress more effectively. Workplaces should prioritize the development of proactive coping strategies through targeted training programs and workshops. Providing employees with tools to manage stress, such as time management training or stress-reduction techniques, could significantly improve their ability to cope with stress in a constructive way. Additionally, fostering a supportive work environment where employees feel encouraged to seek help when dealing with stress can further reduce the reliance on passive coping strategies.

The results concerning stress recovery indicate that employees working 24-hour shifts face greater challenges in recovering from stress compared to those on day or night shifts. The slower recovery observed in the 24-hour shift group may be attributed to the cumulative effects of extended work hours, which can disrupt rest and recovery cycles. This finding suggests that long shifts not only increase stress during work but also hinder the ability to recover fully afterward, which can lead to chronic stress over time. To address this issue, organizations could introduce interventions that promote recovery during and after shifts. For example, ensuring that employees on 24-hour shifts have access to adequate rest periods, breaks, and opportunities for relaxation could facilitate faster recovery and reduce the long-term effects of work-related stress. Additionally, providing employees with resources to support recovery, such as sleep hygiene tips or access to wellness programs, could help alleviate the negative impacts of long shifts on overall health. The findings of this study offer several practical implications for workplace policy and intervention design, particularly in industries where shift work is common. First, reducing the length of shifts, particularly 24-hour shifts, could have a profound impact on reducing stress and improving worker health. Shorter shifts or more frequent rotation of shift types might prevent the accumulation of stress associated with longer shifts. Second, organizations should focus on improving employees' perceived control over their work. Strategies to enhance autonomy, such as allowing employees to choose tasks or have a say in scheduling, could significantly reduce stress. Additionally, fostering a culture of support and empowerment could help employees feel more in control of their work environment, which in turn could lead to better mental and physical health outcomes. Lastly, organizations must invest in developing and promoting effective coping strategies among employees. Providing stress management programs, workshops on problem-solving, and resilience-building techniques can equip workers with the tools they need to handle stress more effectively. Encouraging employees to use proactive coping mechanisms and providing support for those who struggle with passive coping strategies could improve overall workplace well-being and productivity. While the results of this study provide valuable insights, there are several limitations that should be acknowledged. First, the study only considered three shift types (24-hour, day, and night), and future research could explore additional shift configurations, including rotating shifts or part-time schedules. Second, the study focused on self-reported measures of stress, which can be influenced by individual perceptions and biases. Future research could incorporate physiological measures of stress (e.g., cortisol levels) to provide a more objective assessment of stress levels across different shift types. Additionally, future research could explore the role of other factors, such as job demands, social support, and organizational culture, in moderating the relationship between shift work and stress. Investigating these factors in combination with the present findings would provide a more comprehensive understanding of how work schedules affect employee well-being.

In conclusion, this study highlights the significant impact of shift type, perceived control, and coping strategies on employee stress levels and recovery in an industrial context. The findings emphasize the need for organizations to consider the well-being of their workers when designing shift schedules and to invest in strategies that enhance perceived control and promote effective coping mechanisms. By taking a proactive approach to stress management and supporting employees' ability to recover from stress, organizations can improve worker health, reduce burnout, and enhance productivity in the long term.

Declaration of Competing Interest

The authors declare that there were no commercial or financial relationships that could be interpreted as a conflict of interest during the conduct of the study.

6. REFERENCES

AL-hrinat, J., Al-Ansi, A. M., Hendi, A., Adwan, G., & Hazaimeh, M. (2024). The impact of night shift stress and sleep disturbance on nurses quality of life: Case in Palestine Red Crescent and Al-Ahli Hospital. *BMC Nursing*, *23*(1). https://doi.org/10.1186/s12912-023-01673-3.

Almeida, D. M., Wethington, E., & Kessler, R. C. (2002). The Daily Inventory of stressful events: An interview-based approach for measuring daily stressors. *Assessment*, *9*(1), 41–55. https://doi.org/10.1177/1073191102009001006.

Belloni, M., Carrino, L., & Meschi, E. (2022). The impact of working conditions on Mental Health: Novel evidence from the UK. *Labour Economics*, *76*, 102176. https://doi.org/10.1016/j.labeco.2022.102176.

Cattane, N., Mazzelli, M., Begni, V., Mombelli, E., Papp, M., Maj, C., Riva, M. A., & Cattaneo, A. (2024). Molecular mechanisms underlying stress vulnerability and resilience in the chronic mild stress model: New insights from mrna and mirnas data combining. *Brain, Behavior, and Immunity*, *121*, 340–350. https://doi.org/10.1016/j.bbi.2024.07.035.

Caruso C. C. (2014). Negative impacts of shiftwork and long work hours. *Rehabilitation nursing : the official journal of the Association of Rehabilitation Nurses*, *39*(1), 16–25. https://doi.org/10.1002/rnj.107.

Frazier C. (2023). Working Around the Clock: The Association between Shift Work, Sleep Health, and Depressive Symptoms among Midlife Adults. *Society and mental health*, *13*(2), 97–110. https://doi.org/10.1177/21568693231156452.

Stimpfel, A. W., Goldsamt, L., Liang, E., & Costa, D. K. (2022). Work Organization Factors Associated With Nurses' Stress, Sleep, and Performance: A Pre-pandemic Analysis. *Journal of nursing regulation*, *13*(3), 4–12. https://doi.org/10.1016/S2155-8256(22)00085-0

MUSCULOSKELETAL DISCOMFORT IN INFORMAL WORKERS IN LATIN AMERICA: A SYSTEMATIC LITERATURE REVIEW

Monica Rosas Gallegos[1], ORCID: 0009-0004-2907-7455, Aidé Aracely Maldonado Macías[1], ORCID: 0000-0002-4959-161X, Jesús Andrés Hernández Gómez[1], ORCID: 0000-0003-2325-2051, Julio César Ramos Rodríguez[2], ORCID: 0000-0003-4429-1914

[1] Department of Industrial Engineering and Manufacturing
Autonomous University of Ciudad Juarez
Del Charro Ave. 450N
Ciudad Juárez, Chihuahua, 32310

[2] Department of Electrical and Computing Engineering
Autonomous University of Ciudad Juarez
Del Charro Ave. 450N
Ciudad Juárez, Chihuahua, 32310

Corresponding author's e-mail: al244139@alumnos.uacj.mx

Resumen: El trabajo informal carece de regulaciones laborales, seguridad social y condiciones adecuadas, lo que expone a los trabajadores a largas jornadas, posturas inadecuadas, carga excesiva y movimientos repetitivos. Estos factores pueden aumentar el riesgo de Molestias Musculoesqueléticas (MME) y/o trastornos, como dolor lumbar, en el cuello y extremidades, afectando su salud y calidad de vida. Este estudio realiza una revisión sistemática sobre la presencia de MME y/o trastornos en trabajadores informales de América Latina, donde la investigación es limitada. Se emplea el enfoque PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) y se consultan bases de datos como CONSENSUS, PUBMED, SCIELO y SAGE JOURNALS. Los criterios de inclusión abarcan artículos publicados entre 2015 y 2022, en inglés y español, que analicen a esta población y reporten datos específicos sobre MME y/o trastornos. Se excluyeron estudios que no abordaran explícitamente a esta población, que no especificaran su ubicación geográfica o que no incluyeran muestras de trabajadores en sus análisis. Tras aplicar estos criterios, se identificaron solo 5 estudios relevantes, que evidencian una alta prevalencia de MME y/o trastornos en distintas actividades informales, afectando principalmente la espalda, el cuello, zona lumbar, manos y muñecas.

Palabras clave: Empleo informal, Molestias Musculoesqueléticas, Trabajadores informales, PRISMA.

Relevancia para la ergonomía: Esta revisión sistemática contribuye al identificar la prevalencia de MME y/o trastornos en el trabajo informal. Además, promueve la integración de la ergonomía en el empleo informal, mejorando la salud laboral.

Abstract: Informal work lacks labor regulations, social security, and adequate conditions, which exposes workers to long hours, inadequate postures, excessive loads, and repetitive movements. These factors may increase the risk of musculoskeletal discomfort and/or disorders (MSDs), such as lower back, neck, and limb pain, affecting their health and quality of life. This study conducts a systematic review of musculoskeletal discomfort and/or disorders (MSDs) in informal workers in Latin America, where research is limited. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) approach is used, and databases such as CONSENSUS, PUBMED, SCIELO, and SAGE JOURNALS are consulted. The inclusion criteria used include articles in English and Spanish published between 2015 and 2022 that analyze this population and report specific data on musculoskeletal discomfort and/or disorders (MSDs). Studies that did not specifically address this population specify their geographic location or include samples of workers in their analysis were excluded. After applying these criteria, only five relevant studies were identified. These studies show a high prevalence of musculoskeletal discomfort and/or disorders (MSDs) in different informal activities, mainly affecting the back, neck, lumbar area, hands, and wrists.

Keywords: Informal employment, Musculoskeletal Disorders, Informal workers, PRISMA.

Relevance to Ergonomics: This systematic review contributes by identifying the prevalence of musculoskeletal discomfort and/or disorders (MSDs) in informal work. It also promotes the integration of ergonomics in informal employment, improving occupational health.

1. INTRODUCTION

Informal work is defined by the International Labor Organization (ILO) as employment that lacks legal protection, contracts, and benefits (OIT 2018). Authors such as Hoo Lee et al. (2020) agree that this type of employment operates outside the legal framework and is common in small subcontracted companies and the service sector. Rosa (2017) expands this definition to include self-employment and employment in informal enterprises, emphasizing the lack of access to social security. In addition, informal work represents at least 60% of the global workforce, including self-employed workers and workers in unregistered companies. (OIT 2021).

Currently, informal workers face exploitation, insecurity, and low wages, which affect their well-being and productivity (Ganesh, 2023) (Casarreal & Cruz, 2019). Likewise, musculoskeletal discomfort and/or disorders (MSDs) are generated that affect the health of the worker where they manifest as persistent pain in muscles, tendons, or nerves and can last at least a week, affecting any part of the body, from the neck to the lower extremities Krungkraipetch et al. (2012). Mrunalini & Logeswari (2016) also highlight that workers face risks such as back pain, respiratory diseases, and hearing loss due to inadequate conditions. Joronen and Lehtinen (2012) add that handling loads, forced postures, and repetitive movements increase the risk of injury. These authors show that musculoskeletal discomfort and/or disorders (MSDs) are common due to physical effort and poor working conditions. With this lack of regulation and adequate conditions, the risk of suffering from Musculoskeletal discomfort and disorders may increase, impacting their performance and quality of life.

Until now, the literature on musculoskeletal discomfort and/or disorders (MSDs) among informal workers has been scarce in Latin American countries, so this paper presents a systematic review of the literature on musculoskeletal discomfort and/or disorders (MSDs) in informal workers in this region of the world.

2. OBJECTIVES

This research aims to systematically review the literature on musculoskeletal discomfort and/or disorders (MSDs) in informal workers in Latin America, following the PRISMA methodology and using specialized databases.

3. METHODOLOGY

3.1. Search strategy

Artificial intelligence tools and the preferred reporting items for systematic reviews and meta-analysis (PRISMA) method were used to search for information for the systematic review. PRISMA is a guide that helps to organize and present systematic reviews clearly and transparently, ensuring that the study has a defined purpose, a well-structured methodology, and accurate results (Page et al., 2021).

The search strategy focused on articles published between 2015 and 2025 to collect recent research. Four databases (CONSENSUS, PUBMED, SCIELO, and SAGE JOURNALS) were consulted, and studies were selected in English and Spanish. The search used combined keywords and specific questions such as: "What musculoskeletal discomforts have occurred in informal workers in Latin America?" "Musculoskeletal pain in informal workers in Mexico", "Musculoskeletal pain in Latin America workers", and "Musculoskeletal disorders in informal employment in Latin America". Boolean operators: (Musculoskeletal disorders) AND NOT (stress)) Moreover, (informal work) was also used to optimize the accuracy of the results (See Figure 1).

3.2. Inclusion criteria

The inclusion criteria focused on selecting scientific articles published in the last 10 years to ensure topicality and relevance. We included studies that analyzed musculoskeletal discomfort and/or disorders (MSDs) in informal workers in Latin America that included samples from this population in their research.

3.2. Exclusion criteria

Duplicate scientific articles and those that did not address informal work or did not specify it were excluded. Studies that did not focus on informal workers in Latin America or did not include samples from this population in their analysis were also discarded.

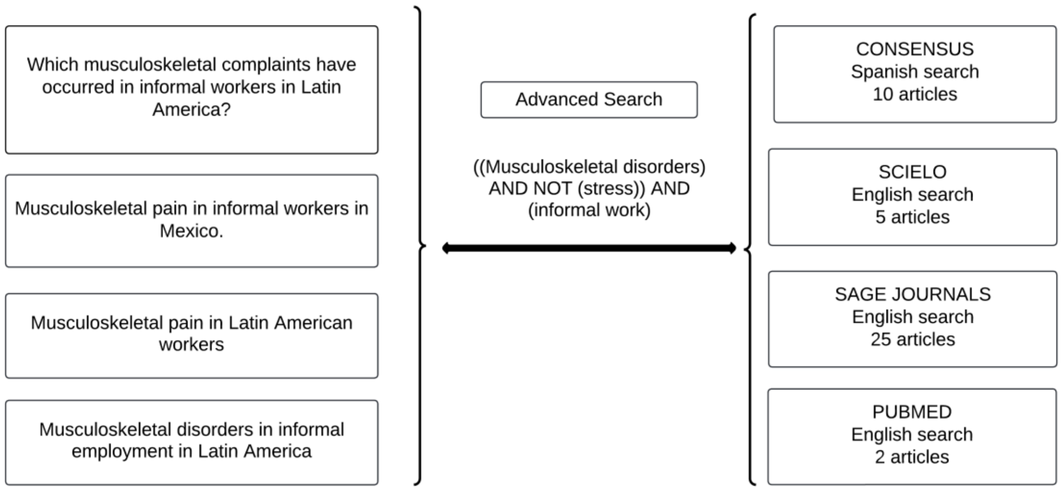


Figure 1. Search strategy

3.3. Search and study selection

A database search used key terms related to the topic, prioritizing articles published in the last 10 years to ensure their relevance. Initially, the titles were revised to shortlist potentially valuable documents. Then, the inclusion and exclusion criteria were applied by reading titles and abstracts, ensuring that the studies dealt with musculoskeletal discomfort and/or disorders (MSDs) in informal workers in Latin America, and included samples in their analysis.

The selection process was documented with a PRISMA flowchart (See Figure 2), recording the number of studies evaluated, excluded, and included. In the initial search, 42 articles were identified. After removing duplicates (n=10), the remaining 32 studies were reviewed, of which those that did not address informal work, did not specify its context in Latin America, or did not include samples of workers were discarded. Finally, five relevant articles were selected for the study.

4. RESULTS

Informal work lacks labor regulations, exposing workers to inadequate conditions and occupational risks. Awkward postures, physical exertion, and a lack of ergonomics can cause musculoskeletal discomfort and/or disorders (MSDs).

Table 1 presents an analysis of 5 selected studies, detailing the methodologies used and the results obtained. In each of these studies, the Nordic Standardized Questionnaire (NMQ) or the Cornell Musculoskeletal Discomfort Questionnaire

(CMDQ) was applied to identify the areas of the body most affected by musculoskeletal discomfort and/or disorders (MSDs) in informal workers. In addition, these studies include various statistical analyses to improve the interpretation of the data based on samples of informal workers in different locations in Latin America, which allows a broader view of the problem to be obtained.

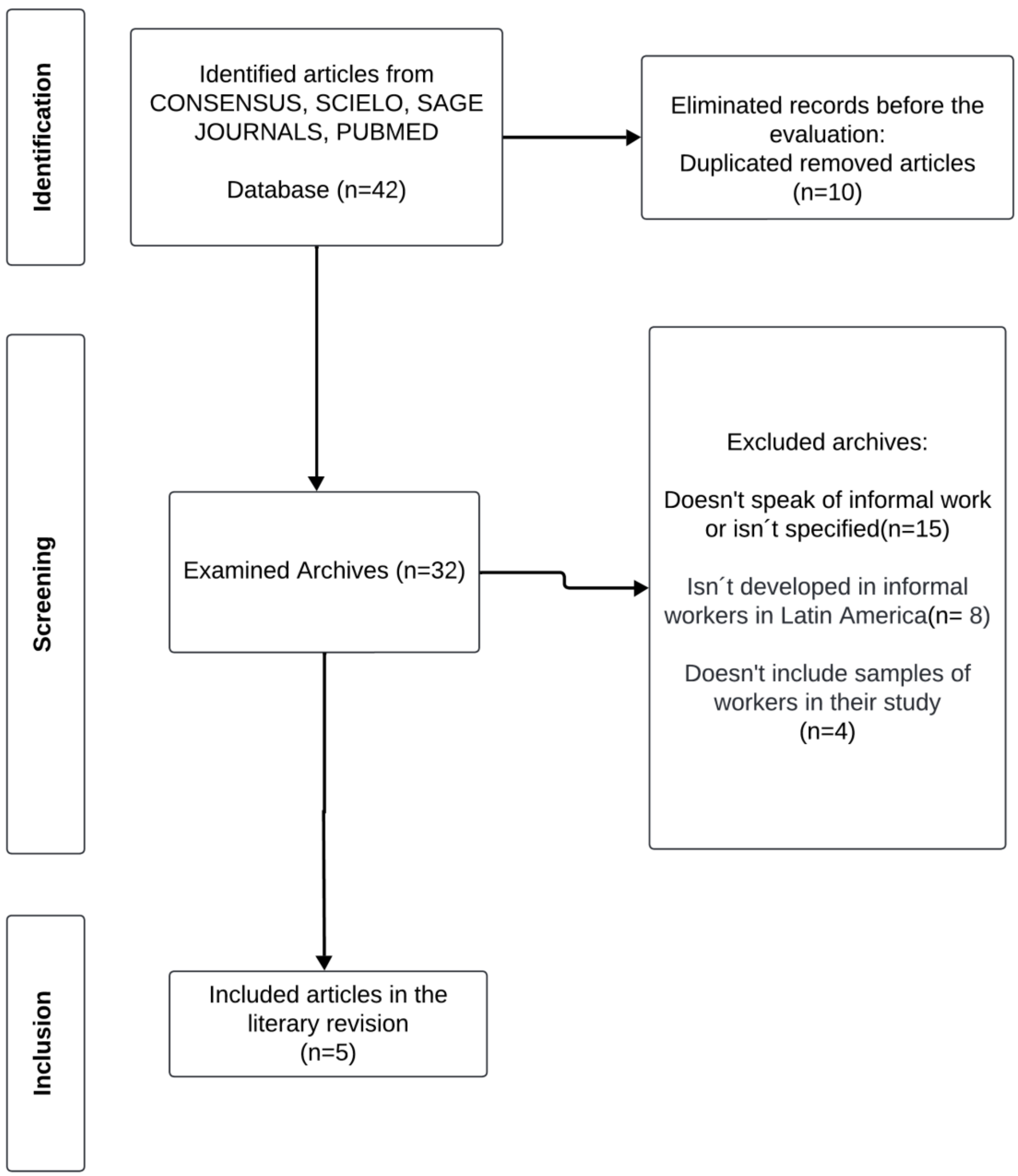


Figure 2. PRISMA Flowchart

Table 1. Analysis of articles about musculoskeletal discomfort and/or disorders (MSDs)

<table>
<tr><th>Study</th><th>Authors</th><th colspan="2">Description</th><th>Methodological tools</th><th>Results</th></tr>
<tr><td rowspan="4">1</td><td rowspan="4">(Bustamante et al., 2019)</td><td>Population</td><td>Informal recyclers</td><td rowspan="4">Nordic Standardized Questionnaire (NMQ)

Sociodemographic and working conditions surveys

Statistical analysis: frequency distribution, measures of central tendency and variability</td><td rowspan="4">The most common symptoms in informal recyclers were in the lower back (66%), neck (61%) and upper back (59%).</td></tr>
<tr><td>Sample Size</td><td>115</td></tr>
<tr><td>Location</td><td>Colombia</td></tr>
<tr><td>Methods</td><td>Cross-sectional descriptive study</td></tr>
<tr><td rowspan="4">2</td><td rowspan="4">(Sousa et al., 2015)</td><td>Population</td><td>Informal miners</td><td rowspan="4">Nordic Standardized Questionnaire (NMQ)

Statistical analysis: Non-parametric tests</td><td rowspan="4">60.6% of miners reported MSDs, such as lower back (41.5%), midback (31.5%), lower extremities (28.8%), arms (20.8%) and shoulders (16.4%).</td></tr>
<tr><td>Sample Size</td><td>371</td></tr>
<tr><td>Location</td><td>Brazil</td></tr>
<tr><td>Methods</td><td>Cross-sectional descriptive study</td></tr>
<tr><td rowspan="4">3</td><td rowspan="4">(Müller et al., 2022)</td><td>Population</td><td>Informal artisanal fishermen</td><td rowspan="4">Nordic Standardized Questionnaire (NMQ)

Sociodemographic and working conditions questionnaire

Statistical analysis: measures of central tendency and dispersion</td><td rowspan="4">Artisanal fishermen have MSDs in the lumbar area (86.4%), wrists and hands (73.5%), and upper back (66.8%).</td></tr>
<tr><td>Sample Size</td><td>248</td></tr>
<tr><td>Location</td><td>Brazil</td></tr>
<tr><td>Methods</td><td>Cross-sectional epidemiological study</td></tr>
<tr><td rowspan="3">4</td><td rowspan="3">(Sortillón et al., 2024)</td><td>Population</td><td>Informal sculptors</td><td rowspan="3">Cornell Musculoskeletal Discomfort</td><td rowspan="3">The sculptors have MSDs in the lumbar</td></tr>
<tr><td>Sample Size</td><td>585</td></tr>
<tr><td>Location</td><td>Mexico</td></tr>
</table>

		Methods	Longitudinal observational study	Questionnaire (CMDQ) Método Rapid Upper Limb Assessment (RULA) Statistical analysis with multivariate logistic regression (MLR) ANOVA	area (10.88%), right arm (8.83%), upper back (8.56%), neck (7.57%), left knee (8.54%) and right knee (8.15%).
5	(Morales-Quispe et al., 2016)	Population	Informal recyclers	Nordic Standardized Questionnaire (NMQ) Sociodemographic and working conditions survey Statistical analysis: absolute and relative frequencies of variables, statistical tests such as chi-square (X^2)	In informal recyclers, MSDs were present in the lumbar area (54.4%), shoulders (44.7%), middle back (43.9%), neck (43.9%), wrists and hands (36.9%), ankles and feet (30.7%), knees (27.2%).
		Sample Size	114		
		Location	Peru		
		Methods	Cross-sectional descriptive study		

Research in informal recyclers has shown that the most common musculoskeletal discomfort and/or disorders (MSDs) affect the lower back, neck, knees, and upper back (Bustamante et al., 2019) (Morales-Quispe et al., 2016). Similarly, a study on artisanal fishing workers showed that 93.5% suffered from musculoskeletal discomfort and/or disorders (MSDs) affecting the lower back, hands, and upper back (Müller et al., 2022). A study in a sample of informal sculptors showed that 67.6% suffer from musculoskeletal discomfort and/or disorders (MSDs) affecting the lower back, arm, neck, and knees (Sortillón et al., 2024). Similarly, informal mining exposes workers to musculoskeletal discomfort and/or disorders (MSDs) in the lower back and dorsal area, which are highlighted due to inadequate posture and physical exertion (Sousa et al., 2015).

The results indicate a high prevalence of musculoskeletal discomfort and/or disorders (MSDs) in informal occupations such as sculpture, mining, recycling, and artisanal fishing. Figure 3 shows the number of studies reported in each body area, highlighting the lumbar region, neck, and upper back, impacting the worker’s performance and quality of life.

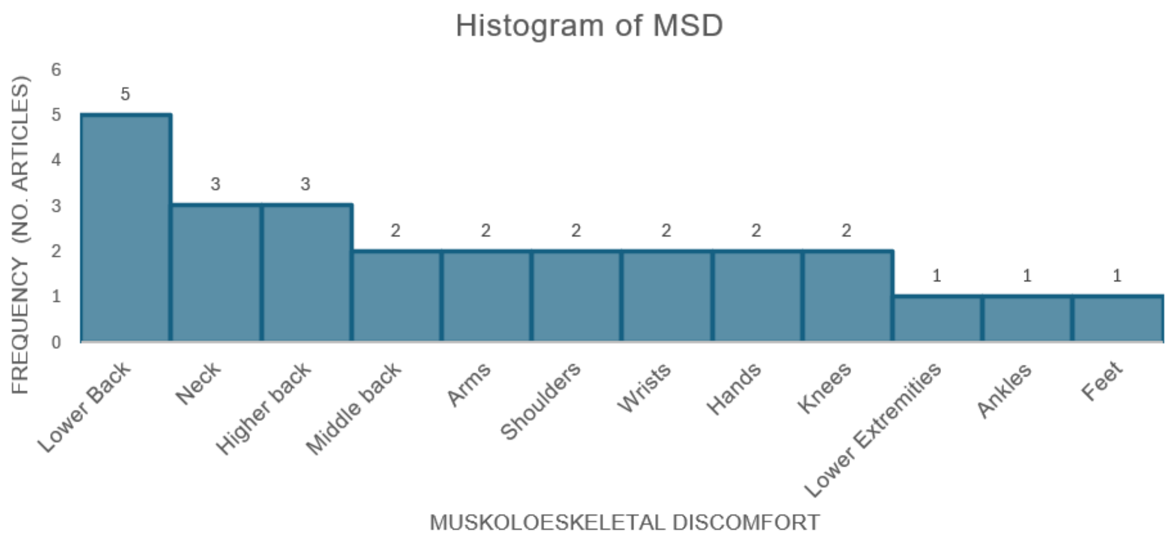


Figure 3. Histogram: Musculoskeletal discomfort and/or disorders (MSDs) Frequency

In addition, the studies included in this review indicate the prevalence of musculoskeletal discomfort and/or disorders (MSDs) in 12 body parts. The lumbar area is prevalently reported in all articles from 10.88% to 86.4%. Figure 4 presents the prevalence of musculoskeletal complaints in the studies included in the literature review.

Regarding formal workers, the most frequent musculoskeletal discomfort and/or disorders (MSDs) body part among workers is also the lower back. The Mexican Institute of Social Security (IMSS) registered more than 300 thousand consultations of workers with insurance in 2017 for this condition, which can cause disability and affect the quality of life (IMSS, 2017). Accordingly, lower back discomfort is the most frequently affected body part among formal and informal workers in the literature reviewed.

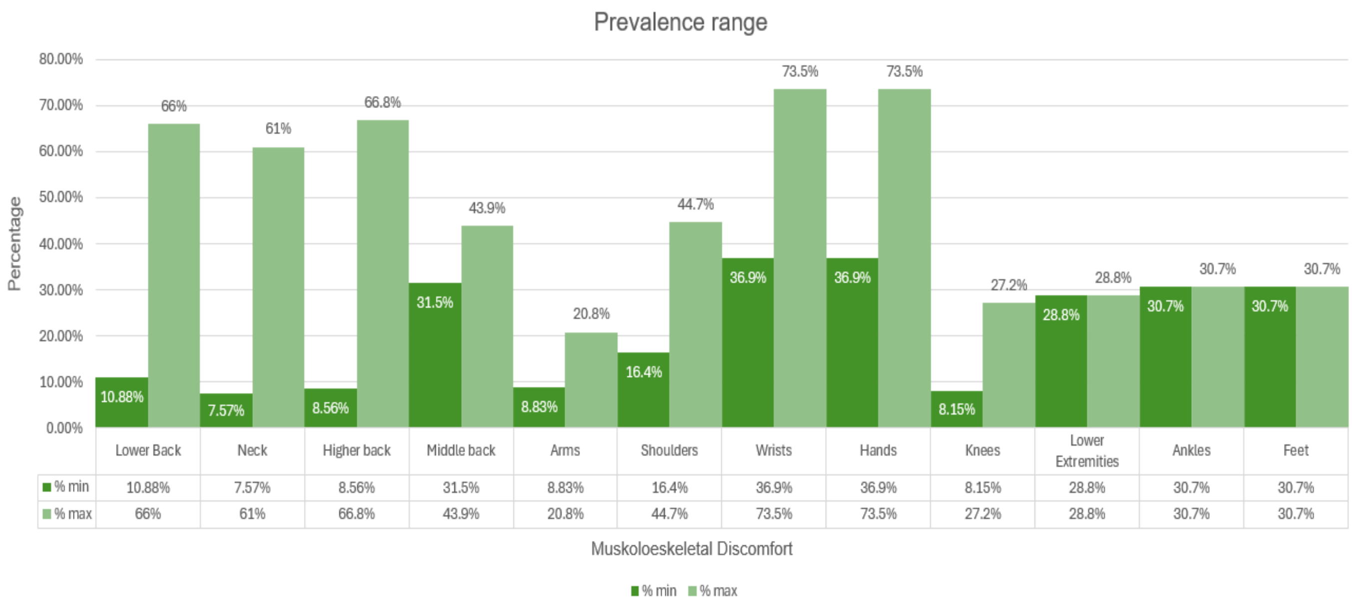


Figure 4. Prevalence ranges of musculoskeletal discomfort and/or disorders (MSDs) in informal workers from the studies found

Only one of the five studies reviewed proposed ergonomic intervention for informal sculptors. Based on the results of the studies, the following ergonomic intervention proposals are recommended for these sectors in general, whether formal or informal. In this case study, Sortillón et al. (2024) propose informal sculptors' training in correct postures, an adaptation of the work environment with adjustable stations, and an ergonomic guide with recommendations on space distribution, appropriate tools, and active breaks.

Additionally, some authors proposed other interventions that may apply to informal workers. Velikanov et al. (2019) propose that miners optimize the design of cabins and controls in machinery to improve posture and reduce physical load. Dempsey et al. (2018) suggest advanced technology such as exoskeletons, wearable sensors, and teleoperation to minimize effort and correct postures. For fishing, Bloswick & Dzugan (2014) propose an ergonomic training program that encompasses biomechanics, load handling, and stretching, allowing fishermen to adopt better postures and reduce muscle fatigue, while Mirka et al. (2011) highlight the importance of ergonomic tools designed to improve posture and reduce physical exertion. Finally, for recyclers, Emmatty et al. (2021) recommend ergonomic work tables and adjustments in waste sorting height to reduce the load on the spine and upper extremities, in addition to proposing a hierarchical framework of intervention, which includes tool redesign, ergonomic training, and task rotation to minimize physical load (Emmatty & Panicker, 2019).

5. CONCLUSIONS

The results indicate high prevalences of MME in various informal occupations in the samples studied in the studies included in the literature review. The most affected body parts are the lower back, neck, upper back, wrists, and hands, impacting the worker's performance and quality of life. This literature review offers evidence that formal and informal employees suffer from musculoskeletal discomfort and/or disorders (MSDs), and the lower back stands out as the most frequent, highlighting the importance of improving ergonomics in their workplaces to prevent these problems. This highlights the relevance and urgency of further studying and improving working conditions in the informal sector, where the lack of access to social security and preventive measures makes these conditions a neglected occupational health problem. Implementing ergonomic strategies and tools, active breaks, and education in proper postures could reduce the incidence of musculoskeletal discomfort and/or disorders (MSDs) and improve the health and productivity of informal workers. In addition, these findings emphasize the need for further research and public policy actions to mitigate the adverse effects of these working conditions.

6. REFERENCES

Bloswick, D. S., & Dzugan, J. (2014). Ergonomics Training in the Commercial Fishing Industry: Emerging Issues and Gaps in Knowledge. *Journal of Agromedicine*, *19*(2), 87-89. https://doi.org/10.1080/1059924X.2014.910063

Bustamante, E. M. G., Contreras, O., Salas, S. S., Julio, Z. V., & Sierra, C. (2019). *Muscle-skeletal symptoms in informal recyclers of Cartagena de Indias (Colombia)*. https://www.semanticscholar.org/paper/Muscle-skeletal-symptoms-in-informal-recyclers-of-Bustamante-Contreras/e38c4d0f05222da660fb575f02baed27ddb0bcb8

Casarreal, J., & Cruz, M. (2019). Informal employment: An explanation from the demand. *Accounting and Administration. National Autonomous University of Mexico*, *66*(1). https://doi.org/10.22201/fca.24488410e.2021.2595

Dempsey, P. G., Kocher, L. M., Nasarwanji, M. F., Pollard, J. P., & Whitson, A. E. (2018). Emerging Ergonomics Issues and Opportunities in Mining. *International Journal of Environmental Research and Public Health*, *15*(11), 2449. https://doi.org/10.3390/ijerph15112449

Emmatty, F. J., & Panicker, V. V. (2019). Ergonomic interventions among waste collection workers: A systematic review. *International Journal of Industrial Ergonomics*, *72*, 158-172. https://doi.org/10.1016/j.ergon.2019.05.004

Emmatty, F. J., Panicker, V. V., & Baradwaj, K. C. (2021). Ergonomic evaluation of worktable for waste sorting tasks using digital human modelling. *International Journal of Industrial Ergonomics*, *84*, 103146. https://doi.org/10.1016/j.ergon.2021.103146

Ganesh, M. N. (2023, junio). Formalisation of Workforce and Legal Protection Including Social Security for Unorganised or Informal Workers. *International*

Journal for Multidisciplinary Research (IJFMR), *5*. https://www.ijfmr.com/papers/2023/3/3456.pdf

Hoo Lee, B., Swider, S., & Tilly, C. (2020). Informality in action: A relational look at informal work. *SAGE Publications*. https://journals-sagepub-com.ezproxy.uacj.mx/doi/epub/10.1177/0020715220944219

IMSS. (2017). *At the IMSS, there were more than 300 thousand consultations for low back pain in 2017 | Website «Bringing the IMSS closer to the Citizen»*. https://www.imss.gob.mx/prensa/archivo/201810/246

Joronen, M., & Lehtinen, S. (2012). Small-scale enterprises and the informal economy. *on Occupational Health and Safety*, *22*. https://www.riskreductionafrica.org/wp-content/uploads/2015/01/AfricanNewsletter2_2012.pdf

Krungkraipetch, N., Krungkraipetch, K., Kaewboonchoo, O., Arphorn, S., & Sim, M. (2012). INTERVENTIONS TO PREVENT MUSCULOSKELETAL DISORDERS AMONG INFORMAL SECTOR WORKERS: A LITERATURE REVIEW. *Faculty of Public Health, Mahidol University*.

Mirka, G. A., Ning, X., Jin, S., Haddad, O., & Kucera, K. L. (2011). Ergonomic interventions for commercial crab fishermen. *International Journal of Industrial Ergonomics*, *41*(5), 481-487. https://doi.org/10.1016/j.ergon.2011.03.006

Morales-Quispe, J., Suárez Oré, C. A., Paredes Tafur, C., Mendoza Fasabi, V., Meza Aguilar, L., & Colquehuanca Huamani, L. (2016). Musculoskeletal disorders in recyclers working in Metropolitan Lima. *Faculty of Medicine*, *77*(4), 357-363.

Mrunalini, A., & Logeswari, S. (2016). MUSCULOSKELETAL PROBLEMS OF ARTISANS IN THE INFORMAL SECTOR- A REVIEW STUDY. *International Journal of Environment, Ecology*. https://www.researchgate.net/profile/A-Mrunalini/publication/325402305_MUSCULOSKELETAL_PROBLEMS_OF_ARTISANS_IN_INFORMAL_SECTOR-_A_REVIEW_STUDY/links/5b0c0827aca2725783eb28d8/MUSCULOSKELETAL-PROBLEMS-OF-ARTISANS-IN-INFORMAL-SECTOR-A-REVIEW-STUDY.pdf

Müller, J. dos S., Silva, E. M. da, & Rego, R. F. (2022). Prevalence of Musculoskeletal Disorders and Self-Reported Pain in Artisanal Fishermen from a Traditional Community in Todos-os-Santos Bay, Bahia, Brazil. *International Journal of Environmental Research and Public Health*, *19*. https://doi.org/10.3390/ijerph19020908

OIT. (2018). *Women and men in the informal economy: A statistical overview*. International Labour Organization (ILO). https://www.ilo.org/es/publications/mujeres-y-hombres-en-la-economia-informal-un-panorama-estadistico-tercera

OIT. (2021). *The transition from the informal to the formal economy: The theory of change*. International Labour Organization (ILO). https://www.ilo.org/es/publications/transicion-de-la-economia-informal-la-economia-formal-teoria-del-cambio

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Alonso-Fernández, S. (2021). PRISMA 2020 Declaration: An updated guide to the publication of systematic reviews. *Spanish Journal of Cardiology*, *74*(9), 790-799. https://doi.org/10.1016/j.recesp.2021.06.016

Rosa, A. (2017). Informality in the Indian labour market: An analysis of shapes and determinants. *The Indian Journal of Labour Economics*. https://doi.org/10.1007/s41027-017-0096-x.

Sortillón, P., Maldonado, A., Saenz, D., Hernandez, J., & De la Vega, E. (2024). *Study of musculoskeletal disorders risk factors and discomfort in sculptors in the north of Mexico*. https://doi.org/10.3233/WOR-220535

Sousa, M., Santos, B., Zaia, J., Bertoncello, D., Andrade, A., Assis, E., Melo teixeira batista, H., Monteiro, C., Maia, P., Quemelo, P., Bezerra, I., & Abreu, L. (2015). Musculoskeletal Disorders In Informal Mining Workers. *International Archives of Medicine*, *8*. https://doi.org/10.3823/1782

Velikanov, V. S., Dyorina, N. V., Pikalova, E. A., & Yuzhakova, Y. V. (2019). Ergonomic component when designing mining machines: New scientific and practical works. *Journal of Physics: Conference Series*, *1399*(4), 044009. https://doi.org/10.1088/1742-6596/1399/4/044009

DIAGNOSIS AND REHABILITATION OF MUSCULOSKELETAL DISORDERS: A PROPOSAL FOR OCCUPATIONAL MONITORING.

Arturo Estrada González[1], orcid.org/0009-0000-8109-6283, Valeria Idrobo Zamorano[2], orcid.org/0000-0003-2338-9410, Lessby Gómez-Salazar [2] orcid.org/0009-0008-2773-8802, Cecilia Andrea Ordoñez-Hernández[3], orcid.org/0000-0001-9296-3768, Beatriz Sibaja Terán[1],orcid.org/0000-0002-0514-6119

[1]**Instituto Politécnico Nacional, CDMX, México,**

[2]**Universidad del Valle, Cali, Colombia,**

[3]**Universidad Pontificia Javeriana, Cali, Colombia,**

Corresponding: bsibajat@ipn.mx

Resumen: Introducción: La revisión bibliográfica recopila los hallazgos de los trastornos músculo esqueléticos (TMEs) publicados de 2020 a 2024. El análisis de la información facilita la detección de las molestias que presentan los trabajadores, así como los pasos que siguen los especialistas para identificar, evaluar y controlar los efectos por no contar con una ergonomía eficiente y eficaz en los Centros de Trabajo. **Objetivo:** Proponer alternativas de diagnóstico y rehabilitación de los trastornos músculo esqueléticos con el fin de tener una referencia del control integral en salud ocupacional. **Metodología:** Es una revisión bibliográfica en PubMed y Google Scholar de 2020 al 2024, las palabras clave combinadas en español fueron: “diagnóstico” “músculo esqueléticos” “musculoesqueléticos” “rehabilitación”, en la versión en inglés se contemplaron las siguientes: “diagnostic” “WRWD” “musculoskeletal disorders. Se consideraron tesis y capítulos de libros con revisiones sistemáticas y metaanálisis que contemplaran las perspectivas de fisioterapia, biomecánica, medicina y otras disciplinas. Se eliminaron las publicaciones duplicadas y no se consideraron publicaciones con ausencia de datos de la metodología, instrumentos de medición y/o técnicas de valoración de los trabajadores. **Resultados:** La población trabajadora abarca principalmente trabajadores de gasolineras, invernaderos, empleados de fábricas, manufactura, de transporte y músicos. La prevalencia de las molestias músculo esqueléticas se ubican en el cuello, los hombros y la parte de la espalda (Fan et al., 2025). Adicionalmente, se observa un complemento del estudio de los TMEs con la fatiga y los factores estresantes (Punnett et al.). El alcance de las intervenciones son ejercicios el lugar de trabajo (Rosmery et al., 2020), tratamiento del SOMA con 10-20 sesiones (Mederos et al., 2021). ejercicios para recuperar el rango articular y fortalecimiento (Otero, 2023), por mencionar algunos. La propuesta con perspectiva de salud ocupacional incluye una historia clínica del trabajador con indicadores de medición de antecedentes ocupacionales, los resultados médicos, fisiológicos y disciplinas complementarias. **Conclusión**: La evidencia resalta las lagunas críticas

en la compresión de la causalidad de los TMEs, de hecho, el dominio del alcance se percibe en los estudios transversales, descriptivos y correlacionales, destacando la falta de seguimiento del trabajador a través de los años para confirmar la evolución y trayectoria de la eficacia de las intervenciones cuando se identifican molestias o padecimientos del sistema músculo esquelético. Las recomendaciones se centran en modificación de las actividades o ejercicios para el trabajador con ausencia de sugerencias en las condiciones de trabajo, que es un reto por atender. Respecto a las acciones correctivas falta una metodología de seguimiento que asegure la evolución y las mejoras que obtiene el trabajador después de la atención de un especialista con el tratamiento de los trastornos músculo esqueléticos desde una perspectiva de la ergonomía en salud ocupacional.

Palabras clave: diagnóstico, ergonomía, salud ocupacional, trastornos músculo esqueléticos, rehabilitación**.**

Relevancia para la Ergonomía: Proporciona información actualizada sobre los avances del estudio de los trastornos músculo esqueléticos, principalmente, sobre la práctica profesional para determinar cuál es el diagnóstico destacable en cada valoración y que se realiza en la rehabilitación para asegurar la recuperación del sistema músculo esquelético de los trabajadores. Es indispensable considerar además de una evaluación, el seguimiento oportuno y la atención necesaria para el cuidado de la salud ocupacional, por lo tanto, la aportación de la difusión es una reflexión de los huecos que existen y de las correcciones que se debe incluir en el ejercicio profesional de la ergonomía.

Abstract: Introduction: This literature review compiles findings on musculoskeletal disorders (MSDs) published from 2020 to 2024. Data analysis facilitates the detection of complaints experienced by workers, as well as the steps specialists follow to identify, evaluate, and manage the effects of a lack of efficient and effective ergonomics in the workplace. **Objective:** To propose alternatives for the diagnosis and rehabilitation of musculoskeletal disorders to provide a reference for comprehensive occupational health management. **Methodology:** This is a literature review in PubMed and Google Scholar from 2000 to 2024. The combined keywords in Spanish were: "diagnosis," "muscle skeletal," "musculoskeletal," "rehabilitation." The English version included the following: "diagnostic," "WRWD," "musculoskeletal disorders." Theses and book chapters with systematic reviews and meta-analyses that addressed the perspectives of physical therapy, biomechanics, medicine, and other disciplines were considered. Duplicate publications were eliminated, and publications lacking data on methodology, measurement instruments, and/or worker assessment techniques were not considered.
Results: The working population primarily includes gas station workers, greenhouse workers, factory workers, manufacturing workers, transportation workers, and musicians. The prevalence of musculoskeletal discomfort is in the neck, shoulders, and back (Fan et al., 2025). Additionally, a complement to the study of MSDs with fatigue and stressors is observed (Punnett et al.). The scope of the interventions includes workplace exercises (Rosmery et al., 2020), SOMA treatment with 10-20

sessions (Mederos et al., 2021), and exercises to recover joint range of motion and strengthening (Otero, 2023), to name a few. The proposal, with an occupational health perspective, includes a medical history of the worker with indicators measuring occupational history, medical and physiological outcomes, and complementary disciplines. **Conclusion:** The evidence highlights critical gaps in our understanding of MSD causality. Indeed, the scope of the study is limited in cross-sectional, descriptive, and correlational studies. This highlights the lack of follow-up of workers over time to confirm the evolution and trajectory of the effectiveness of interventions when musculoskeletal discomfort or conditions are identified. Recommendations focus on modifying workers' activities or exercises, with a lack of suggestions regarding working conditions, which remains a challenge to address. Regarding corrective actions, there is a lack of a follow-up methodology that ensures the evolution and improvements achieved by workers after receiving care from a specialist for musculoskeletal disorders from an occupational health ergonomics perspective. **Relevance to Ergonomics:** Provides up-to-date information on advances in the study of musculoskeletal disorders, primarily on professional practice to determine the relevant diagnosis in each assessment and what is done in rehabilitation to ensure the recovery of workers' musculoskeletal systems. In addition to assessment, it is essential to consider timely follow-up and the necessary attention for occupational health care. Therefore, the contribution of dissemination reflects the gaps that exist and the corrections that should be included in the professional practice of ergonomics.

Keywords: diagnostic, ergonomics, musculoskeletal disorders, occupational health, rehabilitation.

Relevance to Ergonomics: Funding: Instituto Politécnico Nacional, Secretaría de Investigación y Posgrado (SIP) No. 20241590. Management of ergonomics and psychosociology teaching with virtual reality virtual y/or metaverse in nursing staff.

1. INTRODUCTION

Work-related musculoskeletal disorders (MSDs) affect millions of workers worldwide, causing chronic pain, loss of functionality and decreased quality of life (Punnet et al., 2004). These disorders are associated with various occupational exposures, such as repetitive motions, awkward postures, prolonged static positions, and high physical demands. In addition, psychosocial factors, such as high work demands, low control and lack of social support, also play a crucial role in the appearance of MSDs (Fan et al., 2024).

A critical limitation in ergonomic interventions is the variability of their effectiveness in different workplaces and populations. While adjustments to jobs and exercise programs have shown benefits in some cases, other studies report moderate evidence of limited impact when applied in isolation. This variability may be due to differences in implementation, employee adherence, and the specific needs of each work environment (Hoe et al, 2018).

Despite the high prevalence of these disorders and associated costs, the etiology is poorly understood. This lack of knowledge is due, in part, to challenges such as the difficulty of longitudinally tracking occupational exposures over time, inconsistencies in the classification of SRTMs across studies, and the limited ability to address the complex interplay between physical, psychosocial, and organizational factors. This review is relevant for consolidating the evidence on the effectiveness of ergonomic interventions in reducing musculoskeletal pain among workers. By addressing existing gaps and exploring innovative approaches, this review provides practical recommendations for improving health and productivity at work.

2. OBJECTIVE

General Objective

To propose alternatives for the diagnosis and rehabilitation of musculoskeletal disorders to provide a reference for comprehensive occupational health management.

Specific Objectives

a) Review the literature found in the period 2000-2024 on the diagnosis and rehabilitation of the working population.
b) Describe the diagnosis established according to the type of working population to observe the types of musculoskeletal disorders.
c) State the rehabilitation provided to the working population and its favorable and unfavorable implications.
d) Provide alternatives in occupational health care to workers with musculoskeletal disorders.

3. METHODOLOGY

Method

Study Designs: Documentary review of cross-sectional, descriptive, experimental studies, that, analyze ergonomics, fatigue, and factors that contributing to musculoskeletal disorders.

Documents: Studies that include workers from various occupational sectors, without distinction of age, gender or geographical region, will be considered.

Intervention: Studies should focus on workplace risk factors, such as ergonomic, and explore interventions to mitigate these risks.

Control: Comparisons between workers exposed to high ergonomic versus those with lower exposures will be evaluated.

Comparisons: The efficacy of interventions addressing ergonomic and psychosocial factors versus the absence of such interventions in reducing musculoskeletal and respiratory disorders will be evaluated.

Primary outcome: The primary outcome will be prevalence, incidence of severe mental disorders in work settings, levels of worker fatigue/stress.

Time: From 2010 to 2024, all studies should have at least a minimum follow-up of 1 months, which should be specified, to assess outcomes of interest.

Procedures

This is a literature review in PubMed and Google Scholar from 2000 to 2024. The combined keywords in Spanish were: "diagnosis," "muscle skeletal," "musculoskeletal," "rehabilitation." The English version included the following: "diagnostic," "WRWD," "musculoskeletal disorders." Theses and book chapters with systematic reviews and meta-analyses that addressed the perspectives of physical therapy, biomechanics, medicine, and other disciplines were considered. Duplicate publications were eliminated, and publications lacking data on methodology, measurement instruments, and/or worker assessment techniques were not considered

This review will be carried out following the guidelines of the PRISMA Declaration (PRISMA, 2024). After reviewing the titles, abstracts, and full texts, we identified 54 studies. Finally, 10 studies were analyzed for the diagnostic part and seven for rehabilitation.

Characteristics of the included studies

All included studies were cross-sectional, except for one longitudinal study. The studies evaluated diverse populations, including gas station workers, greenhouse workers, factory employees, transportation workers, professional musicians, and university students. The instruments applied ranged from online questionnaires to clinical examinations and ergonomic risk assessments. The studies reported heterogeneity in methodologies, instruments, and target populations.

Advantages and limitations of the studies reviewed

A strength of the studies reviewed lies in their focus on diverse populations and occupational settings, providing a broad perspective on the prevalence of MSDs and risk factors. In addition, many studies used validated tools, such as the Nordic Musculoskeletal Questionnaire and clinical examinations, which improves the reliability of the findings. However, limitations were observed, including variability in study designs, populations, and assessment tools, complicating direct comparisons between studies.

The heterogeneity between the studies reviewed limits the ability to draw definitive conclusions. Differences in study designs, assessment tools, and definitions of musculoskeletal disorders highlight the need for standardized methodologies in future research.

Characteristics of the Included Studies

The studies included in this review encompass a range of methodological designs, including randomized controlled trials, quasi-experimental studies, and pre-post intervention analyses. The populations examined vary from healthcare workers and textile employees to manufacturing and aeronautical industry workers, reflecting a broad spectrum of occupational settings where work-related musculoskeletal disorders (MSDs) are prevalent.

Interventions primarily focus on ergonomic modifications, exercise programs, job rotation strategies, and workplace reintegration schemes. The duration of these interventions ranges from four weeks to twelve months, allowing for both short-term and long-term assessments of effectiveness.

4. RESULTS

Diagnosis of Musculoskeletal Disorders

Table 1 presents a review of assessments of musculoskeletal disorders. It is notable that the Nordic Kuorinka questionnaire is the most preferred method (Laguno et al., 2023; Paredes, 2018; Pérez, 2014; García-Salirrosa, 2020), while clinical assessment or physical examination is less commonly used in practice to determine physical impairments in workers. Of what is found as musculoskeletal disorders, they point out a representative percentage of musculoskeletal pain and body parts, among them, the lumbar area is the one that takes the first place, followed by the upper limbs (Azcona, 2016; Laguno, 2023; Eija, 2006, Herrero, 2019; Paredes, 2018; Balderas, with the absence of an etiological explanation that specifies which work tasks are the generators of pain, discomfort or suffering. From the diagnostic determination there is low back pain (Herrero, 2019; Ramírez-Pozo, 2019; Gaspar, et al., 2023; Balderas et al. 2019), cervicalgia, bursitis, synovitis (Gaspar et al., 2023), however, the prognosis of said evaluated cases was not found.

The main findings showed a high prevalence of musculoskeletal disorders (MSDs) across occupational groups. The most affected areas included the neck, shoulders, and lower back. Psychological stress, physical fatigue, and ergonomic factors such as repetitive tasks and physical overload were identified as significant contributors to MSDs.

Table 2. Diagnosis of musculoskeletal disorders in the working population.

Author, year, country	Working population	Instruments	Musculoskeletal disorders
Laguno, L.R, et al, 2023, Mexico.	Primary caregivers of patients with disabilities in a rehabilitation center.	Nordic Musculoskeletal Symptoms Questionnaire.	Muscle Pain.
Azcona, J.R., et al, 2016, Spain	2,469 companies from different sectors.	High incidence alert system for musculoskeletal disorders (AAITM) composed of four questionnaires: minimum indicative questionnaire, subjective symptom questionnaire, objective clinical questionnaire, and expanded objective clinical questionnaire.	Alert for high incidence of musculoskeletal disorders.
Eija H., et al. 2006, Finland.	Kitchen Workers	Nordic Musculoskeletal Symptoms Questionnaire.	Muscle Pain.
Herrero, V.;. T., et al. 2019, Colombia	Manual and non-manual workers	Owestry Questionnaire.	Low back pain
Ramírez-Pozo, E. & Montalva, M., 2019. Peru.	Workers from 5 operational areas of a refinery	Evaluation of traumatology, neurology, neurosurgery, physical medicine and rehabilitation.	Low back pain
Gaspar, E. et al. ,2023. Spain	The type of worker or economic sector is not specified. The workers perform manual labor, shift work, and rotational work.	Primary Care Electronic Medical Record (PMR-AP), Hospital Emergency Department (HED) database, and the Minimum Basic Data Set. All from 2018.	Low back pain, upper extremity, cervical pain, bursitis, tendonitis, synovitis.
Paredes, M.L. & Vázquez, M. 2018. Spain.	Pediatric and neonatal ICU nursing staff. Three-shift rotation.	Musculoskeletal risk exposure data. Kuorinca Nordic Standardized Questionnaire.	Discomfort in two parts of the body: neck, shoulder (mostly on the right

		REBA Method	side), back or lumbar pain.
Balderas, M., Zamora, M., & Martínez, S., 2019. Mexico	185 tire manufacturing workers.	Open-ended questions related to injuries and the location of the pain. Those identified as having back pain were asked about the characteristics of the injury.	Low back pain, tense shoulders.
Pérez. L.M. & Martínez, S. 2014. Honduras	Cutting department of 49 maquilas of the confession. 526 workers	Nordic Musculoskeletal Symptoms Questionnaire.	Upper limbs, feet and knees.
García-Salirrosas, E.E. & Sánchez-Poma, R. A.2020. Peru.	110 university professors are teleworking.	Nordic Musculoskeletal Symptoms Questionnaire.	Low back pain.

Source: Prepared by authors.

Rehabilitation for work-related musculoskeletal disorders

To provide workers with care to reduce musculoskeletal system discomfort, an ergonomics educational program and training are distinguished (Lee, 2020; Chanchai, 2016; Pehlvan, 2024), stretching and core stabilization exercises (Pehlvan, 2024), as well as warm-up, strengthening, and stretching exercises (Moreira, 2020). The positive effects found by the intervention include pain reduction (Brakenridge et al., 2018; Pehlevan, 2024) and increased muscle strength (Moreira, 2020). Therefore, there is no monitoring of the evolution of musculoskeletal disorders and an assessment of the effectiveness of the treatment and rehabilitation applied to the workforce, whether they improved or were discharged (Table 2).

Table 3. Treatment and rehabilitation actions for musculoskeletal disorders.

Author, year. Country	Applied Technique	Duration, number of sessions	Working Population	Results and Effectiveness of Treatment
Lee, S. et al, 2020, Brazil	Numerical pain rating scale divided by body region (0: no	Assessments at 12, 24,	Office workers with at least 20	Significant differences were found between groups in the

	pain, 10: worst possible pain), Nordic musculoskeletal questionnaire, ergonomic intervention in the workplace.	and 36 weeks	effective hours per week.	neck, shoulder, upper back, and wrist/hand areas, with pain intensity in these regions being greater in the control group compared with the experimental group (p <0.05). Loss to follow-up was high, but there were no significant differences between groups for missing values.
Abdollahi, T. et al, 2020. Iran	Nordic Musculoskeletal Questionnaire, Rapid Whole Body Assessment (REBA) Checklist, ergonomics educational program for nursing staff working in the operating room.	Evaluation of the ergonomics educational program at two-week intervals over a three-month period.	Nursing staff working in the operating room.	It is confirmed that the educational program has positive effects on the working population (*p*=0.03).
Brakenridge, C. et al, 2018. Australia	Nordic Musculoskeletal Questionnaire, activPAL3 (protocol measuring sedentary behavior and prolonged sedentary behavior at work), organizational change	Three months	Office workers	Changes in musculoskeletal pain intensity were not statistically significant; there was a general trend toward pain reduction, but the evidence on the impact of sedentary lifestyle reduction interventions on

	intervention to reduce sitting time, with or without an activity tracker (LUMOback).			musculoskeletal health is largely of low quality.
Chanchai, C. et al, 2016. Thailand	Copenhagen Nordic Psychosocial Musculoskeletal Questionnaire (COPSOQ), an ergonomic intervention consisting of twelve one-hour targeted educational training sessions.	Six months	Orderlies at a tertiary hospital in Thailand	The prevalence rates of symptoms reported in the arm, upper back, and lower back were significantly reduced after the intervention. Upper back, lower back, and arm symptoms disappeared after the intervention in the case group.
Pehlevan, E., Sevgin, O, 2024. Turkey	The McGill Pain Questionnaire (MPQ), the Visual Analogue Scale (VAS), the Fatigue Severity Scale (FSS), the Pittsburgh Sleep Quality Index (PSQI), and the Oswestry Disability Index (ODI) were used for pre- and post-treatment assessments. Ergonomics training and exercise training, including stretching and core stabilization exercises, were provided.	Three exercise sessions over a period of eight weeks.	Workers with chronic lower back pain employed in a plastic molding factory.	ODI, FSS, PSQI, and MPQ scores decreased significantly in both groups. In the intergroup comparison, the exercise group showed a significantly greater decrease in all test scores compared to the control group.
Villalobos, J, Escobar, G.C, 2021.	Nordic musculoskeletal	Three-month	Office workers	The ergonomics program

Peru	questionnaire, ergonomics program that included training, workplace adaptation, and stretching exercises	follow-up of the experimental group to demonstrate compliance with program activities.	who used a computer for more than four hours a day.	significantly reduced the intensity of musculoskeletal discomfort in the cervical, shoulder, and thoracolumbar segments ($p < 0.05$), but did not reduce the frequency of discomfort ($p > 0.05$). Furthermore, the program significantly reduced the level of postural overload ($p < 0.05$).
Moreira, R, et al, 2020. Brazil.	An assessment form containing personal information, the Work Capacity Index, and the Nordic Musculoskeletal Questionnaire. A therapeutic exercise program supervised by two physical therapists included warm-up, strengthening, and stretching exercises.	Twice-weekly, 30-minute exercise program for 12 weeks.	Nursing assistants working in a hospital.	The results showed an increase in trunk flexor muscle strength ($p=0.002$; effect size: 0.77), an improvement in the pressure pain threshold for the longus dorsi muscle ($p=0.001$; effect size >0.8), and a reduction in lower back symptoms ($p=0.002$; OR=6.25). No differences were identified between groups in the strength or flexibility of the back extensor muscles.

Source: Prepared by authors.

Proposal for the surveillance of musculoskeletal disorders

Figure 1 presents a staff monitoring model that proposes that strength, mobility, flexibility, and endurance tests be considered at the beginning of the staff assessment. This phase should also include a physical examination and biomechanical testing to identify any body changes or other potential conditions that require immediate treatment, in addition to assessing workers' perceptions of discomfort or pain they experience while performing their duties. It is therefore important to have all the results of the tests performed on the worker to ensure an accurate diagnosis.

At this point, this diagnosis must be made by an occupational health specialist or physical therapist who can identify which activities the worker performs pose a risk to their occupational health and, at the same time, suggest the appropriate treatment, determine how long it will take for the affected body part to fully or partially recover. They can also identify whether, if the diagnosis is a musculoskeletal disorder, muscle therapy or therapeutic exercises should be started immediately for a speedy recovery. Therefore, it is suggested that if isolated symptoms exist, functional re-education be provided to ensure the worker exercises regularly to improve their physical condition, increase their strength and flexibility, which will serve as protective factors against musculoskeletal disorders.

For workers at medium risk for a musculoskeletal disorder, it is recommended that staff be trained in proper mobility to prevent injuries, strains, or other conditions. Finally, if there is no discomfort, the worker can be discharged and returned to their work area, or the work area can be redesigned to prevent the recurrence of discomfort or muscle disorders.

5. CONCLUSION

The studies reviewed underscore the high prevalence of MSDs in various work settings, driven by a combination of ergonomic, physical and psychosocial factors. While current interventions have shown promise in reducing the risk of MSDs, significant variability in study methodologies limits the ability to generalize findings. Future research should focus on developing standardized diagnostic criteria and exploring the long-term impact of ergonomic and psychosocial interventions to improve musculoskeletal health in the workplace.

It is concluded that it is necessary to increase experimental longitudinal studies on the treatment of musculoskeletal disorders in workers because this will assist all involved disciplines in ensuring workers' health. Furthermore, after observing the method of assessing personnel, it is recommended to reduce the exclusive use of a questionnaire to determine pain intensity. This can be addressed by including other assessment methods to identify the degree of damage caused to the worker's musculoskeletal system. Likewise, it is recommended to increase the determination of a comprehensive occupational health diagnosis in clinical practice, which includes monitoring of the treatment and specialized type of rehabilitation provided to the worker, with the goal of providing care appropriate to the type of occupational exposure.

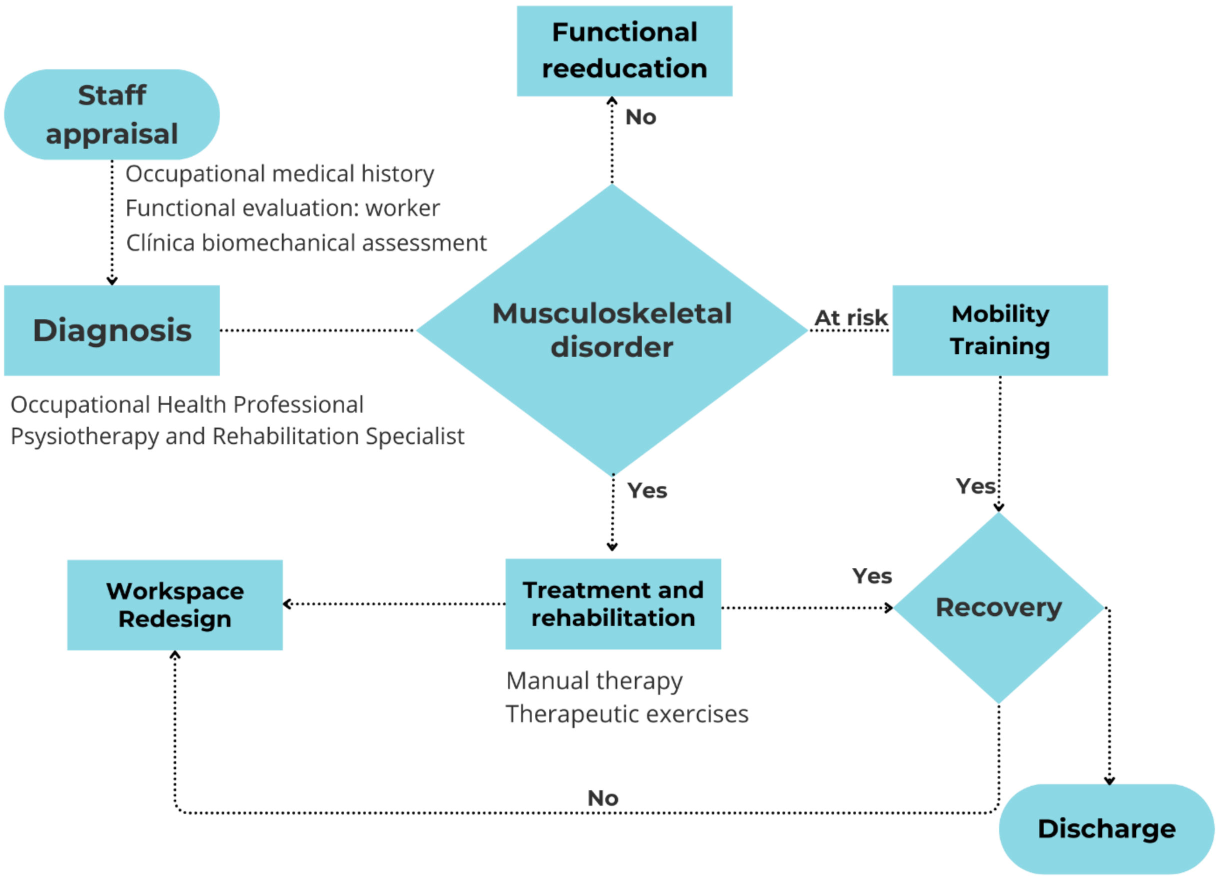


Figura 1. Model for the surveillance of musculoskeletal disorders

Financiamiento: Instituto Politécnico Nacional, Secretaría de Investigación y Posgrado (SIP), No. 20241590, titulado Gestión de la Enseñanza de Ergonomía y Psicosociología con Realidad Virtual y/o Metaverso en Personal de Enfermería.

6. REFERENCES

Abdollahi, T., Pedram Razi, S., Pahlevan, D., Yekaninejad, M. S., Amaniyan, S., Leibold Sieloff, C., & Vaismoradi, M. (2020). Effect of an Ergonomics Educational Program on Musculoskeletal Disorders in Nursing Staff Working in the Operating Room: A Quasi-Randomized Controlled Clinical

Trial. International journal of environmental research and public health, 17(19), 7333. DOI: 10.3390/ijerph17197333

Azcona Castellot, José Ramón, Barrau, Pedro, Tapia Gazulla, Jorge José, Pardillos, José Miguel, Ibarz, Jose Antonio, & Gracia Galve, Alfredo. (2016). Detección precoz de trastornos músculo-esqueléticos: sistema de alertas para la identificación de alta incidencia, correlación con poblaciones envejecidas y aplicación de estrategias. Revista de la Asociación Española de Especialistas en Medicina del Trabajo, 25(4), 240-251.

Balderas, M., Zamora, M., & Mireya, S. (2019). Trastornos musculoesqueléticos en trabajadores de la manofactura de neumáticos, análisis del proceso de trabajo y riesgo de la actividad.Acta Universitaria, 29, e1913. https://www.scielo.org.mx/pdf/au/v29/2007-9621-au-29-e1913.pdf

Brakenridge, C. L., Chong, Y. Y., Winkler, E. A. H., Hadgraft, N. T., Fjeldsoe, B. S., Johnston, V., Straker, L. M., Healy, G. N., & Clark, B. K. (2018). Evaluating Short-Term Musculoskeletal Pain Changes in Desk-Based Workers Receiving a Workplace Sitting-Reduction Intervention. International journal of environmental research and public health, 15(9). DOI: 10.3390/ijerph15091975.

Chanchai, W., Songkham, W., Ketsomporn, P., Sappakitchanchai, P., Siriwong, W., & Robson, M. G. (2016). The Impact of an Ergonomics Intervention on Psychosocial Factors and Musculoskeletal Symptoms among Thai Hospital Orderlies. International journal of environmental research and public health, 13(5), 464. DOI:10.3390/ijerph13050464

Choobineh A, Shakerian M, Faraji M, Modaresifar H, Kiani J, Hatami M. (2021). A multilayered ergonomic intervention program on reducing musculoskeletal disorders in an industrial complex: A dynamic participatory approach. International Journal of Industrial Ergonomics. 86 (x). e103221. https://doi.org/10.1016/j.ergon.2021.103221

Cullen, K.L., Irvin, E., Collie, A., Clay, F., Gensby, U., Jennings, P.A, Hogg-Johnson, S., Kristman, V., Laberge, M., McKenzie, D., Newnam, S., Palagyi, A., Ruseckaite, R., Sheppard, D.M., Shourie, S., Seenstra, I., Van Eerd, D., Amick B.C (2018). Effectiveness of Workplace Interventions in Return-to-Work for Musculoskeletal, Pain-Related and Mental Health Conditions: An Update of the Evidence and Messages for Practitioners. J Occup Rehabil. 28(1):1–15. 10.1007/s10926-016-9690-x

Fan J, Tan X, Smith A.P.,Wang J. (2024). Work-related musculoskeletal disorders, fatigue and stress among gas station workers in China: a cross-sectional study. BMJ. 5;14(7):e081853. 10.1136/bmjopen-2023-081853

García-Salirrosas, E. E., & Sánchez-Poma, R.A. (2020). Prevalencia de trastornos músculo esqueléticos en docentes universitarios que realizan teletrabajo en tiempos de COVID-19. Anales de la Facultad de Medicina. 81(3). 301-307. http://www.scielo.org.pe/pdf/afm/v81n3/1025-5583-afm-81-03-00301.pdf

Gaspar-Calvo, E., Lallana, M.J., Maldonado, L., Aguilar-Palacio, I., Castel-Feced, S., Rabanaque, M.J., Mur-Vispe, E., & Maro, S. (2023). Enfermedad musculoesquelética en población trabajadora: perfil de los afectados y manejo farmacológico. Revista de la Asociación Española de Especialistas en Medicina del Trabajo. 31(1). 9-22. https://scielo.isciii.es/pdf/medtra/v32n1/1132-6255-medtra-32-01-9.pdf

Haukka, E., Leino-Arjas, P., Solovieva, S., Ranta, R., Viikari-Juntura, E., & Riihimäki, H. (2006). Co-occurrence of musculoskeletal pain among female kitchen workers. International archives of occupational and environmental health, 80(2), 141–148. https://doi.org/10.1007/s00420-006-0113-8

Hoe VC, Urquhart DM, Kelsall HL, Zamri EN, Sim MR. Ergonomic interventions for preventing work-related musculoskeletal disorders of the upper limb and neck among office workers. Cochrane Database Syst Rev. 2018 Oct 23;2018(10):CD008570. 10.1002/14651858.CD008570.pub3

Lee, S., Cabegi, F., Moriguchi, C.S., De Oliveira, T. (2020). Effect of an ergonomic intervention involving workstation adjustments on musculoskeletal pain in office workers-a randomized controlled clinical trial. Ind Health. 59(2), 78-85. DOI: 10.2486/indhealth.2020-0188

Llaguno LR, Álvarez LNE, Rosas SDM, Ruiz H.A. (2023). Prevalencia de trastornos musculoesqueléticos en el cuidador primario de pacientes con discapacidad en un centro de rehabilitación en tercer nivel de atención. Rev Mex Med Fis Rehab. 2023;35(1-2):14-18. DOI:10.35366/112576.

López, R., Casajús, J.A., Garatachea, N. (2020). La actividad física como herramienta para reducir el absentismo laboral debido a enfermedad en trabajadores sedentarios: Una revisión sistemática. Rev Esp Salud Publica. 26;92:e201810071. https://www.redalyc.org/articulo.oa?id=17059490080

Moreira, R. F. C., Moriguchi, C. S., Carnaz, L., Foltran, F. A., Silva, L. C. C. B., & Coury, H. J. C. G. (2021). Effects of a workplace exercise program on physical capacity and lower back symptoms in hospital nursing assistants: a randomized controlled trial. International archives of occupational and environmental health, 94(2), 275–284. DOI: 10.1007/s00420-020-01572-z

Paredes, M.L., & Vázquez, M. (2018). Estudio descriptivo sobre las condiciones de trabajo y los trastornos músculo esqueléticos en el personal de enfermería (enfermeras y AAEE) de la Unidad de Cuidados Intensivos Pediátricos y Neonatales en el Hospital Clínico Universitario de Valladolid. Medicina y Seguridad del Trabajo. 64(251). 161-199. https://scielo.isciii.es/pdf/mesetra/v64n251/0465-546X-mesetra-64-251-00161.pdf

Pehlevan, E., & Şevgin, Ö. (2024). Effect of exercise given to factory workers with ergonomics training on pain and functionality: A randomized controlled trial. Work (Reading, Mass.), 78(1), 195–205. https://doi.org/10.3233/WOR-230663

Pérez, L.M., & Martínez, S., (2014). Trastornos músculo-esqueléticos y psíquicos en población trabajadora, maquila de la confesión, Departamento de Cortés, Honduras. Salud de los Trabajadores, 22(2). 129-140. https://ve.scielo.org/pdf/st/v22n2/art04.pdf

Punnet, L. Gold, J. Katz, J.N., & Wegman, D.H. (2004). Ergonomic stressors and upper extremity musculoskeletal disorders in automobile manufacturing: a one year follow up study. Occup Environ Med. 61(8). 668-674. 10.1136/oem.2003.008979

Preferred Reporting Items for Systematic review and Meta-Analyses (PRISMA, 2024). PRISMA 2020 statement paper. https://www.prisma-statement.org/prisma-2020-statement

Ramírez-Pozo, E., & Montalvo, M. (2019). Frecuencia de trastornos musculoesqueléticos en los trabajadores de una refinería de Lima, 2017. Anales de la Facultad de Medicina. 80(3), 337-341. http://www.scielo.org.pe/pdf/afm/v80n3/a11v80n3.pdf

Rodríguez, A.C.,& Barrero, L.H. (2017). Job rotation: Effects on muscular activity variability. Appl Ergon. 18(x). 83-92. 10.1016/j.apergo.2016.11.005

Vicente-Herrero, M. T., Fuentes, S. T. C., Espí-López, G. V., & Fernández-Montero, A. (2019). Dolor lumbar en trabajadores. Riesgos laborales y variables relacionadas. Revista Colombiana de Reumatología, 26(4), 236-246. https://doi.org/10.1016/j.rcreu.2019.10.001

Villalobos-Tupia, J., Escobar-Galindo, C.M. (2022). Programa integral de ergonomía para la reducción de molestias musculoesqueléticas en trabajadores usuarios de computadora, Rehabilitación, 56;(1), 20-27, DOI: 10.1016/j.rh.2021.04.003.

STUDY OF THE MAIN MUSCULOSKELETAL DISORDERS IN CONSTRUCTION WORKERS IN PUERTO PEÑASCO, SONORA

Gilda Tiznado[1], 0009-0001-0573-4279[1], Verónica Espinoza[1], 0009-0004-1654-5766[2], Everardo Flores[1], 0009-0008-0824-9819[3], Jezaharel Ibarra[1], 0009-0005-5810-7518[4], and Joaquín Vásquez Quiroga[2], 0009-0002-3533-9330[5]

[1]División de Ingeniería Industrial e Ingeniería Civil
Subdirección Académica
Tecnológico Nacional de México / ITS de Puerto Peñasco
Blvd. Tecnológico S/N, Colonia Centro-Sur
Puerto Peñasco, Sonora, 83550

[2]División de Ingenierías
Departamento de Ingeniería Industrial
Universidad de Sonora. Unidad Regional Norte
Avenida K S/N, Colonia Eleazar Ortiz
H. Caborca, Sonora, 83600

Email: gilda.tp@puertopenasco.tecnm.mx

RESUMEN: La ergonomía es una disciplina clave tanto para proteger la salud física y mental de los trabajadores como para aumentar la productividad en cualquier industria. Su impacto directo en la eficiencia operativa y la calidad del trabajo es innegable. Un diseño adecuado de los puestos de trabajo, la adaptación de herramientas y el manejo de cargas no solo previenen lesiones y enfermedades, sino que también mejoran el rendimiento laboral y reducen el ausentismo debido a problemas de salud. La ergonomía se enfoca en prevenir la fatiga muscular, las tensiones repetitivas y el estrés mental.

Este estudio tiene como objetivo principal identificar las afectaciones del sistema musculoesquelético en los trabajadores de la construcción en Puerto Peñasco. La investigación se divide en varias etapas, que se detallan a continuación:

La primera etapa consistió en definir el sector a analizar, en este caso, la industria de la construcción en Puerto Peñasco, específicamente los trabajadores de obra; identificando los principales riesgos ergonómicos y las condiciones laborales que podrían generarles problemas musculoesqueléticos.

En la segunda etapa, se eligió el cuestionario nórdico como herramienta para medir el estado del aparato locomotor de los trabajadores. Este cuestionario es ampliamente utilizado en estudios ergonómicos, ya que permite identificar los problemas musculoesqueléticos más comunes. Ofrece información sobre la intensidad, frecuencia y localización del dolor musculoesquelético, lo que facilita la identificación de las partes del cuerpo más afectadas y las actividades relacionadas con diversos trastornos.

La tercera etapa consistió en aplicar el cuestionario a los trabajadores de la construcción. Este se distribuyó entre aquellos que realizan actividades físicas intensas y repetitivas para obtener información detallada sobre el estado de su salud musculoesquelética. Los cuestionarios se completaron de manera anónima, garantizando la confidencialidad de las respuestas.

Una vez recopilados los datos, estos fueron registrados y analizados utilizando el programa estadístico SPSS (Statistical Package for the Social Sciences), que permitió organizar la información de manera estructurada. Con el objetivo de interpretar los datos para determinar los trastornos más comunes en esta industria. Los resultados mostraron que las áreas más afectadas del aparato locomotor en los trabajadores de la construcción de Puerto Peñasco fueron los hombros, la espalda lumbar y las rodillas. Esto refleja las exigencias del trabajo en construcción, que involucra posturas incómodas y esfuerzos físicos constantes.

Una vez interpretada la información, se concluyó el estudio y se presentaron los resultados obtenidos. Se discutió sobre los resultados, así como el contexto de la investigación; tomando decisiones correctivas dentro de la metodología inicial con el fin de obtener mayor veracidad en la información recabada de los sujetos de estudio. Este estudio destaca la importancia de la ergonomía en la mejora de la salud laboral y la productividad, sugiriendo que su implementación puede tener beneficios significativos tanto para los trabajadores como para las empresas del sector.

Palabras clave: Evaluación ergonómica, cuestionario nórdico, obreros de la construcción.

Relevancia para la ergonomía: La investigación ergonómica en la construcción es generar un ambiente laboral más seguro, saludable y eficiente, adaptando las condiciones de trabajo a las capacidades humanas y reduciendo el impacto negativo en la salud de los trabajadores, mientras se optimizan los resultados productivos del sector.

ABSTRACT: Ergonomics is a key discipline both for protecting the physical and mental health of workers and for increasing productivity in any industry. Its direct impact on operational efficiency and work quality is undeniable. Proper workplace design, tool adaptation, and load handling not only prevent injuries and illnesses but also improve job performance and reduce absenteeism due to health problems. Ergonomics focuses on preventing muscle fatigue, repetitive strain, and mental stress.

The main goal of this study is to identify the musculoskeletal effects on construction workers in Puerto Peñasco. The research is divided into several stages, which are outlined below:

The first stage consisted of defining the sector to be analyzed, in this case, the construction industry in Puerto Peñasco, specifically construction workers; identifying the main ergonomic risks and the working conditions that could cause musculoskeletal problems.

In the second stage, the Nordic questionnaire was chosen as a tool to measure the state of the musculoskeletal system of workers. This questionnaire is widely used in ergonomic studies, as it allows the identification of the most common musculoskeletal problems. It offers information on the intensity, frequency and location of musculoskeletal pain, which facilitates the identification of the most affected parts of the body and the activities related to various disorders.

The third stage consisted of applying the questionnaire to construction workers. This was distributed among those who perform intense and repetitive physical activities to obtain detailed information on the state of their musculoskeletal health. The questionnaires were completed anonymously, guaranteeing the confidentiality of the answers.

Once the data was collected, it was recorded and analyzed using the statistical program SPSS (Statistical Package for the Social Sciences), which allowed the information to be organized in a structured manner. The aim was to interpret the data to determine the most common disorders in this industry. The results showed that the most affected areas of the musculoskeletal system in Puerto Peñasco construction workers were the shoulders, lower back and knees. This reflects the demands of construction work, which involves uncomfortable postures and constant physical efforts.

Once the information was interpreted, the study was concluded and the results obtained were presented. The results were discussed, as well as the context of the research; making corrective decisions within the initial methodology to obtain greater veracity in the information collected from the study subjects. This study highlights the importance of ergonomics in improving occupational health and productivity, suggesting that its implementation can have significant benefits for both workers and companies in the sector.

Keywords. Ergonomic assessment, Nordic questionnaire, construction workers.

Relevance to Ergonomics: Ergonomic research in construction aims to create a safer, healthier, and more efficient work environment by adapting working conditions to human capabilities and reducing the negative impact on workers' health, while optimizing the productive outcomes of the sector.

1. INTRUDUCTION

The World Health Organization (WHO) conceptualizes occupational health as a multidisciplinary activity aimed at promoting and protecting the health of workers. The fields of activity are preventive ergonomics, which works in relation to safety and hygiene in the work-study areas, considering the set of habits that the person chooses when performing a specific activity (Quispe, 2021).

Ergonomics is the discipline that studies the interaction between humans and the system elements, such as tools, work environments and processes. Its goal is to design systems that adapt to human capabilities and limitations to improve the efficiency, safety and well-being of workers. (Kroemer, 2019).

Puerto Peñasco is a municipality located in the northwestern part of the State of Sonora, where its main economic activities are tourism and fishing; in view of this, it is determined that construction is a cornerstone of the tourism industry, since it provides the infrastructure and services necessary to attend to the demands of visitors; it allows the development of competitive, sustainable and accessible destinations, guaranteeing a balance between economic growth and cultural preservation.

In consideration of the previous, for the development of the basic infrastructure, lodging, services and attractions, a large number of workers are required, who perform various efforts in their activities and that perhaps due to poor execution or non-optimal conditions in the work center lead to the generation of diseases or physical disturbances in the locomotive system of the workers.

In this sense, a research study was developed to analyze musculoskeletal disorders in construction workers in Puerto Peñasco, Sonora, to determine the zones or areas of the body most prone to suffer any damage and their causes of origin.

The activities that construction workers perform are often physically demanding and repetitive, which can lead to musculoskeletal problems over time and are associated with:

- Lifting and carrying heavy loads: moving materials such as bricks, concrete bags, tools and other heavy objects can cause lower back injuries, mainly in the lumbar region, as well as wear and tear on the joints.
- Forced or awkward postures: working in positions such as bending, kneeling, stooping or with arms outstretched for long periods generates tension in muscles and joints.
- Repetitive movements: activities such as hammering, using drilling or sanding tools, and prolonged cutting can cause muscle tendon disorders.
- Working on uneven surfaces: walking or standing on unstable or slippery ground can cause microtrauma and stress to the feet, ankles and knees, as well as increasing the risk of falls.
- Use of hand tools and heavy machinery: constant vibrations from equipment such as jackhammers or drills can lead to hand-arm vibration syndrome, affecting nerves, blood vessels and bones.
- Static loads and sustained strain: holding tools or materials in a fixed position for long periods can cause muscle fatigue, stiffness and chronic pain in the shoulders, neck and arms.
- Constant climbing and descending: climbing up and down ladders, scaffolding or structures raises the risk of injury to the knee, ankle and hip joints.
- Prolonged exposure to extreme conditions: working in cold or wet climates can exacerbate muscle and joint problems, such as stiffness and chronic pain.

1.1 Objective

To identify, analyze and describe the causes of musculoskeletal disorders in construction workers in Puerto Peñasco, Sonora, in order to understand the associated risk factors to the physical load and working conditions, as well as to deepen in the elements that contribute to the appearance of these disorders, focusing on aspects such as forced postures, repetitive movements, handling of heavy loads and ergonomic conditions of the work environment and to determine an accurate diagnosis that will serve as a basis for future actions.

1.2 Delimitation

Project is limited to specifically assessing the physical conditions of the neck, shoulder and lower back due to construction work.

2. METHODOLOGY

The following are the stages into which the project was divided to carry out each of the evaluation points.

2.1 Identification of the sector to be analyzed

The construction industry is a sector that contributes to the economic progress of a city, as well as to society, as it generates sources of employment for its citizens. Specifically in Puerto Peñasco, construction is strongly focused on tourism, i.e. tourist developments such as condominiums, hotels and vacation complexes, and on private homes or commercial housing (commercial facilities).

Workers in this sector have diverse specialties such as masonry, plumbing, electricity, drywall, detailing, etc., who have great technical skills and knowledge, since they can materialize what is expressed in the designs and projects. They are the workers who build the houses and infrastructure used daily; in addition, their activities are complementary so that the constructions are functional both individually and for the entire community.

It is also important to note that these activities are carried out under diverse climatic and hazardous conditions, in addition to the fact that the work is predominantly manual and with tools, which implies significant health risks.

For the research, contractors and engineers of large construction projects in Puerto Peñasco, Sonora were contacted to include a greater number of people for the study, so the selection was made by convenience. Several construction workers were selected to analyze the repercussions that their work activities have had on their bodies.

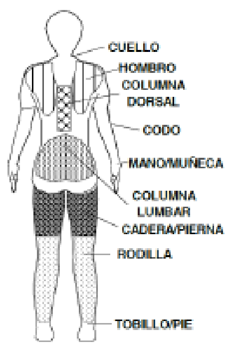
2.2 Selection of measuring instrument

Disorders of the musculoskeletal system, which affect bones, joints, muscles, tendons and ligaments, represent one of the principal causes of pain and disability in the world's population. These disorders are frequently associated with occupational factors, especially in environments where repetitive movements are performed, inappropriate postures are adopted, or heavy loads are handled.

To evaluate and prevent these problems, tools have been developed such as the Nordic survey, an instrument widely used in the field of occupational health. This was developed in 1987 by a group of Scandinavian researchers with the aim of standardizing the evaluation of musculoskeletal disorders in the workplace. Its design emerged from the need for a reliable and valid tool to measure the prevalence of musculoskeletal disorders in different populations and industrial sectors (Kuorinka, 1987). The survey has become an international reference for epidemiological research in the field of occupational health.

The survey is structured to evaluate symptoms such as pain, discomfort, numbness and weakness in different body regions, specifically neck, shoulders and lower back. In addition, it allows identifying the relationship between these symptoms and work activities, which facilitates the implementation of preventive measures.

Figures 1 to 4 below show the instrument applied:



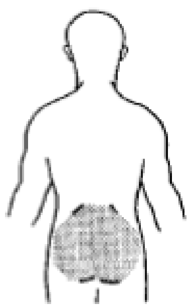
CUESTIONARIO NÓRDICO ESTANDARIZADO DE KUORINKA

Cómo responder el cuestionario:
Responda poniendo una cruz en el cuadro apropiado: una cruz para cada pregunta. Puede tener dudas sobre cómo responder, pero por favor haga lo mejor de todos modos. Responda todas las preguntas, incluso si nunca tuvo problemas en cualquier parte de su cuerpo.

En esta imagen puede ver la posición aproximada de las partes del organismo al que se hace referencia en el cuestionario. Los límites no están bien definidos, y ciertas partes se superponen. Debes decidir por ti mismo en qué parte tiene o ha tenido su problema (si lo tiene).

Problemas con los órganos locomotores		
¿Alguna vez en los últimos 12 meses tuvo problemas (dolor, malestar) en:	Para ser respondido solo por aquellos que han tenido problemas	
	¿Se le ha impedido, en algún momento durante los últimos 12 meses, hacer su trabajo normal (en casa o fuera de casa) debido a los problemas?	¿Has tenido problemas en algún momento durante los últimos 7 días?
Cuello ( ) NO ( ) SI	( ) NO ( ) SI	( ) NO ( ) SI
Hombro ( ) NO ( ) Sí, en el hombro derecho ( ) Sí, en el hombro izquierdo ( ) Sí, en ambos hombros	( ) NO ( ) SI	( ) NO ( ) SI
Codos ( ) NO ( ) Sí, en el codo derecho ( ) Sí, en el codo izquierdo ( ) Sí, en ambos codos	( ) NO ( ) SI	( ) NO ( ) SI
Muñecas / manos ( ) NO ( ) Sí, en la muñeca/mano derecha ( ) Sí, en la muñeca/mano izquierda ( ) Sí, en ambas muñecas/manos	( ) NO ( ) SI	( ) NO ( ) SI
Columna Dorsal ( ) NO ( ) SI	( ) NO ( ) SI	( ) NO ( ) SI
Columna Lumbar ( ) NO ( ) SI	( ) NO ( ) SI	( ) NO ( ) SI
Una o ambas Caderas/Piernas ( ) NO ( ) SI	( ) NO ( ) SI	( ) NO ( ) SI
Una o ambas rodillas ( ) NO ( ) SI	( ) NO ( ) SI	( ) NO ( ) SI
Uno o ambos tobillos / pies ( ) NO ( )SI	( ) NO ( ) SI	( ) NO ( ) SI

Figure 1. Nordic Survey, sheet 1 of 4



CUESTIONARIO NÓRDICO ESTANDARIZADO ESPALDA LUMBAR

Cómo responder el cuestionario: Para problemas a nivel de la espalda lumbar, tome en cuenta las molestias, dolores y disconfort sufridos en la zona punteada que se muestra en la imagen. Limítese a esta zona y no cuente los dolores o molestias de las zonas adyacentes del cuerpo. Existe un cuestionario específico para cada zona.
Responda con una cruz en la respuesta más apropiada (una sola respuesta por pregunta). En caso de duda, elija la respuesta que más se acerque a su caso.

1 ¿Alguna vez has tenido problemas en la espalda lumbar (molestia, dolor o disconfort)?
( ) NO ( ) SI

Si usted respondió NO a la Pregunta 1, NO responda las preguntas 2 a la 8

2 ¿Alguna vez ha sido hospitalizado debido a problemas de espalda lumbar?
( ) NO ( ) SI

3 ¿Alguna vez tuvo que cambiar de trabajo o tarea debido a problemas de la espalda lumbar?
( ) NO ( ) SI

4 ¿Cuál es el tiempo total que usted ha tenido problemas de espalda lumbar durante los últimos 12 meses?
( ) 0 días
( ) 1 a 7 días
( ) 8 a 30 días
( ) Más de 30 días, pero no todos los días
( ) Todos los días

Si usted respondió 0 días a la pregunta 4, NO responda las preguntas 5 a la 8

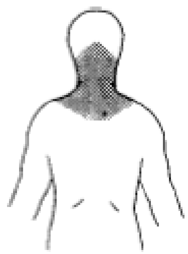
5 ¿Tiene un dolor de espalda lumbar que le hizo reducir su actividad durante los últimos 12 meses?
a. ¿En actividades de trabajo (en la casa o fuera de la casa)?
( ) NO ( ) SI
b. ¿En su tiempo libre?
( ) NO ( ) SI

6 ¿Cuál es el tiempo total que los problemas de espalda lumbar le han impedido realizar su trabajo normal (en la casa o fuera de la casa) durante los últimos 12 meses?
( ) 0 días
( ) 1 a 7 días
( ) 8 a 30 días
( ) Más de 30 días

7 ¿Ha sido consultado por un médico, fisioterapeuta, quiropráctico u otra persona debido a problemas de espalda lumbar durante los últimos 12 meses?
( ) NO ( ) SI

8 ¿Ha tenido problemas de espalda lumbar en cualquier momento durante los últimos 7 días?
( ) NO ( ) SI

Figure 2. Nordic Survey, sheet 2 of 4



CUESTIONARIO NÓRDICO ESTANDARIZADO CUELLO

Cómo responder el cuestionario: Para problemas a nivel del cuello, tome en cuenta las molestias, dolores y disconfort sufridos en la zona punteada que se muestra en la imagen. Limítese a esta zona y no cuente los dolores o molestias de las zonas adyacentes del cuerpo. Existe un cuestionario específico para cada zona.
Responda con una cruz en la respuesta más apropiada (una sola respuesta por pregunta). En caso de duda, elija la respuesta que más se acerque a su caso.

1	¿Alguna vez has tenido problemas en el cuello (molestia, dolor o disconfort)? ( ) NO ( ) SI

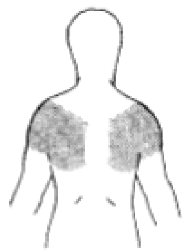
Si respondió NO a la Pregunta 1, no responda las preguntas 2—8

2	¿Alguna vez te has lastimado el cuello en un accidente? ( ) NO ( ) SI
3	¿Alguna vez tuvo que cambiar de trabajo o tareas debido a problemas del cuello? ( ) NO ( ) SI
4	¿Cuál es el tiempo total que usted ha tenido problemas del cuello durante los últimos 12 meses? ( ) 0 días ( ) 1 a 7 días ( ) 8 a 30 días ( ) Más de 30 días, pero no todos los días ( ) Todos los días

Si respondió 0 días a la pregunta 4, no responda las preguntas 5—8

5	¿Tiene un dolor del cuello que le hizo reducir su actividad durante los últimos 12 meses? a. ¿En actividades de trabajo (en la casa o fuera de la casa)? ( ) NO ( ) SI b. ¿En su tiempo libre? ( ) NO ( ) SI
6	¿Cuál es el tiempo total que los problemas del cuello le han impedido realizar su trabajo normal (en la casa o fuera de la casa) durante los últimos 12 meses? ( ) 0 días ( ) 1 a 7 días ( ) 8 a 30 días ( ) Más de 30 días
7	¿Ha sido consultado por un médico, fisioterapeuta, quiropráctico u otra persona debido a problemas del cuello durante los últimos 12 meses? ( ) NO ( ) SI
8	¿Ha tenido problemas de espalda lumbar en cualquier momento durante los últimos 7 días? ( ) NO ( ) SI

Figure 3. Nordic Survey, sheet 3 of 4



CUESTIONARIO NÓRDICO ESTANDARIZADO HOMBRO

Cómo responder el cuestionario: Para problemas a nivel del hombro, tome en cuenta las molestias, dolores y disconfort sufridos en la zona punteada que se muestra en la imagen. Limítese a esta zona y no cuente los dolores o molestias de las zonas adyacentes del cuerpo. Existe un cuestionario específico para cada zona.
Responda con una cruz en la respuesta más apropiada (una sola respuesta por pregunta). En caso de duda, elija la respuesta que más se acerque a su caso.

1	¿Alguna vez has tenido problemas en el hombro (molestia, dolor o disconfort)? ( ) NO ( ) SI

Si respondió NO a la Pregunta 1, no responda las preguntas 2 a la 9

2	¿Alguna vez te has lastimado el hombro en un accidente? ( ) NO ( ) SI, mi hombro derecho ( ) SI, mi hombro izquierdo ( ) SI, ambos hombros
3	¿Alguna vez tuvo que cambiar de trabajo o tareas debido a problemas del hombro? ( ) NO ( ) SI
4	¿Has tenido problemas en el hombro durante los últimos 12 meses? ( ) No ( ) SI, en mi hombro derecho ( ) SI, en mi hombro izquierdo ( ) SI, en ambos hombros

Si respondió No en la pregunta 12, no responda las preguntas 5 a la 9

5	¿Cuál es el tiempo total que ha tenido problemas en el hombro durante los últimos 12 meses? ( ) 1-7 días ( ) 8-30 días ( ) Mas de 30 días, pero no todos los días ( ) Todos los días
6	¿Tiene un dolor del hombro que le hizo reducir su actividad durante los últimos 12 meses? a. ¿En actividades de trabajo (en la casa o fuera de la casa)? ( ) NO ( ) SI b. ¿En su tiempo libre? ( ) NO ( ) SI
7	¿Cuál es el tiempo total que los problemas del hombro le han impedido realizar su trabajo normal (en la casa o fuera de la casa) durante los últimos 12 meses? ( ) 0 días ( ) 1 a 7 días ( ) 8 a 30 días ( ) Más de 30 días
8	¿Ha sido consultado por un médico, fisioterapeuta, quiropráctico u otra persona debido a problemas de hombro durante los últimos 12 meses? ( ) NO ( ) SI
9	¿Ha tenido problemas de hombro en cualquier momento durante los últimos 7 días? ( ) NO ( ) SI

Figure 4. Nordic Survey, sheet 4 of 4

2.3 Application of the measurement instrument

The survey was administered to two random samples of 41 and 20 workers, respectively, who worked in construction sites of tourist developments in the city of Puerto Peñasco.

First, the interviewers introduced themselves and briefly explained the intention of the application of the survey to the contractors and site managers, so that they would consider that the results obtained were for strictly academic purposes and without seeking disagreement or confrontation between workers and employers. Afterwards, 41 workers at the construction sites were randomly selected and given the surveys so that they could answer them personally based on their perception of themselves and their health, as well as allowing them a certain degree of anonymity.

During the process described above, it was notorious to observe some factors that altered the expected results from the first applications. Since what was clearly seen did not coincide with what was answered in the survey responses, it was decided to process the questionnaires as they were and to make a comparison with a second sample of 20 workers. The bias detected in situ can be attributed, among other factors, to the presence of the employer at the time of the interviews.

2.4 Results analysis

The surveys were processed in SPSS statistical software providing measurements of the various variables of interest such as: age, years of experience and the discomfort they might feel in the body areas indicated in this work.

2.5 Results presentation

After processing the data from the second sample, they are presented in graphic form for easy understanding and interpretation, allowing a comparative analysis of the context in which the instrument was applied, as well as conclusions and suggestions for further analysis.

3. RESULTS

The data shown below are the result of the second sampling, due to the invalidation of the first sample for reasons expressed previously. All respondents were male and were accredited as active construction workers with a minimum of 3 years' experience in the industry. The sampling technique used was by convenience. There were 20 instruments applied and analyzed in which the average age of the respondents was 42.75 years and standard deviation was 11 years. The experience in the construction industry shows an average of 19.4 years with a standard deviation of approximately 10 years.

Figure 5 shows the percentage of respondents reporting pain or discomfort in the last 12 months in various body parts.

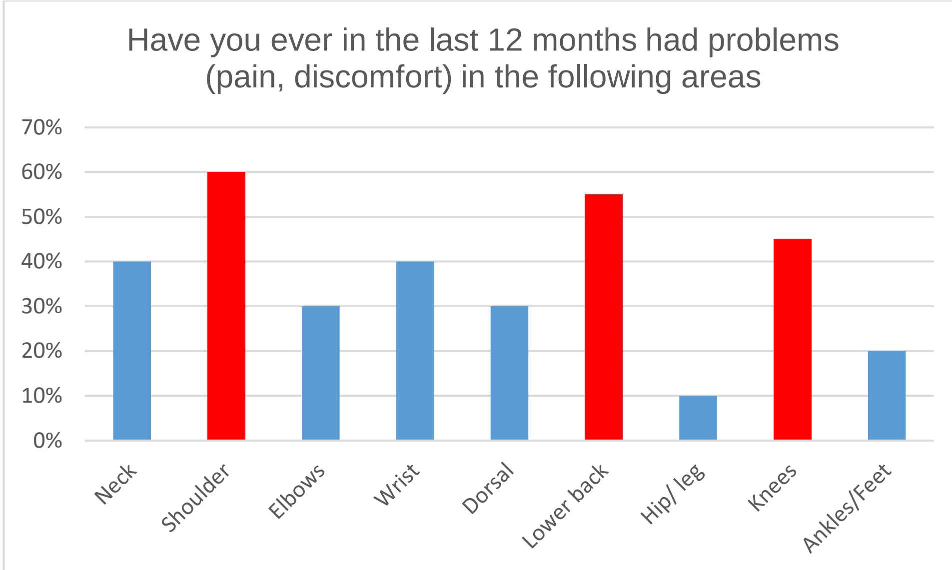


Figure 5. Pain or discomfort in parts of the body

The highest percentage of discomfort, 60%, among the various parts of the body referred to in the study are the shoulders. This percentage includes pain or discomfort in one or both shoulders.

In Mexico, the Instituto Mexicano del Seguro Social (IMSS) reports that shoulder pain is the third leading cause of injury to the musculoskeletal system (Herrera Marrufo, Barrero Solís, Couoh Salazar, Hijuelos García, & Rojas Herrera, 2018) and 40% of people with such a condition must be treated over a year or longer. Figure 6 allows visualizing the distribution of this statistic.

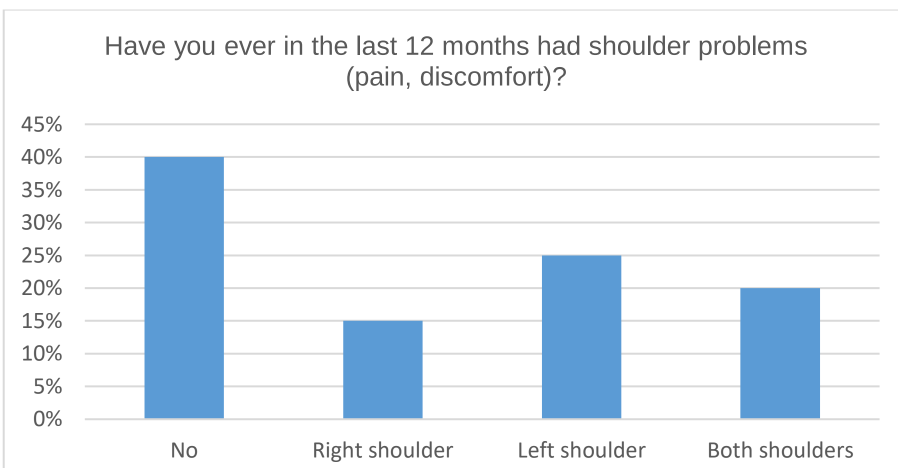


Figure 6. Pain or discomfort in one or both shoulders

According to the World Health Organization (2023), lower back pain or lumbago is defined as the presence of pain in the lower back region, that is, from the lower edge of the ribs to the buttocks. This condition can have a short or prolonged duration, in the latter case it is called chronic low back pain. According to WHO reports, low back pain is the main cause of disability in people worldwide. The instrument showed a percentage of 55% prevalence among the sample, occupying second place in percentage. However, of the cases reported with low back pain in this study, only 45% reported having been consulted for this ailment in the last 12 months, which is shown in Figure 7.

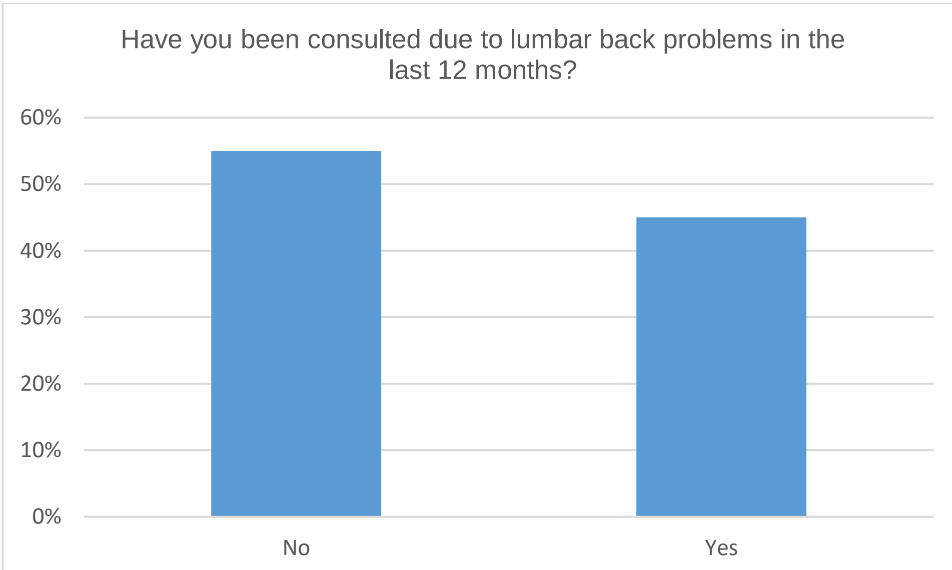


Figure 7. Cases treated medically with lower back problems in the last 12 months

Due to the type of activities that are carried out on a routine daily basis by construction workers, one of the parts of the body that showed a significant percentage of pain or discomfort are the knees. This may be due to activities such as laying floors or tiles, digging, painting, or any task that requires an overload on this part of the body or awkward posture. Forty-five percent of people with knee discomfort mention that this condition has made it impossible for them to perform their work optimally at some point in the last 12 months.

Neck pain shows a high percentage of people with pain or discomfort. In addition, the results show that, of the people with this condition, 25% of them have been limited in performing their work or activities at home in the last year. Sánchez-Aguilar, Pérez-Manríquez, González Díaz and Peón-Escalante (2017) analyzed occupational risk factors in the construction industry in Mexico and their relationship with various diseases. In said study, this industry is recognized as one of the industries that generates the greatest musculoskeletal type disorders. These same authors refer to the case of Taiwan, which reports 13.8% of construction workers with neck problems, a percentage much lower than that found here.

Finally, after considering the various crossings between the different ailments, there is one that is important to mention and that is the one that involves shoulder and lower back disorders simultaneously, since it reaches 40% of people affected, as shown in Figure 8.

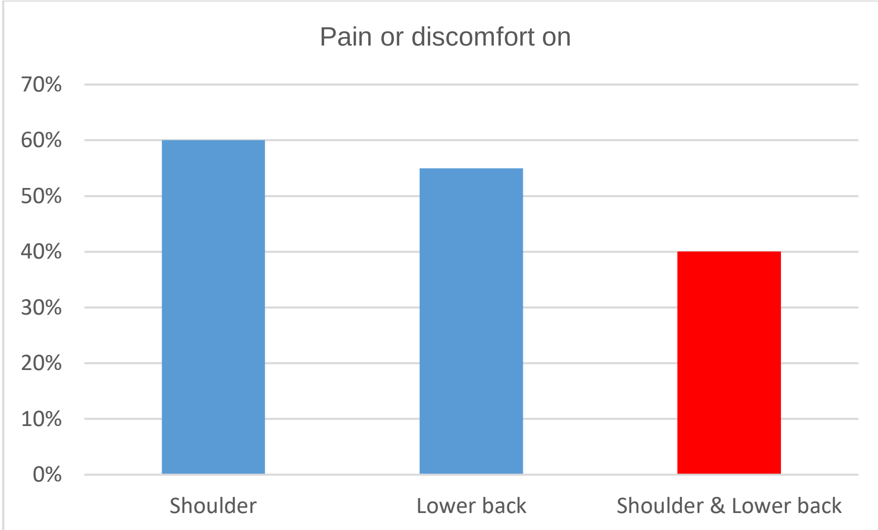


Figure 8. Proportion with presence of shoulder/lower back pain or discomfort

Several parts of the body are affected by activities in the construction industry. It is worth noting the percentages that some of them show (see Figure 5) and how to intuit that, if they are not attended or treated adequately, they could become chronic ailments, which would be detrimental to the worker and his possible employers.

4. DISCUSSIONS AND CONCLUSIONS

It is considered that at the beginning the study was not completely reliable in the results obtained from the first sample. An example of this is the fact that personnel with many years of experience and advanced age did not present any discomfort or injuries. In addition, there was a notable lack of interest on the part of the workers in answering the surveys, which suggests that they did not answer sincerely. Hence the decision not to consider the data from the first sampling in the analysis.

Among the limitations faced by this study was the refusal of some companies to allow surveys of their employees, arguing that the information was confidential and not aligned with their organizational objectives. In the companies where the study was carried out, a certain degree of insecurity was evident in the workers' responses. Therefore, the research team decided to apply the instrument in different conditions and scenarios, i.e., outside the work environment, in a space where employees felt more comfortable to answer honestly. The objective of this modification was to compare the results obtained under these new conditions with the first ones, in order to determine whether the responses were influenced by the company context, where workers might have felt uncomfortable or distrustful regarding the use of the information provided.

The results of the second sampling showed that there are indeed musculoskeletal disorders in construction workers, specifically in the shoulders, lower back and knees, because of tasks involving repetitive movements, forced postures, weight bearing, environmental conditions, among other factors. These injuries usually develop gradually and can become chronic if adequate preventive measures are not taken, such as the implementation of ergonomic practices, the use of protective equipment and training in safe lifting techniques.

Finally, once the research objective has been achieved, it is possible to argue the influence of the work environment on workers' responses due to aspects such as working conditions, hierarchical relationships, concern for job safety, organizational culture, and limited access to resources or space. By understanding the above, it allows ergonomics researchers to design data collection methods that minimize these impacts, providing a more neutral and comfortable environment where workers feel safe to respond honestly and without external pressures.

5. REFERENCES

Herrera Marrufo, M., Barrero Solís, C., Couoh Salazar, A., Hijuelos García, N., & Rojas Herrera, D. (2018). Índice de discapacidad que generan las lesiones de hombro en pescadores que habitan en Telchac Puerto, Yucatán. *Ciencia y Humanismo en la Salud, 5*(1), 9-17. Recuperado de https://revista.medicina.uady.mx/revista/index.php/cienciayhumanismo/article/view/91

Kroemer, K. H. (2019). *Ergonomía: Fundamentos, principios y aplicaciones* (7a ed.). Editorial Médica Panamericana.

Kuorinka, I. J.-S. (1987). Cuestionarios nórdicos estandarizados para el análisis de síntomas musculoesqueléticos. *Ergonomía Aplicada, 18*(3), 233-237.

Organización Mundial de la Salud. (2023). *Dolor lumbar: Datos y cifras*. https://www.who.int/es/news-room/fact-sheets/detail/low-back-pain

Quispe Moncada, BV (2021). *Nivel de conocimiento y aplicación de la ergonomía preventiva en universitarios de la salud, durante la pandemia COVID-19*. Revista Científica de la Universidad Nacional Jorge Basadre Grohmann, 9(1), 75-89. Recuperado de https://revistas.unjbg.edu.pe/index.php/iirce/article/view/1228

Sánchez-Aguilar, M., Pérez-Manríquez, G. B., González Díaz, G., & Peón-Escalante, I. (2017). Enfermedades actuales asociadas a los factores de riesgo laborales de la industria de la construcción en México. *Medicina y Seguridad del Trabajo, 63*(246), 28-39. Recuperado de http://scielo.isciii.es/scielo.php?script=sci_arttext&pid=S0465-546X2017000100028&lng=es&tlng=es.

STUDY OF THE FACTORS THAT INFLUENCE WORK STRESS AT THE TecNM/ TECHNOLOGICAL INSTITUTE OF CD. CUAUHTÉMOC

Erika Elizabeth Caro Trevizo[1], 009-0002-8057-4276, Juan Carlos Bustillos Rodríguez[2], 0000-0002-5485-8323, Verónica Graciela García Cano[3], 0000-0002-9075-787X, Laura Gabriela Villanueva Romero[4], 0000-0002-4833-5286, Daniel Chapa Núñez[5], 0009-0006-8047-6827

[1]División de Estudios de Posgrado e Investigación, Tecnológico Nacional de México Cd. Cuauhtémoc, Av. Tecnológico #137, C.P. 31500. Cd. Cuauhtémoc Chih. México

[2]Departamento de Ciencias Básicas, Tecnológico Nacional de México Cd. Cuauhtémoc, Av. Tecnológico #137, C.P. 31500. Cd. Cuauhtémoc Chih. México

[3]Departamento de Ciencias Básicas, Tecnológico Nacional de México Cd. Cuauhtémoc, Av. Tecnológico #137, C.P. 31500. Cd. Cuauhtémoc Chih. México

[4]División de Estudios de Posgrado e Investigación, Tecnológico Nacional de México Cd. Cuauhtémoc, Av. Tecnológico #137, C.P. 31500. Cd. Cuauhtémoc Chih. México

[5]División de Estudios de Posgrado e Investigación, Tecnológico Nacional de México Cd. Cuauhtémoc, Av. Tecnológico #137, C.P. 31500. Cd. Cuauhtémoc Chih. México

Corresponding author's e-mail: jbustillos@itcdcuauhtemoc.edu.mx

Resumen El estrés laboral se ha convertido en una preocupación importante en el ámbito laboral contemporáneo, afectando la salud y el bienestar de millones de trabajadores. En el sector educativo, las crecientes exigencias y las constantes transformaciones han exacerbado esta problemática. El Instituto Tecnológico de Ciudad Cuauhtémoc, institución clave en la formación de profesionales, no escapa a esta realidad. El presente estudio tiene como objetivo identificar los factores que desencadenan el estrés laboral en esta institución y diseñar estrategias para promover un ambiente de trabajo más saludable y productivo. Como planteamiento del problema de este trabajo se esbozó si el estrés laboral, un fenómeno en aumento, afecta al personal académico y administrativo de la institución debido a factores como la excesiva carga de trabajo, las responsabilidades académicas, la presión por la productividad, la falta de control, las malas relaciones laborales, la inseguridad y la falta de reconocimiento, ya que estos factores generan niveles importantes de estrés, lo que conlleva a un aumento de problemas de salud probablemente relacionados con el estrés, como fatiga, problemas cardiacos, ansiedad y depresión. Estos problemas no sólo afectan el bienestar individual, sino que también impactan negativamente en la calidad de la enseñanza, la eficiencia administrativa y la reputación institucional.

Palabras clave: Salud humana, estrés laboral, sector educativo, excesiva carga de trabajo

Relevancia para la ergonomía: La importancia de esta investigación en cuanto a ergonomía es brindar información respecto a las causas y la relación que existe entre el estrés laboral sufrido tanto por personal dedicado a la educación como de apoyo y ofrecer posibles alternativas para mitigar sus efectos.

Abstract: Workplace stress has emerged as a major concern in the contemporary workplace, affecting the health and well-being of millions of workers. In the educational sector, increasing demands and constant transformations have exacerbated this problem. The Technological Institute of Ciudad Cuauhtémoc, a key institution in the training of professionals, is no exception to this reality. This study aims to identify the factors that trigger workplace stress in this institution and design strategies to promote a healthier and more productive work environment. As a problem statement for this work, founded out if work stress, a growing phenomenon, affect academic and administrative staff at the university due to factors such as excessive workload, academic responsibilities, pressure for productivity, lack of control, poor work relationships, insecurity and lack of recognition, since these factors generate significant levels of stress, which leads to an increase in health problems that are probably related to stress, such as fatigue, heart problems, anxiety and depression. These problems not only affect individual well-being, but also negatively impact the quality of education, administrative efficiency and institutional reputation.

Keywords. Human health, workplace stress, educational sector, excessive workload.

Relevance to Ergonomics: The importance of this research in terms of ergonomics is to provide information regarding the causes and the relationship that exists between work stress suffered by both education and support staff and to offer possible alternatives to mitigate its effects.

1. INTRODUCTION

Every individual irrespective of age deals with stress some way, and it has both physical and emotional implications on individuals, some factors influence the stress level among the workforce which has its impact on individual and organizational productivity (Ahmad & Ashraf, 2016). Stress is the way human beings react both physically and mentally to changes, events, and situations in their lives (Kundaragi & Kadakol, 2015).

Work stress of teachers and other employees in education is a persistent problem as there are many contributing factors, uncertainty or conflicts in their roles and tasks, as well as workload, time pressure, lack of motivation, lack of a cooperative, lack of public recognition and appreciation, as well as work days, postures and work spaces during activities are a very important contributor to work stress (Riezebos & Huisman, 2021).

The work environment, including the physical and mental well-being of workers, depends mainly on the conditions in which they carry out their activities. In Mexico, the NOM-035-STPS-2018 established the necessary guidelines for the identification and mitigation of risks associated with inadequate ergonomic conditions performed during work. Among the main purposes of this norm are the identification of psychosocial risks, the evaluation of the conditions of the work environment, adequate lighting and the preventive measures to follow for the maintenance and improvement of the physical environment.

An institutionalized workplace should heed carefully complete the activities to be made for its employees to avoid health (fatigue, heart problems, anxiety and depression) or physical problems (incorrect posture, overloading of muscles due to repetitive movements, use of incorrect equipment, failure to select ergonomic equipment suitable) associated with work stress (Gerding *et al.*, 2021). The ability to successfully manage stresses related to teaching is critical if education personnel are to survive and thrive in the schools (Ghani *et al.*, 2014).

2. OBJECTIVE

To investigate and understand the specific causes and factors of work-related stress that affect teaching and administrative staff in the university context, establishing the perception and impact of this phenomenon and promoting strategies to address this problem.

3. DELIMITATION

This study focuses specifically on determining the causes and effects of work stress on teaching and support staff at a higher education institution and seeing its relationship with the quality of education provided at the institution.

4. METHODOLOGY

Through a mixed methodology, combining surveys and in-depth interviews, we sought to gain a deeper understanding of the experiences of teaching and support staff, focusing on the causes of work-related stress and proposing practical solutions that contribute to improving their quality of life and, consequently, the quality of the education provided.

This analysis used a descriptive-related numerical technique to observe the points connected with occupational health at work at the Instituto Tecnológico de Cd. Cuauhtémoc. The survey focused on finding the aspects that affect physical care, including ergonomic issues, mental and social care of teaching and administrative staff. The first section was regarding respondents' biographical information such as gender, age, position he/she holds, and length of teaching or staff experience. The second section respondents were asked to indicate the degree to which they found the aspects of their work is stressful.

The sample was made with all members of the teaching and administrative staff of the institute, being a total of 98 respondents, using a method of random selection to ensure that all work levels are reflected. A questionnaire was created that has simple questions and Likert scales to measure key things about health at work, such as stress at work, amount of tasks, space conditions, relationships between people and safety and hygiene measures at work.

5. RESULTS

From the survey carried out, it can be observed that the majority of the personnel who work in the institution rate the amount of work assigned as moderate (45.9%), although a significant part considers it high (42.9%) (Figure 1). The overall stress levels among teachers and staff were high moderate, these results are consistent with the findings of Ghani *et al.,* (2014), for education workers in Malaysia, which indicated that work environment, is the main cause of teachers' stress.

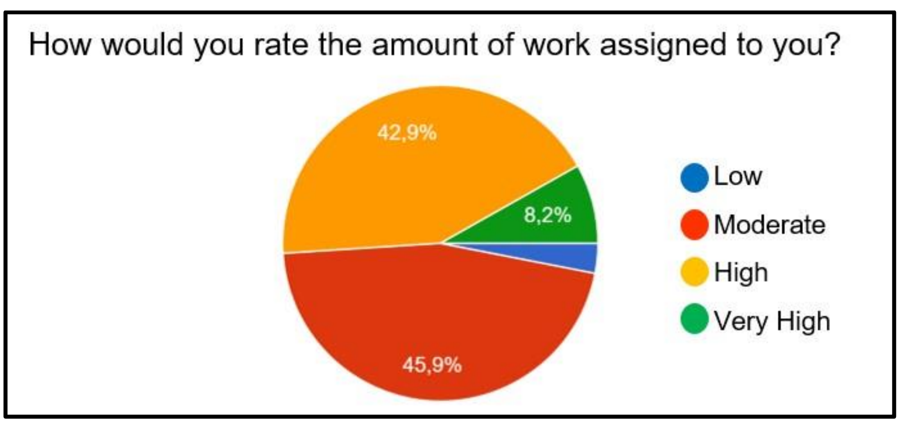


Figure 1. Evaluation of the amount of work assigned.

An analysis was also performed by counting the frequency in order to identify level of perceived stress at work (Figure 2). The results showed that the majority of participants (57.1%) suffer from stress sometimes and 21.4% almost always, according to Bhui *et al.* (2016), these results could mainly relate to factors such as workload, the physical environment (e.g. noisy offices, lack of windows, small rooms, and offices in which the temperature was either too low or too high for comfort), long working hours, heavy workloads and understaffing.

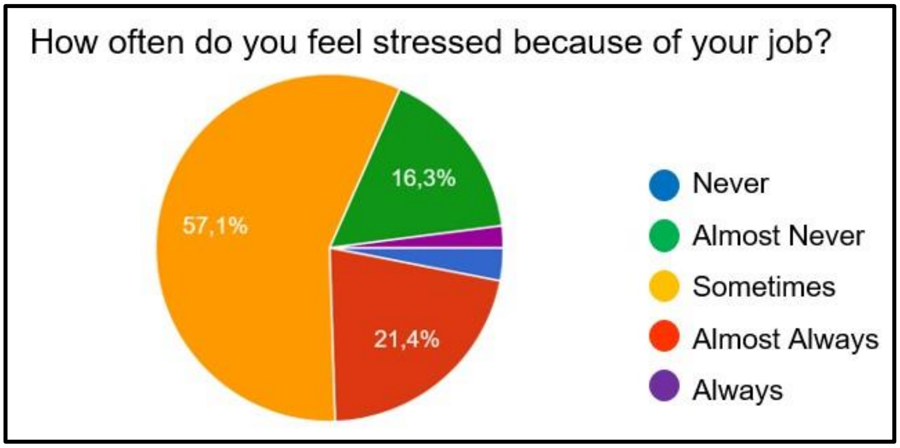


Figure 2. Frequency level of perceived stress at work.

According to Kundaragi and Kadakol (2015), education workers experience stress in different ways and for different reasons such as financial problems, job interviews, presentations, disagreements between coworkers, noise, crowding, pollution, traffic, among others, and this is reflected in different symptoms like anxiety, depression, irritability, fatigue, headaches and if stress persists, there are changes in neuroendocrine, cardiovascular, autonomic and immunological functioning, this was observed in our study (Figure 3), where the personnel who work in the institution have presented any of these symptoms, and this can be due to several causes including ergonomic issues, specifically prolonged posture in offices and classrooms or maintenance, cleaning or gardening activities.

An important component of physical discomfort and work stress for the personnel were office and classroom inner climates, most participants (53.1%) indicated that “temperature” and “ventilation” made then uncomfortable (Figure 4). In this sese, there are many studies in environmental psychology research related to the effect of natural elements for example, window size, sunlight penetration and the presence of plants influences workers’ moods, and which is reflected both in the levels of work stress and in issues associated with physical ailments (Bazley *et al.*, 2015).

This study demonstrated that the university staff often presented physical discomfort during or after your workday, and this were at considerably higher risk of developing work-related musculoskeletal disorders due to poor ergonomic workstations, which directly contributes to issues of work stress (Figure 5). Some symptoms like pain, numbness and tingling in numerous body regions like wrists, shoulders, back and legs and eyestrains, lack of breaks throughout work and improper viewing distance, workplace organization, correct seat height, a good working posture, proper usage of armrest and backrest, straight alignment of the wrist and elbow and their positions while typing may play a role in avoiding countless musculoskeletal complaints (Fatima *et al.*, 2023).

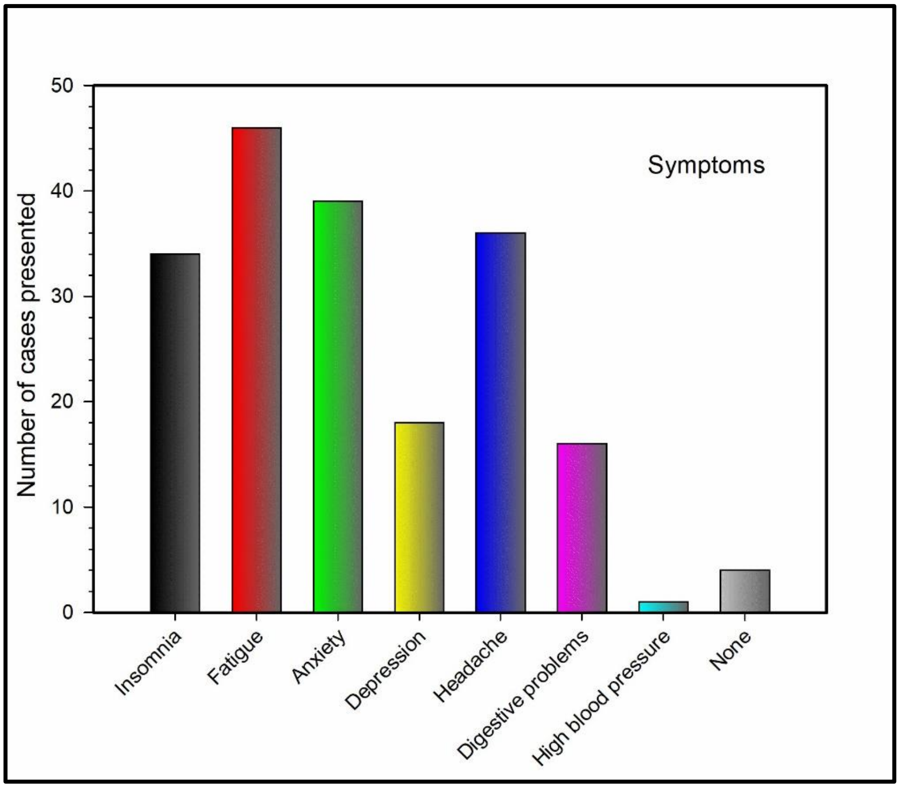


Figure 3. Evaluation of symptoms caused by work stress.

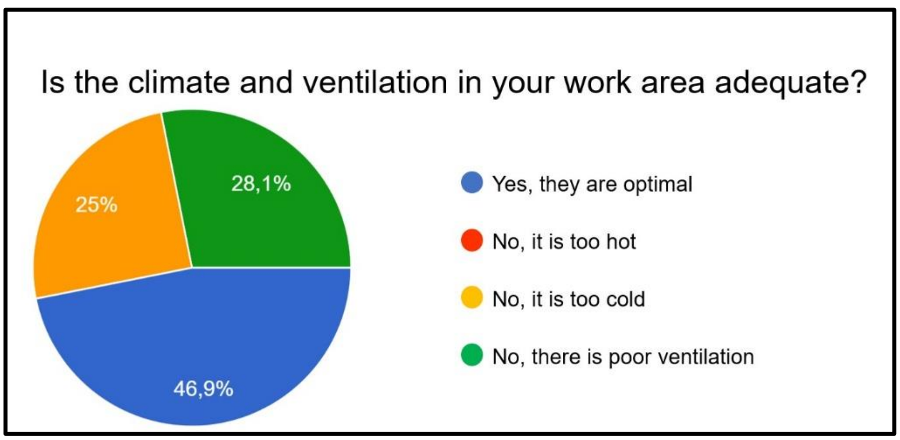


Figure 4. Effect of basic elements associated with the work area.

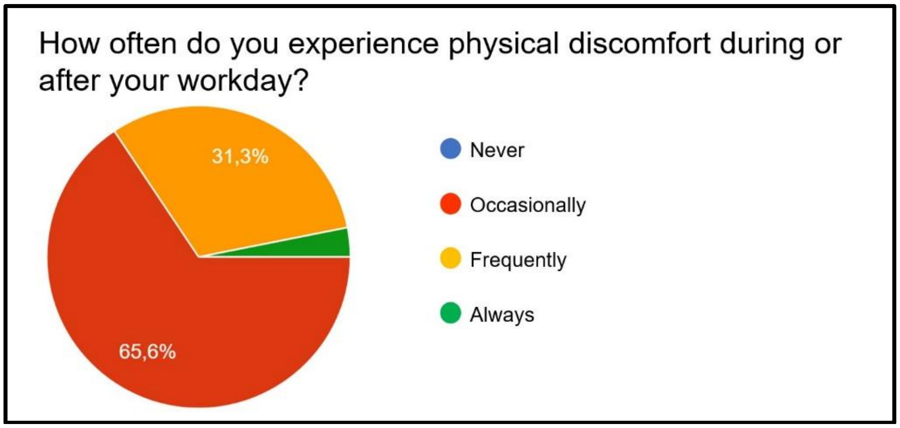


Figure 5. Prescence of physical discomfort during or after workday in staff.

The findings obtained in this study showed that more than half of the participants (65.6%) taken breaks but not on a regular basis, and 25% did not usually takes active breaks (stretching exercises or eye rest) during his work day (Figure 6), these rest are necessary within certain periods during the day, since which enable workers to relieve their fatigue and regain their energy. The implementation of a continuous working day shortens the free time of the workers and makes the recovery process insufficient, consequently, it may cause different fatigue and lead to occupational accidents and high stress levels (Onen *et al.*, 2022).

Figure 6. Frequency of active breaks during your work day.

The quality of the work environment in which employees have constant interactions can determine the employees' level of motivation, subsequent performance, and productivity. The results showed that the majority of participants (87.5%) considered that productivity was affected by physical discomfort resulting from your work environment (Figure 7). Work environment and working conditions with adverse effects on one's physical and mental health can cause anxiety, ultimately reducing job performance in individuals and organizations, like in the institutional educations (Bazley *et al.*, 2015).

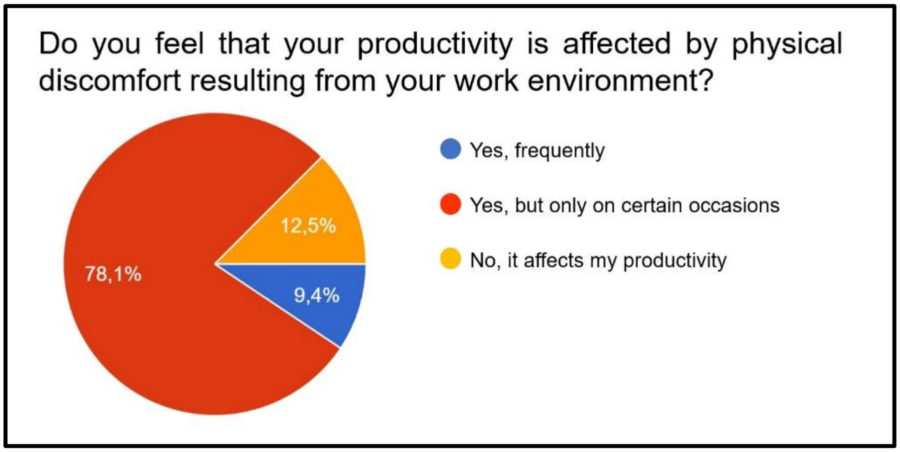


Figure 7. Effect of physical discomfort on work productivity.

In relation to the above, it is possible to generate relationships regarding the factors or causes associated with work stress in the educational sector, specifically at the university level. Based on the findings found in this research, we can classify these factors as follows (Table 1).

Table1. Ergonomic factors associated with work stress.

Ergonomic Factor	Description	Impact on Stress
Small workspaces	Working in small or crowded spaces can create feelings of claustrophobia and overwhelm.	It increases irritability, makes concentration difficult and encourages mental exhaustion.
Lack of adequate lighting	Insufficient or poorly distributed lighting causes eye fatigue, headaches and poor performance.	It causes constant fatigue and negatively affects mood.
Prolonged postures and repetitive movements	Staying in the same position for a long time causes muscle pain and fatigue.	Chronic physical discomfort generates emotional tension and reduces tolerance to work stress.
Excessive noise or poor acoustic conditions	Constant noise causes distractions and makes effective communication difficult.	It increases nervous tension, hinders mental rest and decreases the ability to concentrate.

Based on these results, we allow ourselves to make suggestions on how to largely mitigate, from an ergonomic point of view, the work stress suffered by teachers and support staff at the Technological Institute of Cd. Cuauhtémoc in Table 2.

Table 2. Strategies to mitigate work stress related to an educational institution.

Aspect	Detailed Description
Workspace design	Adjusting workstations with ergonomic furniture (adjustable chairs, desks at the right height and correctly positioned screens) helps maintain a correct posture. This reduces physical fatigue and prevents muscle pain, especially in the back and neck. It also improves concentration, increases productivity and reduces absences due to physical problems.
Injury prevention	Ergonomics encourages healthy practices, such as using equipment designed to avoid repetitive movements or properly adjusting posture at the computer. This reduces the risk of injuries such as carpal tunnel syndrome, tendonitis or eye strain, contributing to peace of mind and improving overall staff performance.
Improving the physical environment	Environmental factors such as lighting, ventilation, temperature and noise control directly influence stress levels. Well-lit spaces with natural light, quiet areas and a comfortable temperature improve the worker experience, reduce distractions and create an environment more conducive to work performance.
Promoting active breaks	Incorporating regular active breaks, including stretching exercises and movements to relax the body, improves blood circulation and reduces physical and mental fatigue. These breaks also promote integration among coworkers, creating a more relaxed and motivating environment.
Promoting comprehensive well-being	An ergonomic work environment fosters a culture of comprehensive well-being, where both the physical and emotional health of staff is prioritized. This strengthens interpersonal relationships, reduces conflicts, improves communication and promotes job satisfaction, creating a positive and highly productive organizational climate.

6. CONCLUSIONS

Based on the results obtained regarding workload and therefore work stress, it has been observed that personnel have presented various symptoms related to this problem, mainly chronic fatigue, anxiety, headaches and insomnia among others, making it necessary to take measures to mitigate these negative effects, such as intermittent breaks and the acquisition of ergonomic furniture to mitigate working hours, especially when working overtime is required. Ergonomics is key to reducing stress at work at the Cuauhtémoc Institute of Technology because it tries to adjust the working conditions to what the staff needs in terms of their body and mind.

7. REFERENCES

Ahmad, N., & Ashraf, M. (2016). The impact of occupational stress on university employees' personality. *Journal of Education and Educational Development, 3*(2).

Bazley, C., Nugent, R., & Vink, P. (2015). Patterns of discomfort. *Journal of Ergonomics, 5*(1), 2015. http://dx.doi.org/10.4172/2165-7556.1000136

Bhui, K., Dinos, S., Galant-Miecznikowska, M., de Jongh, B., & Stansfeld, S. (2016). Perceptions of work stress causes and effective interventions in employees working in public, private and non-governmental organisations: a qualitative study. *BJPsych bulletin, 40*(6), 318-325. https://doi.org/10.1192/pb.bp.115.050823

Fatima, S., Farooqi, A., Fazal, A., Zaheer, R., Khalid, Z., & Rehman, A. (2023). Ergonomic Evaluation of Workstation of University Administrative Staff in Rawalpindi and Islamabad. *Pakistan Journal of Public Health, 13*(2), 45-49. https://doi.org/10.32413/pjph.v13i2.1225

Gerding, T., Syck, M., Daniel, D., Naylor, J., Kotowski, S. E., Gillespie, G. L., et al. (2021). An assessment of ergonomic issues in the home offices of university employees sent home due to the COVID-19 pandemic. *Work, 68*(4), 981-992. https://dergipark.org.tr/en/download/article-file/3211552

Ghani, M. Z., Ahmad, A. C., & Ibrahim, S. (2014). Stress among special education teachers in Malaysia. *Procedia-Social and Behavioral Sciences, 114*, 4-13. doi: 10.1016/j.sbspro.2013.12.648

Kundaragi, P. B., & Kadakol, A. (2015). Work stress of employee: A literature review. *International Journal of Advance Research and Innovative Ideas in Education, 1*(3), 18-23. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=ad95924c672c9a0116b40a9f91c5bd6b5dbd487e

Norma Oficial Mexicana. "NOM-035-STPS-2018." Factores de riesgo psicosocial en (2018).

Onen, C., Sandikci, M. B., & Dincer, E. (2022). Working environment-related leisure time satisfaction levels and health behaviors of university office workers and ergonomic solutions. *Medicine, 11*(2), 814-819. https://10.5455/medscience.2022.01.021

Riezebos, J., & Huisman, B. (2021). Value stream mapping in education: addressing work stress. *International Journal of Quality & Reliability Management, 38*(4), 1044-1061. https://www.emerald.com/insight/0265-671X.htm

ERGONOMIC ANALYSIS OF THE MAN-MACHINE SYSTEM FOR SELLING BURRITOS IN CUAUHTÉMOC, CHIH.

Daena Fernanda Olivas Olivas[1], 0009-0009-1885-6839, Rosa Magallón Márquez[1], Nancy Ivette Arana de las Casas[2], 0000-0003-3537-4515, Juan de Dios Terrazas Marquez[3], 0009-0009-1885-6839, and José Luis Martínez Torres[2], 0009-0000-0786-570X

[1]Industrial Engineering Department, Tecnológico Nacional de México Cd. Cuauhtémoc, Av. Tecnológico #137, C.P. 31500. Cd. Cuauhtémoc Chih. México

2 Graduate Studies and Research Division, Tecnológico Nacional de México Cd. Cuauhtémoc, Av. Tecnológico #137, C.P. 31500. Cd. Cuauhtémoc Chih. México

[3]Basic Sciences Department, Tecnológico Nacional de México Cd. Cuauhtémoc, Av. Tecnológico #137, C.P. 31500. Cd. Cuauhtémoc Chih. México

Corresponding 462BJEC’s e-mail: narana@itcdcuauhtemoc.edu.mx

Resumen: El principal objetivo de este proyecto es la evaluación ergonómica de diversos puestos de trabajo (sistemas hombre-máquina) que se dedican a la venta en la calle de burritos, una actividad económica de importancia en la región de Cuauhtémoc. Chih. La actividad se da al aire libre y se realizaron mediciones de tipo ambiental (luminosidad, ruido, temperatura y viento) y se utilizó la herramienta publicada por la organización inglesa enfocada a la salud y seguridad de los trabajadores (HSE) herramienta enfocada en la evaluación repetitiva de tareas de las extremidades superiores más conocida como ART TOOL por sus siglas en Ingles para realizar el análisis ergonómico, el cual se complementó con encuestas a los trabajadores enfocadas a determinar su percepción general del ambiente laboral y características de clasificación generales (Edad, genero, tiempo laborando, etc..).

Como resultado, en una muestra de doce sistemas hombre-máquina, en base a posturas forzadas y movimientos repetitivos principalmente la herramienta ergonómica arrojo valores críticos lo que implica que es necesario de manera urgente realizar cambios buscando disminuir el riesgo de lesiones musculoesqueléticas.

Palabras clave: Análisis Ergonómico, ART TOOL, Ley Silla, Salud Ocupacional.

Relevancia para la ergonomía: Análisis de sistema-hombre máquina existente en busca de mejorar las condiciones laborales de los trabajadores, incluyendo el cumplimiento con la recién generada “Ley Silla”.

Abstract: The main objective of this project is the ergonomic evaluation of various workstations (human-machine systems) dedicated to street vending of burritos, an economically significant activity in the Cuauhtémoc, Chih. Region. This activity occurs outdoors, where environmental measures (luminosity, noise, temperature, and wind) are conducted. Additionally, an evaluation tool published by the UK Health and Safety Executive (HSE) was used—specifically, the Assessment of Repetitive Tasks of the Upper Limbs (ART TOOL). This ergonomic analysis was complemented with surveys administered to workers, aiming to assess their overall perception of the work environment and collect general classification data (age, gender, years of experience, etc.).

As a result, in a sample of twelve human-machine systems, based on forced postures and repetitive movements, the ergonomic assessment yielded high-risk values for both sides of the body. This indicates an urgent need for changes to reduce the risk of musculoskeletal injuries.

Keywords: Ergonomic Analysis, ART TOOL, “Chair Mexican Law” Occupational Health

Relevance to Ergonomics: Analyzing existing human-machine systems to improve working conditions for vendors and ensure compliance with the newly implemented “Ley Silla.”

1. INTRODUCTION

Street vending of burritos is a key economic activity in Cuauhtémoc, Chih. Region. However, it exposes vendors to ergonomic and environmental challenges such as forced postures, repetitive movements, and extreme temperatures. Although the physical effort required is not substantial, the long working hours (ranging from 9 to 10 hours depending on the stall location) can exacerbate these conditions. These factors may lead to heat stress, fatigue, and injuries, affecting health and productivity. This study aims to analyze these risks to propose ergonomic improvements that enhance vendor’s well-being, safety, and efficiency, ensuring a more suitable and sustainable working environment.

Additionally, the so-called “Ley Silla,” a reform to Mexico’s Federal Labor Law published in the Official Gazette on December 4, 2024, (Expansión, 2024) is relevant to this study, because we are talking about a work day of at least 8 hours and worker’s do not have chairs in which they can rest at times when they do not have clients, which is why they are forced to stand for long periods, a condition that is associated with an increased risk of work-related musculoskeletal disorders (WMSD) as stated in various studies (Anderson, et al., 2021; Jin, et al., 2022; Jo, et al., 2021😉 these disorders increase the risk of labor disabilities, according to data from the Mexican Social Security Institute (IMSS), 20% of the disabilities were related to “dorsopathies and arthropathies, both ergonomic diseases,” (Escutia, 2024).

The ”Ley Silla” mandates that employers provide chairs with backrests for workers in the service and commerce sectors, allowing them to take periodic breaks during their work shifts (Hernández, 2024) which based on studies, dimmish the probability of WMSD, failure to comply with this law can lead to economic sanctions for employers for the equivalent of 250 to 2,500 times the Measurement and Update Unit (UMA) (Alín, 2024).

Based on the above, this project aims to conduct an ergonomic analysis of several burrito vending workstations in the municipality, propose ergonomic improvements, and suggest an ergonomic, adaptable seat for these human-machine systems. Due to despite being part of the informal economy, these workstations contribute significantly to the region's economy and labor force.

2. 464BJECTIVES

2.1 General Objective:

To evaluate the ergonomic and environmental conditions of street burrito vending, considering exposure to extreme temperatures, to identify health and well-being risks for vendors and propose corrective measures to improve their comfort, safety, and work efficiency.

2.2 Specific Objectives:

1. Assess ergonomic risks, analyzing vendors' postures, repetitive movements, and physical exertion, using the ART TOOL for evaluating repetitive upper limb tasks (HSE, 2010).
2. Evaluate the workstation design (table height, utensil arrangement, etc.) and its impact on comfort and efficiency.
3. Measure environmental conditions (temperature, humidity, lighting) affecting vendors.
4. Suggest modifications to workstation design to reduce fatigue and the risk of musculoskeletal injuries.
5. Ensure compliance with the "Ley Silla." Suggesting an ergonomic chair adapted to the man-machine system

3. DELIMITATION

The burrito vending stalls included in this study belong to a single burrito vendor organization. Although various organizations with different human-machine systems operate in the area, only those that met the study requirements and agreed to participate were included.

4. METHODOLOGY

This research was conducted using a qualitative approach, encompassing the following stages:

1. **Participant Observation**: The research team visited various burrito stalls in the region on a designated day to perform an ergonomic workstation analysis

using the ART TOOL (HSE, 2010), as stated by Jafari, et al. (2021) The "ART method was introduced in 2009 by The Health and Safety Executive (HSE) for risk assessment of repetitive tasks leading to musculoskeletal disorders, taking into account the influential factors such as repetition of the movements, force, working posture, vibration, speed of work, duration of work, psychological factors, etc". The assessment states that an exposure score of 22 or more is classified as a high ergonomic risk and further investigation is required urgently (Jafari, et al., 2021).

2. **Interviews**: Structured interviews were conducted to explore workers' general data for classification purposes, psychological factors, job injuries, and environmental concerns, as well as opportunities for improving vendors' tools and equipment.
3. **Data Analysis:** Collected data were analyzed using qualitative and quantitative techniques, such as statistical analysis, and content analysis, to identify relevant patterns, themes, and relationships.
4. **Chair Design:** The need to design a light, ergonomic chair adaptable to different anthropometric measurements, and that could be adapted to the burrito's stand dimensions for storage was detected, on the one hand, to allow workers to rest and avoid future WMSD and on the other hand to comply with the chair law.

5. RESULTS

The sample was of twelve workers, 8 males, and 4 females, with an average age of 25 years. First, results related to the interview are presented.

As illustrated in Figure 1, most workers have less than 1 year's tenure. High turnover is attributed to poor working conditions.

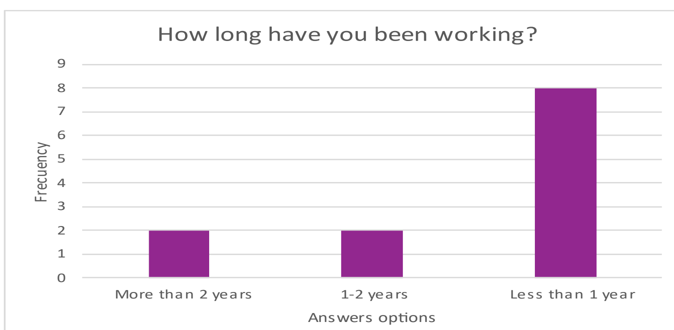


Figure 1. Job Tenure

Concerning injuries and discomfort on the job, only a minority of workers reported work-related injuries (Figure 2), it is important to mention that those who did not report injuries frequently declared persistent back pain, and tiredness likely due to job-related activities.

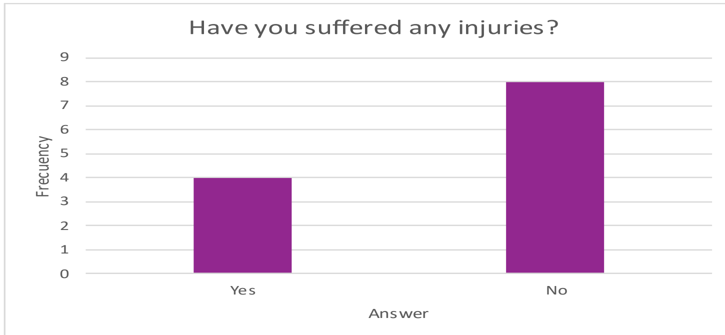


Figure 2. Injuries on the job.

As shown in Figure 3, where workers classify their perception using a Likert scale of 1 to 10 of how hard their job is regarding the weather conditions, 50% mention that extreme temperatures significantly affect work conditions. Given the regional weather, vendors work between 6 AM and 3 PM, a period that can include very low temperatures.

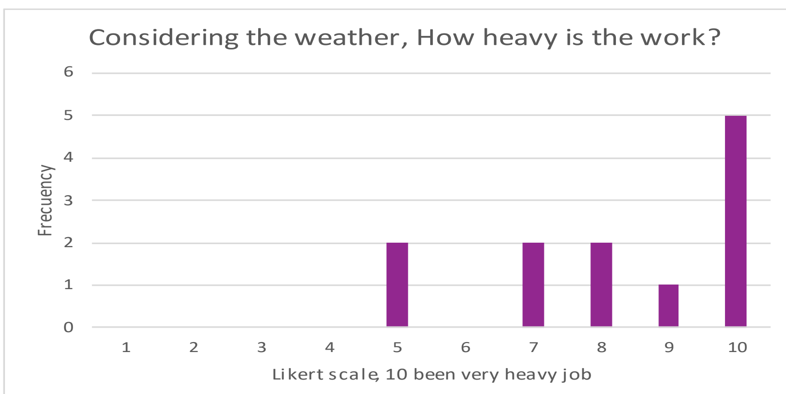


Figure 3. Worker perception of job difficulties.

All workers mentioned that they would like to have a chair adapted to their anthropometric measurements, these are due to some of them having a small chair that is very uncomfortable or heavy to carry around.

Wind conditions were found to be relatively consistent across different stall locations, remaining within tolerable limits for outdoor work (Figure 4)

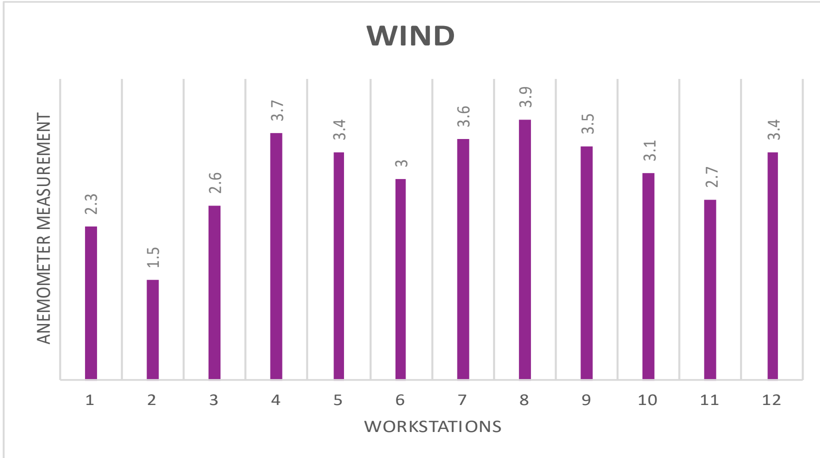


Figure 4. Wind measurements.

Temperature levels varied significantly by location (Figure 5). Some stalls experienced subzero temperatures, while others recorded relatively higher temperatures.

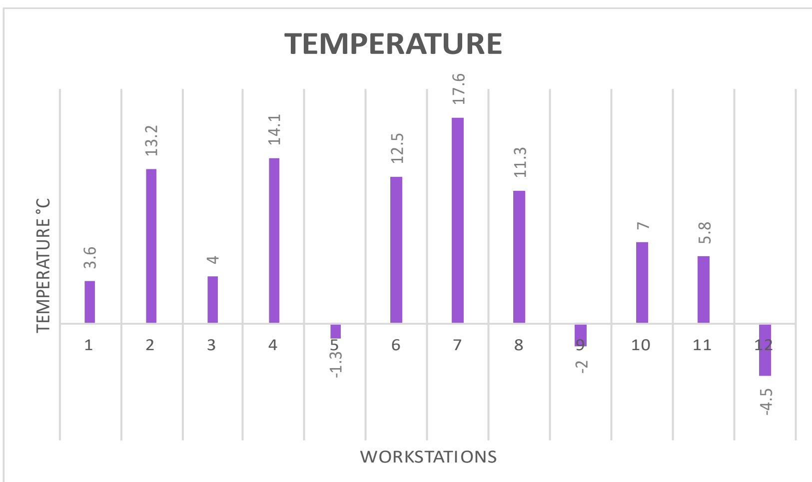


Figure 5. Temperature measurements.

Noise levels ranged between 50 and 80 dB (Figure 6), which is considered low. Given that the human-machine systems are positioned on sidewalks for easy access to roads and customers, ambient noise is minimal.

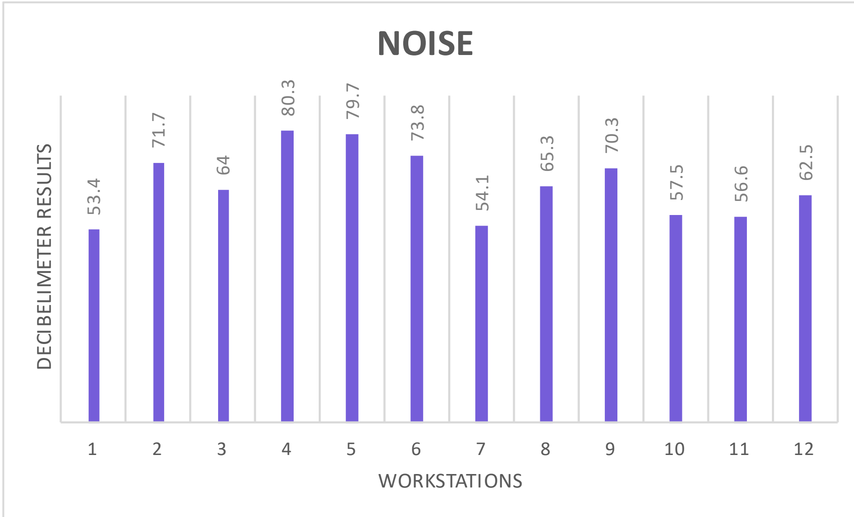


Figure 6. Noise levels

Light levels varied widely depending on the time of day when measurements were taken (Figure 7). Since this is an outdoor activity, natural lighting conditions fluctuate throughout the work shift, despite the presence of small overhead covers.

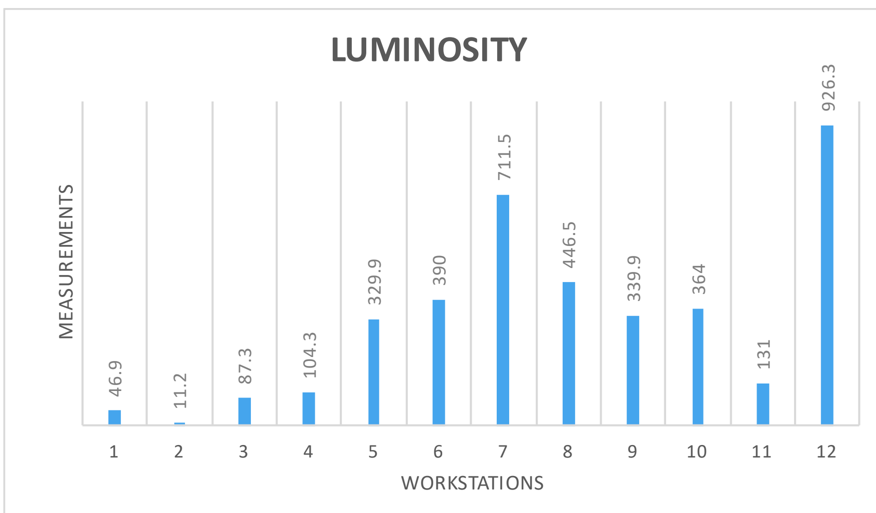


Figure 7. Luminosity levels

In a sample of twelve human-machine systems, the ergonomic analysis was done using the ART Tool, and based on forced postures and repetitive movements, the ergonomic assessment yielded minimum values of 25 for both sides of the body. This indicates an urgent need for changes to reduce the risk of musculoskeletal injuries.

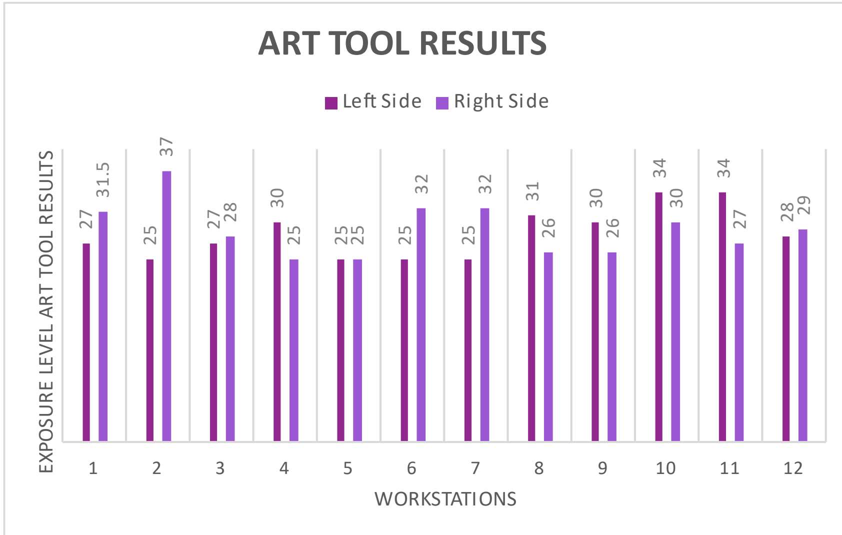


Figure 8. ART tool results.

Following (Figure 9) representative photos of the man-machine system are presented

Figure 9. Man-Machine System

This study recommends the implementation of an adjustable chair designed for different anthropometric measurements (Figure 10), which can be permanently stationed at the vending stalls. This would allow vendors to rest during inactivity periods, improving overall work conditions and health outcomes.

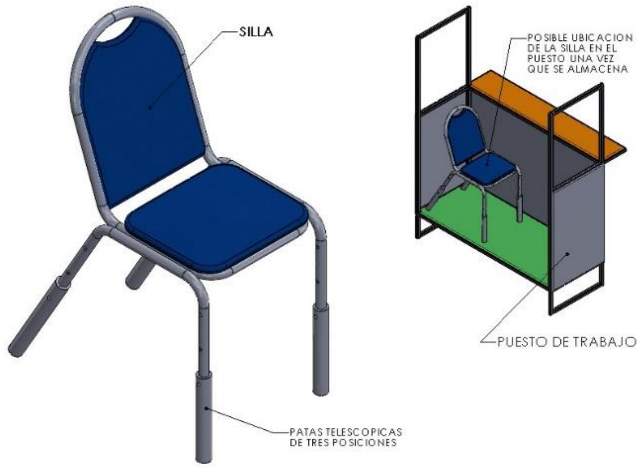


Figure 10. Chair Prototype

6. CONCLUSIONS

This study concluded that, although no previous research has been conducted on this specific occupation, burrito vending is a highly prevalent economic activity in the region. While the work may not appear physically demanding at first glance, long working hours and unfavorable workstation conditions contribute to fatigue and musculoskeletal discomfort, posing a moderate ergonomic risk.

7. CONTRIBUTIONS TO ERGONOMICS

As a key contribution, this study recommends the implementation of an adjustable chair designed for different anthropometric measurements, which can be permanently stationed at the vending stalls. This would allow vendors to rest during inactivity periods, improving overall work conditions and health outcomes.

8. REFERENCES

Alín, P. (2024, 12 5). Ley Silla en México: qué es, cuándo entra en vigor y sanciones. *El País*.

Anderson, J., Williams, A., & Nester, C. (2021). Musculoskeletal disorders, foot health and footwear choice in occupations involving prolonged standing,. *International Journal of Industrial Ergonomics*, Vol. 81.

Escutia, N. (2024, 12 05). *Ley Silla APROBADA, ¿cuándo entra en vigor?* Retrieved from idconline.mx: https://idconline.mx/laboral/2024/12/05/ley-silla-aprobada-cuando-entra-en-vigor

Expansión. (2024, 12 26). La Ley Silla ya es oficial, estos son los derechos de los trabajadores. *Expansión Política*.

Hernández, G. (2024, 10 03). 6 Claves para entender la Ley Silla aprobada por la

Cámara de Diputados. *El Economista*.

HSE. (2024, 06 01). *Assessment of Repetitive Tasks (ART) tool.* Retrieved from Health and Safety Executive _ United Kingdom: https://www.hse.gov.uk/msd/uld/art/

Jafari, A. S., Feyzi, V., Foroozanfar, Z., & Rahimimoghadam, S. (2021). The correlation between ART and OCRA methods used for posture assesment of repetitive taks. *Med Lav*, 370-376.

Jin, X., Dong, Y., Wang, F., Jiang, P., Zhang, Z., He, L., . . . Yang, L. (2022). Prevalence and associated factors of lower extremity musculoeskeletal disorders among manufacturing workers: a cross-sectional study in China. *BMJ Open*.

Jo, H., Lim, O. B., Ahn, Y. S., Chang, S. J., & Koh, S. B. (2021). Negative Impacts of Prolonged Standing at Work on Musculoskeletal Symptoms and Physical Fatigue: The Fifth Korean Working Conditions Survey. *Yonsei Med J.*, 510-519.

UK Health and Safety Executive. (2010, Marzo). *Assessment of Repetitive Taks (ART) Tool.* Retrieved from https://www.hse.gov.uk/msd/uld/art/index.htm

DIAGNOSIS OF THE PACKING AREA TO REDUCE OCCUPATIONAL HAZARDS IN A SHRIMP FREEZING COMPANY

Brenda Guadalupe Delgado Jiménez, ORCID 0000-0002-8289-4823, Diana Alejandra Angulo Camacho, ORCID 0009-0000-7028-4123, Emilia Estéfana Sauceda López, ORCID 0000-0003-4162-981X, Grace Erandy Báez Hernández, ORCID 000-0003-1580-2199

Department of Industrial Engineering
Tecnológico Nacional de México /Instituto Tecnológico Superior de Guasave
Carretera a Brecha Sin Número, Ej. Burrioncito
Guasave, Sinaloa, State 81149
brenda.dj@guasave.tecnm.mx

Corresponding author's e-mail: brenda.dj@guasave.tecnm.mx

Resumen: El presente estudio tiene como objetivo diagnosticar los riesgos ergonómicos y de seguridad presentes en el área de empaque de una empresa acuícola en Guasave, Sinaloa, aplicando dos herramientas clave: el Método RULA (Rapid Upper Limb Assessment) y el Análisis Modal de Efectos y Fallos (AMEF). A través de una observación detallada y encuestas a los trabajadores, se identificaron varias condiciones que afectan la seguridad y el bienestar laboral, tales como posturas incorrectas y movimientos repetitivos, además de factores ambientales como pisos mojados y resbaladizos, y la falta de organización en el área de trabajo.

La evaluación con el Método RULA reveló posturas críticas en tareas como el empuje de camarón a bolsa, lo que representa un alto riesgo para lesiones musculoesqueléticas. Las puntuaciones obtenidas sugieren que, sin intervención, los trabajadores pueden sufrir lesiones a largo plazo, especialmente en las zonas de hombros, muñecas y espalda baja. Por otro lado, el análisis AMEF identificó riesgos significativos, como el piso mojado sin tratamiento antideslizante y el uso insuficiente del equipo de protección personal (EPP), que presentaron altos Números de Prioridad de Riesgo (RPN). Estos riesgos requieren acciones correctivas inmediatas, tales como la instalación de pisos antideslizantes, el fortalecimiento del uso de EPP y la mejora en la señalización y delimitación de las áreas de trabajo.

Las conclusiones del estudio subrayan la necesidad urgente de implementar medidas correctivas para mejorar las condiciones laborales, reducir el riesgo de accidentes y optimizar la eficiencia operativa. Las soluciones propuestas incluyen ajustes ergonómicos en el diseño del lugar de trabajo, la capacitación en el uso adecuado del EPP, y la reorganización del espacio de trabajo para promover un entorno más seguro y eficiente para los empleados.

Palabras clave: Seguridad laboral, Gestión de Riesgos, Evaluación postural, optimización de procesos, Análisis AMEF.

Relevancia para la Ergonomía: La ergonomía se enfoca en identificar y reducir los riesgos laborales asociados a las tareas realizadas en este entorno de trabajo específico. En una industria como la de los productos congelados, especialmente en el área de empaque, los trabajadores suelen estar expuestos a condiciones físicas exigentes, tales como movimientos repetitivos, cargas pesadas, posturas incómodas, y la exposición a temperaturas extremas, lo que incrementa el riesgo de sufrir lesiones musculoesqueléticas y otros trastornos relacionados.

Abstract: The objective of this study was to diagnose the ergonomic and safety risks present in the packing area of an aquaculture company in Guasave, Sinaloa, by applying two key tools: the RULA Method (Rapid Upper Limb Assessment) and the Failure and Effects Modal Analysis (FEA). Through detailed observation and worker surveys, several conditions that affect occupational safety and well-being were identified, such as incorrect postures and repetitive movements, as well as environmental factors such as wet and slippery floors, and lack of organization in the work area.

The RULA Method assessment revealed critical postures in tasks such as pushing shrimp into bags, which represent a high risk for musculoskeletal injuries. The scores obtained suggest that, without intervention, workers may suffer long-term injuries, especially in the shoulder, wrist and lower back areas. On the other hand, the FMEA analysis identified significant risks, such as wet floor without anti-slip treatment and insufficient use of personal protective equipment (PPE), which had high Risk Priority Numbers (RPN). These risks require immediate corrective actions, such as the installation of non-slip floors, strengthening the use of PPE and improving the signage and delimitation of work areas.

The study's findings underscore the urgent need to implement corrective measures to improve working conditions, reduce the risk of accidents, and optimize operational efficiency. Proposed solutions include ergonomic adjustments in workplace design, training in the proper use of PPE, and reorganization of the workspace to promote a safer and more efficient environment for employees.

Keywords: Occupational safety, risk management, postural assessment, process optimization, AMEF analysis.

Relevance to Ergonomics: Ergonomics focuses on identifying and reducing occupational hazards associated with the tasks performed in this specific work environment. In an industry such as frozen products, especially in the packaging area, workers are often exposed to demanding physical conditions, such as repetitive movements, heavy loads, awkward postures, and exposure to extreme temperatures, which increase the risk of musculoskeletal injuries and other related disorders.

1. INTRODUCTION

Nowadays, worker safety and well-being are fundamental aspects to ensure an efficient and healthy work environment, especially in sectors such as aquaculture, where physical and environmental conditions can present ergonomic and safety challenges. Work activities in this sector, such as shrimp handling and packing, require repetitive efforts, forced postures, as well as wet and slippery floors, which can generate significant health risks for workers.

In order to identify and mitigate these risks, ergonomic assessment tools such as the Rapid Upper Limb Assessment (RULA) method are used to detect incorrect working postures and the areas of the body most exposed to possible musculoskeletal injuries. In addition, methodologies such as Modal Effects and Failure Analysis (MEA) are used to assess the risks associated with unsafe conditions in the work environment, such as slippery floors or lack of personal protective equipment.

The objective of this study is to diagnose the ergonomic and safety risks present in an aquaculture company, using both the RULA Method and the AMEF. Based on the results obtained, we seek to propose corrective measures and improvements in working conditions that contribute to the prevention of injuries and accidents, thus promoting the health of employees and the operational efficiency of the company.

2. OBJECTIVE

The objective of this project is to diagnose the packing area in order to reduce occupational risks in a shrimp freezing company by implementing preventive measures based on an ergonomic analysis and improving working conditions. Through the application of tools such as RULA Method and AMEF (Failure Mode and Effects Analysis) to identify, evaluate and prioritize the risks present in the workers and the work environment, in order to ensure the safety, health of employees and operational efficiency of the production process.

3. DELIMITATION

This project was carried out in the packing area of a shrimp freezing company located in the region of Guasave, Sinaloa. The study focused on the identification and evaluation of occupational hazards present in this environment, specifically those associated with postures and repetitive movements in the shrimp packing process. For this purpose, the RULA Method (Rapid Upper Limb Assessment) was applied to evaluate the postures and efforts made by workers, identifying possible risk factors related to ergonomics in their daily work.

The intervention included a detailed diagnosis of the packing area, with the application of the FMEA (Failure Effects Modal Analysis) tool, to detect possible failures in the design of processes and machinery, in addition to addressing ergonomic risks that may affect the health of employees. This comprehensive approach allows not only to identify risks, but also to design strategies to improve working conditions, optimizing efficiency and reducing the risk of musculoskeletal injuries among workers.

4. METHODOLOGY

The study was structured in the following phases:

1. An analysis of the current situation of the company was carried out through direct observation of the packing area, identifying the work flow, the tasks performed by the employees and the environmental conditions.
2. A body posture assessment was carried out using the RULA Method to identify postures that can cause musculoskeletal disorders (MSDs) and provide a tool for prioritizing corrective or preventive interventions in a work environment.
3. Environmental conditions were evaluated by means of surveys of workers in the area to obtain information on perceived risks and problems in their work environment, in addition to direct observation of the workplace to detect hazardous conditions, such as wet floors, lack of signage, cluttered work areas, and inadequate use of personal protective equipment (PPE).
4. The Failure Modes analysis was carried out using the FMEA (Failure Mode and Effects Analysis) tool for each risk, considering the specific situations that could lead to an incident or accident, analyzing the causes and effects that each failure could have.
5. Subsequently, Severity (S), Probability (P) and Detection (D) values were assigned for each failure mode according to the criteria established in the FMEA methodology. The RPN was calculated for each failure mode to prioritize corrective actions according to their potential impact.
6. Improvement proposals were presented based on the results of the RULA Method, AMEF and the analysis of the RPNs obtained to mitigate the identified risks.

5. RESULTS

A detailed tour of the different areas of the company was conducted, ending in the packing area, where an exhaustive analysis of the activities and processes that take place in this section was carried out. During the evaluation, several conditions were identified that could affect the safety and well-being of the workers. Among the most relevant findings were inadequate postures and repetitive movements, which represent a risk of musculoskeletal injuries.

Environmental conditions were also evaluated, such as the state of the floor, which was wet in several areas, constituting a clear risk of slip and fall accidents (as shown in Figures 1 and 2).

Figure 1. Wet floor in carton assembly Figure 2. Wet floor in packing

The packing area was also found to be significantly overcrowded with objects, boxes, crates and work tables, without adequate space delimitation. This lack of organization and order in the work environment considerably increases the risk of accidents and injuries by limiting mobility and creating potential obstacles in the work areas. These factors require prompt attention to improve safety conditions and prevent possible incidents in the future.

Subsequently, a flow chart was designed for the shrimp packing process, as shown in Figure 3.

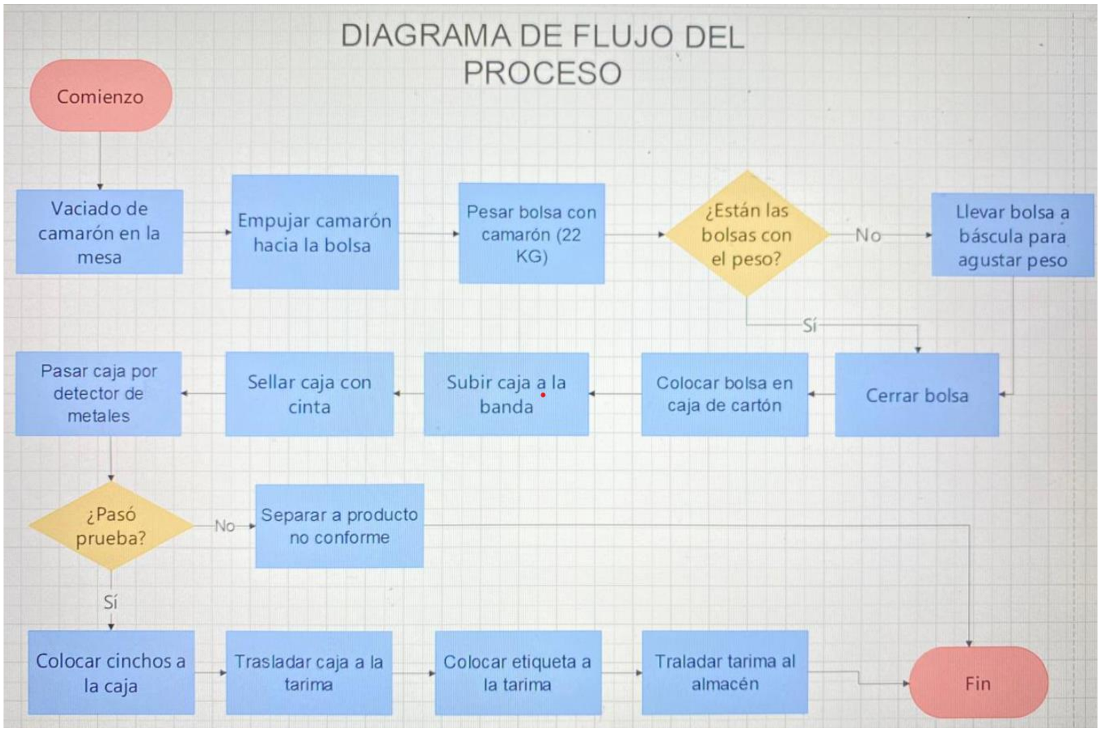


Figure 3. Process flow chart

Once the tasks performed by workers in the packing area were identified, it was decided to apply the RULA Method to evaluate the posture associated with the activity of pushing shrimp into bags, which was one of the most critical postures observed.

Work posture analyzed: *Shrimp push to bag*

The posture adopted by a worker who moves frozen shrimp along the base table, using his hands to manipulate it and fill 22 kg bags, is analyzed. The process consists of manually pushing the shrimp towards one end of the table, where the scale is located, until the weight needed to fill the 22 kg bags is reached.

Once the images taken on video were observed, it was decided that one of the postures to be evaluated would be the one on the left side of the image shown below, since a priori it is considered that it entails an important postural load (see figure 4).

Figure 4. Shrimp push to bag

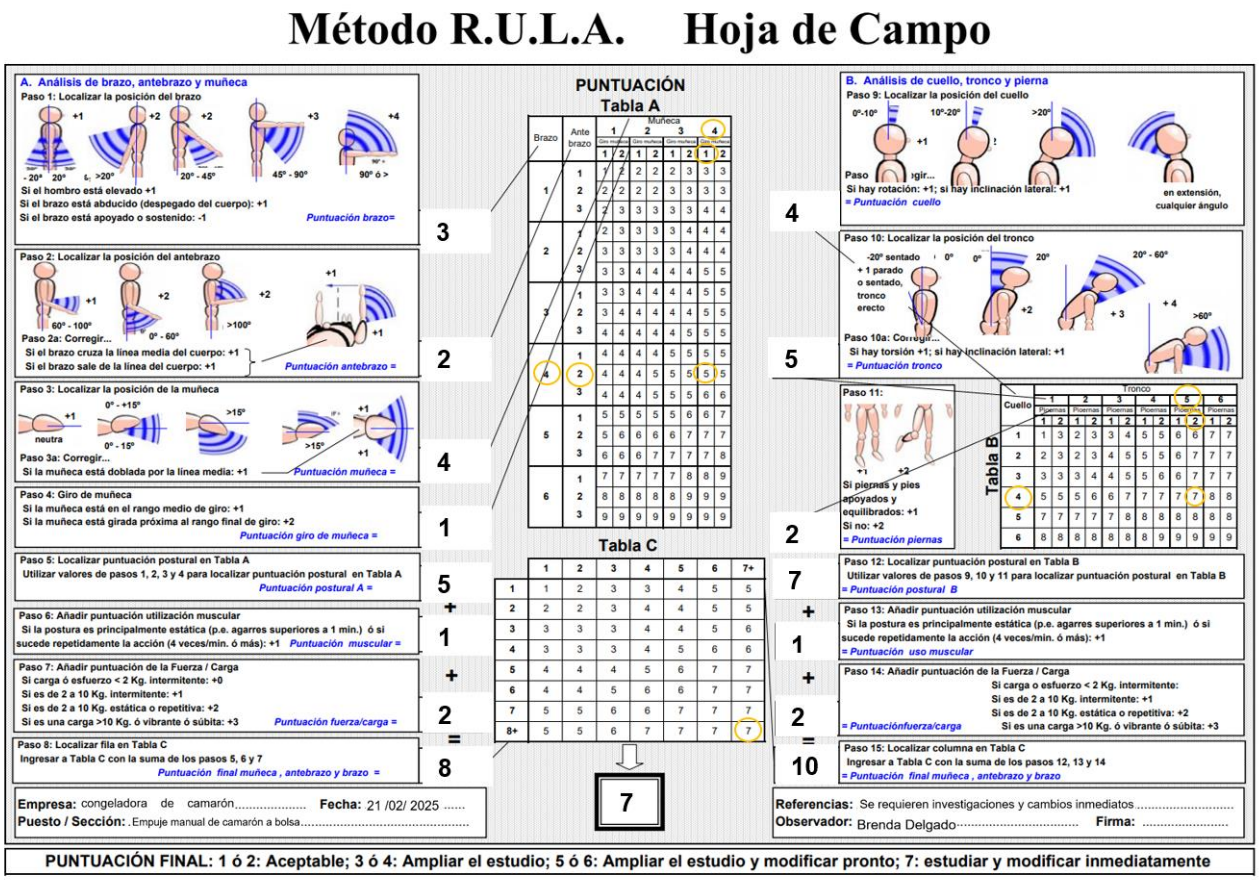


Figure 5. Application format of the Rula method

After performing the evaluation with the RULA (Rapid Upper Limb Assessment) Method (Figure 5), a final score of 7 was obtained, which indicates an **Action Level 4**. This action level corresponds to a situation that requires a more detailed investigation and immediate changes to avoid possible risks to the health of workers.

Subsequently, to complement the diagnosis, an analysis was carried out by means of surveys applied to workers in the packing area; in order to evaluate the environmental conditions and identify the main risks and needs they perceive in their work environment. The results obtained are shown in Table 1.

Table 1: Survey Concentration

SURVEY RESULTS			
Name of respondent	**Detected risk**	**Detected need**	**Years of experience**
Worker 1: José de Jesús N.	Reduced space, which makes it difficult to move between areas and can generate risk situations due to lack of room to maneuver.	Expansion of the work area to improve employee movement and avoid accidents due to lack of space.	2 years
Worker 2: José Antonio L.	Slippery floor, which increases the risk of falls and injuries.	Implementation of an anti-slip floor to reduce the risk of slips and falls, ensuring greater safety.	12 years
Worker 3: Oroldo Martínez	Lack of adequate personal protective equipment, which puts their safety at risk because they do not have the necessary equipment to prevent accidents.	Improve the availability of personal protective equipment for all workers and ensure its proper use.	11 years
Worker 4: Héctor López	Slippery floor, which increases the risk of falls and accidents at work.	Installation of clear evacuation signs to facilitate orientation in emergency situations and ensure staff safety.	16 years
Worker 5: Juan Ruiz	Slippery floor, which represents a significant risk of falls and possible injuries in the workplace.	Provision of adequate personal protective equipment for all workers, improving safety at work.	4 years
Worker 6: Alejandro Cervantes	Slippery floor, which could lead to fall accidents.	Expansion of the work area and use of adequate personal protective equipment to ensure a safer work environment.	7 years

The next activity carried out was a detailed analysis of the situations raised by the workers in the packing area, also incorporating the most critical circumstances observed during the tour of the company. Within the framework of this analysis, a FEMEA (Failure Mode and Effects Analysis) of risks was developed, where the main problem was the wet floor without anti-slip treatment, which presented the highest Risk Priority Number (RNP) as shown in Table 2.

Table 2: FEMEA - Failure Mode and Effects Analysis (Problems in the Shrimp Packing Area)

Function	Failure Mode	Cause	Effect	Severity (S)	Probability (P)	Detection (D)	NPR (Priority Risk Number)
Wet floor	Floor without anti-slip treatment and always wet in the area.	Lack of maintenance and resources.	Slips and falls. Injuries to workers.	9	8	4	288
Lack of signage	Lack of adequate signage of risks and evacuation routes.	Lack of planning and resources.	Serious accidents in case of emergency.	8	7	3	280
Lack of delimitation of areas	Work areas and safety zones are not marked.	Disorganization and lack of protocols.	Disorder in the work area, accidents.	7	6	6	252
Lack of adequate personal protective equipment	Personnel do not use adequate or insufficient protective equipment.	Lack of training and security control.	Injuries and diseases due to exposure.	8	6	6	288

RPN Interpretation and Prioritization:

- High priority (RPN > 250): Hazards with higher RPNs, such as those related to wet floor (288) and lack of proper PPE (288), should be addressed immediately with urgent corrective actions.
- Medium priority (RPN between 200-250): Hazards such as lack of area delineation (252) require medium-term corrective action.
- Immediate corrective action: Should be taken for problems with the highest RPN and significant impact on worker safety.

In response to this situation, corrective actions were proposed to mitigate this risk (see Table 3).

Table 3: AMEF- Recommended Actions and Responsible Parties

Function	Failure Mode	Cause	Effect	Severity (S)	Probability (P)	Detection (D)	NPR (Priority Risk Number)	Recommended actions	Responsable
Wet floor	Floor without anti-slip treatment and always wet in the area.	Lack of maintenance and resources.	Slips and falls. Injuries to workers.	9	8	4	288	Installation of non-slip floors and a maintenance system to keep the area dry.	Maintenance Department
Lack of signage	Lack of adequate signage of risks and evacuation routes.	Lack of planning and resources.	Serious accidents in case of emergency.	8	7	3	280	They include the installation of clear and visible signage, as well as periodic evacuation drills.	Safety Department
Lack of delimitation of areas	Work areas and safety zones are not marked.	Disorganization and lack of protocols.	Disorder in the work area, accidents.	7	6	6	252	It is recommended to clearly mark work areas and safety zones to avoid accidents and improve organization in the workplace.	Safety Department
Lack of adequate personal protective equipment	Personnel do not use adequate or insufficient protective equipment.	Lack of training and security control.	Injuries and diseases due to exposure.	8	6	6	288	Ensure that all employees receive appropriate PPE and are trained in its correct use.	Safety Department

The analysis conducted through the AMEF, with its specific recommendations and assigned responsible parties, provides an initial plan to mitigate risks in the shrimp packing area. Each function has a clear action and a designated responsible person to ensure its successful implementation.

6. DISCUSSION/CONCLUSIONS

The application of the RULA Method in the aquaculture company has made it possible to identify critical work postures that represent significant ergonomic risks for the workers. In particular, handling tasks in the shrimp packing area, such as the shrimp-to-bag pushing process, proved to be especially problematic. The high scores obtained indicate a high risk of musculoskeletal injuries, especially in areas such as the shoulders, wrists and lower back. If corrective measures are not implemented, workers could be exposed to long-term injuries, highlighting the urgent need to modify the postures adopted during these tasks. Possible solutions include adjustments in workplace design, incorporation of ergonomic equipment, and optimization of work techniques to reduce physical strain and muscle tension.

Regarding the results obtained through the Modal Analysis of Effects and Failures (MEA) and the interpretation of the Risk Priority Numbers (RPN), the following conclusions can be drawn:

The risk associated with wet floors presented an RPN=288, which is high, evidencing a significant impact on worker safety. The main cause identified is the lack of anti-slip treatment on the floors and the persistent humidity in the work areas, which increases the probability of falls and injuries. To mitigate this risk, it is recommended to install slip-resistant flooring, establish an efficient drainage system, and clean regularly to keep surfaces dry. In addition, periodic inspections are suggested to ensure continued compliance with these measures.

Inadequate or insufficient use of personal protective equipment represents another critical risk with an RPN=288 also high. This problem stems from the lack of training and control over the use of PPE, which exposes workers to possible injury and illness. Corrective actions include the adequate provision of PPE for each worker (gloves, boots, protective clothing, among others), as well as the implementation of training programs on the correct use of this equipment. In addition, periodic reviews are recommended to ensure that PPE is being used properly at all times.

The absence of adequate signage for evacuation routes and risk areas presents a significant risk in emergency situations, with an RPN of 280. It is recommended that clear and visible signage be installed in all risk areas, especially on evacuation routes. In addition, it is essential to carry out periodic evacuation drills to ensure that employees are properly prepared to act in the event of an emergency. The lack of adequate delineation of work areas and safety zones has been identified as an additional risk with an RPN of 252. Recommended corrective actions include clear delineation of work areas and safety zones, training of personnel in the proper organization of work space, and implementation of an orderly zoning system to facilitate work and safety management.

7. REFERENCES

Diario Oficial, Secretaría de Trabajo y Previsión Social. (1999). NORMA Oficial Mexicana NOM-004-STPS-1999, Sistemas de protección y dispositivos de seguridad en la maquinaria y equipo que se utilice en los centros de trabajo.

Diario Oficial, Secretaría de Trabajo y Previsión Social. (2001). NORMA Oficial Mexicana NOM-011-STPS-2001, Condiciones de seguridad e higiene en los centros de trabajo donde se genere ruido.

Diario Oficial, Secretaría de Trabajo y Prevención Social. (2008). NORMA Oficial Mexicana NOM-025-STPS-2008, Condiciones de iluminación en los centros de trabajo.

Diario Oficial, Secretaría de Trabajo y Previsión Social. (2008). NORMA Oficial Mexicana NOM-001-STPS-2008, Edificios, locales, instalaciones y áreas en los centros de trabajo-Condiciones de seguridad.

Diario Oficial, Secretaría de Trabajo y Previsión Social. (2008). NORMA Oficial Mexicana NOM-017-STPS-2008, Equipo de protección personal-Selección, uso y manejo en los centros de trabajo.

Diario Oficial, Secretaría de Trabajo y Previsión Social (2009). NORMA Oficial Mexicana NOM-030-STPS-2009, Servicios preventivos de seguridad y salud en el trabajo-Funciones y actividades.

Diario Oficial, Secretaría de Trabajo y Previsión Social (2009). NORMA Oficial Mexicana NOM-016-STPS-1993, Relativa a las condiciones de seguridad e higiene en los centros de trabajo referente a ventilación.

NOM-035-STPS-2018: A SYSTEMATIC LITERATURE REVIEW FROM 2018 TO 2024

Nancy Ivette Arana de las Casas[1], 0000-0003-3537-4515
Thelma Arvizo Aragon[2], 0009-0005-5962-5210, David Sáenz Zamarrón[1], 0000-0002-5045-4997, Diego Velasco Soto[1], 0000-0007-9736-0107 and Brenda Rivera Avitia[3], 0009-0000-4568-0968

[1]Graduate Studies and Research Division, Tecnológico Nacional de México Cd. Cuauhtémoc, Av. Tecnológico #137, C.P. 31500. Cd. Cuauhtémoc Chih. México

[2]Industrial Engineering Department, Tecnológico Nacional de México Cd. Cuauhtémoc, Av. Tecnológico #137, C.P. 31500. Cd. Cuauhtémoc Chih. México

[3]Computer Systems Departament, Tecnológico Nacional de México Cd. Cuauhtémoc, Av. Tecnológico #137, C.P. 31500. Cd. Cuauhtémoc Chih. México

Corresponding author's e-mail: narana@itcdcuauhtemoc.edu.mx

Resumen: La investigación sobre la NOM-035-STPS-2018, norma mexicana sobre el trabajo y los factores de riesgo psicosocial, ha aumentado significativamente desde el 2018, año en que se publicó en el Diario Oficial de la Federación, hasta el 2024. Este proyecto tuvo como objetivo realizar un análisis sistemático del estado del arte que revise el estado actual de conocimiento de la norma, y sus instrumentos, determinar su efectividad en detectar riesgos psicosociales y fomentar ambientes organizacionales positivos en México.

Palabras clave: NOM-035-STPS-2018, Factores de riesgo Psicosocial, Salud Ocupacional, Estrés Laboral.

Relevancia para la ergonomía: Hoy en día, los factores psicosociales juegan un papel fundamental en los ambientes laborales, y forman parte de la ergonomía cognitiva. Su estudio es crucial, ya que la carga mental y organizacional (factores psicosociales) en los entornos de trabajo actuales supera a la carga física.

Abstract: Research on NOM-035-STPS-2018 a Mexican standard on work and related psychosocial risk factors has surged significantly from 2018 when it was published in the Federation Official Gazette of Mexico to 2024. This project aimed to create a comprehensive compendium that reviews the current state of knowledge about this regulation, and its instruments assessing its effectiveness in addressing psychosocial risks and fostering positive organizational environments in Mexico.

Keywords. NOM-035-STPS-2018, Psychosocial risk factors, Occupational Health, Laboral stress

Relevance to Ergonomics: Nowadays, psychosocial factors play a fundamental role in work environments and are part of cognitive ergonomics. Its study is crucial, since the mental and organizational load (psychosocial factors) in today´s work environments exceed the physical load.

1. INTRODUCTION

Psychosocial factors can be risk factors for health originating in the organization of work, generating physiological, emotional, cognitive, and behavioral responses that are popularly known as stress and can be precursors of disease in certain circumstances of intensity, frequency, and duration (Luna-Chavez, 2019). To diminish these factors in Mexican organizations, the NOM-035-2018 standard "Psychosocial Risk Factors at Work, identification, analysis, and prevention" was developed and has been mandatory for all labor organizations since October 23, 2019.

Research on NOM-035-STPS-2018 has surged significantly from 2018 when it was published in the Federation Official Gazette of Mexico to 2024. The standard focus is on interpersonal relationships, related to worker's well-being and for the seeking of factors conducive to the good performance of work teams that result in optimal performance, cordial relationships, healthy integral health status, and good management of work pressure (Guillén & Delgado, 2024).

This project aimed to create a comprehensive compendium that reviews the current state of knowledge about this regulation, and its instruments assessing its effectiveness in addressing psychosocial risks and fostering positive organizational environments in Mexico.

To achieve this, a documentary methodology focusing on understanding and interpreting relevant phenomena was used. To gather pertinent information, the following databases were meticulously analyzed: Dialnet, EBSCO, SciELO, Frontiers, Redalyc, Researchgate, and Google Scholar. Our review encompassed 197 products considered significant published during the specified period.

The analysis revealed various products, including articles, theses, book chapters, books, manuals, standards, general documents, and editorials. Key topics addressed included improvements in organizational environments, validation of the norm measurement instruments, norm training information, implementation impacts, legal foundations, emotional compensation, and social responsibility.

In conclusion, most of the products are related to seeking improvement in organizational environments, standard analysis, and validating the standard instruments, while the introduction of NOM-035 represents a significant step forward, further revisions are necessary to enhance its theoretical and methodological framework regarding the management of psychosocial risk factors.

2. OBJECTIVES AND DELIMITATION

2.1 General Objective

The main objective of this work is to create a comprehensive compendium that reviews the current state of knowledge about the "NOM-035-STPS-2018: Psychosocial risks factors at work – Identification, analysis, and prevention"; in such a way that this allows inferring the effectiveness of this standard, for the attention of psychosocial risks and fostering positive organisational environments in Mexico.

2.3 Delimitation

To gather pertinent information, the following databases were meticulously analyzed: Dialnet, EBSCO, SciELO, Frontiers, Dialnet, Redalyc, Researchgate and Google Scholar. Our review encompassed 197 products considered significant published during the specified period.

3. METHODOLOGY

The design was descriptive and compilation. A documentary methodology (systematic review) was used following Kitchenham (2004) and Okoly & Achabram (2010), the mentioned methodology follows eight steps to do a systemic review: Determine the review purpose; protocol, and training; literature search; screening for inclusion; quality evaluation; data mining; studies synthesis and review writing (Acosta, et al. 2023), to provide an overview of current knowledge, to highlight the limits of this knowledge, and to confirm, where applicable, the interest in further investigating the subject. The study considered research that has been published during the period 2018-2024. To gather pertinent information, the following databases were meticulously analyzed: Dialnet, EBSCO, SciELO, Frontiers, Redalyc, Researchgate and Google Scholar. Our review encompassed 197 products considered significant published during the specified period.

4. RESULTS

One hundred ninety-seven products related to the NOM-035-STPS were analyzed; they were published from 2018 to 2024, as shown in Figure 1. As can be seen, the number of products has grown significantly and exponentially over the years. Table 1 shows the categories of product types, approach, and team.

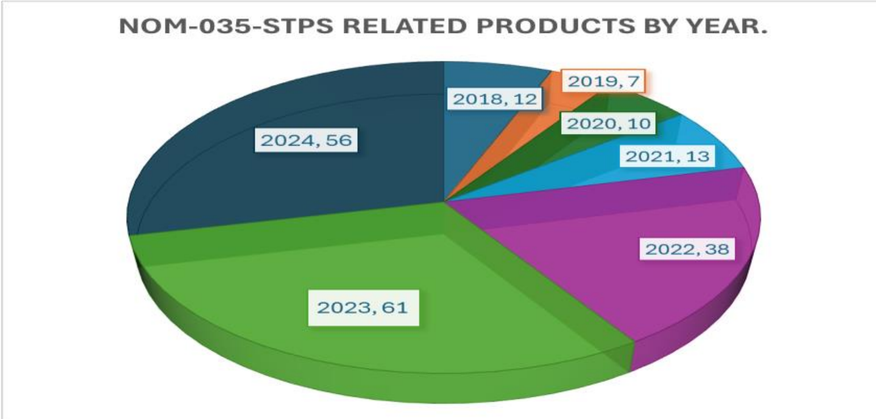


Figure 1. NOM-035-STPS-2018 Products analyzed by year.

Table 1. Product categories.

Product Types	Article	Book Chapter	Manual	Editorial	Standard	Document	Thesis
Approach	Legal Foundation	Standard Analysis	State of the art	Instrument validation.	Software	Standard Information	Organizational
Issue	Organizational Improvement	Instrument validation.	Emotional salary	Social Responsibility	Legal Foundation	Implementation Impact	Training

Regarding product type, 64% were articles, 20.30% were book chapters, and 12.2% were theses. The rest (3.5%) were distributed in manuals, editorials, and standard and document publications.

In 2018, 33% of the products analyzed were a thesis, the percentage lowered over the years by 2022 it was 18.42%, and in 2023 11.48%, by 2024 it was only 3.57%, from this it can be concluded that the first years of the standard were important in the academic world, in fact 25% of the thesis analyzed (24) were published in the 2018-2019 period.

Also, it is important to mention that 100% of the standards, documents, and editorials related to the norm were published from 2018 to 2020 which can be named the standard introduction period (Table 2).

Table 2. Product type results

	Product Type						
	Article	**Book Chapter**	**Manual**	**Editorial**	**Standard**	**Document**	**Thesis**
2018	3	1		1	1	2	4
2019	4					1	2
2020	6	2		1			1
2021	10	2					1
2022	20	11					7
2023	38	15	1				7
2024	45	9					2
Total	126	40	1	2	1	3	24

Regarding articles generated by qualitative or quantitative research, the quantity has increased exponentially over the years as shown in Figure 2.

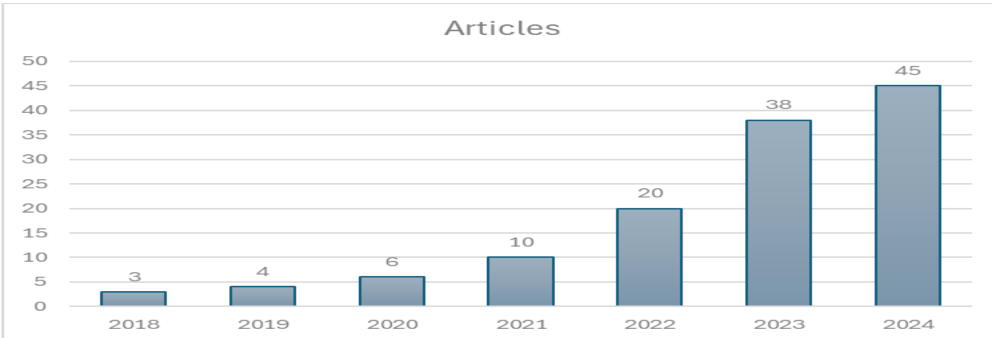


Figure 2. Article quantity by year.

The approach is mostly organizational (76%) as can be seen in Table 3, searching for organizational environment improvement (70.05%) (Table 4), followed by the standard analysis and information (9.13%).

Table 3. Product approach results

	Approach						
	Legal Foundation	Standard Analysis	State of the art	Instrument validation	Software	Standard Information	Organizational
2018	1					4	7
2019		1				1	5
2020		2		1			7
2021		3	3	1			6
2022		1		5	2		30
2023	3	2	1	3	1	1	50
2024	2	3	1	1	1		45
Total	6	12	5	11	4	6	150

Table 4. Product issue results

	Issue						
	Organization Environment Improvement	Instrument validation	Emotional Salary	Social Responsibility	Implementation Impact	Legal Foundation	Training
2018	6	1				1	4
2019	4		1		1		1
2020	5	2	1	1			1
2021	9	1			2	1	
2022	33	5					
2023	47	3	1	3	2	4	1
2024	34	3	1	6	4	2	3
Total	138	15	4	10	9	8	10

Also of significant importance is the validation of the standard instruments, which have grown in the last years, Last in to conclude table 5, shows the general results by year.

Table 5. General results by year.

Year	General results
2018	Preliminary studies were conducted on psychosocial risk factors at work, aligning with the NOM-035 standard. Some research groups identified psychosocial risks and were able to measure their impact on workplace environments, which is a key requirement of NOM-035 (Heredia et al., 2018; Maciel, 2018; Gonzalez, 2018; Aranda, 2018; Calderon & Moreno, 2018). Additionally, other researchers focused on disseminating knowledge about the implementation of the standard, raising awareness of its implications, legal fundamentals, and measurement instrument validation. This effort likely contributed to preparing companies for the standard adoption in the following years (Almirall, et al., 2018; Rubio et al., 2018; Vasallo, 2018; Skillsinnovation, 2018, Social, 2018; Ocampo & Gómez, 2018; Villagrán, et al. 2018).
2019	Research on NOM-035 progressed beyond mere training and identifying psychosocial risks (Flores, et al. 2019; Luna-Chavez, et al., 2019; Colmenares-De la Torre, et al., 2019; García, 2019), encompassing aspects such as leadership in risk management (Saldaña et al., 2019), emotional salary as a well-being strategy (Félix et al., 2019), and the impact of the standard's implementation in workplaces (García, 2019). This indicates a process of adaptation and analysis of the actual effects of the standard on organizations.
2020	Research conducted in 2020 on NOM-035 addressed six key areas: identification of psychosocial risks, instrument validation, training, emotional salary, implementation, and social responsibility. Studies evaluated psychosocial risk levels in various work environments, identifying the factors that affect employee well-being and trained workers in relation (Ortega, 2020; Martínez et al., 2020; Cano et al.,2020, Parga, et al, 2020, Hernandez, 2020). Some other studies validated the standard and analyzed its impact on organizations, ensuring that companies understand its correct application, for example Littlewood-Zimmerman, et al, (2020), mentioned as a result of their investigation that the five instrument categories comply with an Alfa Cronbach minimum of .7, but do not satisfy the construct derivative of a factorial exploratory analysis (Littlewood-Zimmerman, et al., 2020; Uribe, et al., 2020) On the other hand, Cázarez (2020) found that emotional salary (non-monetary benefits, work climate, recognition) has a direct impact on the perception of psychosocial risk at work, highlighting the importance of emotional well-being. Studies by Altatorre et al. (2020) and Uribe et al. (2020) demonstrated that the norm implementation leads to changes in organizational culture and validated its implementation procedures. Guardado's (2020) research revealed that companies integrating mental health and workplace well-being into their social responsibility strategies can significantly reduce psychosocial risks.
2021	Research conducted in 2021 on NOM-035 continued to delve into psychosocial risk identification, standard training, the implementation impact, and standard instrument validation. Studies revealed psychosocial risk levels in various work environments, highlighting organizational factors that affect workers' well-being (Estrada, 2021; Cotonieto, 2021; Méndez et al., 2021; Patlán, 2021, and Zavala &Juárez, 2021) Research by Ríos et al. (2021) focused on validating the implementation processes of the standard and developing training strategies for companies and employees. Other research showed that the application of NOM-035 has led to changes in organizational culture and improved the management of psychosocial risks (Zaldivar & Encalada, 2021; Martínez; Duarte, et al., 2021; Patlán, 2021) Research by Brito et al. (2021) confirmed that NOM-035 meets the criteria for identifying psychosocial risks (reliability level α=.91; .79) and that its application can be effective in the long term with specific improvements in its implementation.

Table 5. General results by year (Continuation)

Year	General results
2022	This year's research focused on identifying psychosocial risks, validating the standard, comparing it with other tools, generating information, and developing technological tools for implementation. Studies validated that NOM-035 meets the criteria for preventing psychosocial risks and identified opportunities for improvement in its application (Portilla et al., 2022; Márquez et al., 2022; Martínez et al., 2022; Gutiérrez et al., 2022; Flores, et al., 2022; Roldán, 2022) Meanwhile, others were able to detect psychosocial risk levels in various work environments, identifying factors that affect workers' health, enhancing productivity, reducing staff turnover, and boosting operational staff commitment, while avoiding fines for non-compliance of the standard (Benítes et al., 2022; López, 2022; Ugarte, 2022; Santoyo et al., 2022; Chan & Lopez, 2022; Reynoso, 2022; López, 2022; Bautista & Cázarez, 2022; Diaz, et al., 2022; Pino, et al., 2022; Becerra-Núñez, et al., 2022; Alcalá, et al., 2022; Carrasco & Higuera, 2022; Soliz, 2022; Sánchez, 2022; Muro, et al., 2022; Cruz & Aguirre, 2022; Acosta-Fernández, et al. 2022; Realyvázquez, et al., 2022; García, et al. 2022; Díaz, et al., 2022; Ramírez, et al., 2022; Luna, et al., 2022) Also, there is notable research, which compares NOM-035 with other psychosocial risk assessment methodologies, or differences by gender, highlighting its advantages and limitations (Valle, et al., 2022; Asadobay, 2022; Arroyo, 2022; Salan, 2022) and Palomo-Chavez, et al. (2022) generated relevant to improve the understanding and application of the standard within organizations. Additionally, software designed to facilitate the application and monitoring of NOM-035 was implemented in companies to optimize its use in workplace environments (Palafox et al., 2022; Caldera, 2022).
2023	Relevant information on the standard was collected to improve its understanding and application, also legal issues were address, and an analysis matrix was created (Hernández-De la Cruz & García, 2023; Martínez, 2023; Aldape, et al., 2023; Hernandez, 2023; Morales-Romero, 2023; Sarti, et al., 2023; Suárez, et al., 2023) Most of the research this year focused on identifying, measuring, and analyzing psychosocial risks in workplace environments. Following the implementation of NOM-035, the studies aimed to detect factors affecting workers' mental health, such as excessive workload, lack of control over work, adverse organizational conditions, interpersonal relationships, issues in the work environment, lack of recognition and development opportunities, emotional exhaustion, and work-related stress (Lebrija, et al., 2023; Duarte, et al., 2023; Ortíz-Brito, et al., 2023; Torres, 2023; Ramos & Centeno, 2023; García & Bojórquez, 2023; Hernández & Velazco, 2023; Jiménez, 2023; Pérez, et al., 2023; Jasso, et al., 2023; Aguilar, et al., 2023; Solorio, 2023; Florentino, 2023; Mercado, et al., 2023; Moctezuma, et al., 2023; Valdez, et al., 2023; Sánchez & Alemán, 2023; Fonseca, et al., 2023; Carrillo-Gómez, et al., 2023; Pérez, 2023; Correa, et al., 2023; Reyes, 2023; Saavedra & Ävila, 2023; Chicaiza, 2023; Andrade, 2023 Chi & Canto, 2023; Pérez & Vázquez, 2023; Medina, 2023; Salgado, 2023; Correa, et al., 2023; Martínez-Mejía, 2023; Noriega, et al., 2023; Cota-Salazar, 2023; Medina, 2023; Cavazos, 2023). Measurement instrument validation is still important to some researchers, ensuring its applicability and effectiveness (Quiroga, 2023; Cano-Gutierrez, et al., 2023; Garza-Carranza, et al., 2023; Martínez-Mejía & Martínez-Guerrero, 2023) Other researchers concentrated on looking at the relation between the NOM-035 standard and burnout (emotional exhaustion), finding a good statistical correlation (Bernal, et al. 2023), the comparison involving different subjective tools used to measure mental workload (including NOM-035) concluding that NASA-TLX is the most used tool (Acosta, et al., 2023), minorities labor inclusion and gender equity (Villalobos & Villalobos, 2023) and the relation between the emotional salary and the psychosocial risk factors in the working environment (Garcia-Rosas et al., 2023; Carpio, et al., 2023). The standard implementation has generated significant changes in the organizational structure and the employees' performance. This year, studies on this topic focused on

	evaluating how the standard has been applied in different sectors and what effects it has had on work culture, worker well-being, and operational efficiency (Soto-Flores, et al., 2023; Hernandez-De la Cruz & García, 2023; Gaviño, et al., 2023; Camiade & Pérez-Castrejon, 2023; Contreras, 2023). Tools, including specialized software, were developed to facilitate the implementation and monitoring of NOM-035 (Campos & Cruz, 2023), intervention programs to improve the organizational environment based on the norm (Duarte, 2023), a methodology for emotional classification (Roldán-Castellanos, et al., 2023), and a healthy organization conceptual Model (Cetina-Canto, et al., 2023)
2024	This year's research focused mainly on identifying psychosocial risks in very diverse organizational systems, both industrial and service-related, in second place, generating information to understand and validate the standard is still something that worries the investigator's community, comparing it with other tools, and developing technological tools for implementation and monitoring is still present. All types of organizations have taken the evaluation of the psychosocial risk level of their workers very seriously, not only to comply with regulations (Evaluation obligation NOM-035-STPS-2018) but also seeking the well-being of their workers, and in this way reduce desertion, increase productivity and reduce training costs, among many other factors that also have a great impact on labor systems (Vera, et al., 2024; Ramírez-Hernández, et al., 2024; Bucio-Gutiérrez, et al., 2024; Salguero, et al., 2024; Rocha-Gallegos, et al., 2024; Millán, et al., 2024; Hernández, et al., 2024; Quintana-Alvarez, et al., 2024; Antonio-Ortega, 2024; De León, et al., 2024; Moreno-Rodríguez, 2024, Vargas & Ruiz, 2024; Neura & Miranda, 2024; Castillo-Granados, 2024; Barreras, et al., 2024; Gutiérrez-Herrera & López, 2024; Gutiérrez-Hernández, et al., 2024; Reyes-Sánchez, et al., 2024; Díaz-Valdez, 2024; Jiménez, 2024; Saldaña, et al., 2024; Herrera, et al., 2024; García, et al., 2024; Carbajal & Muñoz, 2024; Celis, 2024; García, 2024; Carbajal & Muñoz, 2024; Ríos & Espinoza, 2024; Campos-García, et al., 2024; González, et al., 2024; Martínez, et al., 2024; Miguel & Velázquez, 2024). Concerning standard information and validation, researchers have different opinions, some state that after multiple reliability and validity tests, the results show that the standard measurement instrument lacks sufficient statistical properties to reliably identify Mexican employees who suffer from a high psychological risk (Madero et al., 2024; Briones-Torres, et al., 2024), in contrast other researchers validate the instrument (Garza-Carranza, et al., 2024; Gutiérrez-Hernandez, et al., 2024; Nava-Gómez, et al., 2024; Tipan & Serrano, 2024). About NOM-035, information this year is given by various authors, especially with training workers in the norm understanding (Beltran, et al., 2024; Muñoz-López, 2024). Comparing different factors with the NOM-035 over the years is an area of some authors, this year Echegoyen, et al. (2024) compared the Business Model with Social and Labor Responsibility to the standard, finding a good correlation, Tresgallo (2024) try to find an association between psychosocial risk factors and working accidents, without been successful. It is important to mention that only very few studies this year were made concerning the implementation impact of the standard in organizations (Guadarrama, et al., 2024; Granados & de Jesús, 2024; Pérez & Muñoz, 2024; Woldolk, et al., 2024) an issue that is important to address to continue improving, other one it will be the emotional salary, which only Vazquez, et al. (2024) tackle.

5. CONCLUSION

The NOM-035-STPS-2018 has shown to be a great tool for Mexican organizations that by law must pay attention to psychosocial factors in their workers, seeking to disseminate stress symptoms derived from a worker's perception of a nonperfect work environment.

By promoting a proactive approach to creating healthy work environments, this standard encourages organizations to implement measures that reduce stress, foster positive interpersonal relationships, and enhance job satisfaction. Additionally, it emphasizes the importance of clear communication, workload management, and emotional support, leading to increased motivation, lower turnover rates, and improved overall organizational performance. In essence, NOM-035-STPS-2018 is a key tool for fostering a sustainable and employee-centered workplace culture

6. References

Acosta-Fernández, M., Aguilera-Velasco, M., Torres-Lopez, T.M. & Pozos-Radillo, B.E. (2022). Factores psicosociales y formación académica. Percepción de residentes y profesores. Medicina Interna de México, 38(1), 51-66.

Acosta, J. L., Cuello, Y., García, J., & Almeda, Y. (2023). Modelos para la valoración de la carga mental de trabajo: una revisión sistemática. Revista San Gregorio, 1(55), 158-180.

Aguilar, J. I. & Murillo, J. J. (2022). Riesgos Psicosociales. Identificación y análisis de varianza en una empresa del sector hotelero. EDUCATECONCIENCIA, 30(36). 262-287.

Aguilar, J. I., Medina, P. M., Flores, A. E., & Arvizu, R. (2023). Identificación y análisis de niveles de riesgo psicosocial con perspectiva de género en empresas privadas. Ingenio y Conciencia Boletín Científico de la Escuela Superior Ciudad Sahagún, 10(20), 1-7.

Aguirre, M., Aguirre, M., Sanchez, G., Navarrete, F., & Rojas, L. (2024). La obligatoriedad de establecer normas dentro de la empresa para reducir el indice de estrés laboral. Revista Iberoamericana de Ciencias, 334-501.

Alatorre, R., Ordaz, C. P., Díaz, C. L., & Jasso, A. D. J. (2020). El estrés laboral en los centros de trabajo en México (caso de estudio), en correlación al enfoque de la NOM-035-STPS 2018. Innovación y Desarrollo Tecnológicos: Revista Digital. Pp 339-349.

Aldape, Z., Flores, J. A., & Soto, A. M. (2023). Factores de riesgo psicosocial en el trabajo. La norma NOM-035-2018 para MIPYMES en México. Encuentro Internacional de Educación en Ingeniería.

Alfaro-Vázquez, C. A. (2024). Análisis de factores y estrategias normativas para prevenir y erradicar la violencia laboral en los centros de trabajo en México. En México en el mundo - Cultura de paz, diversidad, inclusión y legalidad. Universidad de Guadalajara.105-125

Almirall, P. J., Torres, J. L., Cruz, L., Cruz, L., Rama, N. P., & Santana, E. E. (2018). Factores psicosociales laborales, riesgos y efectos. Un estudio piloto para la posible introducción de una norma. Revista Cubana de Salud y Trabajo, 19(2), 3-13.

Andrade, E. (2023). Manual De Procesos para la Identificación, Análisis y Prevención de los Factores de Riesgo Psicosocial para Gineser SC. Obtenido 13/12/24 de https://ginesersc.mx/files/GSRSC-GP-MP 004MANUALDEPROCESOSPARALAIDENTIFICACINANLISISYPREVENCINDELOSFACTO

RESDERIESGOPSICOSOCIALPARAGINESERSC.pdf
Antonio-Ortega, R. (2024). Factores de riesgo psicosocial (NOM-035-STPS-2018), calidad de vida en el trabajo e intención de permanencia de los trabajadores en una empresa aseguradora (Estado de México 2023-2024). Diagnóstico y propuesta de mejora. Obtenido 13/12/24 de http://hdl.handle.net/20.500.11799/141528
Aranda Avilés, A. (2018). Identificación y análisis de factores de riesgo psicosocial en una empresa del giro metalmecánico. Obtenido 13/12/24 de https://hdl.handle.net/20.500.12930/1172
Arredondo, M., Diana, A., Ochoa, M. C., & Gallegos, M. (2024). Factores de riesgo psicosocial en el trabajo en el personal de salud en un hospital general. Horizonte De Enfermería, 35(3), 937–956
Asadobay Escobar, P. D. R. (2022). Evaluación de los factores de riesgos psicosociales y estrés laboral en los trabajadores del centro de salud n-3, Riobamba (Master's thesis). Obtenido 17/12/24 de https://dspace.uniandes.edu.ec/handle/123456789/14910
Balam, C. del C., & López, C. Z. (2024). Herramienta digital para estudiar el comportamiento y las emociones de los estudiantes universitarios. Revista Científica De Ingenierías Y Arquitectura, 3(1), 7–21.
Barreras, G. M., Ibarra, A., Atrip, L. G., Diaz Muro, M. E., & García Cazares, C. N. (2024). La identificación, análisis y prevención de factores de riesgo psicosocial según la NOM-035-STPS-2018 en la subdirección de servicios administrativos en una institución de educación superior del estado de sonora. Revista de Investigación Académica Sin Frontera: Facultad Interdisciplinaria De Ciencias Económicas Administrativas - Departamento De Ciencias Económico Administrativas-Campus Navojoa, 1(42).
Barroso, C.& Pérez-Castrejón, E. M. (2023). El Análisis de la implementación de la Norma Oficial Mexicana-035 y de las estrategias de comunicación utilizadas al interior de una empresa privada. Revista Internacional de Relaciones Públicas, 13(25), 189-200.
Becerra-Núñez, D., Alba-Pimentel, B. M., & Cardona-Torres, L. M. (2022). Psychosocial Risk Factors at Work in Family Physicians Assigned to a Family Medicine Unit. Atención Familiar, 29(3), 135-141
Beltran, H. A., Romero, E. A., Ortega, N., Alcalde, A. G., & Esteves, T. L (2024). Las metodologías ágiles y su uso en el cumplimiento de la normatividad federal en una Pyme: Agile methodologies and their use in compliance with federal regulations in an SME. LATAM Revista Latinoamericana de Ciencias Sociales y Humanidades, 5(1), 2857-2866.
Benítez Martínez, A. T., Bello Parra, D., & Peralta Maroto, A. (2022). Diagnóstico basado en la NOM-035-STPS-2018 para la identificación de riesgos psicosociales en las áreas de trabajo de una empresa de la región de Xalapa. Revista Ciencia Administrativa, (2).
Briones, F. A., Galarza, D. M., & Palacios, O. A. (2024). Aplicación y alcance de la NOM-035-STPS-2018. Revista de Psicología de la Universidad Autónoma del Estado de México, 13(39), 321-355.
Brito-Ortíz, J. F., Soto, G., & Lago, A. (2021). Validación y consistencia interna del

cuestionario para identificar los factores de riesgo psicosocial de la NOM-035-STPS-2018 en centros de trabajo ubicados en México.

Bucio-Gutierrez, D., Olivera-Zura, A. F., Maya-Campos, E. I., Hernández-Torres, S. G., & Reyna-Castillo, M. (2024). Factores psicosociales en el trabajo industrial de la zona sur de Tamaulipas: una valoración estructural-no paramétrica de la NOM-035-STPS-2018. Dilemas contemporáneos: Educación, Política y Valores.

Caldera Hermosillo, A. E. (2022). Diseño y evaluación de una herramienta tecnológica para apoyar al cumplimiento empresarial de la NOM-035-STPS-2018. URI: http://hdl.handle.net/11317/2283

Calderón-Mafud, J. L., & Moreno, M. P. (2018). Liderazgo negativo, riesgo psicosocial y salud en el trabajo. TEMAS DE INVESTIGACIÓN EN SALUD OCUPACIONAL, 71.

Calderón, P., González, M. R., & Marquez, A. (2022). ANÁLISIS DE LA NORMA OFICIAL MEXICANA SOBRE FACTORES DE RIESGO PSICOSOCIAL EN EL TRABAJO DESDE EL ENFOQUE DE LA PSICOMETRÍA: . Academic Journal of Studies in Society, Sciences and Technologies–Geplat Papers, 3(2).

Cano-Gutierrez, J. C., Olguin, J.E. Camargo, C., López-Barreras, (2020). Psuchosocial Factor Evaluation in Metal-Mechanic Workers with Particular Reference to Mental Load: A Case in Ensenada, Baja California.In Evaluating Mental Workload for Improved Workplace Performance. Realyvásquez-Vargas, A., Arredondo-Soto, K. C., Hernández-Escobedo, G., & González-Reséndiz, J. (Eds.). IGI Global. 138-160

Cano-Gutierrez, J. C., Olguin, J.E. Camargo, C., López-Barreras, J.A., García, B.R., & García, J.L. (2023).Psychosocial risk factors identification in Mexican workers and RGIII validation. Work. 2023;76(1):189-203. doi: 10.3233/WOR-220316. PMID: 36847055.

Castillo, A. (2024). Acercamiento a la NOM-035-STPS-2018: Su aplicación en Población Docente. Red de Investigación en Salud en el Trabajo, 7(S5), 118.

Chan, J. Y. & Lopez, L. E., (2022). Incidencia de factores de riesgo psicosocial en una empresa de servicios con base en la nom-035-stps-2018. Revista de Desarrollo sustentable, Negocios, Emprendimiento y Educación, 4(36), 42-51.

Chan, J. Y. & Lopez, L. E. (2023). Propuesta de políticas para la prevención y mitigación de factores de riesgo psicosocial en una empresa de servicios. RILCO DS: Revista de Desarrollo sustentable, Negocios, Emprendimiento y Educación, 5(45), 110-127.

Colmenares-De la Torre, J., Guzmán-Suárez, O. B., Cordero-Beltrán, I., & Lara-Orozco, R. (2019). Diagnóstico de factores de riesgo psicosocial en empresa confi tera de Jalisco. Salud Jalisco, 6(1), 64-69.

Campos, F., & Araujo, A. (2023). El Sistema De generacion de alertas para el Cumplimiento de la nom-035 de la STPS: Articulo de Investigacion. RICT Revista de Investigación Científica, Tecnológica e Innovación, 1(1), 27-31.

Campos-García, J. E., Falcón-Reyes, L. P., Franco-Trejo, C. S., Chavez-Lamas, N. M., González-Álvarez, A. K., & Medrano-Rodríguez, J. C. (2024).

Características laborales y nivel de estrés en docentes universitarios. In Conference Proceedings, Jornadas de Investigación en Odontología 4 (4) 43-48

Cano-Gutierrez, J. C., Olguin, J.E. Camargo, C., López-Barreras, J.A., García, B.R., & García, J.L. (2023).Psychosocial risk factors identification in Mexican workers and RGIII validation. Work. 2023;76(1):189-203.

Cano-Gutierrez, J. C., Pérez-Morán, J. C., Bernal-Baldenebro, B., Arenas-Meneses, D., Vazquez-Lira, R., & Olguín-Tiznado, J. E. (2023). Factor structure and measurement invariance of the psychosocial risk factors inventory of NOM-035-STPS-2018. Frontiers in Psychology, 13, 1022707.

Carrillo-Gomez N, Jiménez-Angel LM, Saucedo-Montes E. (2023). Identificación y análisis de factores de riesgo psicosocial en trabajadores de buque tanques de la Región Madero, mediante la aplicación de la guía de referencia II de la NOM 035 de la STPS de 2018. Revista Médica Industrial. 2023; Vol. 2 (2) 1-8.

Cázares, C. (2020). La inclusión del salario emocional en México. Norma NOM-035-STPS-2018. Factores de riesgo psicosocial en el trabajo-Identificación, análisis y prevención. Cambios y Permanencias, 11(1), 602–624.

Celis, A. B. (2024). Clima organizacional y bienestar desde la perspectiva del directivo universitario. European Public & Social Innovation Review, 9, 1-20.

Cetina, T. E., Castillo, V., Rodríguez, R. & Centeno, G. (2023). Organizaciones Saludables: una Propuesta Integradora para su Estudio. Revista Salud y Administración, 10(30), 43-62.

Chan, J. Y. & Lopez, L. E. (2022). Incidencia de factores de riesgo psicosocial en una empresa de servicios con base en la nom-035-stps-2018. Revista de Desarrollo sustentable, Negocios, Emprendimiento y Educación, 4(36), 42-51.

Chicaiza Satán, M. M. (2023). Estudio de los factores de riesgo psicosociales (FRP) en la empresa Plastiazuay SA en la ciudad de Cuenca en el período marzo-julio 2023 (Bachelor's thesis). Obtenido 14/12/24 de http://dspace.ups.edu.ec/handle/123456789/27953

Contreras, C.A. (2023). Acciones De Prevención y Contención por los Servicios Preventivos de Medicina del Trabajo en Ciudad Del Carmen y Plataformas Marinas de Petróleos Mexicanos durante el Primer año de la Pandemia por Covid-19. Memorias De Un Hecho Sin Precedente. Revista Médica Industrial. 2(2). 9-15.

Correa, V. L., Chávez, L. Á., & López, L. M. (2023). Análisis comparativo de los niveles de estrés en una institución gubernamental del sureste mexicano durante la pandemia por COVID-19. Revista Ciencia Administrativa, (1).

Correa, V. L., de los Ángeles Morfinez, V., & Meza, C. M. (2023). Determinación de niveles de estrés y principales estresores en una empresa transnacional en el puerto de Veracruz. Revista Ciencia Administrativa, (2). 38

Cota-Salazar, D. A. A. Diagnóstico de riesgo psicosocial y entorno organizacional en el Poder Judicial del Estado de BCS. INTERVENCIONES PSICOLÓGICAS, 141-157.

Cotonieto-Martínez, E. (2021). Identificación y análisis de factores de riesgo psicosocial según la NOM-035-STPS-2018 en una universidad mexicana. Journal of Negative and No Positive Results, 6(3), 499-523.

Cruz Soriano, A. El estrés laboral y el clima institucional en los docentes. La visión del estrés desde las perspectivas multidisciplinarias para mejorar la calidad de la educación con tendencia a comunidades sostenibles, 105-124

Curiel, M. C., & Muñoz, E. L. G. (2024). Evaluación ergonómica con enfoque de sistemas de una muestra de manicuristas en la zona metropolitana de Guadalajara. Red de Investigación en Salud en el Trabajo, 7(S5), 39-40.

Curiel, M. C., & Muñoz, E. L. G. (2024). Ergonomic Assesment with a System Approach of a sample of manicurists in the metropolitan area of Guadalajara. En Ergonomia Ocupacional. Investigaciones y Aplicaciones. Vol. 17. 158-167

De León González, M., Ramirez Montemayor, B. G., Madinaveitia Ramirez, F. A., Félix Martínez, A. G., & González Treviño, L. G. (2024). Estudio de factores de riesgo psicosocial en docentes del ITSSPC, conforme a la Nom-035-STPS-2018. Revista IPSUMTEC, 7(2), 105–114.

Díaz, M. E., Teran, M.C., Rivera, A., López, A.S. & Lizárraga, I.E, (2022). Analysis of the Prevalence of Psychosocial risk factors in three economic sectors. Ergonomía Ocupacional, Investigaciones y Aplicaciones. Vol. 15. 413 – 424

Díaz, M. E., López, F.O., Teran, M.C., Rivera, C., & López, A.S. (2022). (2022). Análisis de los factores de riesgos psicosociales en la industria automotriz en México. South Florida Journal of Development, 3(4), 4374-4383

Díaz, D. G., Anaya, A., & Santoyo, F. (2022). Factores de riesgo psicosocial y calidad de vida durante el confinamiento por covid-19 en universidades. RIDE. Revista Iberoamericana para la Investigación y el Desarrollo Educativo, 12(24).

Díaz-Valdes, V., Aguilar-Fernández, M., & Álvarez-Cedillo, J. (2024). Mapa Causal del estrés laboral en México. Medicina y Seguridad del Trabajo, 70(275).

Duarte, E. (2023). Programa de intervención para mejorar el entorno organizacional de una empresa con base en la NOM-035-STPS-2018. Trascender, contabilidad y gestión, 8(24), 70-100.

Duarte, S.M. & Vega, M. Á. (2021). Perspectivas y retos de la NOM-035-STPS-2018 para la atención de riesgos psicosociales y la promoción de entornos organizacionales favorables en México. Trascender, contabilidad y gestión, 6(17), 48-86

Duarte, E., Montesinos, S., & Calvo, J. (2023). Mejora del clima organizacional de una empresa de servicios basado en la NOM-035-STPS-2018. Unaciencia Revista de Estudios e Investigaciones, 16(30), 49-60.

Echegoyen, C. A., Cecilia, R. E., & Campos, J. F. (2024). Entorno favorable y riesgos psicosociales. Una mirada desde el Modelo de Empresa con Responsabilidad Sociolaboral y la Norma 035. JÓVENES EN LA CIENCIA, 28, 1–6

Estrada, J. (2021). Análisis de la NOM-035-STPS-2018, en empresa Sedipssa Comercializadora SA de CV. Obtenido 14/12/24 de https://ri.ujat.mx/handle/20.500.12107/3792

Federico, O. S., Sepulveda, C. O., Rosalez, F. A., & Perez, J. C.. (2022). Implementación de la NOM-035-STPS-2018 en empresas agrícolas de la Costa de Caborca, Sonora y su relación con la calidad de vida laboral. INVURNUS, 17(1).

Feliz, R., Chavez, M.E., Vallejo-Trujillo, S., Sotelo, J. E., Guzmán, E. I., Torres, C. D., ... & Recaman, A. L. (2019). REVISTA IMPULSA DE UNIVERSIDAD LA SALLE CUERNAVACA Vol. 7 No. 21.

Fonseca-Gutiérrez, M. D. J., Quiroz-Benhumea, L., Méndez-Salazar, V., & Hernández-Ortega, Y. (2023). Enfermeras/os Mexiquenses el Riesgo Psicosocial y Pandemia en un Hospital de Tercer Nivel. Revista Salud y Cuidado, 2(1), 4-17.

Gallegos, R. B., & Acevedo, J. (2023). El clima laboral, retos disciplinares. Trabajo social UNAM, (31), 29-44.

García, C., Meza, G. Díaz, G.R. & Mercado, S.M. (2023). Factores de riesgos psicosociales y estrés laboral en una empresa de administración de alimentos. En Factores Psicosociales de riesgo en las Organizaciones. Coordinadores: Eneida Ochoa, Carlos Mirón, Santa Mercado & Claudia García. 94-110.

García Díaz, G. C. (2019). Análisis criminológico de la implementación de la NOM-035-STPS-2018: factores de riesgo psicosocial en el trabajo–identificación, análisis y prevención (Doctoral dissertation, Universidad Autónoma de Nuevo León). Obtenido 17/12/24 de http://eprints.uanl.mx/27573/

García, D. P., & Bojórquez, G. I. (2023). NOM-035, pieza estratégica para generar un clima organizacional favorable en una institución privada de educación. En Factores Psicosociales de riesgo en las Organizaciones. Coordinadores: Eneida Ochoa, Carlos Mirón, Santa Mercado & Claudia García. 9-26.

García, E. , Cheverria,, S., Gaytán, D., & Gutierrez, S. (2023). Capítulo 20. La retribución no económica en profesionales de enfermería adscrito a un hospital Covid-19. En La diversidad organizacional, un reto para la administración contemporánea, Dir. Virginia Azuara Pugliese. 239-254.

García, E., Rivera, B., Rebollar, Á., Floriano, C., & Mendoza, N. (2022). Identification and Analysis of Psychosocial Risk Factors according to NOM-035-STPS-2018 in a Higher Education Institution in Mexico. Ergonomía Ocupacional, Investigaciones y Aplicaciones. Vol. 15 374- 394

García, F. L. (2019). Desarrollo e implementación de la NOM-035-STPS-2018 en la empresa "PREVEER" en Ciudad de México. Obtenido 17/12/24 de https://rinacional.tecnm.mx/jspui/handle/TecNM/5989

García, K.A., Gutiérrez, M.G., Gutiérrez, J.M. Gutiérrez, P.R. & Galaviz, L.E. (2024). Evaluation of the workload in the middle management of an automotive company. En Ergonomia Ocupacional. Investigaciones y Aplicaciones. Vol. 17. 462-473

García, R. A. (2023). Implementación de la Norma 035-STPS-2018 en instituciones de educación superior, una obligación de poco cumplimiento. La visión del estrés desde las perspectivas multidisciplinarias para mejorar la calidad de la educación con tendencia a comunidades sostenibles, 68.

García, R., Flores, J. A., Ruiz, J. I., Flores, D. N., & Hernández, L. F. (2024). Análisis del clima organizacional en el ámbito universitario: Un estudio de caso en una universidad. Revista NeyArt, 2(3), 1–13.

Garza-Carranza, M. T. D. L., Gaspar-Hernández, M. F., López-Lemus, J. A., & Atlatenco-Ibarra, Q. (2024). Análisis psicométrico de la validez del cuestionario de factores de riesgo psicosociales incluido en la norma NOM-035-STPS-2018. Psicumex, 14.

Gaviño, J., Ultreras-Rodríguez, A. y Sánchez, A. (2023). Comportamiento Organizacional para el Balance Integral Humano desde la NOM-035 en escenario post-pandemia COVID-19. Revista Científica Empresarial DEBE-HABER, 1(2), 41-57.

Godínez, M. T. (2024). Factores de riesgo psicosocial y su asociación con la presencia de accidentes en un centro de trabajo de la ciudad de México. Memorias 11o. Foro de Investigación de la Red de Posgrados en Salud en el Trabajo, 7(S5), 129-131

González, A. P., Noverola, C. I., de la Fuente, C. S., Pérez, I., & García, R. (2024). Estrés laboral, diagnóstico y recomendaciones para una cultura corporativa saludable. Estudio de Caso. Ciencia Latina Revista Científica Multidisciplinar, 8(5), 12059-12078.

González, J. H. (2018). Factores psicosociales en el trabajo: Norma-035 factores de riesgo psicosocial. Obtenido 14/11/24 de http://www.repositorioinstitucional.uson.mx/handle/20.500.12984/1537

Guadarrama, B. X., Pérez, A. R., Roque, N., & Sanchez, I. (2024). Aprendizaje y creación del conocimiento de las Pymes en Morelos para afrontar los requerimientos de la NOM 035. En Modelos e intervención organizacional para el desarrollo de las organizaciones en México. 64-81

Guardado, S. C. (2020). La NOM 035 ¿Una nueva visión de la responsabilidad social empresarial?. Revista Universitaria Digital de Ciencias Sociales. Vol. 11, No. 20. 1-7

Guillén, R. D. S. (2024). Obesidad y estrés en el trabajo: más allá del atracón. Psic-Obesidad, 13(49), 11-15.

Gutiérrez-Hernández M, Maldonado-Macías A, Jara H, Hernández J, Barajas-Bustillos M. (2024). Psychosocial factors assessment for the mexican standard 035: a validation of the domain of workplace violence in the automotive industry. Rev. Fac. Nac. Salud Pública. 42

Gutiérrez, I. G., & Toriz, G. (2024). Liderazgo Transformacional Femenino y su Influencia en Riesgos Psicosociales de las Farmacias del Centro Histórico de Puebla. Hitos de Ciencias Económico Administrativas, (88), 238-256.

Gutiérrez, M. G., Reyes, R. M., Riva, J. D. L., Maldonado, A. A., & García, H. (2022). Norma Oficial Mexicana 035, Factores de riesgo psicosocial en el trabajo: validación del dominio relaciones en el trabajo. RIDE. Revista Iberoamericana para la Investigación y el Desarrollo Educativo, 12(24).

Heredia Cedano, K. N. (2018). Diagnostico de Factores de Riesgo Psicosocial Identificacion y Prevencion: Un Estudio de Caso. Obtenido 14/11/24 de https://rinacional.tecnm.mx/jspui/handle/TecNM/5418

Herrera, M.J., Ramirez, J.A. & Rodrígues, B.I. (2024). Identification, evaluation and control of Psychosocial risk factors and organizational environment in a Brewing Industry in Mexico City. En Ergonomia Ocupacional. Investigaciones y Aplicaciones. Vol. 17. 357-363

Hernández, B., & Velazco, A. G. (2023). Aplicación de la NOM-035-STPS-2018 para evaluar los factores de riesgo psicosocial y su relación con los trastornos psicosomáticos en trabajadores mexicanos. Impacto psicosocial de las empresas. Ed. Patlán, Juana. 94-110

Hernandez de la Cruz, M. & Sanchez, L. A. (2023). Análisis de Riesgos Psicosociales y Factores Laborales: Identificación y Prevención. Ciencia Latina: Revista Multidisciplinar, 7(6), 8434-8450

Hernández, J. P. (2020). Los factores psicosociales de riesgo laboral en México. Noticias CIELO, 1(3).

Hernández, G., Venegas, F. Y., Ordoñez,, S. G, & Gatica, L. (2024). NOM 035¿ Solución al estrés laboral?. Horizontes de la Contaduría en las Ciencias Sociales, (20).

Hernández, M. J., Mendoza, L. A., & Gutierrez, E. (2023). La mediación en las organizaciones. Un factor para promover el entorno organizacional favorable. RILCO: Revista de Investigación Latinoamericana en Competitividad Organizacional, 5(18), 77-86.

Hernández Pacheco, F. (2023). Interpretación y aplicación de la Norma Oficial Mexicana 035 para la Dirección de Recursos Humanos en Bibliotecas. En la Bibliotecología y los estudios de la información ante los procesos resilientes. Coord. Hector Ramos & Egbert Sánchez. 187-206

Hilarios, L. M., Aguilar, J. I., Flores, Á., & Marrufo, J. A. (2022). Psychosocial Risks Identification And Analysis Of Levels In Workers Of Instituto Tecnológico Superior De Ciudad Constitución Considering Gender Perspective As An Identification Factor. Ergonomía Ocupacional, Investigaciones y Aplicaciones. Vol. 15. 404.- 412

Iñiguez, R. I, Iñiguez, F. J., Iñiguez,, A. I., Corona, V., & Vazquez, M. A. (2022). Aplicación de la NOM-35 en las organizaciones de la región Ciénega de Jalisco. Estudios de la Ciénega, (03), 113-122.

Jasso, L., Mendoza, C. P., & Segovia, M. D. P. (2023). Capítulo 90. Evaluación del Clima Organizacional con base a NOM-035. Para la empresa Cotromma SA de CV. En REDESLA.LA 410-420

Jiménez Cortéz, S. (2024). Factores de riesgo psicosociales en mujeres trabajadoras de UMF 73. Obtenido 12/12/24 de https://cdigital.uv.mx/server/api/core/bitstreams/0f6741b1-b85b-4818-bbea-99b2aa039827/content

Jimenéz de la Cruz, J. C., & Romero Aguirre, G. de los Ángeles. (2022). Evaluación de Riesgos Psicosociales en docentes de Educación Básica, Media y Superior en el contexto de la Pandemia SARS- Cov-2. Multidisciplinary Health Research, 7(1). https://doi.org/10.19136/mhrjc22uj11

Jiménez, I.S.,(2023). Aplicación De La Norma Oficial NOM-035 como Herramienta Para Aumentar La Productividad y Lograr Un Entorno Organizacional Favorable En Los Centros De Trabajo. Obtenido 12/12/24 de https://rinacional.tecnm.mx/jspui/handle/TecNM/6537

Kitchenham, B. (2004). Procedures for performing systematic reviews. Keele University, https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=29890a936639862f45cb9a987dd599dce9759bf5

Lebrija, D. I., Lopez, L. E., & Ojeda, R. N.. (2023). Medición de niveles de riesgo psicosocial en empresa de amenidades hoteleras en Yucatán de acuerdo a la NOM-035-STPS-2018. RILCO: Revista de Investigación Latinoamericana en Competitividad Organizacional, 5(20), 15-31

Littlewood-Zimmerman, H. F., Uribe-Prado, J. F., & Rodríguez, M. Á. G. (2020). Confiabilidad y validez de las 5 categorías del cuestionario NOM-035 de 72 ítems. Ciencias Administrativas. Teoría y Praxis, 16(1), 72-86. DOI: https://doi.org/10.46443/catyp.v16i1.252

Loera, G. E. & Silva, M. B.(2022). Capítulo 18. Factores de riesgo psicosociales de una empresa alimentaria basados en Norma 035-2018-STPS. EL RETO DE LA MULTIMODALIDAD Y LA TRANSVERSALIDAD EN LA ERA DIGITAL Y LOS TIEMPOS DE PANDEMIA, 293.

López, J. (2022). Implementación de la nom-035-stps-2018; en la empresa agua purificada leona vicario en balancán, tabasco. Obtenido 19/11/24 de https://rinacional.tecnm.mx/jspui/handle/TecNM/6948

Lopez, J. A. (2023). Factores protectores de estrés psicosocial de la Policía Municipal De Puerto Vallarta. Archivos de Criminología, Seguridad Privada y Criminalística, (30), 102-110.

López, L., & López, J. (2024). Efectos de los Riesgos Psicosociales en las Empresas Mexicanas. DIVULGARE Boletín Científico de la Escuela Superior de Actopan, 12(Especial), 44-51

Luna-Chávez, E. A., Anaya-Velasco, A., & Ramírez-Lira, E. (2019). Diagnóstico de las percepciones de los factores de riesgo psicosociales en el trabajo del personal de una industria manufacturera. Estudos de Psicologia (Campinas), 36, e180148.

Luna, K., Cuadras, O., Valdez, E., Aguilar, L.Y., & Rodríguez, J.M. (2022). Physical Condition and Fatigue Assessment of a Fruit Stand. Ergonomía Ocupacional, Investigaciones y Aplicaciones. Vol. 15. 314 - 331

Maciel Alvarado, M. S. (2028). Modelo sistémico para el diagnóstico y manejo del estrés laboral en empresas de hospedaje. Obtenido 12/12/25 de https://tesis.ipn.mx/bitstream/handle/123456789/29560/Tesis_B161261_Maciel%20Alvarado%20Marcia%20Sof%C3%ADa_MAIT_EST_IPN.pdf?sequence=1

Madero, S. M., Montes, J. L., & del Castillo, E. (2024). Evaluación de la norma 035 para la medición de los factores de riesgo psicosocial en el entorno laboral mexicano. Contaduría y administración, 69(1), 77-99.

Martinez-Balderrama, R., Jacobo-Galicia, G. J., Ramírez-Barreto, M. E., Paz-Delgadillo, J. M., & Cruz-Sotelo, S. E. (2022). NOM-035-STPS-2018: Opportunities for Better Implementation–A Review. Ergonomics and Business Policies for the Promotion of Well-Being in the Workplace, 64-71.

Martínez Jiménez, I. M. (2021). La NOM 035 y su impacto en los centros de trabajo. Obtenido el 23/11/24 de

https://repositorioinstitucional.uabc.mx/bitstream/20.500.12930/8884/1/DER019723.pdf
Martínez, S. M, Vega, E., Romero, G., S., De la Fuente, C.S. & Pérez, I. (2020). Identificación de riesgos psicosociales en trabajadores administrativos de una universidad pública. Evidencias multidisciplinarias en salud, 122.
Martínez-Mejía, E., & Martínez-Guerrero, J. I. (2023). Evaluación del cuestionario de la Guía de Referencia III NOM-035-STPS-2018: limitaciones, implicaciones y retos de su validez. En Evidencias Multidisciplinarias en Saludos. 122-129
Martínez-Mejía, E. (2023). Factores de riesgo psicosocial en el trabajo, entorno organizacional y violencia laboral en la actividad económica terciaria de la Ciudad de México. Región y sociedad, 1-27.
Martínez, J. R., Alvarado, L., Sánchez, J., Sandoval, D. A., & Rodríguez, M. A. (2024). Determinación de generadores de estrés laboral y sus afectaciones dentro de la ingeniería. Revista NeyArt, 2(4), 29–43.
Martínez, Y. D. (2023). Normatividad colombiana y mexicana en riesgo psicosocial en el trabajo. Obtenido el 23/11/24 de https://repository.uniminuto.edu/handle/10656/18721
Medina, M., D. Navarro, I., & Torres, D.A. 8 Preguntas para entender la NOM-035. Obtenido el 23/11/24 de https://www.advisorsgroup.com.mx/adwp2012/wp-content/uploads/2020/02/426283347-Nom-035-8-PREGUNTAS.pdf
Mejía-Bernal, G. A., Rodríguez-González, M., & Chávez-Salazar, G. (2023). Desgaste Emocional y su relación con Riesgos psicosociales en docentes del Instituto Tecnológico de Aguascalientes. Conciencia Tecnológica, (65), 1-9.
Méndez, E. M. & Mul, J. (2021). Implicaciones de los factores de riesgo psicosocial y la nom-035-stps-2018 en la calidad de vida laboral. RILCO DS: Revista de Desarrollo sustentable, Negocios, Emprendimiento y Educación, 3(16), 8.
Mendez, J. A., & Gonzalez, M. T. 2021). Satisfacción de vida y riesgos psicosociales en el trabajo: la NOM-035 frente al bienestar. Revista de Psicología de la Universidad Autónoma del Estado de México, 10(20), 80-102.
Méndez, E. M. & Mul, J. (2021). Implicaciones de los factores de riesgo psicosocial y la nom-035-stps-2018 en la calidad de vida laboral. RILCO DS: Revista de Desarrollo sustentable, Negocios, Emprendimiento y Educación, 3(16), 8.
Mercado, S. M., Espinoza, M.V., Ochoa, E. & Fernandez, M.T. (2023). Factores de riesgo psicosocial en empresas de la industria del entretenimiento del sur de Sonora. En Factores Psicosociales de riesgo en las Organizaciones. Coordinadores: Eneida Ochoa, Carlos Mirón, Santa Mercado & Claudia García. 43-54.
Mexicana, N. O. (2018). NOM-035-STPS-2018. Factores de riesgo psicosocial en el trabajo–identificación, análisis y prevención. Obtenido el 23/11/24 de https://skillsinnovation.mx/wp-content/uploads/2023/07/NOM-035.pdf
Miguel, M.U & Velázquez, Y. (2024).Riesgos psicosociales y ansiedad percibidos por trabajadores administrativos en la ciudad de Oaxaca. Revista Mexicana de Salud y Cuidado Ambiental, 1-12.
Miguel-Vidal, M.U & Velázquez-Narváez, Y. (2024).Riesgos psicosociales y ansiedad percibidos por trabajadores administrativos en la ciudad de

Oaxaca. Revista Mexicana de Salud y Cuidado Ambiental, 1-12.

Millán Tinoco, V., Martínez Demetrio, M., Aldazaba Jácome, G., & Platas Quiroz, L. (2024). Identificación y análisis de factores de riesgo psicosociales en una empresa de confecciones textiles: Identification and analysis of psychosocial risk factors in a textile manufacturing company. LATAM Revista Latinoamericana De Ciencias Sociales Y Humanidades, 5(1), 2978 – 2991. https://doi.org/10.56712/latam.v5i1.1811

Moctezuma, A., Gomez, M., Sánchez, A. G., Salgado, J. D., & Escalona, M. E. (2023). Factores de riesgo psicosocial en profesionales de enfermería del área quirúrgica: Psychosocial risk factors of nursing staff in the surgical area. Latam: revista latinoamericana de Ciencias Sociales y Humanidades, 4(6), 15.

Morales-Romero, R. G. (2023). Teaching strategies to socialize NOM 035 in students of administrative economic sciences of a higher education institution. Journal Educational Theory/Revista de Teoría Educativa, 7(17).

Moreno, B. M., Luna, R. E., Pacheco, B. J., & Valdéz, X. G. (2024). Diagnóstico de factores de riesgo psicosocial en alumnos del modelo dual del Instituto Tecnológico Superior de Poza Rica con base en la NOM-035-STPS-2018. Investigación para la mejora de las prácticas educativas desde una perspectiva holística. 327-334

Moreno, B.V., Díaz, E. & Beltrán, R. (2023). Evaluación Postpandemia de los Riesgos Psicosociales en el personal docente: Caso Instituto Tecnológico de Chetumal. En Impacto de la educación superior en la agenda 2030. Coord. Mtro. José Juan Paz Reyes. 67-84.

Moya, J. A., Pacheco, H., & Ramirez, J. M. (2022). Factores de riesgo psicosocial en médicos residentes de un hospital público de segundo nivel en el Estado de Querétaro (México). Identificación mediante la NOM-035-STPS-2018. Psicología, Educación & Sociedad, 1(2).

Muñoz-López, S. I. (2024). Análisis de la NOM-035-STPS-2018 en nuestro derecho laboral. Revista Multidisciplinaria de Ciencias, Innovación y Desarrollo. 21-27

Murrieta, Y. A., & Ochoa, E. (2023). Evaluación de factores de riesgo psicosocial en empresa del sector manufacturero. En Factores Psicosociales de riesgo en las Organizaciones. Coordinadores: Eneida Ochoa, Carlos Mirón, Santa Mercado & Claudia García. Pp. 55-68.

Nava-Gómez, M. E., Brito-Ortíz, J. F., Cruz-González, A. A., Ruiz-Bugarin, C. L., Román-Brito, G. A., Brito-Nava, E., & Contreras-Preciado, M. A. Calidad Psicométrica del Cuestionario de contenido del Trabajo Aplicado al Personal de Enfermería para Identificar el Estrés Laboral. RGSA - Revista de Gestao social e ambiental. 18(10) 1-15

Neyra, R., & Miranda, D. (2024). Seguimiento de la NOM 035 STPS 2018 en diez empresas retail de México. Red de Investigación en Salud en el Trabajo, 7(S5), 140-142.

Noriega, G., Barraza, R.A. & Ochoa, E. (2023). Evaluación de riesgos psicosociales en una empresa inmobiliaria de Ciudad Obregón, Sonora. En Factores

Psicosociales de riesgo en las Organizaciones. Coordinadores: Eneida Ochoa, Carlos Mirón, Santa Mercado & Claudia García. 68-78.

Ocampo-González, A. D. J., & Morales, C. C. (2018). Presencia del síndrome de Burnout en enfermeras de la Unidad de Cuidados Intensivos. Boletín Científico de la Escuela Superior Atotonilco de Tula, 5(10).

Okoli, C., & Schabram, K. (2015). A guide to conducting a systematic literature review of information systems research. Communications of the Association for Information Systems, 43, 879-910.

Ortega Torres, T. (2020). Diagnóstico Organizacional de Aerolíneas Ejecutivas SA de CV: Evaluación de la Cultura y el Clima Laboral e Identificación de los Factores de Riesgo Psicosociales con base en la NOM-035-STPS-2018. Obtenido el 23/11/24 de http://hdl.handle.net/20.500.11799/109614

Ortíz-Brito, J. F., Nava-Gómez, M. E., Juárez-García, A., Brito-Nava, E., Román-Brito, G. A., & Esquivel-Lagunas, O. (2023). Vulnerabilidad por sexo y nivel académico en la exposición a factores psicosociales en el trabajo bajo la NOM-035-STPS-2018 en una empresa del sector comercial joyero. Revista Mexicana de Salud en el Trabajo REMESAT enero/junio, 10(20), 10-17.

Palafox, H., Raygoza-Romero, J. M., Navarro, C. X., Bermudez, K., Zatarain-Aceves, H., & Caro, K. (2022, November). Evaluation of the NOM-035 Smart Manager: A System for Identifying the Psychological Risk Factors Levels of University Academics. In International Conference on Ubiquitous Computing and Ambient Intelligence (189-200). Cham: Springer International Publishing.

Palomo-Chávez, J. I., Castro-Guijarro, J. I., & Ibarrarán-Rodríguez, T. D. F. (2022). La Violencia laboral; un grave problema en los centros de trabajo Workplace Violence; a serious problem in the work centers. Ciencias Administrativas y Teoría y Praxis. https://doi.org/10.46443/catyp.v19i2.340

Parga, D. A., Prieto, E. A., DURAN DOSAL, Edwin Elibe. Psychosocial Risk Management in an Occupational Health Provider Institution in Mexico, Implementation and Application of NOM 035STPS / Gestión De Riesgo Psicosocial En Institución Prestadora De Salud Ocupacional En México, Implementación y Aplicación Norm. Red de Investigación en Salud en el Trabajo, [S.l.], v. 3, n. S1, p. 24, nov. 2020. ISSN 2594-0988.

Patlán, J. (2021). Salud ocupacional y factores de riesgo psicosocial en el trabajo. Impacto psicosocial de las empresas. En Impacto Psicosocial de las Empresas. Juana Patlán Perez. Ed. UNAM.

Patlán, J. (2021). Introducción al impacto psicosocial de las empresas. En Impacto Psicosocial de las Empresas. Juana Patlán Perez. Ed. UNAM.

Pérez Hernández, B. (2023). Evaluación y análisis de factores de riesgo psicosocial en médicos legistas del turno matutino Zona Sur de la Unidad Departamental de Medicina Legal de la Ciudad de México en junio de 2021. Obtenido de https://repositorio.lasalle.mx/handle/lasalle/2683

Pérez, L. V., Hernández, N., Alvarado, G., & Silva, M. B. (2023). Capítulo 18. Uso de la NOM 035-STPS en una empresa de transporte público. La diversidad organizacional, un reto para la administración contemporánea, 221-230

Pérez, M. (2023). Entorno organizacional favorable: Identificación y análisis de factores de riesgos psicosociales en una empresa del sector de hidrocarburos: Enabling organizational environment: Identification and análisis of psychosocial risk factors in a hydrocarbon sector company. UNIVERSCIENCIA, 21(64). 67-75

Pérez, R. L & Gonzalez, E. L. (2024). Impacto de una intervención desde el análisis y diseño macroergonómico para reducir la fatiga laboral de los empleados de un Call center. Red de Investigación en Salud en el Trabajo, 7(S5), 35-36.

Portilla, R. I., Gasca, C. A., Flores, L. R., Estrada, E., & Rocha, E. A. (2022). Pre evaluación de la norma 035 en pymes usando una aplicación web. Ciencia Latina Revista Científica Multidisciplinar, 6(3), 4241-4256.

Ramírez, E., López, M., Velarde, J.M, Naranjo, A. & Verdin, F.D. (2022). Study of Psychosocial Factors and Mental Load Associated with the Packing Process in an Agricultural Company. Ergonomía Ocupacional, Investigaciones y Aplicaciones. Vol. 15. 88 – 94

Ramos, M. A. & Centeno, G. (2023). Diagnóstico de factores de riesgo psicosocial en una empresa de transporte público de Yucatán. Praxis Psy, 23(38).

Realyvázquez, A., Gutierrez, M. J., Tello, L.A., Arredondo, K., & Salinas, A. (2022). Application of NOM-035-STPS-2018 in a Call Center in Tijuana, Mexico. Ergonomía Ocupacional, Investigaciones y Aplicaciones. Vol. 15. 395.- 403

Reyes-Sánchez, J., Garcia, M. A., Barrientos, J. M., & Estrada, E. D. (2024). Evaluación de los Riesgos Psicosociales en las Empresas Manufactureras. Ciencia Latina Revista Científica Multidisciplinar, 8(5), 12102-12122.

Rios Estrada, R. S., Ramírez Alcántara, H. T., & Torres Sánchez, A. T. (2021). Una reflexión de la Norma Oficial Mexicana 035 en torno al debate de la tensión capital-trabajo. Administración Y Organizaciones, 24(47), 30–46

Ríos, R. & Guadarrama, R. (2024). Prevalencia del síndrome de burnout en los trabajadores de la representación estatal del ISSSTE Morelos. Red de Investigación en Salud en el Trabajo, 7(S5), 136-137.

Rivera, S.G., Sotelo, P., Martínez, C.E. (2024). Gender Equality for the Growth and Development of the State of Tamaulipas . Journal of International Crisis and Risk Communication Research , 531–545.

Robles, R. E. (2023). El estrés laboral y el teletrabajo en México con la pandemia. Estudios de derecho, 80(176), 39-53.

Roldán-Castellanos, F. A., Pérez-Olguín, I. J. C., Gutiérrez-Vázquez, A., Méndez-González, L. C., & Rodríguez-Picón, L. A. (2023). Emotional classification method (ECW): a methodology for measuring emotional sustainability in a work environment utilizing artificial intelligence. Axioms, 12(2), 97.

Roldán Hernández, G. (2022). Cultura organizacional: riesgos psicosociales en el trabajo y adaptación psicosocial como mediadores del desgaste ocupacional en una cooperativa transportista en Puebla. Obtenido de https://repositorio.iberopuebla.mx/handle/20.500.11777/5243

Romero, M. & Flores, N. (2023). Efectos psicosociales de la violencia de género en el trabajo. Revista Emprendedores al servicio de la pequeña y mediana empresa. 6-9

Rubio-Avila, S. M., & Gómez-Sánchez, R. V. (2018). Factores psicosociales en el trabajo. Revista Colombiana de Salud Ocupacional, 8(2). DOI: https://doi.org/10.18041/2322-634X/rcso.2.2018.5427

Salan Cárdenas, P. E. (2022). Factores de riesgo psicosocial y la motivación laboral de los trabajadores del centro de salud artezon. Obtenido de https://dspace.uniandes.edu.ec/handle/123456789/14907

Saldaña Orozco, C. S., Gutiérrez-Carvajal, O. I., Polo-Vargas, J. D., Rentería, G. M. I., & Franco, L. A. (2024). El efecto de los factores psicosociales laborales sobre el estrés y bienestar de trabajadores de restaurantes y bares de México. Cuadernos de Administración, 40(80), 1-12

Salgado, C. A. (2023). Riesgo psicosocial en un centro de servicios. Obtenido de https://repositorio.lasalle.mx/handle/lasalle/2823

Sánchez Cruz, C. F. (2022). Factores de riesgo psicosocial en empresas de servicios de seguridad privada y de limpieza (Valle de Toluca 2021-2022). Dignóstico e implementación de la NOM-0035-STPS-2018. Obtenido de http://hdl.handle.net/20.500.11799/137422

Sandoval, J. M. (2023). Riesgos psicosociales del trabajo en economías deprimidas: un ensayo sobre México. Revista De La Facultad De Ciencias Económicas, 31(2), 125–143.

Sierra, D. A., Esquinca, A. & Dena, M. A. (2023) El efecto del Salario Emocional en el compromiso Organizacional y el rendimiento de los Empleados de Industria Maquiladora. Un estudio en Ciudad Juárez, México. En Seguridad y Salud en el Trabajo: Aportes Multidisciplinarion. Ed. Litoral. 19-36.

Soto-Flores, R; M., Cuevas-Zuñiga, I. Y., Yanin-Duarte, J. & Gómez-Quiroz, A. (2023). Corporate Social Responsibility and the Application of NOM-035 in a Consulting Services Company. Proceedings of the 4th South American International Industrial Engineering and Operations Management Conference, Lima, Peru, May 9-11. 603-613

STPS. (2018). NORMA Oficial Mexicana NOM-035-STPS-2018, Factores de riesgo psicosocial en el trabajo-Identificación, análisis y prevención. Obtenido el 23/11/24 de https://f.hubspotusercontent10.net/hubfs/5476768/NOM%20035-STPS-2018.pdf

Suárez, E., Bautista, A. & Jácome, K. I. (2023). Los factores de riesgo psicosocial en la legislación laboral mexicana. Ciencia Administrativa, Num. 2. 81- 87

Suárez Jasso, E., Bautista Navarro, A., & Jácome Domínguez, K. I. (2023). Los factores de riesgo psicosocial en la legislación laboral mexicana. Revista Ciencia Administrativa, (2). 81

Tipán, D. O. & Preciado, M. D. L. (2024). Validez de contenido para cuestionarios de factores psicosociales en el trabajo. En Paradigmas en la investigación de salud en el trabajo. Coord. Preciado, M.L. & Pozo, B.E. 39-52.

Quintana-Alvarez CA, Castro-Gómez AA, Rivera-González M, Rodríguez-Sánchez VY, Borunda-Vega A, Martínez-Sevilla AP, Gutiérrez-Morales D.

Ponderación de los factores de riesgo psicosocial en las Unidades Médicas de Petróleos Mexicanos durante 2022; Revista Médica Industrial. 2023; Vol. 1 (3).

Quiroga Tamez, M. M. D. L. (2023). La solución del conflicto laboral a través de la mediación y sus efectos en la disminución de los factores de riesgos psicosociales de los trabajadores en el marco de la NOM-035 Secretaría de Trabajo y Previsión Social (Doctoral dissertation, Universidad Autónoma de Nuevo León). Obtenido de http://eprints.uanl.mx/25561/1/1080328892.pdf

Ramírez-Hernández, D. Y., Monreal-Aranda, O., & Ruiz-Ramos, L. (2024). Factores de riesgo psicosocial presentes en una empresa maquiladora de H. Matamoros, Tamaulipas. Revista Mexicana de Salud y Cuidado Ambiental, 41-55.

Reynoso Álvarez, B. G. (2022). Riesgos psicosociales, según la NOM-035, en personal médico de clínicas COVID-19. Obtenido el 20/12/2024 de https://hdl.handle.net/20.500.12930/9272

Rocha-Gallegos, A., González-Segura, C. M., del Pilar Varela-Hernández, L., Bonilla-Suárez, C. B., & García-García, M. (2024). Identificación de factores de riesgo por estrés generado en alumnos de educación media superior bajo la NOM-035-STPS. Investigación y Ciencia de la Universidad Autónoma de Aguascalientes, (93).

Rocha, A., Patlan, J. & Barrera, G. (2022). 3.4 Factores de riesgo psicosocial en médicos de pregrado y posgrado en México. En Trabajo digno y saludable en la era COVID: Desafios y oportunidades. Coordinadores Santiago Gascón., Luis M. Fernández., Salas, F. & Amilcar Torres. 78-85.

Saldaña, C., Bustos, R., Barajas, A., & Ibarra, G. (2019). Liderazgo y riesgo psicosocial en instituciones de educación superior en México. Revista Venezolana de gerencia, 24(88), 1239-1248.

Salguero, F. D., Gámez, D. I., Erro-Salcido, L. F., Córdova-Cárdenas, G. M., & Mendivil-Valdez, Y.. (2024). Factores psicosociales presentes en el personal obrero de una industria maquiladora artesanal. Journal of the Academy, (11), 243-262.

Santoyo Telles, F., Echerri Garcés, D., & Figueroa Hernández, J. A. (2022). Evaluación de la validez del cuestionario de los factores de riesgo psicosocial y evaluación del entorno organizacional propuesto por la NOM-035-STPS-2018. Contaduría y administración, 67(3).

Soliz, R.L. (2022). El Impacto de los factores de riesgo psicosocial en trabajadores del sector industrial.Trascender, Contabilidad y Gestión. Vol. 7 (20), 71-81

Torres Ramos, N. V. (2023). implementacion de la norma oficial mexicana NOM-035-STPS-2018, Factores de riesgo psicosocial en el trabajo: Identificacion, analisis y prevencion, en una institucion de educacion superior tecnologica. Obtenido el 20/12/2024 de http://51.143.95.221/handle/TecNM/7923

Ugarte, R. (2022). Identificación de posibles controversias laborales en el T-MEC utilizando indicadores relacionados con el Burnout de la NOM-035-STPS-2018 aplicada a la empresa CEWS en Ciudad Juárez, Chihuahua. Anuario de derecho, comercio internacional, seguridad y políticas públicas, (1), 1-13.

Uribe Prado, J. F., Gutiérrez Amador, J. C., & Amézquita Pino, J. A. (2020). Critique on the psychometric properties of a measurement scale for psychosocial risk factors proposed in NOM 035 of the STPS in Mexico. Contaduría y administración, 65(1).

Valdez, M. R., Esparza, I.G. & Ochoa, E. (2023). Factores de riesgo psicosocial del trabajo que afectan el desempeño en administrativos de educación superior. En Factores Psicosociales de riesgo en las Organizaciones. Coordinadores: Eneida Ochoa, Carlos Mirón, Santa Mercado & Claudia García. 27-42.

Vargas, M. D. C., & Ruiz, M. (2024). Diagnóstico de los factores del clima laboral como estrategia para medir la calidad de vida y la seguridad laboral. In Estrategias administrativas: en las empresas postpandemia. 109-132.

Vassallo, M. (2018). Factores de riesgo psicosocial en el trabajo. Obtenido el 20/11/2024 de https://www.academia.edu/download/60910943/NOM035_MV20191015-56151-u74nyl.pdf

Vázquez, S., Gutiérrez, S., Lara, J. S., Arellano, S. M., & Puente, R. G. (2024). Salario Emocional como estrategia para Fortalecer el Capital Humano en una Empresa de Cereales y Pastas, SA de CV. Pistas Educativas, 46(148).

Vera, J. G. S., Vera, M. A. M., Martínez, R., & García, M. F. (2024). Evaluación de los factores de riesgo psicosocial en una universidad pública. RECAI Revista de Estudios en Contaduría, Administración e Informática, 13(37), 1-14.

Villagrán Rueda, S., Rodríguez Ortíz, M., & Aldaba Andrade, M. D. (2018). Factores de Riesgo Psicosociales Detrimento a la Salud Ocupacional. Somatizaciones en victimas de Mobbing. Obtenido el 20/11/2024 de http://148.217.50.3/jspui/handle/20.500.11845/1241

Villalobos, C. R. & Villalobos, V. X. (2023). Políticas de inclusión laboral para población lgbtqi+: Un análisis contextual. En Topicos en Inclusión, Derechos Humanos, Cultura y Sociedad: Estudios Interinstitucionales. Coord. Christian Huerta, Juan López y Sara Gutierrez. Ed. Univ. Guadalajara. 149-168

Woolfolk, L. E., Ibarra, L. E., & Mendoza, F. A. (2024). El impacto del ODS 3 en la disminución de factores psicosociales en PyMes de Hermosillo, Sonora. Nau Yuumak Avances de Investigación en Organizaciones y Gestión, 3(5), 1-24.

BIOMECHANICAL CALCULATION OF DYNAMIC FORCES IN THE ARM DURING MANUAL LOAD HANDLING.

Lamberto Vázquez Veloz, ORCID1 0000-0002-1270-4537, Manuel Antonio Rivera Rodríguez, ORCID2 0000-0002-3714-3908, Irvin Ariel Madrid Castillo, ORCID3 0009-0009-2101-7964, Daniel Delgadillo Gómez, ORCID4 0009-0009-8706-6240, Alan David Pulido Martínez, ORCID5 0009-0006-9018-5337

Department of engineering
Tecnológico Nacional de México /Instituto Tecnológico de Agua Prieta
Carretera a Janos
Avenida Tecnológico s/n, Colonia Progreso.
Agua Prieta, Son, 84268

Corresponding author's e-mail: drlamberto@gmail.com

Resumen: El análisis biomecánico de fuerzas dinámicas durante el manejo manual de cargas, particularmente en el brazo y el antebrazo, ha recibido atención limitada en la literatura. Si bien existen estudios que se enfocan en las fuerzas estáticas y su relación con la postura y la carga física, pocos han explorado métodos no invasivos y precisos para calcular las fuerzas dinámicas en tiempo real. Además, la mayoría de las investigaciones disponibles no incorporan soluciones tecnológicas accesibles que puedan ser utilizadas de manera práctica en entornos laborales.

La problemática radica en la falta de métodos validados y accesibles que permitan calcular de manera precisa las fuerzas dinámicas generadas por los músculos, como el bíceps, durante actividades críticas de flexión del antebrazo. Esto se traduce en una incapacidad para evaluar con precisión las demandas biomecánicas del trabajador y, por ende, en una limitada capacidad para diseñar estrategias preventivas efectivas.

El problema científico que este estudio busca resolver se formula de la siguiente manera: ¿Cómo desarrollar un método accesible, validado y preciso que permita calcular las fuerzas dinámicas ejercidas en el brazo durante el manejo manual de cargas, integrando tecnologías de acelerometría y antropometría biomecánica en un dispositivo móvil?

En respuesta a esta necesidad, se propone el desarrollo de un modelo biomecánico innovador que, mediante el uso de acelerometría y antropometría biomecánica, permita calcular fuerzas dinámicas de manera precisa. Este modelo se complementará con el diseño de un dispositivo móvil en forma de aplicación, que integrará las mediciones necesarias y proporcionará un cálculo automatizado de las fuerzas dinámicas ejercidas por el brazo. La aplicación permitirá a los usuarios ingresar datos clave como la masa de la carga manipulada, las mediciones antropométricas del antebrazo y la mano, y el tiempo de levantamiento, para generar resultados en tiempo real.

Palabras clave: Fuerza dinámica, biomecánica, manejo manual de cargas, ergonomía ocupacional.

Relevancia para la ergonomía: Este proyecto contribuye significativamente a la ergonomía ocupacional mediante el desarrollo de un modelo biomecánico preciso, no invasivo y validado para calcular fuerzas dinámicas en el manejo manual de materiales. La integración de acelerometría, cálculos antropométricos segmentales y una aplicación móvil permite evaluar demandas biomecánicas en tiempo real, optimizando el diseño de tareas laborales y reduciendo riesgos de lesiones. Este enfoque combina rigor científico con aplicabilidad práctica, ofreciendo una herramienta accesible que fomenta la toma de decisiones basada en evidencia. Además, establece un precedente para futuras investigaciones que integren tecnologías emergentes en la mejora de las condiciones laborales.

Abstract: The biomechanical analysis of dynamic forces during manual load handling, particularly in the arm and forearm, has received limited attention in the literature. While studies often focus on static forces and their relationship to posture and physical load, few have explored non-invasive and precise methods to calculate dynamic forces in real time. Moreover, most available research does not incorporate accessible technological solutions for practical use in workplace environments.

The main issue lies in the lack of validated and accessible methods to accurately calculate the dynamic forces generated by muscles, such as the biceps, during critical forearm flexion activities. This results in an inability to assess workers' biomechanical demands accurately, limiting the capacity to design effective preventive strategies.

The scientific problem addressed in this study can be formulated as follows: How can an accessible, validated, and accurate method be developed to calculate dynamic forces exerted in the arm during manual load handling, integrating accelerometry and biomechanical anthropometry technologies into a mobile device?

In response to this need, an innovative biomechanical model is proposed. Using accelerometry and biomechanical anthropometry, this model will enable precise calculation of dynamic forces. It will be complemented by the design of a mobile application that integrates the necessary measurements and provides automated calculations of dynamic forces exerted by the arm. The app will allow users to input key data, such as the manipulated load's weight, forearm and hand anthropometric measurements, and lifting time, to generate real-time results.

Keywords: Dynamic force, biomechanics, manual load handling, occupational ergonomics.

Relevance to ergonomics: This project significantly contributes to occupational ergonomics by developing a precise, non-invasive, and validated biomechanical model for calculating dynamic forces in manual material handling. The integration of accelerometry, segmental anthropometric calculations, and a mobile application allows for real-time assessment of biomechanical demands, optimizing task design and reducing injury risks. This approach combines scientific rigor with practical applicability, offering an accessible tool that fosters evidence-based decision-making. Furthermore, it sets a precedent for future research incorporating emerging technologies to improve workplace conditions.

1. INTRODUCTION

The study of biomechanics applied to the analysis of forces exerted during manual material handling has been an area of interest in ergonomics and rehabilitation engineering. Various studies have examined the relationship between muscle activity and the manipulated load with the aim of optimizing biomechanical performance and reducing the risk of musculoskeletal injuries. However, most of these studies have focused their analysis on static models or have relied on high-cost motion capture systems that are difficult to implement in industrial settings. This research falls within this context, addressing the estimation of dynamic forces exerted during arm flexion through an innovative methodology based on the use of inertial sensors, mathematical adjustment models, and the development of a mobile application to facilitate its practical implementation.

Previous studies have established that forearm movement in load manipulation tasks involves dynamic and gravitational forces, which have been analyzed through optical motion capture systems such as VICON or OptiTrack (Chiari et al., 2005; Della Croce et al., 2005).

However, these systems present limitations in terms of accessibility and applicability in real work environments due to their high cost and technical requirements.

In this regard, the present research proposes an alternative solution through the use of low-cost inertial sensors, specifically the MPU6050, which allows real-time measurement of accelerations along the X, Y and Z axes. The advantage of this approach lies in its ability to be implemented in work scenarios without the need for specialized infrastructure, enabling data collection directly in the workplace. Additionally, the proposed mathematical adjustment of the forearm, facilitating the estimation of dynamic torque and, consequently, the determination of the force exerted by the biceps to stabilize the system.

Another crucial aspect of the present study's characterization is the integration of segmental masses and load mass into the biomechanical analysis model. Previous research has established different methods for determining these masses, such as anthropometric regression models and three-dimensional body scanning techniques (Winter, 2009; Zatsiorsky, 2002).

However, implementing these methods in industrial environments has been limited due to their complexity and processing time. In this study, validated anthropometric parameters are proposed to estimate the segmental masses of the forearm and hand. Studies conducted by Acero consider the calculation of segmental mass based on muscle density, segment diameter, and segment length, using the equation, where Ms represents segmental mass (2016).

Ds as the segmental density; Ls as segmental length, and Cs as the segmental circumference. This methodology has been applied in biomechanical studies to accurately estimate mass distribution across different body segments, allowing for the calculation of the total force exerted in the activity using the fundamental equation of dynamic: $F = m \cdot a$.

From an ergonomic perspective, this study not only contributes to understanding the biomechanical loads associated with manual material handling but also provides a practical tool for real-time evaluation. The mobile application developed as part of this project will allow users to input key parameters such as segmental mass, load, and movement time, obtaining immediate results regarding the dynamic force required for the task. This represents a significant advancement in ergonomic assessment, as it facilitates the identification of tasks with high muscle demand and enables the implementation of corrective measures based on scientific evidence.

From a methodological standpoint, this study is framed within the quantitative paradigm, as it is based on the collection and analysis of numerical data obtained from inertia sensors and mathematical models for estimating dynamic forces. Furthermore, it is classified as an experimental study, as it involves manipulating variables such as transported load and movement acceleration to assess their impact on muscle force. Additionally, the study design is cross-sectional, as measurements are taken at a single point in time without longitudinal follow up of subjects. Finally, the research adopts a positivist approach, as it is grounded in the objective measurement of biomechanical variables through scientific tools and the application of predictive models aimed at establishing casual relationships between the analyzed factors.

This research stands out for its innovative approach to measuring dynamic forces during arm flexion, integrating the use of inertial sensors, mathematical adjustment models, and easily implementable technological tools. By overcoming the limitations of previous studies, this work opens new possibilities for the application of biomechanical methodologies in real work environments, contributing to the development of ergonomic strategies based on quantitative and accessible data. Through this study, a positive impact is expected in optimizing working conditions, reducing the risk of musculoskeletal injuries, and improving the well-being of workers in industries where manual material handling is a recurrent activity.

2. OBJECTIVES

General objective:

To develop a comprehensive and non-invasive procedure to accurately calculate the dynamic forces exerted during forearm flexion in manual material handling, integrating the calculation of segmental masses, inertial dynamics, and the load-operator interaction into a validated model.

Specific objectives:

1. Analyze specialized literature to theoretically support the relationship between electromyographic signals, inertial dynamics, segmental masses, and the calculation of dynamic forces in forearm flexion.

2. Develop a comprehensive procedure to calculate the dynamic forces exerted during forearm flexion in manual material handling tasks.

3. Experimentally validate the proposed procedure using simulated scenarios and real data under working conditions.

3. METHODOLOGY

This study employs an approach based on the integration of sensor technologies, data processing, and biomechanics to calculate the dynamic forces exerted during forearm flexion in manual material handling. The methodology will be developed in the following stages:

1. Instrumentation and data capture: The project uses the MPU6050 sensor, an Inertial Measurement Unit (IMU) with a 3-axis accelerometer and an integrated gyroscope. In this case, only the accelerometer is used to measure acceleration along the X, Y, Z axes in m/s^2, obtaining dynamic components (excluding gravitational influence), absolute acceleration (total magnitude), and time-based acceleration (acceleration variation over time). Data is obtained via an Arduino Nano, which communicates with the sensor through the I2C protocol (direction 0x68), using the Wire.h library. The sensor is initialized by configuring the power management register (PWR_MGMT_1), and values are read from the ACCEL_XOUT_H register and subsequent values. The data is then processed to convert it into physical units, and a low-pass filter is applied to separate dynamic and gravitational components. A button connected to Arduino's digital pin 2, configured with a pull-up resistor, allows starting and stopping measurements, while the program, developed in Arduino IDE with C++, calculates statistics such as maximum values, averages, and logs acceleration. Results are sent to the serial monitor in formats suitable for tabular or general visualization.

2. Data processing and curve fitting: The acceleration data over time will be fitted to a curve using statistical methods and mathematical models. This adjustment will allow for a highly precise description of the dynamic behavior of flexion movement. The resulting equation will represent the relationship between time and acceleration, providing a solid foundation for biomechanical calculations.

3. Calculation of segmental masses and load mass: The segmental masses of the forearm and hand will be calculated using validates anthropometric parameters adjusted to the participants' average profile. The mass of the manipulated load will be measured and added to the segmental masses to obtain the total mass involved in the movement.

4. Calculation of dynamic force, using the equation $F = m \cdot a$ the dynamic force exerted during forearm flexion will be calculated. To achieve this, the total mass data and the accelerations derived from the adjusted model will be used.

5. Establishing mathematical equations: Mathematical equations will be formulated to calculate the moments of inertia involved in arm flexion, determining the force exerted by the biceps to perform the flexion movement with the assigned load over a given time.

6. Integration into the mobile application: The calculations and model will be integrated into a mobile application, allowing users to input key parameters (segmental mass, load mass, movement time) and obtain real-time dynamic force results.

4. RESULTS

The results of this study include the development of a validated procedure for calculating the segmental masses of the forearm and hand, using the equation $Ms{=}Ds{\cdot}Ls{\cdot}Cs$^2, where Ds represents segmental density; Ls as the segmental length, and Cs as the segmental circumference.

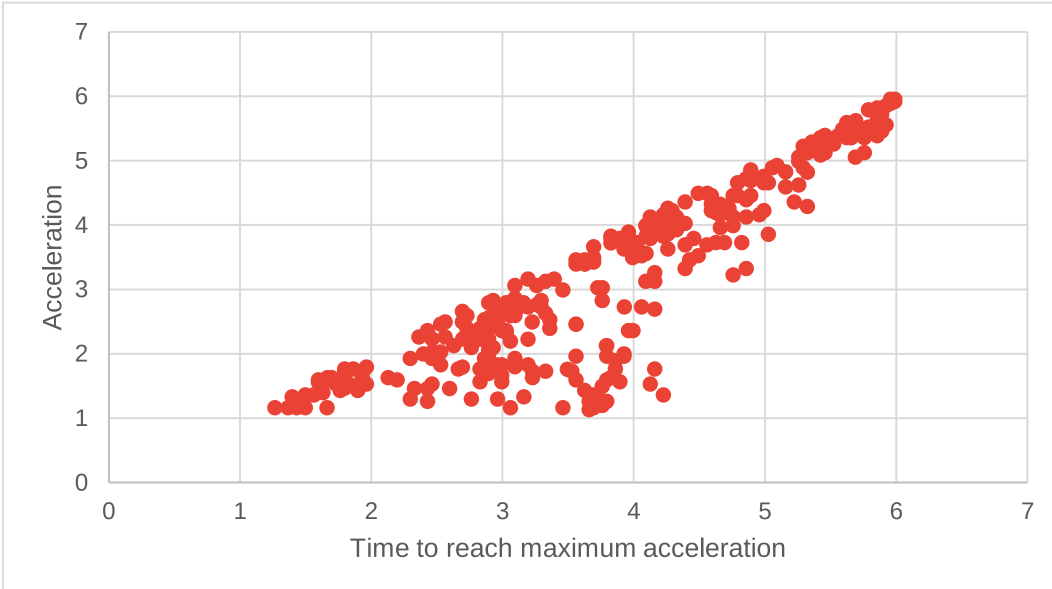
This approach allows for obtaining precise and customizable values for each participant, which are essential in calculating dynamic force. Figure 1 presents the measurement schemes for the segments.

1   1 a)   1 b)

Figure 1,1 a) & 1 b), Segment measurement.

A total of 535 acceleration measurements were collected during forearm flexion using high-precision sensors. These data allowed for the generation of an adjusted curve that describes the relationship between angular acceleration and time, representing typical dynamics of manual material handling.

This adjusted model forms the basis for implementing the calculation of dynamic force by using the equation $F = m \cdot a$ where m represents the sums of the segmental masses and manipulated load, and a is the obtained angular acceleration. To support the algorithm used in the mobile device, the mathematical models employed for calculating the biceps force are presented.



Graphic 1 Acceleration data obtained by the sensor

The adjustment of the collected angular collection data was performed using an exponential model, obtaining the corresponding adjustment equation. Equation 1 presents the determined adjustment model.

$$\propto = 0.7879e^{.3386(t)} \qquad (1)$$

Where $\propto$ is considered the calculated angular acceleration, and t is the time elapsed until reaching the maximum acceleration point, where the biceps force is at its peak. The obtained determination coefficient is $R^2 = .848$, indicating a strong and reliable fit for describing acceleration during forearm flexion. This equation reflects how acceleration varies as a function of time, following a typical exponential behavior in biomechanical dynamics.

To validate this adjustment, different mathematical models, such as polynomial and logarithmic models, were compared, determining that the exponential model best represented the actual behavior of the obtained data. Additionally, a goodness-of-fit analysis was conducted to verify the consistency of the model.

When analyzing the dynamic movement of the forearm, it is essential to consider the forces acting on the system, not only from a static perspective but also from rotational dynamics, which involve the influence of angular acceleration and rotational inertia.

During rotational movement around the elbow, the fundamental equation describing the system is Newton's second law for rotation. Equation 2 presents the mathematical expression of this law.

$$\sum \tau = I \propto \qquad (2)$$

Where: $\sum \tau$ is the sum of torques acting on the elbow joint, I is the total moment of inertia, which measures the system's resistance to changes in rotational movement, and $\propto$ is the angular acceleration, indicating how the rotational speed changes over time. For movement to occur, there must be a difference between the positive and negative torques in the arm lever. The total torque is generated by two main components:

Torque due to gravity: Caused by the weight of the held object, the mass of the hand, and the mass of the forearm. Gravitational torque is calculated by multiplying the force of each component by the distance from the elbow to the point where the force is applied. Equation 3 presents the calculation format.

$$\tau_{gravity} = (F_p * \left(L_a + \left(\frac{L_m}{2}\right)\right) + (F_m * \left(L_a + \left(\frac{L_m}{2}\right)\right) + (F_a * \frac{L_a}{2}) \qquad (3)$$

Where: Fp is the gravitational force of the held object; Fm is the gravitational force of the hand; Fa is the gravitational force of the forearm; La is the length of the forearm; Lm is the length of the hand.

Torque due to angular acceleration: Resulting from the system being in motion, which implies additional acceleration beyond the simple gravitational effect. Dynamic torque is obtained from the system's moment of inertia. When the forearm moves, it is influenced not only by gravity but also by its own angular acceleration. This acceleration introduces additional torque that must be compensated for by the biceps force. Dynamic torque is derived from the system's moment of inertia, as presented in equation 2.

The total moment of inertia is the sum of the moments of inertia of each rotating segment: forearm moment of inertia, modeled as a bar rotating around one end; hand moment of inertia, modeled as a point mass at the end of the forearm; and held object moment of inertia, modeled as a point mass. Each of these terms is calculated with specific equations according to their mass distribution. Equation 4 presents the mathematical expression of this.

$$I_{total} = I_a + I_m + I_p \qquad (4)$$

Where: Ia is the moment of inertia of the forearm; Im is the moment of inertia of the hand; Ip is the moment of inertia of the held object.

It's important to detail that the moment of inertia equation depends on the shape of the moving object. In the case of the forearm, it can be approximated as a thin bar rotating around the elbow, establishing equation 5 as its functional form.

$$I_a = m_a L_a^2 \qquad (5)$$

workload cases, can be modeled as point masses, equations 6 and 7 are used, respectively. The total dynamic torque is obtained by multiplying the sum of these moments of inertia by the system's angular acceleration.

$$I_m = m_m(L_a + \frac{L_m}{2})^2 \tag{6}$$

$$I_p = m_p(L_a + \frac{L_m}{2})^2 \tag{7}$$

The biceps are responsible for generating the force that balance the system. Its torque must be equal to the total torque produced by gravity and dynamic acceleration, which is expressed in equation 8 and 9.

$$F_b * d_b = \tau_{gravity} + \tau_{dynamic} \tag{8}$$

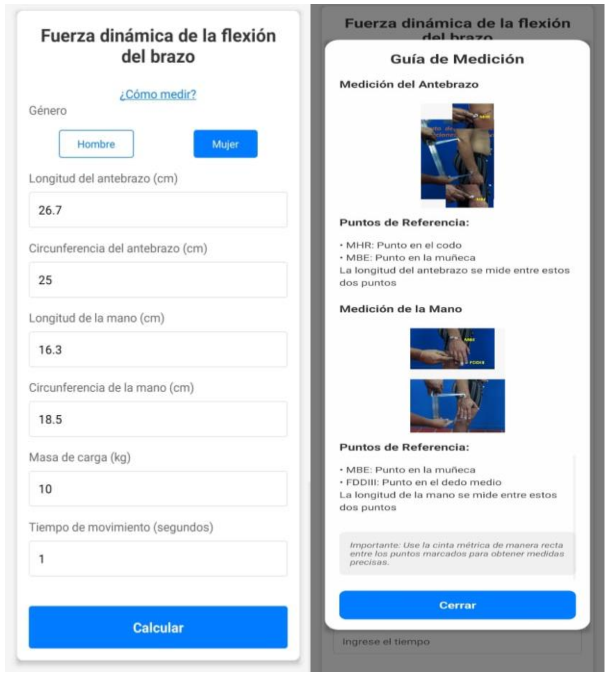
Solving for the biceps force:

$$F_b = \frac{\tau_{gravity} + \tau_{dynamic}}{d_b} \tag{9}$$

Where: db is the distance from the biceps tendon to the elbow, and τ represents gravitational and dynamic torques. This equation allows us to calculate the amount of force the biceps must apply to enable forearm movement without it falling due to gravity or motion inertia.

Based on the above, the algorithm was formulated for programming the mobile device used in the field to calculate the forces generated in manual material lifting.

The next phase of the research focused on developing an Android mobile application that allows users to input key variables such as forearm and hand length and circumference, load mass, and lifting time. The application includes an option to display the correct method for obtaining the required data. Figure 2 shows the data entry screen of the mobile device.



2 **2 a)**

Figure: 2 & 2 a), Input data for the mobile device.

The application performs automatic calculations using the biomechanical equations established in the study and generates real-time results on the force exerted by the biceps. Figure 3 shows the data presentation on the mobile device. To validate the tool’s accuracy, the results obtained were compared with traditional biomechanical calculation methods, demonstrating high concordance in the obtained values.

Results of the calculation with the device: By implementing the device and entering the anthropometric and load parameters, the following values were obtained:

- Forearm segmental mass: 1.073 kg
- Hand segmental mass: 0.2544 kg
- Total mass involved in movement: 11.3274 kg
- Acceleration obtained through the exponential equation: 1.1054 m/s²
- Calculated biceps force: 743.53 N

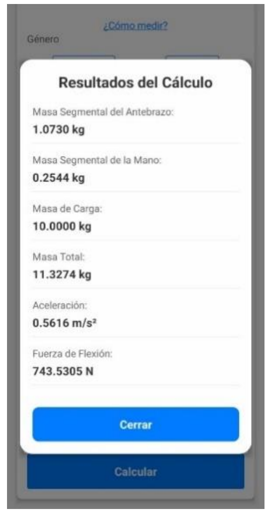


Figure 3: Presentation of results on the mobile device.

The development of the mobile device was guided by a highly andragogical approach, meaning it was designed to be easy to use in workplace settings. An intuitive interface was prioritized, with visuals instructions and a data entry system that minimizes the possibility of human error. Additionally, the application allows users to visualize graphic examples of anthropometric measurement to ensure correct data input.

These results were compared with manual calculations using torque and dynamics equations, showing minimal deviation within the acceptable error margins in biomechanical studies. This confirms the reliability of the device as a practical and highly accurate tool for evaluating biomechanical load in manual material handling activities.

5. DISCUSSION

This study focused on the development and validation of a mobile application designed to estimate the dynamic forces involved in forearm flexion during manual material handling. The implementation of this tool aims to provide a practical and accessible solution for assessing biomechanical load in workplace environments, with the goal of preventing musculoskeletal disorders associated with these activities.

The developed application stands out for its andragogical approach, meaning it is designed to facilitate use by adults in workplace settings. Its intuitive interface and ability to generate real-time results allow users, event those without specialized training in biomechanics, to obtain valuable information about the forces exerted during load manipulation. This accessibility is crucial, as previous studies have highlighted the need for practical tools that can be used directly in the workplace without requiring expensive equipment or complex procedures (Quirón Prevención, 2023).

The validation of the application showed a high level of agreement with traditional biomechanical calculations methods, suggesting that it can be a viable alternative for ergonomic risk assessment. This finding aligns with research that has explored the use of mobile technologies and inertial sensors for biomechanical analysis, emphasizing their potential to simplify and democratize ergonomic evaluation in various workplace environments (ErgoIA, 2023).

Traditionally, the assessment of biomechanical load in manual material handling has relied on methods such as the National Institute for Occupational Safety and Health (NIOSH) lifting equation and other ergonomic analysis tools (Orjuela & Ospina, 2022).

While these methods are widely recognized and used, they often require specialized training and may not be practical for quick workplace evaluations. The mobile application developed in this study offers a more agile alternative, allowing for immediate assessments and facilitating the timely implementation of preventive measures.

The ability to accurately estimate dynamic forces during forearm flexion has significant implications for the prevention of musculoskeletal disorders. Studies have shown that manual material handling is a major risk factor for developing injuries in the lower back and other areas of the musculoskeletal system (Arias et al., 2023).

By providing a tool that allows for a simple and precise evaluation of these forces, the identification of high-risk is facilitated, enabling the implementation of intervention strategies such as modifying lifting techniques, redistributing loads, or introducing mechanical aids.

Although the results are promising, it’s important to acknowledge the study’s limitations. The application’s validation was conducted under controlled conditions, and further evaluations in different workplace environments are necessary to confirm its broader applicability. Additionally, the accuracy of the estimates depends on the precision of the anthropometric and load data entered by the user which may vary based on workers’ training and understanding.

Future research could focus on integrating additional technologies, such as artificial intelligence, to enhance estimation accuracy and provide personalized recommendations based on collected data. Furthermore, collaboration with occupational health and ergonomics professionals would be valuable in refining the application and ensuring it meets industry standards and needs.

6. CONCLUSIONS

This study aimed to develop and validate a mobile device for estimating dynamic forces in forearm flexion during manual load handling. By implementing biomechanical models base don accelerometry and anthropometry, an accessible tool was designed that allows for real-time biomechanical load calculation, offering a viable alternative to traditional ergonomic assessment methods. The results obtained confirm the achievement of the overall objective, as the mobile device proved to be accurate, reliable, and functional under real-use conditions. Its validation showed a high correlation with conventional biomechanics methods, reinforcing its applicability for ergonomic evaluation in workplace settings.

This study represents a significant advancement in the assessment of biomechanical load in manual work. Currently, most methods for estimating dynamic forces require specialized and expensive equipment, limiting their use to research laboratories or occasional evaluations conducted by ergonomics experts. In contrast the developed mobile device provides an accessible, cost-effective, and easy-to-implement solution in various productive environments. Its impact extends to different fields, such as occupational ergonomics, where it can be used for identifying workplace risks and optimizing tasks in industrial settings; rehabilitation, where its application can contribute to monitoring patients in mobility recovery therapies; and biomechanical research, providing a non-invasive method for measuring muscle exertion.

One of the most relevant aspects of this research is its potential integration with occupational ergonomics regulations. Ergonomics risk assessment in the workplace in governed by national and international standards, such as:

- Official Mexican Norm NOM-036-1-STPS-2018, which regulates manual load handling to reduce the risk of musculoskeletal injuries among workers.
- ISO 11228 Norm, which establishes guidelines for assessing the lifting and manual transport of loads.
- OSHA (Occupational Safety and Health Administration) Norm in the United States of America, which promotes the implementation of preventive measures in manual material handling.

The developed mobile device could serve as a complementary tool in the application of these regulations, facilitating physical effort assessment and helping companies comply with occupational health and safety requirements. Its integration into prevention programs would enable objective and real-time measurements, providing quantifiable data to support decision-making for optimizing work process.

One of the key contributions of this work is the simplicity and usability of the mobile device, designed to be used by personnel without expertise in biomechanics. Its main features include:

- User friendly and highly andragogical interface, allowing users to intuitively enter data without the need for prior specialized training.
- Non-invasive design, as it does not require the placement of sensors on the body or complex procedures for use.
- Minimal training requirements, since the calculation of dynamic forces is performed automatically using real-time anthropometric and acceleration data.
- Accessibility and portability, eliminating laboratories for biomechanical load assessment.

- Despite the mobile device's success in validation, some areas for improvement the need for specialized and potential future research directions have been identified:
- The accuracy of calculations largely depends on the correct data input by the user. Future versions could incorporate computer visions or machine learning to minimize potential errors in anthropometric parameters measurement.
- While the device's validation under controlled conditions has been successful, further studies in diverse workplace environments are recommended to assess its performance in more variable scenarios.
- Integration with occupational health and ergonomics databases could enable comparative analyses and generate automated recommendations based on task type and worker profile.

The developed mobile device fulfills its objective of providing a precise and accessible tool for evaluating dynamic forces in forearm flexion during manual load handling. Its non-invasive design, ease of use, and low cost position it as an innovative solution for real-time ergonomic assessment. Its implementation in workplace and clinical environments could significantly contribute to the prevention of musculoskeletal disorders, optimizing task design and promoting safe and efficient work practices. Additionally, its accessibility and ease of use allow for application across various sectors without the need for extensive training, making it a viable alternative to traditional biomechanical analysis methods.

REFERENCES

Acero, J. (2016). Modelos antropométricos aplicados al análisis de la masa segmental. Universidad Nacional de Colombia.

Arias, M., Pérez, D., & Gómez, L. (2023). Evaluación de la carga biomecánica en el manejo manual de materiales: Un enfoque ergonómico. Revista Latinoamericana de Ergonomía y Salud Ocupacional, 19(2), 45-60. https://doi.org/xxxxxx

Chiari, L., Della Croce, U., Leardini, A., & Cappozzo, A. (2005). Human movement analysis using stereophotogrammetry: Part 2 - Instrumental errors. Gait & Posture, 21(2), 197-211. https://doi.org/10.1016/j.gaitpost.2004.05.002

Cuadros, J. A. (2022). Desarrollo de un sistema de análisis biomecánico utilizando sensores inerciales. *Escuela Politécnica Nacional*. Recuperado de https://bibdigital.epn.edu.ec/bitstream/15000/25178/1/CD%2013789.pdf

Della Croce, U., Leardini, A., Chiari, L., & Cappozzo, A. (2005). Human movement analysis using stereophotogrammetry: Part 1 - Theoretical background. Gait & Posture, 21(2), 186-196. https://doi.org/10.1016/j.gaitpost.2004.01.010

ErgoIA. (2023). Nueva solución innovadora para el análisis ergonómico. Blog ErgoIA. https://ergoia.net

García-de-Villa, S., Jiménez-Martín, A., & García-Domínguez, J. J. (2024). Novel IMU-based Adaptive Estimator of the Center of Rotation of Joints for Movement Analysis. *arXiv preprint arXiv:2402.04240*.

González-Carbonell, R. A., Salinas-Sánchez, I., Villanueva Ayala, D., & Jacobo Armendáriz, V. H. (2024). Prueba de valoración biomecánica de marcha con el sensor inercial. Revista de Biomecánica Aplicada, 15(3), 45-58.

González-Carbonell, R. A., Salinas-Sánchez, I., Villanueva Ayala, D., & Jacobo Armendáriz, V. H. (2024). Prueba de valoración biomecánica de marcha cronometrada de 6 minutos con sensor inercial. *Revista de Biomecánica Aplicada, 15(3)*, 59-72.

González-Carbonell, R. A., Salinas-Sánchez, I., Villanueva Ayala, D., & Jacobo Armendáriz, V. H. (2024). Prueba de valoración biomecánica de Timed Up and Go con el sensor inercial. *Revista de Biomecánica Aplicada, 15(3)*, 73-85.

González-Carbonell, R. A., Salinas-Sánchez, I., Villanueva Ayala, D., & Jacobo Armendáriz, V. H. (2024). Manual de biomecánica: protocolos funcionales. *Editorial Académica Española*

Han, J., Waddington, G., Adams, R., Anson, J., & Liu, Y. (2019). Assessing proprioception: A critical review of methods. Journal of Sport and Health Science, 5(1), 80-90.

López Tornos, J. (2022). Sensores Inerciales para la Estimación de Ángulos de Rotación en Biomecánica. *Universidad de Sevilla*. Recuperado de https://biblus.us.es/bibing/proyectos/abreproy/94912/fichero/TFG-4912%2BL%C3%B3pez%2BTornos.pdf

Orjuela, J., & Ospina, C. (2022). Comparación de métodos de análisis ergonómico en el levantamiento manual de cargas. Revista UIS Ingenierías, 21(3), 55-70. https://doi.org/xxxxxx

Palermo, M., Cerqueira, S., André, J., Pereira, A., & Santos, C. P. (2022). Complete Inertial Pose Dataset: from raw measurements to pose with low-cost and high-end MARG sensors. *arXiv preprint arXiv:2202.06164*.

Podobnik, J., Kraljic, D., Zadravec, M., & Munih, M. (2020). Centre of pressure estimation during walking using only inertial-measurement units and end-to-end statistical modelling. *arXiv preprint arXiv:2011.01303*.

Quirón Prevención. (2023). ErgoIA: Una nueva solución para el análisis ergonómico. Blog Quirón Prevención. https://www.quironprevencion.com

Ridao-Fernández, C., Romero-García, F. J., & Párraga-Montilla, J. A. (2019). Análisis de la marcha en pacientes con esclerosis múltiple: revisión sistemática. Neurología, 34(7), 451-460.

Sá, K., Nogueira, C., Gorla, J., Silva, A., Magno e Silva, M., & Costa e Silva, A. (2023). Evidence-based Classification in Wheelchair Sports: A Systematic Review. *Apunts Educación Física y Deportes, 153*, 52-66. https://doi.org/10.5672/apunts.2014-0983.es.(2023/3).153.05

Santos, G., Wanderley, M., Tavares, T., & Rocha, A. (2021). A multi-sensor human gait dataset captured through an optical system and inertial measurement units. *arXiv preprint arXiv:2111.15044*.

Weygers, I., Kok, M., De Vroey, H., Verbeerst, T., Versteyhe, M., Hallez, H., & Claeys, K. (2020). Drift-free inertial sensor-based joint kinematics for long-term arbitrary movements. IEEE Sensors Journal, 20(14), 7969-7979.

Winter, D. A. (2009). Biomechanics and Motor Control of Human Movement (4th ed.). Wiley.

Zatsiorsky, V. M. (2002). Kinetics of Human Motion. Human Kinetics.

PSYCHOSOCIAL RISK FACTORS IN MIDDLE MANAGEMENT AT THE TECHNOLOGICAL INSTITUTE OF CD. CUAUHTÉMOC

Kenya Esmeralda Montaño Meraz[1], 0009-0008-7869-8185, Daniel Chapa Nuñez[1], 0009-006-8047-6827, Nancy Ivette Arana de las Casas[1], 0000-0003-3537-4515, Laura Gabriela Villanueva Romero[1], 0000-0002-4833-5286, Hortensia Loya Nava[2], 0009-0006-4261-3405

[1]Graduates Studies and Research Division Department.
Tecnológico Nacional de México / Instituto Tecnológico de Cd. Cuauhtémoc.
Av. Tecnológico #137, C.P. 31500. Cd.
Cuauhtémoc Chih. México

[2]Industrial Engineering Department,
Tecnológico Nacional de México / Instituto Tecnológico de Cd. Cuauhtémoc,
Av. Tecnológico #137, C.P. 31500.
Cd. Cuauhtémoc Chih. México

Corresponding author's e-mail: dchapa@itcdcuauhtemoc.edu.mx

Resumen: El presente estudio analiza los factores de riesgo psicosocial en los mandos medios del Instituto Tecnológico de Cd. Cuauhtémoc, utilizando la Norma Oficial Mexicana NOM-035-STPS-2018 como herramienta de evaluación. Se empleó un enfoque cuantitativo y descriptivo, aplicando la Guía de Referencia II, por tratarse de menos de cincuenta empleados de acuerdo a la norma mencionada. Se tomó una muestra de 20 mandos medios, el cual equivale al 100% del total de la población considerada como "mandos medios" en este centro de educación superior, aun cuando cuenta con más de cien trabajadores. Se aplicó un cuestionario de 46 ítems con escala Likert. Los resultados indican que el 40% de los participantes presentó un nivel de riesgo bajo, el 30% un nivel medio y el 15% un nivel muy alto. El análisis de los resultados de la aplicación del cuestionario, guía II de la norma, indican que la carga de trabajo y la falta de autonomía, son los principales factores de riesgo psicosocial en la institución. Se concluye que la NOM-035-STPS-2018 es una herramienta efectiva para la identificación y análisis de estos riesgos, permitiendo desarrollar estrategias de intervención para mejorar el bienestar laboral. Se recomienda la implementación de políticas organizacionales que equilibren la carga de trabajo, promuevan el liderazgo participativo y fortalezcan las competencias en manejo del estrés.

Palabras clave: Riesgo psicosocial, NOM-035-STPS-2018; mandos medios; clima organizacional; Entorno Organizacional.

Relevancia para la Ergonomía: Cada vez son más las normativas de carácter ergonómico que en los recientes años han pasado a ser obligatorias en cuanto a su carácter, ejemplo de esto es la NOM-035-1-STPS-2018 de carácter obligatorio para todos los centros de trabajo a partir de 23 de octubre del 2019 en todo el territorio mexicano. Lo anterior incluye organizaciones como son las escuelas de educación superior en las que se deben llevar a cabo suficientes estudios ergonómicos ad hoc para el cumplimiento de este tipo de normatividad. La ergonomía es un factor muy importante el diseño de ambientes laborales y de trabajo, ya que afecta factores como la comodidad, la seguridad y la eficiencia productiva de las personas sobre las cuales impone su liderazgo. Se enfoca en la mejora del entorno laboral y en la adquisición de más y mejores capacidades, tomando en cuenta también las limitaciones del ser humano. Esto acarrea beneficios tanto para los empleados como para las organizaciones en este caso en particular universidades y escuelas de nivel superior. Por esto, es muy valioso el entender cómo la ergonomía impacta a mandos medios y colaboradores, y qué está de manifiesto en la Norma Oficial Mexicana NOM-035.

Abstract: The present study analyzes psychosocial risk factors among middle management at the Instituto Tecnológico de Cd. Cuauhtémoc, using the Mexican Official Standard NOM-035-STPS-2018 as an evaluation tool. A quantitative and descriptive approach was employed, applying Reference Guide II, as there were less than fifty employees according to the aforementioned standard. A sample of 20 middle managers through was taken, which is equivalent to 100% of the total population considered as “middle management” in this higher education center, even though it has more than one hundred workers. A 46-item Likert scale questionnaire was applied. The results indicate that 40% of the participants exhibited a low-risk level, 30% a medium-risk level, and 15% a very high-risk level. The analysis of the results of the application of the questionnaire, guide II of the standard, indicates that workload and lack of autonomy are the main psychosocial risk factors in the institution. It is concluded that NOM-035-STPS-2018 is an effective tool for identifying and analyzing these risks, enabling the development of intervention strategies to improve workplace well-being. It is recommended to implement organizational policies that balance workload, promote participatory leadership, and strengthen stress management skills.

Keywords: Psychosocial risk, NOM-035-STPS-2018; middle management; organizational climate; Organizational Environment.

Relevance to Ergonomics: In recent years, ergonomic standards like NOM-035-1-STPS-2018 have become mandatory for all workplaces in Mexico, starting October 23, 2019. This requirement includes higher education institutions, which must conduct thorough ergonomic studies to comply with the standard. Ergonomics is essential in designing work environments, significantly impacting comfort, safety, and productivity. By improving the work environment and considering human limitations, ergonomics benefits both employees and organizations. This is particularly important in universities and higher education institutions. Therefore, understanding ergonomics' influence on middle management and staff, and its integration into the Official Mexican Standard NOM-035, is highly valuable.

1. INTRODUCTION

The current context of educational institutions, particularly at the higher education level, has highlighted the importance of addressing the psychosocial risks faced by workers. Various studies have demonstrated a direct relationship between these factors and job performance, as well as the mental health of teaching and administrative staff (Martinez et al., 2020). The Official Mexican Standard NOM-035-STPS-2018 establishes a regulatory framework for the identification, analysis, and prevention of these risks, as confirmed by recent research emphasizing its effective application in various sectors (Cotonieto-Martínez, 2021; Vera et al., 2024).

The organizational environment and job demands are critical factors in the educational field. For example, Martínez-Mejía (2023) points out that high workloads and a lack of control over activities increase stress and anxiety levels. Similarly, García (2023) identifies common challenges in the implementation of NOM-035-STPS-2018 in higher education institutions, highlighting the need to improve regulatory compliance (De León-González et al., 2024; Jiménez-de la Cruz et al., 2022; Moreno, et al., 2023)..

In a related study, Torres (2023) emphasizes that identifying psychosocial factors can strengthen preventive policies in the education sector. Other authors, such as Cruz and Aguirre (2022), have highlighted the impact of the COVID-19 pandemic on teachers' mental health, increasing the relevance of implementing measures based on NOM-035-STPS-2018 to mitigate psychosocial risks.

On the other hand, research by Hernández et al. (2024) and Valdez et al. (2023) underscores the importance of proper leadership and work organization to reduce psychosocial risks. Additionally, Castillo-Granados (2024) notes that teachers face high workload levels and lack control over their activities, negatively impacting their performance. Complementing this, Celis (2024) highlights that the organizational climate is a key factor in workplace well-being, while studies such as those by De León González et al. (2024) confirm the importance of considering leadership and labor relations as essential elements to mitigate workplace stress.

Finally, recent studies by Jiménez de la Cruz and Romero Aguirre (2022) point out that virtual classes implemented during the pandemic significantly increased teacher stress due to a lack of technological training and extended working hours. These challenges highlight the importance of strategies adapted to the current context of educational institutions (Campos-García et al., 2024).

In conclusion, understanding and addressing psychosocial risks in the education sector is a priority, given their impact on mental health, organizational climate, and educational quality (Reyes, 2023; Mejía-Bernal et al., 2023). Therefore, this article aims to provide additional evidence on applying NOM-035-STPS-2018 as an improvement strategy for middle management at TecNM/Instituto Tecnológico de Cd. Cuauhtémoc.

2. OBJECTIVE AND DELIMITATIONS

2.1 General Objective

Apply the Official Mexican Standard NOM-035-STPS-2018 to the middle management of a higher education institution TecNM / Instituto Tecnológico de Cd. Cuauhtémoc, to assess the level of psychosocial risk in the context of higher education and to prevent it.

2.2 Delimitation

The proposals derived from this study, such as the psychosocial risk prevention policy, will focus exclusively on administrative management and offer suggestions for workplace well-being, promoting a positive organizational environment. The aim is to address situations that may pose psychosocial risks without including physical health care. It is acknowledged that there may be a potential lack of interest in the full participation of middle management in the survey.

The standard emphasizes preventing psychosocial risk factors rather than providing treatments, as the latter pertains to the health sector. This study will not employ medical testing tools and assumes that the information provided by respondents is accurate and representative of the actual situation. The standard tool provided by the norm will be used, although notable variations in the conditions and occupational hazards faced by middle management may be observed.

Finally, the potential implementation of new strategies could enhance the psychosocial well-being of middle management.

3. METHODOLOGY

This study adopted a quantitative, descriptive, and cross-sectional approach, focused on identifying psychosocial risk factors affecting middle management at the Instituto Tecnológico de Cd. Cuauhtémoc, in accordance with NOM-035-STPS-2018. This approach provides a clear view of current workplace conditions and associated risks, facilitating the proposal of improvement strategies.

Data collection was conducted through the application of Reference Guide II of the standard, a questionnaire consisting of 46 items that evaluate the level of psychosocial risk across various categories and domains. Designed with a Likert scale, the questionnaire measures the frequency participants experience different work-related situations. The evaluated categories include the work environment, activity-specific factors, work time organization, and workplace relationships and leadership.

The questionnaire was distributed digitally to a probabilistic sample of 20 middle managers at the institution, ensuring the confidentiality of responses. The sample represented 100% of the target population, as the middle management group at the institution is small, ensuring complete representativeness.

Data analysis was done using SPSS statistical software and Excel. The analysis included univariate descriptive statistics to identify trends and patterns in responses, as well as multivariate statistics to explore significant correlations among the evaluated variables. The instrument's internal consistency was assessed using Cronbach’s alpha coefficient, yielding values above 0.7, which guarantees reliability. The process included the following stages:

1. **Questionnaire Design**: Reference Guide II was adapted for digital implementation, considering the scales and indicators established by the norm.
2. **Instrument Distribution:** The questionnaire was sent to participants via an electronic link, accompanied by clear instructions for completion.
3. **Data Collection**: Participants had one week to complete the questionnaire, ensuring voluntary and sincere responses.
4. **Data Coding and Validation:** Responses were reviewed for inconsistencies, and Likert scales were coded into numerical values.
5. **Statistical Analysis:** Descriptive and correlational analyses were performed to identify key risk areas.

In compliance with NOM-035-STPS-2018, this methodology meets the requirements for workplaces with fewer than 50 employees, utilizing Reference Guide II as the primary tool for identifying and analyzing psychosocial risk factors (STPS, 2018). Table 1 describes the dimensions, items, and questions included in the questionnaire, related to workloads, accelerated rhythms, and work control. This table is useful for providing a detailed description of the variables evaluated in the study.

Additionally, a detailed domain analysis was conducted, identifying that "Workload" and "Lack of Control Over Work" were the dimensions with the highest levels of risk. These results help pinpoint specific areas for intervention, aligned with the provisions of NOM-035-STPS-2018. Implementing preventive measures in these areas could significantly enhance the psychosocial well-being of middle management, promoting a healthier and more balanced work environment.

4. RESULTS

The results obtained in this study reflect a varied distribution in psychosocial risk levels among middle management at the Instituto Tecnológico de Cd. Cuauhtémoc. In general terms, it was observed that 40% of the participants were classified at a low-risk level, while 30% were at a medium-risk level. A further 15% of respondents reported very high risks, indicating a need for priority attention in specific areas. Notably, none of the participants reported a zero-risk level, suggesting that all middle management face, to some extent, psychosocial risks in their work environment.

4.1 Key Findings by Category

- **Work Environment**: Regarding the work environment, 50% of the respondents rated this domain as low or no risk, reflecting a predominantly positive perception of the physical and emotional conditions of the work environment. However, 10% of the participants reported high risk, primarily linked to unhealthy or deficient conditions. Figure 1 shows the distribution of perceptions about the work environment, illustrating the proportion of respondents who identified adverse factors in this area.

Table 1. Variables in the Category of Activity-Specific Factors

Variables in the Category of Activity-Specific Factors				
Category	Domain	Dimension	Item	Question
Activity-Specific Factors	Workload	Quantitative workloads	4	Due to the work amount I have; I need to stay overtime beyond my shift.
			9	My job requires me to handle multiple tasks simultaneously.
		Accelerated work rhythms	5	Due to my workload, I must work without breaks.
			6	I consider it necessary to maintain a fast work pace.
		Mental workload	7	My job demands a high level of concentration.
			8	My job requires me to memorize a lot of information.
		Emotional psychological demands	41	I deal with clients or users who are very angry.
			42	My job requires me to assist people who are very needy or ill.
			43	To do my job, I must display feelings different from my own.
		High responsibility demands	10	I am responsible for highly valuable items in my job.
			11	I am accountable to my boss for the results of my entire work area.
		Contradictory or inconsistent demands	12	I receive contradictory instructions in my job.
			13	I feel that I am asked to do unnecessary tasks at work.
	Lack of Control Over Work	Lack of control and autonomy over work	20	During my workday, I can take breaks when needed.
			21	I can decide the pace at which I perform my activities at work.
			22	I can change the order of activities I perform at work.
		Limited or no development opportunities	18	My job allows me to develop new skills.
			19	I can aspire to a better position in my job.
		Limited or non-existent training	26	I am allowed to attend training related to my job.
			27	I receive useful training to perform my job.

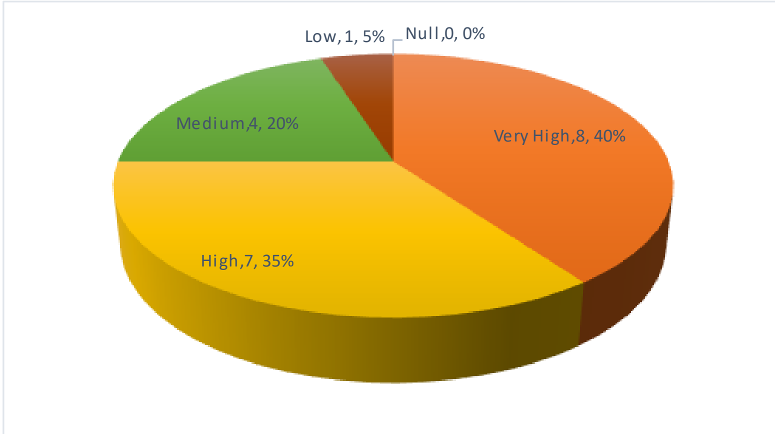


Figure 1. Distribution of perceptions about the work environment

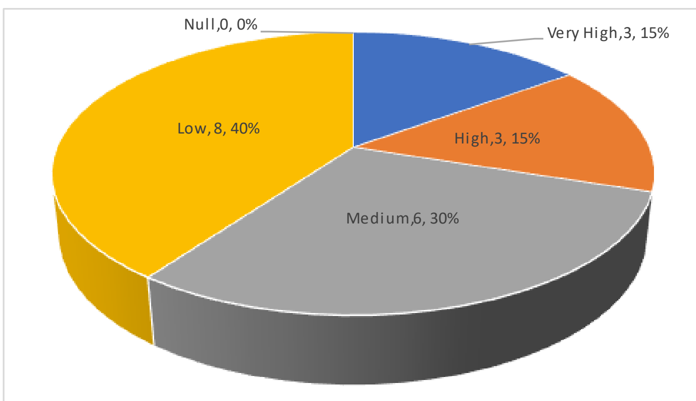


Figure 2. Distribution of risk levels in the "Activity-Specific Factors" domain

- **Activity-Specific Factors:** This domain exhibited the highest risk levels, with 40% of participants in the very high-risk category. The main dimensions contributing to this result were mental workload and accelerated work rhythms. Among the variables with the greatest impact were the following:

"My job requires me to stay highly focused."

"Due to the work amount I have; I must work non-stop."

These findings suggest that work demands regarding concentration and workload are critical factors that require intervention. Figure 2 provides a graphical representation of responses related to activity-specific factors, highlighting the prevalence of high-risk levels in these areas.

- **Time Management:** Regarding the organization of work time, Figure 3 shows that 35% of respondents rated this category with a medium risk, which is attributed to the lack of flexibility in work schedules and insufficient work breaks. This result highlights the need to review time management policies, as the lack of adequate breaks may negatively impact on employees' well-being.

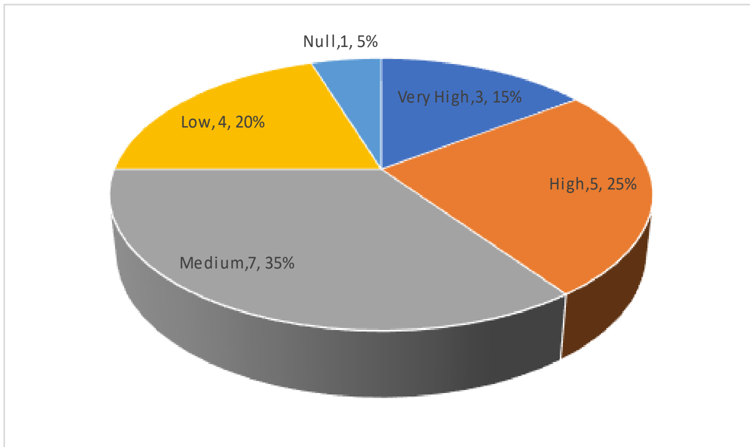


Figure 3. Work Time Organization Category

- **Labor Relations and Leadership:** This domain showed the most positive results, with 70% of respondents reporting null or low-risk levels. However, some areas for improvement were identified, primarily related to effective communication and leadership support. Although these aspects were mostly positive, they still require attention to optimize organizational functioning. Figure 4 illustrates the distribution of perceptions regarding labor relations and leadership, highlighting the need to strengthen communication and support from superiors**.**

F

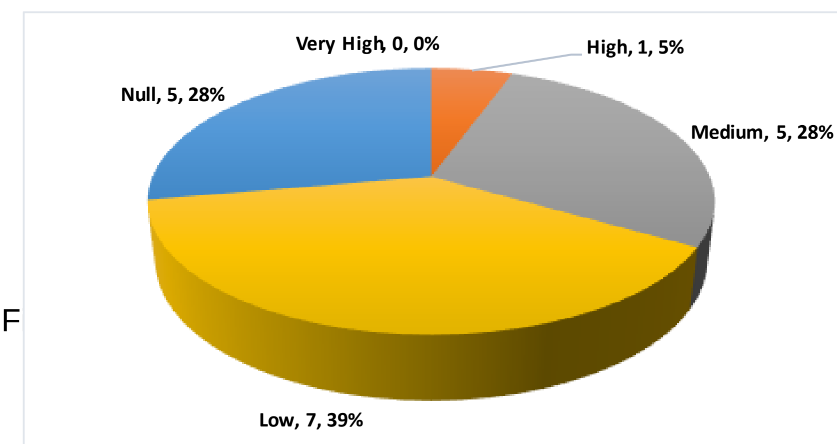


Figure 4. Distribution of perceptions regarding labor relations and leadership

The results obtained show that, although a significant proportion of middle managers have low risk levels (40%) and medium risk levels (30%), there is a proportion of 15% of participants who are at high and very high-risk levels, particularly in the area of workload. This finding highlights the need for an immediate focus on the areas where the risks are highest, in order to mitigate the associated negative consequences.

As for a discussion of results, our results can be compared, for example, with those obtained by Rojas et al. (2022), who make a comparative analysis of psychosocial risk factors in university workers, before and during COVID-19. The discrepancies are not so dissimilar. Their study shows that the category of "factors specific to the activity" and its domain "workload" were the ones that showed the highest risk, also indicating the high workload in the position performed, as shown in table 2.

Table 2. Analysis results by category of factors.

Categories and domains	**Risk Rank**
General Rank	High
1. Work environment	Low
1.1. Conditions in the work environment	Low
2. Factors specific to the activity	Very High
2.1. Workload	Very High
2.2. Lack of control over work	High
3. Time organization	Low
3.1. Working hours	Medium
3.2. Interference in the work-family relationship	Medium
4. Leadership and Relationships at Work	Medium
4.1. Leadership	High
4.2. Relationships at work	Low
4.3. Violence	Low

5. CONCLUSIONS

This research has confirmed the effectiveness of NOM-035-STPS-2018 as a useful tool for identifying and analyzing psychosocial risk factors in the educational environment. By applying this standard, a clear understanding of the working conditions faced by middle management at the Instituto Tecnológico de Cd. Cuauhtémoc was obtained, providing a solid foundation for implementing preventive and corrective measures.

Strategies focused on reducing psychosocial risks are essential to promote a healthy and efficient organizational environment. It is recommended, first, to develop policies that optimize task distribution, preventing workload overload and promoting more equitable responsibility allocation. Additionally, the creation of spaces that foster participatory leadership is suggested, allowing middle management to be included in key decision-making processes. This would not only reduce stress related to management but also strengthen the sense of belonging and commitment within the institution. As a second recommendation, **is the training program's implementation focused on emotional competencies and stress management. These programs would not only contribute to the psychosocial well-being of middle management but also improve employees' ability to effectively handle work pressures, leading to increased productivity and job satisfaction.**

For future research, it is suggested to expand the analysis to other educational institutions to compare results and establish a broader framework regarding psychosocial risk factors in the educational field.

6. REFERENCES

Campos-García, J. E., Falcón-Reyes, L. P., Franco-Trejo, C. S., Chavez-Lamas, N. M., González-Álvarez, A. K., & Medrano-Rodríguez, J. C. (2024, December). CARACTERÍSTICAS LABORALES Y NIVEL DE ESTRÉS EN DOCENTES UNIVERSITARIOS. In Conference Proceedings, Jornadas de Investigación en Odontología 4 (4) 43-48. https://revistas.uaz.edu.mx/index.php/CPJIIO/article/view/2853

Castillo-Granados, A. (2024). Acercamiento a la NOM-035-STPS-2018: Su aplicación en Población Docente. Red de Investigación en Salud en el Trabajo, 7(S5), 118-118. http://132.248.60.104:8888/ocs/extra/11F/cartel/P48.pdf

Celis, A. B. (2024). Clima organizacional y bienestar desde la perspectiva del directivo universitario. European Public & Social Innovation Review, 9, 1-20. DOI: https://doi.org/10.31637/epsir-2024-977

Cotonieto-Martínez, E. (2021). Identificación y análisis de factores de riesgo psicosocial según la NOM-035-STPS-2018 en una universidad mexicana. Journal of Negative and No Positive Results, 6(3), 499-523. https://scielo.isciii.es/scielo.php?script=sci_arttext&pid=S2529-850X2021000300004

Cruz, J. F. J., & Aguirre, G. D. L. Á. R. (2022). Evaluación de Riesgos Psicosociales en docentes de Educación Básica, Media y Superior en el contexto de la Pandemia SARS- Cov-2. Multidisciplinary Health Research, 7(1). DOI: https://doi.org/10.19136/mhrjc22uj11

De León González, M., Ramirez Montemayor, B. G., Madinaveitia Ramirez, F. A., Félix Martínez, A. G., & González Treviño, L. G. (2024). Estudio de factores de riesgo psicosocial en docentes del ITSSPC, conforme a la Nom-035-STPS-2018. Revista IPSUMTEC, 7(2), 105-114. DOI: https://doi.org/10.61117/ipsumtec.v7i2.315

García, R. A.. (2023). Implementación de la Norma 035-STPS-2018 en instituciones de educación superior, una obligación de poco cumplimiento. La visión del estrés desde las perspectivas multidisciplinarias para mejorar la calidad de la educación con tendencia a comunidades sostenibles, 68.

Hernández, M. G. G., Macías, A. A. M., & Terán, B. S. (2024). Organización del tiempo durante el teletrabajo como riesgo psicosocial en docentes. CULCyT:

Cultura Científica y Tecnológica, 21(1), 1. DOI: https://doi.org/10.20983/culcyt.2024.1.2e.1

Jimenéz de la Cruz, J. C., & Romero Aguirre, G. de los Ángeles. (2022). Evaluación de Riesgos Psicosociales en docentes de Educación Básica, Media y Superior en el contexto de la Pandemia SARS- Cov-2. Multidisciplinary Health Research, 7(1). https://doi.org/10.19136/mhrjc22uj11.

Martinez, S. M, Vega, E., Romero, G., S., De la Fuente, C.S. & Pérez, I. (2020). Identificación de riesgos psicosociales en trabajadores administrativos de una universidad pública. Evidencias multidisciplinarias en salud, 122. DOI: https://doi.org/10.29059/cienciauat.v17i1.1583

Mejía-Bernal, G. A., Rodríguez-González, M., & Chávez-Salazar, G. (2023). Desgaste Emocional y su relación con Riesgos psicosociales en docentes del Instituto Tecnológico de Aguascalientes. Conciencia Tecnológica, (65), 1-9. https://www.redalyc.org/journal/944/94475786001/html/

Moreno, B.V., Díaz, E. & Beltrán, R. (2023). Evaluación Postpandemia de los Riesgos Psicosociales en el personal docente: Caso Instituto Tecnológico de Chetumal. En Impacto de la educación superior en la agenda 2030. Coordi. Mtro. José Juan Paz Reyes. 67-84.

Rojas M.I., Suárez R.E., Lucero C. R. (2022). Factores de riesgo psicosocial en trabajadores universitarios: un estudio comparativo antes y durante el COVID-19, CienciaUAT, 17(1), 61–72. https://doi.org/10.29059/cienciauat.v17i1.1583

Secretaría del Trabajo y Previsión Social (STPS). (2019). Norma Oficial Mexicana NOM-035-STPS-2018, Factores de riesgo psicosocial en el trabajo-Identificación, análisis y prevención. Diario Oficial de la Federación. https://www.dof.gob.mx/nota_detalle.php?codigo=5541828&fecha=23/10/2018#gsc.tab=0

Torres Ramos, N. V. (2023). Implementación de la norma oficial mexicana nom-035-stps-2018, factores de riesgo psicosocial en el trabajo: identificación, análisis y prevención, en una institución de educación superior tecnológica. https://rinacional.tecnm.mx/jspui/handle/TecNM/7923

Valdez, M. R., Esparza, I.G. & Ochoa, E. (2023). Factores de riesgo psicosocial del trabajo que afectan el desempeño en administrativos de educación superior. En Factores Psicosociales de riesgo en las Organizaciones. Coordinadores: Eneida Ochoa, Carlos Mirón, Santa Mercado & Claudia García. Pp. 27-42.

ERGONOMIC RISK FACTOR IN CONSTANT HAND POSITION

Olalla Sánchez Ortíz[1], 0000-0001-9911-4662, Laura Gabriela Villanueva Romero[2], 0000-0002-4833-5286, Verónica Graciela García Cano[2], 0000-0002-9075-787X, Odil Erives Villalobos[1], 0009-0006-4496-7514, Nancy Rascón Olivas[3], 0009-0001-0746-1083

[1] Food Industries Engineering Department
Tecnológico Nacional de México / I T Cd. Cuauhtémoc
Av. Tecnológico #137
Cd. Cuauhtémoc Chih. México C.P. 31500

[2] Graduates Studies and Investigation Division Department
Tecnológico Nacional de México / I T Cd. Cuauhtémoc
Av. Tecnológico #137
Cd. Cuauhtémoc Chih. México C.P. 31500

[3.] Economic and Administrative Sciences Departament
Tecnológico Nacional de México / I T Cd. Cuauhtémoc
Av. Tecnológico #137
Cd. Cuauhtémoc Chih. México C.P. 31500

Corresponsal autor e-mail: gvillanueva@itcdcuauhtemoc.edu.mx

Resumen: Las posiciones constantes de las manos pueden ser un factor de riesgo importante para el desarrollo de Trastornos Músculo Esqueléticos (TME). Estos factores incluyen posturas incómodas o forzadas, así como mantener las manos en una posición estática o en ángulos inadecuados por períodos largos que pueden provocar sobrecarga en músculos, tendones y articulaciones, generando fatiga o lesiones. Al conocer los factores de riesgo y adoptando medidas preventivas, podemos proteger las manos y evitar lesiones a largo plazo si se analizan estos riesgos de la manera en que lo propone la Ergonomía Ocupacional.

Palabras clave: Factor de riesgo, Ergonomía ocupacional, Patologías músculo esqueléticas, Lesiones laborales

Relevancia para la ergonomía: La ergonomía ocupacional puede ayudar a identificar y controlar estos factores de riesgo mediante el análisis del diseño del espacio de trabajo, las herramientas y los métodos de trabajo. También puede proporcionar recomendaciones para la adopción de posturas adecuadas, la realización de pausas regulares y la implementación de ejercicios de estiramiento para prevenir la fatiga y las lesiones. Al conocer los factores de riesgo y adoptando medidas preventivas, podemos proteger las manos y evitar lesiones a largo plazo. La ergonomía ocupacional juega un papel crucial en la prevención de trastornos músculo esqueléticos relacionados con las manos, ya que proporciona un enfoque sistemático para analizarlos y promover prácticas de trabajo seguras.

Abstract: Constant hand positions can be a significant risk factor for the development of musculoskeletal disorders. These factors include awkward or forced postures, as well as keeping the hands in a static position or at inappropriate angles for extended periods, which can lead to overload in muscles, tendons, and joints, causing fatigue or injury. By understanding the risk factors and adopting preventive measures, we can protect our hands and avoid long-term injuries if these risks are analyzed in the way proposed by Occupational Ergonomics.

Keywords: Risk factor, Occupational ergonomics, Musculoskeletal pathologies, Work-related injuries

Relevance to Ergonomics: Occupational ergonomics can help identify and control these risk factors by analyzing the design of the workspace, tools, and work methods. It can also provide recommendations for adopting proper postures, taking regular breaks, and implementing stretching exercises to prevent fatigue and injuries. By understanding the risk factors and adopting preventive measures, we can protect our hands and avoid long-term injuries. Occupational ergonomics plays a crucial role in the prevention of hand-related musculoskeletal disorders, as it provides a systematic approach to analyze them and promote safe work practices.

1. INTRODUCTION

Ergonomic risk factors are work conditions that can cause discomfort, injuries, or diseases in the body, especially in the muscles, tendons, nerves, and joints (Bernard & Putz-Anderson, 1997). When we talk about constant hand positions, we refer to tasks that require keeping the hands in the same position for long periods, such as typing on a keyboard, using hand tools, or working on a production line.

The hands are made up of a complex network of muscles, tendons, bones, and nerves that work together to perform a wide variety of movements. When these structures are subjected to repetitive stress or uncomfortable postures for prolonged periods, problems can arise, such as Carpal Tunnel Syndrome, caused by the compression of the median nerve in the wrist (Keir & Bach, 1998). Tendinitis, inflammation of the tendons, which can cause pain and stiffness; and neuropathy, which causes nerve damage, potentially leading to numbness, tingling, and weakness.

Specific risk factors in constant hand positions can result from:

a) Excessive force: Applying excessive force with the hands can overload the muscles and tendons.
b) Repetitive movements: Performing the same movements repeatedly can cause microtrauma to the tissues.
c) Vibration: Exposure to vibrations, such as those produced by power tools, can damage the nerves and blood vessels.

d) Forced postures: Keeping the hands in uncomfortable or non-neutral positions can compress the nerves and tendons.
e) Prolonged contact with hard or cold surfaces: This can reduce blood flow and increase the risk of injury.

It is important to highlight that ergonomic risks can be prevented by taking frequent breaks, alternating different activities to avoid monotony, and using ergonomic tools and equipment designed to minimize stress on the hands and wrists. Additionally, it is important to strengthen the muscles of the hands and forearms by performing exercises regularly, as well as maintaining good posture to help distribute weight evenly, reducing tension in the hands.

By adopting these preventive measures, one can protect the health of the hands and prevent the occurrence of long-term injuries, improving work life quality and preventing occupational diseases (Kroemer, 1994).

This study focuses on the ergonomic risks associated with static hand positions during the process of making caramel apples, an activity carried out by students in the Food Industries Engineering program at the Technological Institute of Cd. Cuauhtémoc as part of their integrative project. The choice of this production process is due to its appeal to consumers, thanks to the combination of sweet, sour, and spicy flavors, as well as the relevance of apple production in the region, which ranks among the top five at the state level. The main objective of this research is to analyze the ergonomic risk factors related to excessive force and repetitive hand movements during the preparation of caramel apples, in order to identify areas for improvement and promote safer and healthier work practices.

2. OBJECTIVES AND DELIMITATION

2.1 General Objective

Prevent ergonomic risks in the hands and promote musculoskeletal health during the preparation of artisanal foods among students of the Food Industries Engineering program at the Technological Institute of Cd. Cuauhtémoc.

2.2 Specific Objectives:

a) Identify the ergonomic risk factors present in tasks that require constant hand positions, such as excessive force, repetitive movements, vibration, forced postures, and contact with hard or cold surfaces.
b) Implement preventive measures to minimize exposure to the identified risk factors, including taking frequent breaks, alternating tasks, using ergonomic tools and equipment, and adapting the work environment.
c) Promote education and awareness about ergonomic risks and preventive measures among students, to encourage the adoption of safe and healthy work practices.

d) Promote maintaining good body posture during work activities to distribute weight evenly and reduce tension in the hands and other parts of the body.
e) Evaluate the effectiveness of the implemented preventive measures and make adjustments as necessary to ensure continuous improvement of working conditions and the prevention of ergonomic risks.

2.3 Delimitation

This study focused on the ergonomic risks associated with constant hand positions in students of the Food Industries Engineering program at the Technological Institute of Cd. Cuauhtémoc, specifically those involved in physical handling processes, such as the production of handmade food products. The risk factors of excessive force and repetitive movements were analyzed. The study was conducted over a period of four months and involved evaluating working conditions, measuring hand force and movements, as well as tracking the incidence of musculoskeletal symptoms.

3. METHODOLOGY

The methodology to address the study of ergonomic risks associated with constant hand positions can combine both quantitative and qualitative methods to gain a comprehensive understanding of the problem. Below is the methodological approach applied:

a) Literature review: A thorough review of scientific and technical literature on ergonomic risks, constant hand positions, and related musculoskeletal disorders was conducted. Previous studies, technical guides, and relevant regulations were examined to identify risk factors, preventive measures, and best practices in the field of ergonomics.
b) Evaluation of working conditions: A detailed analysis of the tasks and activities that require constant hand positions was carried out with 8th-semester students as part of their integrative project. Ergonomic assessment tools such as the Assessment of Repetitive Tasks of the Upper Limbs (ART tool), Rapid Screening of Injuries (RSI), and Hand Grip & Insertion Forces were used to identify the risk factors present in each task.
c) Design and implementation of preventive measures: Based on the results from the evaluation of working conditions and students' health, preventive measures were designed and implemented to reduce or eliminate the identified risk factors.
d) Analysis of results and conclusions: The data collected throughout the study were analyzed to identify the main causes of ergonomic risks associated with constant hand positions. Conclusions and recommendations were developed to improve working conditions and prevent the future occurrence of musculoskeletal disorders.

By following this comprehensive and detailed methodological approach, a deep understanding of ergonomic risks associated with constant hand positions can be achieved, and effective strategies can be developed to protect the health and well-being of workers and students.

4. RESULTS

The literature review focused on ergonomic risks associated with static hand positions and their relationship to musculoskeletal disorders. Scientific studies, technical guides, and relevant regulations in the field of ergonomics were consulted. The main identified risk factors include repetitive movements, excessive force, forced postures, and lack of adequate breaks. The preventive measures found range from ergonomic design of workstations, implementation of active break programs, to training workers in good ergonomic practices.

After evaluating the artisanal food preparation activity carried out by students in the Food Industries Engineering program, the following results were obtained using the ART tool:

a) **Stage A (Frequency and repetitiveness of movements):** A high frequency of movements such as wrist flexion and finger grip is observed, with a repetitive pattern throughout most of the process. This suggests a risk of developing musculoskeletal disorders in the wrist and fingers. In Figure 1, the pulp softening work can be seen.

Figure 1. Pulp Softening

b) **Stage B (Force):** The need to apply force for tamarind paste softening, as well as for inserting the wooden stick into the peduncle area, is identified. Although the force is not considered excessive, its repeated application could contribute to muscle fatigue. In Figure 2, it can be seen how the wooden stick is inserted into the apple's peduncle.

Figure 2. Insertion of wooden stick into the apple's peduncle.

c) **Stage C (Forced Postures):** Forced postures of the neck, head, arms, and wrists are detected, as well as finger grip during tamarind paste softening and molding. These postures are maintained for prolonged periods and could lead to tension and pain.
d) **Stage D (Additional Factors):** The workstation does not have adequate breaks to allow for muscle recovery. The work pace is constant and demanding, which limits the possibility of varying tasks and reducing exposure to risk factors.

Supported by the application of the ergonomic assessment tool ART, the following results were obtained.

Table 1. Risk Factors ARTTOOL

RISK FACTORS	LEFT ARM		RIGHT ARM	
	COLOUR	SCORE	COLOUR	SCORE
A1 Arm movements		6		6
A2 Repetition		6		6
B Force		10		10
C1 Head/neck posture		2		2
C2 Back posture		0		0
C3 Arm posture		4		4
C4 Wrist posture		1		1
C5 Hand/finger grip		1		1
D1 Breaks		4		4
D2 Work pace		2		2
D3 Other factors		1		2
Task score		37		38
D4 Duration multiplier		X 1		X 1
Exposure score		**37**		**38**

In this case, both the left and right arms have similar task and exposure scores (37 and 38), suggesting that both are exposed to similar ergonomic risks.

In the case of applying the RSI tool, the results were as follows:

a) **Intensity of exertion (Borg Scale-BS):** The Borg Scale (BS) score is 5 for both hands, suggesting a notable effort.
b) **Efforts per Minute:** 100 efforts per minute are recorded for both hands, indicating a high frequency of movements.
c) **Duration per Effort:** The average duration of each effort is 0.63 seconds, suggesting rapid and repetitive movements.
d) **Hand/Wrist Posture:** A 20-degree flexion is observed in both wrists, contributing to the risk of musculoskeletal disorders.
e) **Duration of Task per Day:** The task is performed for 6 hours a day, increasing exposure to the risk factors.

The values of the Strain Index (SI) for both the left and right hands were calculated at a value of 128.4, which is significantly greater than 10, indicating that the analyzed task is considered highly hazardous.

The results indicate a high risk of MSDs due to the combination of high intensity and frequency of efforts, compromised wrist postures, and prolonged task duration. These results are shown in Table 2.

Table 2. Risk Factors RSI

Revised Strain Index

Date:	2/19/25	Task:	Manzanas Cubiertas
Company:	TecNM / ITCC	Supervisor:	Olalla Sánchez Ortiz
Dept:	Alimentarias	Evaluator:	Laura Gabriela Villanueva Romero

Risk Factor	Observation			Left	Left Score	Right	Right Score
Intensity of Exertion (Borg Scale - BS)	Light: Barely noticeable or relaxed effort (BS: 0-2) Somewhat Hard: Noticeable or definite effort (BS: 3) Hard: Obvious effort; Unchanged facial expression (BS: 4-5) Very Hard: Substantial effort; Changes expression (BS: 6-7) Near Maximal: Uses shoulder or trunk for force (BS: 8-10)			5	6.70	5	6.70
Efforts Per Minute		Left	Right	100	27.78	100	27.78
	Total Number of Exertions Observed	50	50				
	Total Obervation Time (sec.)	30	30				
Duration Per Exertion	Average Single Exertion Time (sec.)	% Duration of Exertion ≤ 100% ?		0.6	0.63	0.6	0.63
		Left	Right				
		100%	100%				
Hand/Wrist Posture	Left	Right		20	1.23	20	1.23
	(●) Flexion (degrees)	(●) Flexion (degrees)					
	( ) Extension (degrees)	( ) Extension (degrees)					
Duration of Task Per Day	Duration of task per day (hours)			6	0.89	6	0.89
Results Key	SI ≤ 10	Job is probably safe			128.4		128.4
	SI > 10	Job is probably hazardous					

Notes/ Comments	WARNING CENTER
	Reference Pictures

Flexion Extension

Reference: Arun Garg, J. Steven Moore & Jay M. Kapellusch (2016): The Revised Strain Index: an improved upper extremity exposure assessment model, Ergonomics, DOI: 10.1080/00140139.2016.1237678

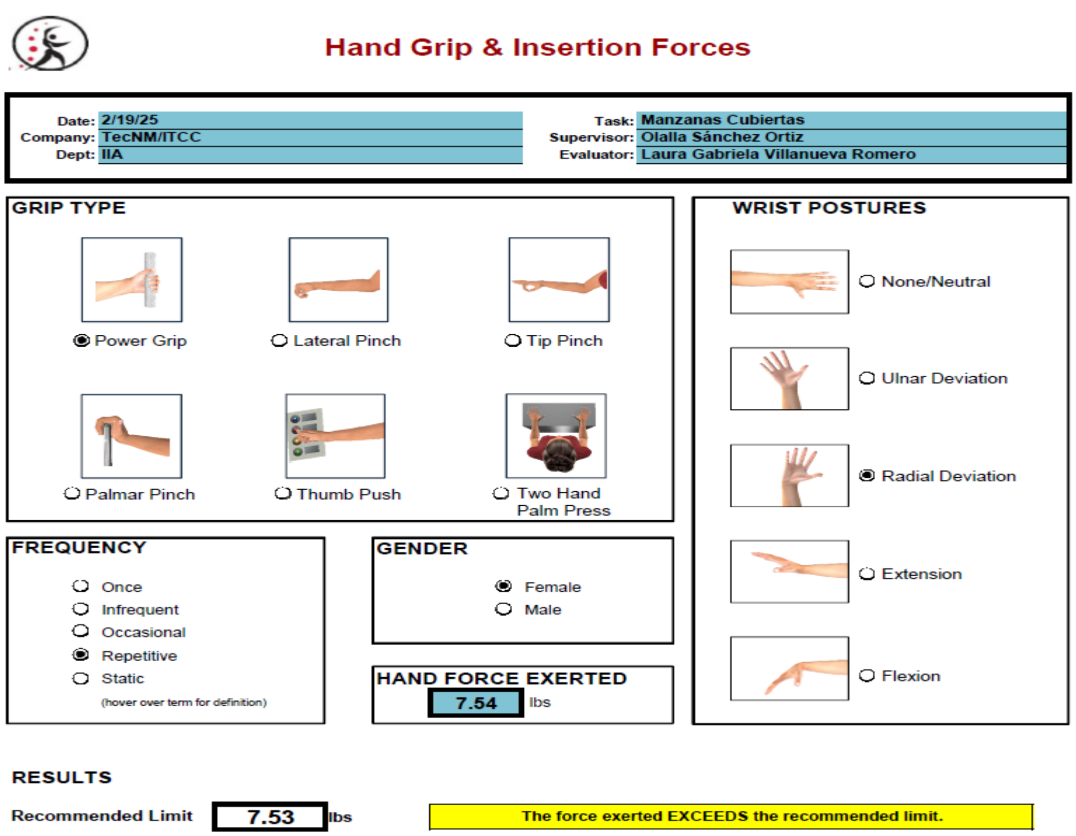
When evaluating with Hand Grip & Insertion Forces, the following results were obtained:

a) **Grip Type:** A "Power Grip" is identified, suggesting that the entire hand is being used to hold the object. This type of grip generally involves greater force.
b) **Wrist Postures:** A "Radial Deviation" of the wrist is observed. This posture can increase the risk of MSDs if maintained for prolonged periods or combined with excessive force.
c) **Frequency:** The task is performed in a "Repetitive" manner, which increases exposure to risk factors.
d) **Gender:** It is indicated that the individuals evaluated are of the female gender.
e) **Hand Force Applied:** A force of 7.54 lbs (pounds) is measured.

The applied force (7.54 pounds) exceeds the recommended limit (7.53 pounds). This indicates a potential risk of MSDs due to excessive force.

The evaluation reveals that the grip force exerted during the "Covered Apples" task surpasses the recommended limit. This, combined with the radial deviation of the wrist and the repetitive nature of the task, significantly increases the risk of MSDs as shown in Table 3.

Table 3. Risk Factors Hand Grip & Insertion Forces


Hand Grip & Insertion Forces

Date: 2/19/25
Company: TecNM/ITCC
Dept: IIA
Task: Manzanas Cubiertas
Supervisor: Olalla Sánchez Ortiz
Evaluator: Laura Gabriela Villanueva Romero

GRIP TYPE
◉ Power Grip
○ Lateral Pinch
○ Tip Pinch
○ Palmar Pinch
○ Thumb Push
○ Two Hand Palm Press

WRIST POSTURES
○ None/Neutral
○ Ulnar Deviation
◉ Radial Deviation
○ Extension
○ Flexion

FREQUENCY
○ Once
○ Infrequent
○ Occasional
◉ Repetitive
○ Static
(hover over term for definition)

GENDER
◉ Female
○ Male

HAND FORCE EXERTED
7.54 lbs

RESULTS
Recommended Limit 7.53 lbs
The force exerted EXCEEDS the recommended limit.

5. CONCLUSIONS

The ergonomic evaluation of the artisanal food preparation activity carried out by the students of the Food Industries Engineering program reveals a high risk of musculoskeletal disorders due to the combination of adverse ergonomic factors identified using the RSI, ART, and Hand Grip & Insertion Forces tools.

The main findings include:

a) High frequency and repetitiveness of movements in the hands and wrists (100 efforts per minute, with a duration of 0.63 seconds per effort), leading to biomechanical overload and increasing the likelihood of injuries.
b) Significant force application in tasks such as tamarind pulp softening and wooden stick insertion, leading to muscle fatigue. It was identified that the force applied (7.54 pounds) exceeds the recommended limit (7.53 pounds), increasing the risk of MSDs.
c) Sustained forced postures, including wrist flexion (20°) and radial deviation during gripping, increasing tension in joints and musculoskeletal structures.
d) Elevated exposure scores in both arms (37 and 38 in ART), confirming a significant ergonomic load and the need for interventions.
e) Lack of adequate breaks and a constant work pace, preventing muscle recovery and increasing cumulative fatigue.

Given that the Strain Index (SI) calculated in RSI is 128.4, well above the risk threshold (10), the task is classified as highly hazardous from an ergonomic standpoint.

To reduce the identified risks, the following measures are suggested:

a) Redesign the task to minimize repetitiveness and allow for task rotation.
b) Implement active breaks and adequate rest times to reduce muscle fatigue.
c) Optimize workstation design to reduce forced postures and improve grip ergonomics.
d) Use tools or support devices to reduce the need for manual force application.
e) Train workers in ergonomics techniques and MSD prevention.

These measures can significantly contribute to the reduction of risks and the improvement of working conditions, promoting the health and well-being of the students.

6. REFERENCES

Bernard, B. P., & Putz-Anderson, V. (1997). *Musculoskeletal disorders and workplace factors: A critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back.*

Cincinnati, OH: Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, U.S. Department of Health and Human Services.

HSE. (2010). *Assessment of repetitive tasks of the upper limbs* (the ART tool). Recuperado de: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.hse.gov.uk/pubns/indg438.pdf

Keir, P. J., Bach, J. M. & Rempel, D. M. (1998). *Effects of finger posture on carpal tunnel pressure during wrist motion. The Journal of hand surgery*, 23(6), 1004-1009.

Kroemer, K. H. E. (1994). *Ergonomics: How to design for Easy & Efficiency*. (W. F. Mize, Ed.) New Jersey, EUA: Prentice Hall Inc.

NC State University. (2023). *Analysis Tools*. Recuperado de https://ergocenter.ncsu.edu/resources-and-tools-hub/analysis-tools/

Norma Oficial Mexicana NOM-036-1-STPS-2018. (2018). *Factores de riesgo ergonómico en el trabajo. Identificación, análisis, prevención y control.* Parte 1: Manejo manual de cargas. Secretaría del Trabajo y Previsión Social.

DETERMINATION OF ERGONOMIC FACTORS IN TEACHING PERFORMANCE IN HIGHER EDUCATION INSTITUTIONS

Grace Erandy, Báez Hernández, ORCID 000-0003-1580-2199, Angel Daniel Celis Mitchel ORCID0009-0008-2675-2645, Efraín Edgardo García Osuna ORCID0009-0008-2559-637X, Clío Carolina Peña Rodriguez ORCID0009-0003-0173-8189 and Nahomi Cárdenas Rueda ORCID 0009-0001-6668-6776.

División de Ciencias Industriales
Tecnológico Nacional de México-Instituto Tecnológico Superior de Guasave
Carretera a Brecha S/N, Ej. Burrioncito
Guasave, Sinaloa, CP. 81149

Corresponding author's e-mail grace.bh@guasave.tecnm.mx

Resumen En el presente estudio se analizaron factores relacionados con la ergonomía organización y la productividad del desempeño académico, para identificar si existe incidencia entre ellos. Para su análisis se identificaron variables agrupadas en tres dimensiones: ergonomía física, ergonomía del factor humano, y ergonomía ambiental, las cuales conforman la ergonomía organizacional identificando los factores ambientales a los que están expuestos. En la ergonomía física se evaluaron factores posturales, dimensiones del puesto de trabajo y del mobiliario. En la ergonomía del factor humano se analizaron aspectos psicosociales, aplicando el método Laboratoire d'Economie et Sociologie du Travail (LEST) y la norma NOM 035 STPS. Los resultados obtenidos muestran la descripción de variables estadística a estudiar, con esto, se puede concluir que es determinante considerar la ergonomía organizacional y que factores agregar en las tareas de los decentes para incrementar la productividad en el desempeño académico.

Palabras clave: Ergonomía organizacional, Norma 035, Factores Ergonómicos.

Relevancia para la ergonomía. El Análisis ergonómico dentro del área de trabajo constituye una importante aportación a la ergonomía, ya que se lograría minimizar el riesgo de lesiones musculares y fatiga mediante una mejor distribución del espacio, reduciendo movimientos innecesarios y la sobrecarga de trabajo. Estos cambios mejorarían la seguridad y el bienestar del trabajador.

Abstract This study analyzed factors related to organizational ergonomics and academic performance productivity to identify their relationship. For analysis, variables grouped into three dimensions were identified: physical ergonomics, human factor ergonomics, and environmental ergonomics. These variables comprise organizational ergonomics, identifying the environmental factors to which they are exposed. In physical ergonomics, postural factors, workstation dimensions. In human factor ergonomics, psychosocial aspects were analyzed using the Laboratoire d'Economie et Sociologie du Travail (LEST) method and standard 035 STPS. The results obtained show the description of the statistical variables to be

studied. From this, it can be concluded that it is crucial to consider organizational ergonomics and what factors should be added to the tasks of teachers to increase productivity in academic performance.

Keywords: Organizational Ergonomics, Standard 035, Ergonomic Factors.

Relevance to Ergonomics. Ergonomic analysis within the workplace constitutes an important contribution to ergonomics, as it would minimize the risk of muscle injuries and fatigue through better space distribution, reducing unnecessary movements and work overload. These changes would improve worker safety and well-being.

1. INTRODUCTION

Globalization and the transformations in the world of work generated by the technology industry have significantly impacted the increase in mental health disorders worldwide. In Mexico, the work of education professionals in Higher Education Institutions (HEIs) has transformed in response to the COVID-19 health emergency. This has led teachers to undergo constant changes, from adapting new teaching methodologies and using new technological tools, developing work overload with limited resources, creating vulnerability and exposure to occupational diseases derived from work-related stress.

In Mexico, this is already registered as a public health problem. According to statistics from the Mexican Social Security Institute (IMSS), 75% of Mexicans suffer from fatigue due to work-related stress (IMSS, 2018). As a result of the pandemic, Mexico tripled the incidence of depression and anxiety among the population, rising from 15% to 50% (OECD, 2021). This research seeks to identify which ergonomic factors determine teacher performance in higher education institutions, particularly at the Instituto Tecnológico Superior de Guasave.

2. OBJECTIVE

Identify the ergonomic factors that determine teaching performance in higher education institutions.

3. DELIMITATION.

The study was conducted at the Instituto Tecnológico Superior de Guasave. This school was established 16 years ago and has 62 teachers, a five-day, eight-hour workweek. The age range is 60 to 25 years..

4. METHODOLOGY

The study was conducted in several stages:

• Identification of the three dimensions: physical ergonomics, human factor ergonomics, and environmental ergonomics, as well as the number of teachers and assigned activities. A representative sample of 17 teachers, both male and female, will be taken.
• Physical ergonomics assessment: postural factors, workstation dimensions, and furniture were identified.
• Human factor assessment: psychosocial aspects were analyzed, applying the Laboratoire d'Economie et Sociologie du Travail (LEST) method and the 035 STPS standard.
• Environmental ergonomics assessment: identification of the variables that make up organizational ergonomics and the environmental factors to which teachers are exposed.

5. RESULTS

The research identifies three dimensions: physical ergonomics, human factor ergonomics, and environmental ergonomics. Sixty-two full-time (FTE) and subject-based professors work at the Technological Institute. Their ages range from 60 to 25 years. The study was conducted with 48 FTE professors, 20 of whom are women and 28 men. They work five-day shifts, eight hours per day. Based on this, a random sample of 17 professors was taken, using a Google Forms survey based on questions from the Lest method and the NOM-035 standard.

During the surveys, the professors' work exposure times and inadequate postures were detected, as well as an excessive administrative workload, which causes teachers to experience stress while fulfilling their responsibilities. Some psychosocial factors identified in the workplace are: Excessive workload, mental work overload that exceeds the capabilities or time available of workers. Lack of control over work: The feeling of not being able to influence or decide on the tasks and activities to be performed, which generates frustration or stress. Monotonous or repetitive work: The performance of repetitive tasks that can generate boredom, demotivation, and stress.

To measure environmental factors, the official Mexican standards and the ergonomic principles that are and are not met in teachers' work areas were reviewed.

Table 1. List of Mexican Official Standards applied to the company's production process.

Table 2. Standards Applicable to Workplace Comfort.			
STANDART	**MEETS**		**OBSERVATIONS**
	YES	**NO**	
NOM-001-STPS-2008 Buildings, premises, installations, and areas in workplaces - Safety conditions.		**X**	There is a need to improve the maintenance of ventilation conditions in cubicles.
NOM-011-STPS-2001 Safety and hygiene conditions in workplaces where noise is generated.		**X**	Classrooms and offices have semi-controlled noise levels.
NOM-017-STPS-2008 Personal protective equipment - Selection, use, and management in workplaces.		**X**	Only a few personnel have ergonomic chairs.
NOM-019-STPS-2011 Establishment, integration, organization, and operation of safety and hygiene committees.		**X**	The health and safety commission, which oversees working conditions, should have more training.
NOM-025-STPS-2008 Workplace lighting conditions.	**X**		They have good lighting.
NOM-026-STPS-2008 Safety and hygiene colors and signs, and risk identification.		**X**	There are clear signs in the work areas to avoid accidents.
NOM-030-STPS-2009 Occupational safety and health preventive services - Functions and activities.	**X**		Teachers have access to health services and wellness programs.
NOM-035-STPS-2018 Psychosocial risk factors at work - Identification, analysis, and prevention.		**X**	Teachers present stress and workload.

Table 2. List of applied Ergonomic Principles

Applied Ergonomic Principles

Principle	Observations
Principle 2: Use elbow height as a reference.	Workstations should allow teachers to write and use their tools without straining their posture.
Principle 4: Find the correct posture for each task.	Assess whether teachers have adjustable chairs and ergonomic desks.
Principle 6: Minimize fatigue.	Implement active breaks and check for class overload that causes excessive fatigue.
Principle 7: Minimize direct pressure.	Check if teachers have adequate surfaces to support themselves and avoid strain on wrists and arms.
Principle 8: Adjust and change posture.	Facilitate teachers to alternate between sitting and standing to improve circulation.
Principle 9: Provide adequate space and access.	Ensure that classrooms and offices have sufficient space for unobstructed movement.
Principle 12: Improve work organization.	Evaluate whether there is an efficient distribution of time and whether work tools are organized to reduce unnecessary effort.

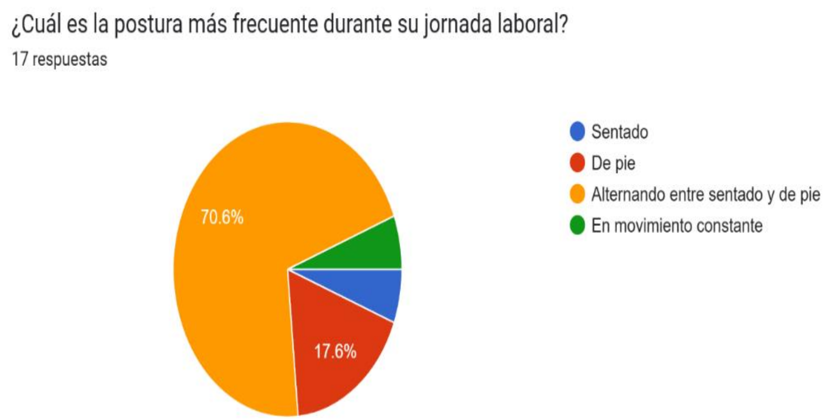


Figure 1 Teachers' working postures

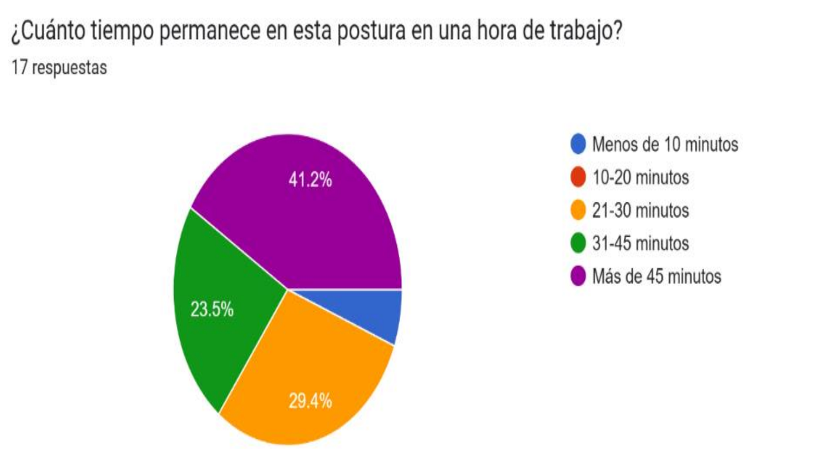


Figure 2 Exposure time in that position

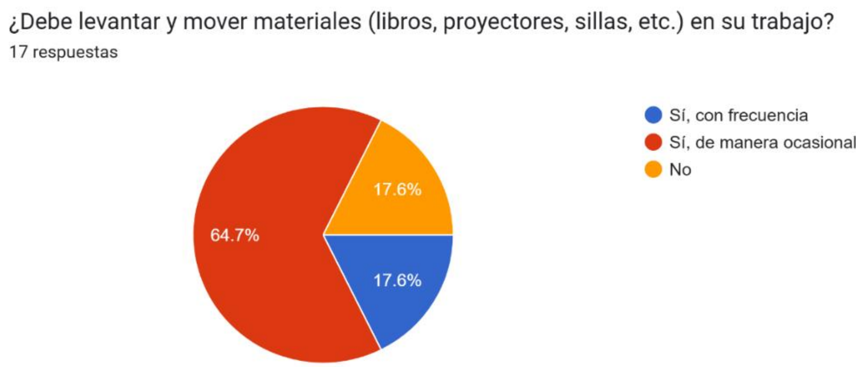


Figure 3 Lifting of materials during the day

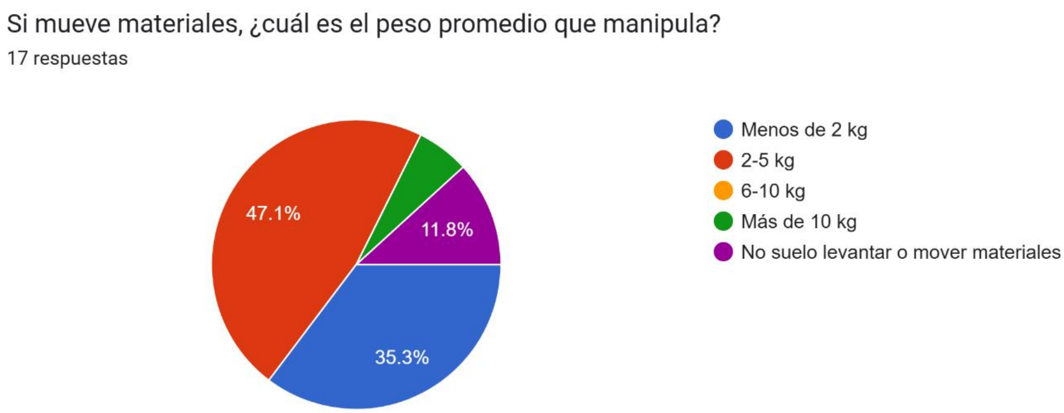


Figure 4 Weight of the materials lifted during the day

The results of the survey of 17 teaching staff reveal that the majority of respondents (64.7%) have more than 10 years of work experience and a weekly workload of more than 30 hours (64.7%).

Regarding posture during the workday, it was found that the majority of respondents (70.6%) alternate between sitting and standing, and that 41.2% of them remain in this position for more than 45 minutes. Furthermore, it was found that 88.2% of respondents must constantly travel to other classrooms or buildings, traveling distances of up to 500 meters or more (23.5%).

Regarding environmental conditions, it was found that 70.6% of respondents consider the ventilation in their work area to be adequate, while 58.8% consider the temperature to be comfortable. However, 29.4% of respondents considered the lighting in their work area to be inadequate.

Regarding physical load, it was found that 64.7% of respondents must occasionally lift heavy objects, and that 47.1% of them handle objects weighing 2-5 kg. Additionally, it was found that 70.6% of respondents considered that noise in their work area occasionally interferes with their teaching work.

6. CONCLUSIONS

This research identified the ergonomic factors affecting teachers at the Technological Institute. The characteristics of their work were identified, as well as the physical, environmental, and organizational factors involved in each of their activities. Based on the survey, it was determined that classroom activities, which average 45 to 50 minutes in length, cause circulation problems and physical fatigue due to the constant movement between buildings and the carrying of materials. Under ambient conditions, the temperature is adequate, but the underlying problem is the lighting in the work area. An analysis of standard 025-STPS-2008 is suggested.

Overall, the results suggest the importance of implementing ergonomic measures to improve the health and well-being of teachers, such as reducing physical workload and noise, and improving autonomy and control over their work.

7. RECOMENDATIONS

Implement measures to reduce physical strain and noise in the workplace, improve teachers' autonomy and control over their work, provide training and resources to improve teachers' health and well-being, and conduct regular assessments of the work environment to identify areas for improvement.

8. REFERENCES

Estrés laboral y su relación con el desempeño académico: ¿puede la NOM-035 aplicarse en instituciones educativas? (2024, noviembre 10). NOM-035-STPS-MX. Recuperado de https://nom-035-stps-mx.com/articulos/articulo-estres-laboral-y-su-relacion-con-el-desempeno-academico-puede-la-nom035-aplicarse-en-instituciones-educativas-186515

Método LEST: González, P., & Fernández, R. (2005). *Método LEST: Un enfoque para la evaluación de factores de riesgo psicosocial en el trabajo*. Revista Mexicana de Psicología, 22(1), 45-56. https://doi.org/10.xxxx/xxxxxx (Si esta fuente es de un artículo académico, asegúrate de sustituir el DOI o URL correspondiente)

Muñoz Hernández, R., González Martínez, C. V., Martínez Benítez, M. N., Sánchez García, H. E., Medina Torres, D., & Cruz Gómez, J. J. (2021). Perspectivas y retos de la NOM-035-STPS-2018 para la atención de factores de riesgo psicosocial en el sector educativo. Revista de Ciencias Sociales, 27(2), 45-60. Recuperado de https://www.scielo.org.mx/scielo.php?pid=S2448-63882021000200048&script=sci_arttext

NORMA Oficial Mexicana NOM-001-STPS-2008, Edificios, locales, instalaciones y áreas en los centros de trabajo-Condiciones de seguridad. (2007, 13 noviembre). Diario Oficial de la Federación. https://www.dof.gob.mx/normasOficiales/3540/stps/stps.htm

NORMA Oficial Mexicana NOM-015-STPS-1994, relativa a la exposición laboral de las condiciones térmicas elevadas o abatidas en los centros de trabajo. (1993, 19 julio). Diario Oficial de la Federación. https://dof.gob.mx/nota_detalle.php?codigo=4699279&fecha=30/05/1994#gsc.tab=

Norma Oficial Mexicana NOM-035-STPS-2018: Secretaría del Trabajo y Previsión Social. (2018). *NOM-035-STPS-2018: Factores de riesgo psicosocial en el trabajo-Identificación, análisis y prevención*. Diario Oficial de la Federación. https://www.dof.gob.mx

NORMA Oficial Mexicana NOM-036-1-STPS-2018, Factores de riesgo ergonómico en el Trabajo-Identificación, análisis, prevención y control. Parte 1: Manejo manual de cargas. (2017, 29 noviembre). Diario Oficial de la Federación. https://www.dof.gob.mx/normasOficiales/7468/stps11_C/stps11_C.html

Pérez, L., & Sánchez, M. (2024). Implementación del diagnóstico de factores de riesgo psicosocial basado en la NOM-035-STPS-2018 en instituciones educativas. Revista de Psicología Educativa, 10(3), 123-130. Recuperado de https://dialnet.unirioja.es/descarga/articulo/8567474.pdf

ERGO GAME

Cristian Vinicio López Del Castillo, Marcos Efrén Córdova Medina, Isrrael García Silva, Dinora Monroy Meléndez, Jazmín Argelia Quiñónez Ibarra

Ingeniería Industrial en Productividad y Calidad
Universidad de la Sierra
Carretera Moctezuma-Cumpas
Moctezuma, Sonora

Corresponding author's e-mail: clopez@unisierra.edu.mx

Resumen: El proyecto "ERGO Game" es una herramienta educativa interactiva destinada a enseñar conceptos fundamentales de ergonomía a través de actividades lúdicas. Su objetivo principal es promover la comprensión y aplicación de los principios ergonómicos mediante el uso de juegos de memoria y asociación para mejorar la retención de información. Está dirigido a estudiantes de ergonomía, trabajadores y participantes en programas de formación, para prevenir problemas de salud derivados de malas posturas y uso incorrecto de herramientas, así como para fomentar la cultura de prevención de riesgos laborales y el bienestar personal.

ERGO se basa en los principios de la ergonomía cognitiva, que estudia la relación entre el diseño de entornos y las capacidades cognitivas humanas. Para jugar se utilizan 32 cartas agrupadas en cinco categorías clave: posturas correctas e incorrectas, herramientas ergonómicas y convencionales, consejos prácticos de ergonomía, diseño del puesto de trabajo y trastornos musculoesqueléticos. Las cartas facilitan la comprensión de estos conceptos y ayudan a los jugadores a identificar y recordar prácticas adecuadas.

El juego se puede desarrollar de dos modos: Asociación, en el que los jugadores deben relacionar imágenes con los conceptos de ergonomía correspondientes; y Memoria, en el que los jugadores deben encontrar parejas de cartas iguales, estimulando la memoria visual. Las dos modalidades se pueden jugar de forma individual o cooperativa, y ambas promueven el aprendizaje autónomo y el trabajo en equipo. Además, potencian habilidades cognitivas como la memoria visual, la concentración y el razonamiento lógico, todas ellas esenciales para aplicar de forma eficaz las prácticas ergonómicas, facilitando la comprensión de conceptos clave a la vez que se promueve la salud y el bienestar en diversos entornos.

Palabras Clave: Ergonomía Cognitiva, Seguridad, Entorno Laboral

Relevancia para la Ergonomía: El Juego ERGO promueve significativamente el aprendizaje y la concienciación sobre prácticas ergonómicas a través de un enfoque lúdico e interactivo. Al estar diseñado con base en la ergonomía cognitiva permite que los participantes refuercen conceptos clave como posturas adecuadas, uso de herramientas ergonómicas y prevención de trastornos musculoesqueléticos de una manera accesible y dinámica.

Abstract: The ERGO Game project is an interactive educational tool intended to teach fundamental concepts of ergonomics through playful activities. Its main objective is to promote the understanding and application of ergonomic principles by using memory and association games to enhance information retention. It is aimed at ergonomics students, workers and participants in training programs, to prevent health problems coming up from bad postures and the incorrect use of tools, as well as to foster the culture of occupational risk prevention and personal well-being.

ERGO is based on the principles of cognitive ergonomics, which studies the relationship between the design of environments and human cognitive abilities. 32 cards are used to play the game. They are grouped into five key categories: correct and incorrect postures, ergonomic and conventional tools, practical ergonomics tips, workstation design, and musculoskeletal disorders. The cards facilitate the understanding of these concepts and help players identify and remember appropriate practices.

The game can be played in two modes: Association, on which players match pictures with the corresponding ergonomics concepts; and Memory, on which players must find matching pairs of cards, stimulating visual memory. The two modes can be played individually or cooperatively, and both promote autonomous learning and teamwork. They also enhance cognitive skills such as visual memory, concentration, and logical reasoning, all essential to effectively apply ergonomic practices, facilitating the understanding of key concepts while promoting health and well-being in various environments.

Keywords: Cognitive Ergonomics, Safety, Work Environment

Relevance to Ergonomics: The ERGO Game significantly promotes learning and awareness of ergonomic practices through a playful and interactive approach. Once its design is based on cognitive ergonomics, it allows participants to reinforce key concepts such as adequate postures, use of ergonomic tools, and prevention of musculoskeletal disorders, in an accessible and dynamic way.

1. INTRODUCTION

Within the field of ergonomics, educating about adequate practices and postures is essential to prevent health problems related to inadequate postures and the use of incorrect tools in different environments. The project of the ERGO game emerges as an interactive and educational tool, designed to promote the learning of ergonomic concepts in a playful way; combining memory and association activities to enhance the retention of information.

Aimed primarily at students of ergonomics, workers who are interested in improving their knowledge of ergonomic practices, and participants in training programs, the ERGO game seeks to facilitate the understanding of key concepts in ergonomics and their application both in daily life and in the work environment. Through its two game modes (Association and Memory) ERGO promotes the learning of ergonomics in an attractive way. In the "Association" mode, players must relate different cards with ergonomic concepts, which reinforces their ability to

analyze and connect logically. In the "Memory" mode, players look for pairs of cards, thus training their cognitive abilities related to ergonomics.
Overall, ERGO is not only an educational game but also an instrument that seeks to effectively develop the culture of prevention and safety in the workplace and in the personal sphere, while it highlights the importance of ergonomics as a key factor for people's health and well-being.

2. GENERAL OBJECTIVE

To promote the understanding, application and awareness of the principles of cognitive ergonomics to improve health, well-being and efficiency in daily life activities and the ones at work through an interactive educational tool.

2.1 Specific objectives

• To promote the learning of ergonomic concepts through recreational activities that reinforce their application in daily life activities and the ones at work.

• To raise awareness on the importance of maintaining adequate postures and using ergonomic tools to prevent injuries and to improve quality of life.

• To provide practical ergonomic advice and strategies that can be applied immediately to optimize comfort and productivity.

• To develop cognitive skills such as visual memory and selective attention through interactive games, facilitating the permanency of good ergonomic practices.

3. DELIMITATION

The "ERGO Game" is specially designed for students and professionals willing to deepen into the field of ergonomics. Its target audiences are:

• Students who are being trained in topics related to ergonomics and who wish to learn in a practical and fun way the essential concepts that they can later apply them in their professional activities and on daily life activities.

• Workers in various industries who are interested in improving their knowledge of ergonomic practices to reduce injury risks, to improve their well-being in the labor environment and to promote a culture of health and prevention in the workplace.

• It can also be used in professional training environments. i.e. workshops and others where collaborative learning is fostered and where good ergonomic practices are reinforced in an interactive and dynamic way.

This approach allows both those who are in the learning phase and those who seek to improve their work environment to benefit from the game, while they also obtain a solid understanding of the importance of ergonomics.

4. METHODOLOGY

Description of the game cards:

There are 32 cards, grouped into five categories:

1. Correct and incorrect postures: The cards show visual examples of how to stay in adequate postures and how to avoid harmful postures.

2. Ergonomic and conventional tools: These cards help to identify and make comparisons between ergonomically designed tools and conventional tools.

3. Ergonomic advice with visual examples: These cards provide practical advice on how to improve everyday life by applying ergonomics. Some cards include images along with a text.

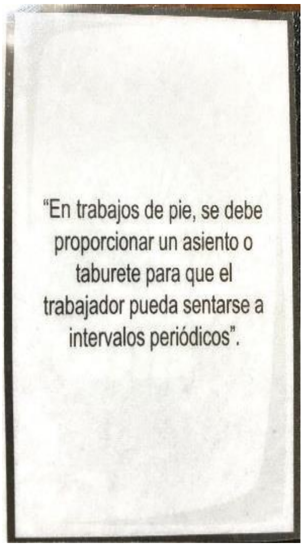
4. Design of workstations, illumination, and noise.

5. Musculoskeletal disorders.

Each type of card is designed to address a specific aspect of ergonomics, helping the players identify and remember as many good practices as possible, as well as the inadequate actions to be avoided in their daily life activities and the ones at the workplace.

Inducer Cards:

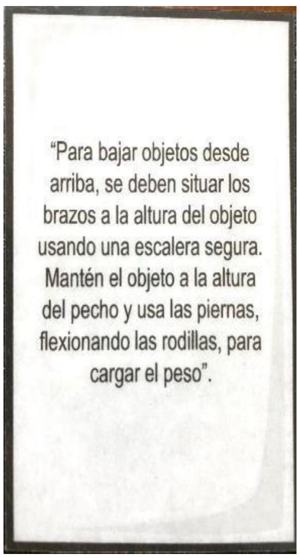
Answer cards:


"En trabajos de pie, se debe proporcionar un asiento o taburete para que el trabajador pueda sentarse a intervalos periódicos".


"Realizar la actividad en posición sentada, si es viable, o utilizar un apoya-pie alternando el pie de apoyo".


"El túnel carpiano es un canal en la muñeca que protege al nervio mediano; su compresión provoca dolor, entumecimiento y debilidad en la mano. Mantén una postura neutra de la muñeca al trabajar y realiza pausas frecuentes para estiramientos, reduciendo la tensión en la zona ".


"Evitar tener deslumbramientos molestos y situar las lámparas fuera del campo visual del trabajador".

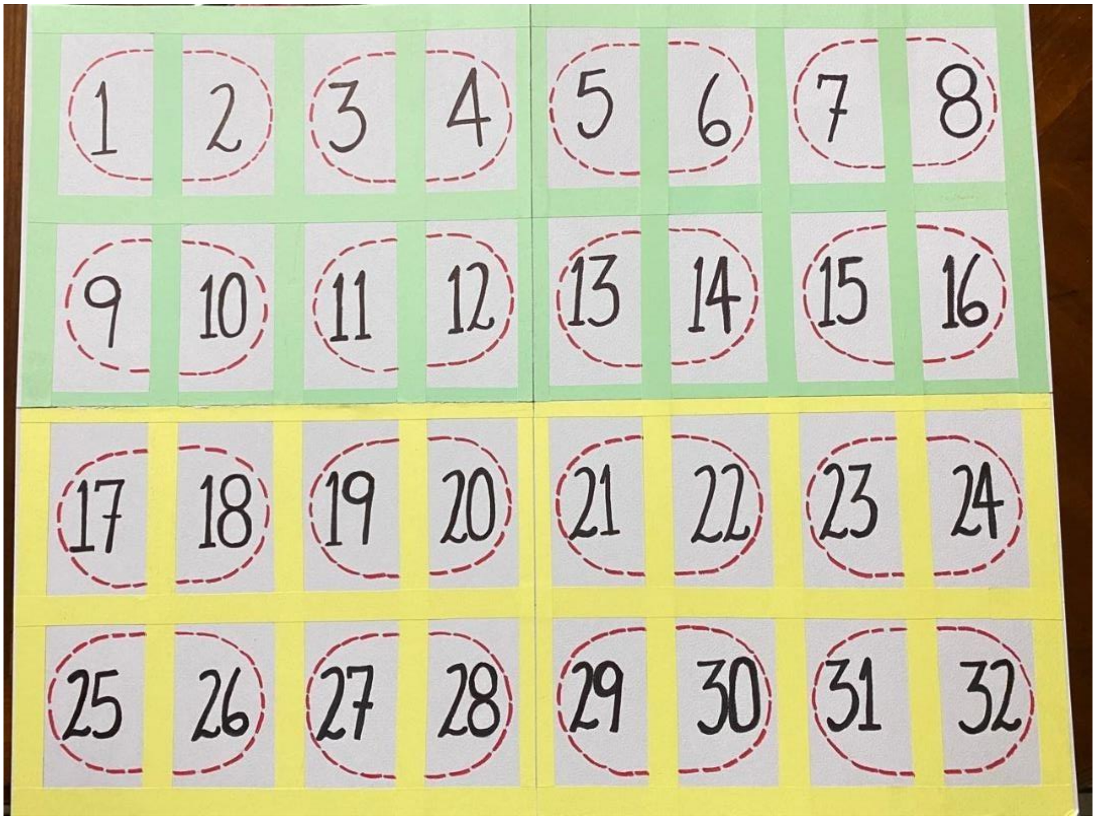

"Para bajar objetos desde arriba, se deben situar los brazos a la altura del objeto usando una escalera segura. Mantén el objeto a la altura del pecho y usa las piernas, flexionando las rodillas, para cargar el peso".


"Alicate ergonómico. Diseñado para ajustarse cómodamente a la mano, reduciendo la tensión y aumentando la eficiencia".


"Mantén la espalda correctamente, ayudan los resortes para levantar cargas, inclinaciones hidráulicas o lados removibles".


"Mantén la espalda recta y apoyada; la pantalla debe de estar a la altura de la vista".

Game board: numbered from 1 to 32, and divided in two colored sections (green and yellow).



Mode 1: Association Game

1. Game structure:
Inducer cards are placed in the odd numbers of the board game; answer cards are distributed among players.

2. Way of playing:
Players take turns. Each player places an answer card on the even number next to the inducer card that he/she thinks it is associated with and then explains why they are associated. This encourages logical reasoning, the ability to make connections, and the practice of oral argumentation.

Mode 1 variables and considerations:
• A volunteer playing as a referee determines whether every association is or isn't correct before moving on.
• If a player associates an answer card incorrectly, the card is taken back to his/her deck and the turn passes to the next player, to ensure dynamism.
• If both players associate all of their cards correctly in the same number of attempts, the result is considered a tie.

The first player who runs out of cards -when there's not a possibility for a tie- is the winner.

Mode 2: Memory Game

1. Game structure:
Inducer cards are placed face down on the top of the game board (green section) and answer cards are placed face down on the bottom (yellow section). This game mode has a focus on visual memory.

2. Way of playing:
Players take turns to flip up an inducer card and an answer card trying to get two cards that are associated. If they are, the player takes them and starts making his/her cards deck.

Mode 2 variables and considerations:
• When a player flips up two cards that don't match, the cards are faced down again, and then it's another player's turn. Once he/she and the rest of players see the unmatched cards and memorize their position, every one -on its turn- can later try to flip up two associated cards, and take them into his/her deck.
• When there are no cards left on the game board, the player with the most cards wins.

Mode 2 variants:
• This mode allows 2 to 4 players:.

- Individual game (two players): Every player tries to beat the opponent by getting the most of the cards.
- Cooperative game (two or more teams): Players work together to match most of the cards, with the goal of completing the game as quickly as possible. This encourages discussion and collaborative learning about ergonomics.

5. RESULTS

Cognitive ergonomics is the branch of ergonomics that studies and applies knowledge in basic psychology to the design of work environments, tasks, systems, etc. In other words: it is about adapting objects, spaces, systems and even work schedules to the natural operating of the person's cognitive abilities to enhance them and prevent them from their deterioration.
Basic psychological processes such as perception, attention or memory are directly conditioned and related to the "ERGO game".

The benefits of the "ERGO Game" related to cognitive ergonomics are mentioned below:
• **Visual memory training**: The practice of memorizing positions and remembering pairs of cards reinforces visual memory and selective attention.
• **Encouraging concentration**: The need to remember where the cards are, increases the players' ability to pay attention and concentrate.
• **Development of reasoning**: By justifying the association of cards, players practice articulating their thoughts, get to think more critically and develop argumentative oral expression.
• **Improved social skills**: Taking turns speaking and listening to others promotes communication and interaction between players.

General considerations:

Playful learning: Both game modes are examples of how learning can be fun and engaging. They facilitate the acquisition of knowledge through playful interaction, which is essential to maintain interest in learning.
Comprehensive cognitive development: The combination of association skills, logical reasoning, visual memory and oral argumentation, contributes to comprehensive cognitive development, preparing learners for future academic challenges.

6. CONCLUSION

In conclusion, the "ERGO Game" is presented as an innovative and effective tool to teach key ergonomics concepts in an interactive and fun way. Its design is aimed at strengthening cognitive skills such as visual memory and logical reasoning, allowing participants to learn while they are enjoying a playful experience. Through dynamic activities, participants not only acquire theoretical knowledge, but also internalize it through practice, reinforcing their understanding and their application into real contexts. Both game modes -Association and Memory- are designed to stimulate critical skills, such as the ability to make logical connections and the ability of recalling information from visual memorization.
The "ERGO Game" effectively combines cognitive learning and ergonomic practice, achieving a balance between education and entertainment.

7. REFERENCES

(November 25, 2022). Visibility On Agency. Cognitive ergonomics: what it is, what it is for. Eleva. https://elevadesk.com/blogs/ergonomia-en-el-trabajo/ergonomiacognitiva-que-es-para-que-sirve

Miguel, L. (May 3, 2023). What is cognitive ergonomics? Some examples | INESEM. Education and Society Channel. https://www.inesem.es/revistadigital/educacion-sociedad/ergonomia-cognitiva/

EVALUATION OF ERGONOMIC RISKS IN A MEDICAL PRODUCTION AREA

Guadalupe Hernández-Escobedo, Orcid: https://orcid.org/0000-0002-7516-972X**; Jose Fermin Cauich-Figueroa; Arturo Realyvázquez-Vargas, Orcid:** https://orcid.org/0000-0003-2825-2595**; Amalia Carmina Salinas-Hernandez**; **Samuel Alvarado-Nangüelu**

Departmento de Ingeniería Industrial
Tecnológico Nacional de México/Instituto Tecnológico de Tijuana
Calzada Tecnológico S/N
Fraccionamiento Tomás Aquino
Tijuana, Baja California 22414

Corresponding author's e-mail: ghernan@tectijuana.mx

Resumen: El proyecto tiene como objetivo la evaluación ergonómica para implementar un programa de atención y seguimiento de enfermedades laborales, las cuales están expuestas los colaboradores que trabajan en determinadas áreas de manufactura. La naturaleza artesanal de los procesos en dichas áreas expone a los trabajadores a movimientos repetitivos y largos ciclos de trabajo, aumentando el riesgo de enfermedades laborales relacionadas con la ergonomía y consideradas con alto riesgo ergonómico. La ausencia de diagnósticos, evaluaciones y atenciones adecuadas podría resultar en enfermedades laborales y altos costos y gastos para la empresa. Para abordar dichos riesgos, el proyecto se enfoca en implementar medidas preventivas y correctivas, así como establecer un sistema integral de monitoreo para garantizar la salud y seguridad de los trabajadores. Se utiliza el método OCRA para evaluar de manera específica el riesgo ergonómico, aplicando acciones dirigidas a minimizar estos riesgos y proteger la salud a largo plazo de los colaboradores, dado que los trastornos musculoesqueléticos pueden tener efectos irreversibles en estos. El resultado de todas las acciones emprendidas, fueron visualizadas en la reducción de los riesgos ergonómicos de tal forma que, el indicador usado para ello, fue visiblemente reducido.

Palabras clave: Evaluación de riesgos ergonómicos, industria médica, área de producción, técnicas ergonómicas

Relevancia para la ergonomía: El presente proyecto sirvió para mejorar las condiciones laborales de las y los colaboradores de una empresa médica, particularmente en un proceso que se lleva a cabo de forma artesanal. Se siguió una metodología que tuvo como objetivo la disminución de los riesgos de índole ergonómico. Para ello, se realizaron evaluaciones ergonómicas que permitieron descubrir aquellas áreas de mejora y que, mediante la implementación de mejoras desde la perspectiva ingenieril, cognitiva y organizacional, se redujeron y/o eliminaron los riesgos ergonómicos. Esto ayudó a visualizar la importancia de resolver problemas de las empresas utilizando el enfoque ergonómico, además de las consideraciones legales en su aplicación de ésta. Particularmente, la industria médica debería ser la principal industria que utiliza este enfoque en la resolución de problemáticas que tienen las y los colaboradores a consecuencia del trabajo.

Abstract: The project aims to carry out an ergonomic assessment to implement a program of attention and monitoring of the occupational diseases, to which employees working in certain manufacturing areas are exposed. The artisanal nature of the processes in these areas exposes workers to repetitive movements and long work cycles, increasing the risk of occupational diseases related to ergonomics and considered to have a high ergonomic risk. The absence of adequate diagnosis, evaluation and care could result in occupational diseases and high costs and expenses for the company. To address these risks, the project focuses on implementing preventive and corrective measures, as well as, establishing a comprehensive monitoring system to guarantee the health and safety of workers. The OCRA method was used to specifically assess ergonomic risk, applying actions aimed to minimize these risks and to protect the long-term health of employees, given that musculoskeletal disorders can have irreversible effects on them. The result of all the actions undertaken was seen in the reduction of ergonomic risks in such a way that the indicator used for this was visibly reduced.

Keywords. Evaluation of ergonomic risks, medical industry, production area, ergonomic techniques.

Relevance to Ergonomics: This project served to improve the working conditions of the collaborators of a medical company, particularly in a process that is carried out in an artisanal manner. A methodology was followed that aimed to reduce those ergonomic risks. To do so, ergonomic assessments were carried out, that allowed the discovery of those areas of improvement, and, through the implementation of improvements from the engineering, cognitive and organizational perspective, ergonomic risks were reduced and/or eliminated. This helped to visualize the importance of solving company problems using the ergonomic approach, in addition to, the legal considerations in its application. Particularly, the medical industry should be the main industry which uses this approach in the resolution of problems, that collaborators have as a result of work.

1. INTRODUCTION

This research is focused on the evaluation and improvement of ergonomic conditions in manufacturing areas, especially in the production of heart valves within a medical company. Given the highly manual and artisanal nature of the production processes, significant ergonomic risks have been identified that potentially affect the health and well-being of employees, thus increasing, in the same way, the incidence of musculoskeletal diseases and generating costs and expenses for the company in this area. Among the actions carried out was the implementation of a comprehensive ergonomic assessment program to identify and correct the risks associated with manufacturing processes. The absence of adequate preventive measures not only endangers the health of employees, but also negatively impacts productivity and the company's operating costs.

Through the application of the OCRA method, it was intended to evaluate ergonomic risks in detail and thus develop a monitoring system, that allowed the implementation of effective corrective measures. Therefore, the project addressed specific ergonomic challenges faced in the area of fabric sewing, where key risk factors were identified and solutions were proposed for their mitigation. In addition, the economic impact was analyzed through work-related disabilities, suggesting strategies to optimize medical surveillance programs and to reduce associated costs and expenses. This comprehensive approach sought to protect the health of employees and improve efficiency and quality in manufacturing operations.

Currently, the company has grown exponentially in its operations in the cardiovascular sewing area, the area of interest, which has a process that is considered 90% artisanal, that increases the probability of having disabilities or work accidents in the collaborators, who work in this area. Due to this constant growth, it has as a consequence not adequately controlling ergonomic risks, with a high rate of undetected cases or of those detected, they are not given a timely and punctual follow-up, increasing the number of disabilities of the collaborators. That is, the exposure of the collaborators to physical risks, repetitive movements and forced postures during the sewing-knitting production process can potentially cause significant health problems, especially as musculoskeletal disorders due to the nature of the operations. It is crucial that the department has in-depth knowledge of the operations and work areas of the staff in order to develop actions to reduce ergonomic risks and to improve the work stations and the work environment. Therefore, it is imperative to analyze ergonomic risks and apply preventive measures to reduce or eliminate them. To achieve this, the legal reference is the NOM-036-STPS-2015 standard, “Ergonomic risk factors - Identification, prevention and monitoring” (STPS, 2018), which addresses the risk factors associated with ergonomic elements, furniture and facilities in companies. Therefore, the objective set out in the project was to evaluate ergonomic risks in heart valve operations through the use of ergonomic techniques in order to reduce illnesses and injuries in employees.

The participating company is a medical device manufacturing company made up of three business units; one of which, an area of interest in the research, makes heart valves from fabric and animal tissues, a process in which 90% of its activities are carried out by hand. This process has physical demands on employees and ergonomic risk factors are correlated to these demands. Likewise, these contribute significantly and have a high impact on the health of employees. In addition, the lack of adherence and follow-up in medical surveillance programs has increased disabilities, affecting the health of employees, showing these bodily limitations to carry out daily activities, or conditioned to certain work activities. Consequently, the economic impact has been quantified at approximately six million pesos during 2024 and projecting risk premium payments that will be around three million pesos during 2025.

Likewise, additional impacts have been found that can be seen in the personal and professional development of employees and in the company. For example, on the part of employees, the deterioration of the quality of life as a result of these risks. These can affect, for example, the health and physical well-being of the work environment, observed through muscle tension, pain in the neck, back and joints and problems in the spine, consequently due to the adoption of bad postures, repetitive movements and the use of inadequate chairs, among others. In addition, on the part of companies, the consequences can be seen in the repercussions of increased costs, decreased productivity, increased legal obligations, among others (Bestraten et al, 2008).

In general, to detect ergonomic risks, the frequency of musculoskeletal injuries of workers was examined and, to do so, the health of employees was monitored before, during, and after the project. Personal interviews were conducted with those who were identified with injuries and the risks of the activities carried out in the workplace were assessed, thus generating histories for follow-up. Here, it was discovered that the heart valve production area was the one that showed the highest number of cases. Therefore, the risk areas were evaluated considering various parts of the body, establishing potential limitations to mentioned motor capacities through frequent exposures. Likewise, the historically presented incidents were analyzed to locate the work areas with the highest incidence of them. This was done to find the work area with the highest incidence, discovering that one area in particular exhibited the highest number of cases. Subsequently, the OCRA method was used to discover the potential ergonomic risks, using video technologies. These activities were carried out with the consent of the collaborators, who participated, and the information obtained was handled confidentially and considering ethical aspects. The analysis activities considered the work day, and its elements, among which are scheduled breaks, meal times and effective work times performing the process operations. In this way, work cycles, and the distribution of time during the working day were established, carefully observing the risks found in these.

2. BACKGROUND

In this section, information behavior, information sources, databases, user productivity, usability and errors are presented.

2.1 Ergonomic Risks

A risk factor is a work condition that increases the probability, that the employee will receive harm from commented condition. These factors can be classified as: ergonomic, environmental, psychosocial and social, microclimate, physical, technological, and safety. To determine the importance of the risk, three factors are considered: intensity, frequency and exposure time. Therefore, intensity is understood as the magnitude of the effort, movement, or posture exerted and frequency as the number of times the risk is repeated in a given time. The exposure time is allowed for depending on the analysis to be carried out; the exposure time can be taken per work cycle, that is, the actions that the worker repeats in a given time, or the time of the work day can be taken. On the other hand, risk factors at work can be ergonomic, environmental, and safety. Ergonomic risk factors are the physical and mental demands, that the task imposes on the worker, increasing the probability of suffering harm (Méndez González, 2020). Among the most common are forced postures, manual handling of loads and repetitive movements.

2.2 Ergonomic Analysis

Ergonomic assessment techniques are methods that help to analyze whether a job or task may represent a risk for the employee, potentially causing a health disorder, commonly musculoskeletal (Giral Nieto, Serrano García and Moreno Sánchez, 2021). There are various studies that evaluate the presence of risk factor levels, and depending on the method, the risk level can be found. These methods can also be represented in the form of a table to be filled out manually, or they can be found on digital internet platforms with a better developed environment, such as the "Ergonautas" page, which was used in this project. Likewise, different institutions such as the University of Biomechanics of Valencia have designed their own software in which these methods are considered, adding certain modifications, and in turn generating ergonomic assessment reports. In general, there are two levels of analysis, one that is implemented to identify the risks, and one in which the ergonomic risk factors previously detected are evaluated. That is, a preventive analysis and a corrective one. It is extremely important to emphasize that, in reality, the job is not evaluated, what is evaluated is the ergonomic risk present in the job (Diego-Mas, 2016).

2.3 Occupational Repetitive Action (OCRA)

The OCRA method has been established as the preferred method for risk assessment due to repetitive movements in the upper extremities. Its use is recommended by the ISO 11228-3 and EN 1005-5 standards. It is a complete method that involves several aspects to consider, such as: repetitiveness, forced postures, whether dynamic or static, forces, forced movements, recovery times, exposure to cold, vibrations and work rhythms. All of this is taken into consideration to have an accurate assessment of the risk index, which is being presented in the task (Ministerio de Protección Social, 2011). This large number of aspects that are considered make the method very elaborate but extensive, which is why, in order to carry out assessments more quickly, the OCRA Check-List method emerged, which is a simplified form of the OCRA method (Diego-Mas, 2016).

3. METHODOLOGY

For the development of the project, the methodology used consisted of the following primary activities in the search for the expected results, which are:

1. Macro-ergonomic mapping.

All areas were assessed to determine the degrees of risk affecting various parts of the employees' bodies, including the right hand, left hand, neck, right arm/shoulder, left arm/shoulder, trunk, vision, left wrist, right wrist, right foot, and left foot (Diego-Mas, 2016). These areas were assessed due to their critical importance in most manufacturing processes, as any damage to these regions could limit the ability of workers to perform their functions.

2. Documentary study.
In this phase, an analysis was carried out of the incidents presented in the medical service regarding the incidences of musculoskeletal diseases of occupational origin, in which it can be determined and the areas of greatest impact are the sewing areas. The results on ergonomic and general diseases illustrate the behavior of these ergonomic diseases on site, visually identifying within the building where these activities are carried out. Here, the areas that represent the greatest impact due to ergonomic issues in the collaborators located in mentioned building are determined. In addition, it is reflected in the macro ergonomic analysis and therefore, these are the ones that will be specifically evaluated to seek actions that favor risk reduction.

3. Ergonomic analysis.
In this phase, the focus was mainly on performing ergonomic analyses through the applicable methodologies, determining with the data from this research and with the help of the diagram for ergonomic risk assessments, it was determined to perform the analysis with the OCRA method. This was when determining the ergonomic risks in a job, it was necessary to evaluate all those risks, that may affect the worker whether or not they are in their position (Gadea, Sevilla and García, 2011). To perform this evaluation with the indicated method, it was necessary to record videos of the operations and analyze them. In these analyses, the technical actions or activities that are performed in sewing and the number of times each one occurs, as well as the time it takes for each one of them were obtained. All of this data was entered into the software along with the exact distribution of the work day. These include breaks, meal times and time spent sewing. It is important to mention that the distribution of these times must be as close to reality as possible since it would affect the potential results.

4. Implementation of improvements.
Through the results obtained from the ergonomic evaluations, the number of repetitive movements, that were reduced was determined, and, in order not to impact the product, this was done through temporary stitches. These changes were made in collaboration with the Engineering and Quality Teams, as they were directly involved in the process. Here, the proposed actions of changes in the process could affect the risks detected and, in this way, it was expected to reduce illnesses or injuries due to ergonomic factors. Likewise, for the development of a functional workstation from this perspective, it was crucial to have anthropometric studies of the collaborators. These studies provided statistical information on the anthropometric measurements of the collaborators, thus, allowing the design of a workstation that would fit their individual physical needs. This was despite to make

changes to the work tables by using a servomotor on each table to automatically adjust its height according to the needs of the collaborators. Another consideration was to add curvatures to the front of the tables to allow the worker to approach the microscope without having to bend the neck excessively forward. In addition, this curvature benefited people of robust build by facilitating the entry and comfortable support of their arms, something complex on tables with straight edges. On the sides, on the other hand, a flange was included to prevent the components from protruding from the work area and a slope was added to the back of the table to provide adequate support and thus facilitate anchoring the microscope.

5. Ergonomic improvement analysis.
The greatest ergonomic risk detected is repetitiveness and cycle times, which is why the OCRA evaluation method was determined, since it helped to measure these risks in detail, and thus understand the risks in detail, and in a quantitative manner. In this way, various ergonomic evaluations were carried out at the beginning to contribute to the understanding of the risks present, and consequently, to propose actions with greater impact to seek their reduction. To verify the effectiveness of the proposed and implemented changes, ergonomic exit evaluations were carried out where collaborators can measure the reduction achieved, the proposed changes obtaining the following result, and numerically verifying the effectiveness of what was done.

4. RESULTS

As a result of the methodology used, it was found that certain operations showed a high risk, ranging from 19.95 to 13.48 points on the risk measurement scale. For this reason, mitigation and risk reduction actions were developed, focusing mainly on two areas. The first was on engineering or impact controls on the process, and the determination of infrastructure and process requirements. The second was focused on employees, and support activities in their work day in reference and considering the origin of ergonomic risks before, during, and after their exposure. In particular, a comprehensive behavioral program was developed for the structured, and sustained reduction of ergonomic risks, and focused on changing the habits of employees.

During the development of the project, it was found that mitigation and reduction actions should focus on two main points: engineering or process impact controls, and the determination of requirements for infrastructure, and processes, as well as the structuring of the control process for collaborators with ergonomic problems, before, during, and after being exposed to the risk. With all this, a comprehensive program was obtained focused on the reduction of commented ergonomic factors in a structured, and sustainable manner. Although the greatest impact on risk reduction occurs directly in the process, the other two topics significantly favor the impact on collaborators, which goes beyond their job responsibilities.

Regarding engineering controls, and their impact on the process, this was determined based on the reduction of repetitive movements through the change of work method, which included temporary stitches in the product. Regarding the determination of ergonomic requirements for infrastructure, changes were made in the work stations considering the physical limitations of the collaborators. The activity focused on the redesign of workstations that consider the physical differences of the collaborators when performing their activities. For example, the tables contemplated the use of technical attachments, that allowed the change of height in direct relation to the height of the collaborator using mentioned table. Another example is the elimination of straight lines in the tables, in such a way, that they allowed the approach of collaborators with different physical builds, allowing, at the same time, the anchoring of a work tool such as the microscope. The following table shows the results obtained, particularly to exhibit the difference between before, and after the improvements were implemented.

	ACTUAL				CON MEJORAS			
	RIGHT		LEFT		RIGHT		LEFT	
HARMONY	19.95	Risk	13.48	Risk	19.95	Risk	13.48	Risk
COREVALVE	16.90	Risk	14.03	Risk	16.90	Risk	14.02	Risk
AORTICO	34.20	Risk	5.98	Risk	14.26	Risk	2.49	Very low risk
EVOLUT	99.13	Risk	10.00	Risk	41.28	Risk	4.17	low risk
AVALUS	114.82	Risk	6.64	Risk	47.73	Risk	2.77	Very low risk

Imagen 5.1: Final results of the evaluation after the improvements **Fuente:** Direct

On the other hand, regarding the management of employee behavior, various activities were carried out. These included: warm-up exercises prior to entering the work station; active breaks throughout the work day focusing on guided activities to exercise the mind and body in the hope of relaxing muscles and reducing musculoskeletal fatigue during the work day; effective breaks that, in addition to the previous activity, were considered based on the assessment of the well-being of employees, and the expected productivity to maintain an efficient and continuous work flow; and finally, various activities were developed aimed at ensuring the follow-up of each of the activities mentioned above. This was to promote a culture of prevention, and to respond appropriately to those situations, that may potentially arise without losing operational continuity, and thus hoping to strengthen organizational resilience in the work environment.

5. CONCLUSIONS

The greatest ergonomic risk detected was repetitiveness and cycle times, which is why it was determined that the OCRA evaluation method was the appropriate one to measure the ergonomic risks implicit in the process. Therefore, ergonomic evaluations were carried out, understanding in detail, and in a quantitative way the initial conditions in mentioned processes. This served as a basis for proposing, and carrying out actions aimed at reducing ergonomic risks. These actions were directed at the work method, and physical changes in the work stations, on the one hand; and at the change in the behavior of the collaborators, on the other. Subsequently, ergonomic evaluations were carried out to measure the impact of commented actions, and thus verify and measure the results obtained.

Therefore, it was verified that the impact was positive, demonstrating the effectiveness of the actions carried out. This was done through the verification of the ergonomic risks implicit in the manufacturing process, finding that they were of low or null impact. In this way, preventive, corrective, and reactive plans were also established for potential situations that could create ergonomic risks in future manufacturing processes, since the products are constantly being redesigned considering new work methods and technologies. For this reason, it was also established, that the collaborators are the most valuable element in the manufacturing processes in the participating company, so it was recommended to follow in detail the recommendations, protocols, and proposals that have as their objective the physical, and mental health of the collaborators as a means to achieve organizational objectives. This is considering the physical, and mental skills, and limitations of the collaborators within an adequate work environment where the observed problems are addressed.

6. ACKNOWLEDGMENTS

We would like to acknowledge to the TecNM/Instituto Tecnológico de Tijuana for funding the study. We would also like to thank to the participants and their organization for contributing with this study. The interpretations and views in this paper, however, are solely those of the authors.

7. REFERENCES

Bestraten, M.; A. Hernández, P. Mendaza, & Silvia Nogareda (2008). Ergonomía (5ta ed.). Instituto Nacional de Seguridad e Higiene en el Trabajo, Torrelaguna, 73 – 28027 Madrid. Recuperado (17/05/24) en: https://www.insst.es/documents/94886/710902/Ergonom%C3%ADa++A%C3%B1o+2008.pdf/18f89681-e667-4d15-b7a5-82892b15e1fa

Diego-Mas, J. A. (2016). ¿Cómo evaluar un puesto de trabajo? Ergonautas Universidad Politécnica de Valencia. Recuperado (18/05/24) en: http://www.ergonautas.upv.es/art-tech/evaluacion/evaluacion.htm

Específica, P. D. V. S. (2000). Posturas Forzadas. Comisión de Salud Pública. Consejo Interterritorial del Sistema Nacional de Salud. Recuperado (17/05/24) en:

https://www.agefec.org/Almacen/protocolos%20y%20programas/manipulacion%20de%20cargas%20posturas.pdf

Gadea, R., Sevilla, M., & García, A. (2011). Engopar (5ta ed.). Madrid, España: Paralelo Edición SA. Recuperado (18/05/24) en: http://ergopar.istas.net/ficheros/documentos/Manual_del_metodo_ERGOPAR_completo.pdf

Giral Nieto, A. P., Serrano García, M. L., & Moreno Sánchez, Y. Y. (2021). Propuesta para prevenir enfermedades osteomusculares adquiridas por movimiento repetitivos en los trabajadores de cosecha de Herbs SAS (Tesis doctoral, Corporación Universitaria Minuto de Dios). Recuperado (17/05/24) en: https://repository.uniminuto.edu/bitstream/10656/13513/1/TE.RLA_GiralAngie-SerranoMaria-MorenoYuly_2021

Méndez González, A. (2020). Ergonomía cognitiva crono ergonomía---Ergonomía temporal. Turnos rotativos. Análisis y soluciones de gestión. Recuperado en: https://dspace.umh.es/bitstream/11000/5654/1/MENDEZ%20GONZALEZ%2c%20ANGEL%20TFM.pdf

Ministerio de la Protección Social. (2011). Guía técnica para el análisis de exposición a factores de riesgo ocupacional. Bogotá, D. C.: Imprenta Nacional de Colombia. Recuperado (05/19/24) en: https://fondoriesgoslaborales.gov.co/documents/normatividad/normasproyecto/1-Guia-Tecnica-Analisis-Exposicion.pdf

Secretaría del Trabajo y Prevención Social (STPS). (2018). NOM-036-STPS-2018, Factores de riesgo ergonómico en el Trabajo-Identificación, análisis, prevención y control: Manejo manual de cargas. Ciudad de México: STPS. Recuperado (20/05/24) en: https://www.dof.gob.mx/normasOficiales/7468/stps11_C/stps11_C.html

EVALUATION OF POSTURAL RISK IN ADMINISTRATIVE WORKERS OF A COMMERCIAL SERVICES COMPANY

Juan Lázaro González Narváez, ORCID: 0009-0009-0214-0780, Jathanna Amairani Sánchez Cab, ORCID: 0009-0009-0367-846X, Yamel Karina Correa Orozco, ORCID: 0009-0006-4977-7103

Department of Physiotherapy
Faculty of Health Sciences. University Autonomous of Carmen
Ave. Central s/n Esq. Fracc. Mundo Maya.
Ciudad del Carmen, Campeche. 24153

Corresponding author´s e mail: jlgleznar@gmail.com

Resumen: En la actualidad la sociedad empresarial da poca importancia a los temas ergonómicos, sin considerar que los riesgos de salud están latentes, ocasionando que con el paso del tiempo se agraven, afectando el rendimiento laboral de los trabajadores. Aproximadamente el 12% de los trabajadores en pantallas de visualización de datos, han sufrido enfermedades y bajas laborales, en consecuencia, se ha registrado una disminución en la productividad entre un 10 a 20%. En Estados Unidos, se menciona que el ausentismo y los gastos médicos se incrementan entre 45,000 y 54,000 millones de dólares por año. En el año 2022 el Instituto Mexicano del Seguro Social (IMSS), refirió 5481 T.M.E., las principales son síndrome de túnel carpiano 1144; dorsopatías 2836; tenosinovitis 626; otras sinovitis, tenosinovitis y bursitis 563 y epicondilitis 312. El objetivo de esta investigación fue evaluar el nivel de riesgo ergonómico asociado al puesto de contador con las condiciones presentes en su área de trabajo durante la realización de sus labores cotidianas. Este proyecto fue desarrollado en el área administrativa de un buffet de contadores en una casa-oficina ubicada en Ciudad del Carmen, Campeche. Metodología: Se realizó un estudio sustentado por el Método Rosa. Se observó a 6 trabajadores que integran el área de trabajo referida, realizando sus actividades laborales y su interacción con el mobiliario cotidiano. En la evaluación sensorial, se identificó solamente a una persona del sexo femenino de la cuarta década de la vida, en el puesto de trabajo de contador, que, para realizar sus actividades laborales, debía permanecer sentada frente a su computadora gran parte de su jornada laboral de 8 horas al día, durante los 6 días a la semana de su turno. Se efectuó la toma de fotografías y video filmación de la trabajadora durante la realización de sus actividades durante el segundo y tercer día de la evaluación. Resultados: Silla: Alta para la complexión física de la trabajadora, el asiento no permite mantener una correcta postura, sin posibilidad de regulación. Los reposabrazos no son ajustables, impidiendo su graduación. El respaldo no permite una posición adecuada ni es regulable, lo que resulta incómoda dicha posición. En relación al uso del teléfono y pantalla: La ubicación del teléfono obliga a realizar mayores desplazamientos para alcanzarlo. El monitor se encuentra a un nivel bajo.

El tiempo de uso de uso de ambos aditamentos, es mayor al de una hora de manera continua a lo largo de la jornada laboral. Uso de ratón y teclado: Para utilizar el ratón, el trabajador, adopta posturas incómodas para su manipulación. Al utilizar el teclado de su equipo, debe adoptar de igual manera posturas inadecuadas como extensión, adducción y abducción de las muñecas. El tiempo de uso es mayor a una hora en su jornada laboral. Conclusión: El puesto de trabajo administrativo evaluado, presentó riesgo postural muy alto, por lo que es necesario realizar modificaciones de manera inmediata, con la finalidad de evitar la aparición de trastornos músculo-esqueléticos (TME) en el trabajador.

Palabras clave: **ROSA, administrativos, riesgo postural**

Relevancia para la ergonomía: La evaluación ergonómica de manera continua de los puestos de trabajo permite identificar los riesgos asociados a la aparición de trastornos músculo-esqueléticos, por lo tanto, su aplicación favorece la adopción de medidas preventivas, incrementa el costo beneficio y productividad de los trabajadores.

Abstract: Currently, business society gives little importance to ergonomic issues, without considering that health risks are latent, causing them to worsen with the passage of time, affecting the work performance of workers. Approximately 12% of workers in data visualization screens have suffered illnesses and sick leave, consequently, a decrease in productivity between 10 to 20% has been registered. In the United States, it is mentioned that absenteeism and medical expenses increase between 45,000 and 54,000 million dollars per year. In the year 2022, the Mexican Institute of Social Security (IMSS) reported 5481 MSD, the main ones being carpal tunnel syndrome 1144; dorsopathies 2836; tenosynovitis 626; other synovitis, tenosynovitis and bursitis 563 and epicondylitis 312. The objective of this research was to evaluate the level of ergonomic risk associated to the position of accountant with the conditions present in their work area during the performance of their daily tasks. This project was developed in the administrative area of an accountants' buffet in a home-office located in Ciudad del Carmen, Campeche. Methodology: A study based on the Rosa Method was carried out. Six workers were observed in the referred work area, carrying out their work activities and their interaction with the daily furniture. In the sensory evaluation, only one female person of the fourth decade of life was identified, in the position of accountant, who, in order to perform her work activities, had to remain seated in front of her computer for a large part of her workday of 8 hours a day, during the 6 days a week of her shift. Photographs and video footage were taken of the worker during her activities on the second and third day of the evaluation. Results: Chair: High for the worker's physical complexion, the seat does not allow her to maintain a correct posture, with no possibility of adjustment. The armrests are not adjustable, preventing its graduation. The backrest does not allow an adequate position and is not adjustable, which makes the position uncomfortable. Regarding the use of the telephone and screen: The location of the telephone makes it necessary to make greater displacements to reach it. The monitor is at a low level. The time of use of both devices is longer than one hour continuously throughout the workday. Use of mouse and keyboard: To use the mouse, the worker adopts uncomfortable postures for its manipulation. When using the keyboard of his computer, he must also adopt inadequate postures such as extension, adduction and abduction of the wrists. The time of use is longer than one hour during the workday. Conclusion: The administrative workstation evaluated presented a very high postural risk, so it is necessary to make immediate modifications in order to avoid the appearance of musculoskeletal disorders (MSD) in the worker.

Keywords: ROSA, administrative, postural risk.

Relevance to Ergonomics: Continuous ergonomic evaluation of workstations allows the identification of risks associated with the appearance of musculoskeletal disorders; therefore, its application favors the adoption of preventive measures and increases the cost-benefit and productivity of workers.

1. INTRODUCTION

Currently, business society gives little importance to ergonomic issues, without considering that health risks are latent, causing them to worsen over time, affecting the work performance of workers.

According to NOM-036-1-STPS-2018, ergonomic risks are defined as “Those that can lead to over physical effort, repetitive movements or forced postures in the work developed, with the consequent fatigue, errors, accidents and occupational diseases, derived from the design of the facilities, machinery, equipment, tools or work station” (Secretaría del Trabajo y Previsión Social, 2018).

Incorrect postures cause various discomforts in the worker, constantly forcing joints. Tremblay (2017), refers to office work as sedentary, since, reclining or sitting postures are adopted which generate an energy expenditure less than or equal to 1.5 METS.

Approximately 12% of workers in data visualization screens have suffered illnesses and sick leave, consequently, a decrease in productivity between 10 to 20% has been registered. According to official figures, it is revealed that absenteeism and medical expenses increase between 45,000 and 54,000 million dollars per year in the United States (Bongers, 2006).

The World Health Organization (WHO) has referred to Musculoskeletal Disorders (MSD) as the main cause of disability worldwide, since they cause limited mobility and dexterity, resulting in early retirement, reduced quality of life and low capacity for social participation (OMS, 2021).

Musculoskeletal disorders are considered as “a set of injuries and symptoms that affect the musculoskeletal system and its associated structures, i.e. bones, muscles, joints, tendons, ligaments, nerves and blood vessels” (Junta de Andalucía, n.d.).

In the year 2022, the Mexican Institute of Social Security (IMSS) reported 5481 E.M.T., the main ones being carpal tunnel syndrome 1144; dorsopathies 2836; tenosynovitis 626; other synovitis, tenosynovitis and bursitis 563 and epicondylitis 312 (IMSS, n.d.).

Evaluating ergonomic risks in offices implies the fact of reducing and identifying the risks present in administrative work. The ROSA method (Rapid Office Strain Assessment), is a precise tool that helps to recognize ergonomic risks in the use of data display screens, whose objective is to prevent the appearance of Musculoskeletal Disorders, increase productivity and preserve well-being in the work environment (Instituto de Biomecánica, 2024).

Sela (2021) examined the personnel of the administrative area of the Autonomous Decentralized Government of Cumandá using the ROSA method, analyzing the personnel in a seated posture in front of their computers during their work period. They identified that the level of risk is very high in 41% of the workers, 28% with high risk and 31% with improvable risk.

In addition, Castro (2022) observed, through the application of the ROSA method, the conditions of 22 administrative employees of the company Electro Sur Este SAA in their workplace, finding that 85% presented an improvable risk and only 15% a high risk.

2. OBJECTIVE

To evaluate the level of ergonomic risk associated to the accountant's position with the conditions present in his work area during the performance of his daily tasks.

3. DELIMITATION

This project is aimed at the administrative work area in an accountant's buffet in a home-office located in Ciudad del Carmen, Campeche. The ergonomic analysis was carried out during the performance of typical work activities of a female worker in the accounting area for a period of 3 days. The first day was used for sensory evaluation, and the second and third days were used for taking photographs and video filming of the activities.

4. METHODOLOGY

A study based on the Rosa Method was carried out to evaluate the ergonomic risks of the administrative workers that could be present on site and thus evaluate if they have presented any discomfort.

In this study, 6 workers in the work area were observed performing their work activities and interacting with the furniture used in the office on a daily basis.

During the sensory evaluation, only one female worker of the fourth decade of life was identified, in the position of accountant, who, in order to perform her work activities, had to remain seated in front of her computer for a large part of her workday of 8 hours a day, during the 6 days a week of her shift. The activities she performs are recording and classifying financial information through specialized software, preparing financial reports and presentations for management areas, reviewing paper files, as well as collating accounting information from various clients.

Likewise, it was corroborated that this workstation was improvised for its operation, derived from the fact that the space where it is located is occupied by a great diversity of furniture and shelter material, therefore, the environmental conditions in which it is developed were not initially planned for its inclusion.

Photographs and video footage were taken of the worker during her activities on the second and third day of the evaluation, in order to verify the variability or maintenance of her working condition.

The ROSA method, acronym for Rapid Office Strain Assessment, is a checklist to assess the level of risks commonly associated with office jobs. The method is applicable to positions of The most common elements of these workstations (chair, work surface, screen, keyboard, mouse and other peripherals) are considered in the evaluation. The most common elements of these workstations (chair, work surface, screen, keyboard, mouse and other peripherals) are considered in the evaluation. As a result of its application, an assessment of the measured risk and an estimate of the need to act on the workstation to reduce the level of risk is obtained (Diego, 2019).

The ROSA methodology indicates that there are 5 levels of action for the workstation. This action level will tell the investigator if it will be necessary to perform an action on the workstation and its urgency to act and this can vary from level 0, that no action is needed, level 4 will indicate that an urgent action is needed. The other actions will have their level of action and risk (Diego, 2019).

5. RESULTS

The evaluation scores are shown in the following tables. The adoption of forced postures throughout the workday, derived from the inadequate furniture in which they carry out their daily activities, stands out as relevant.

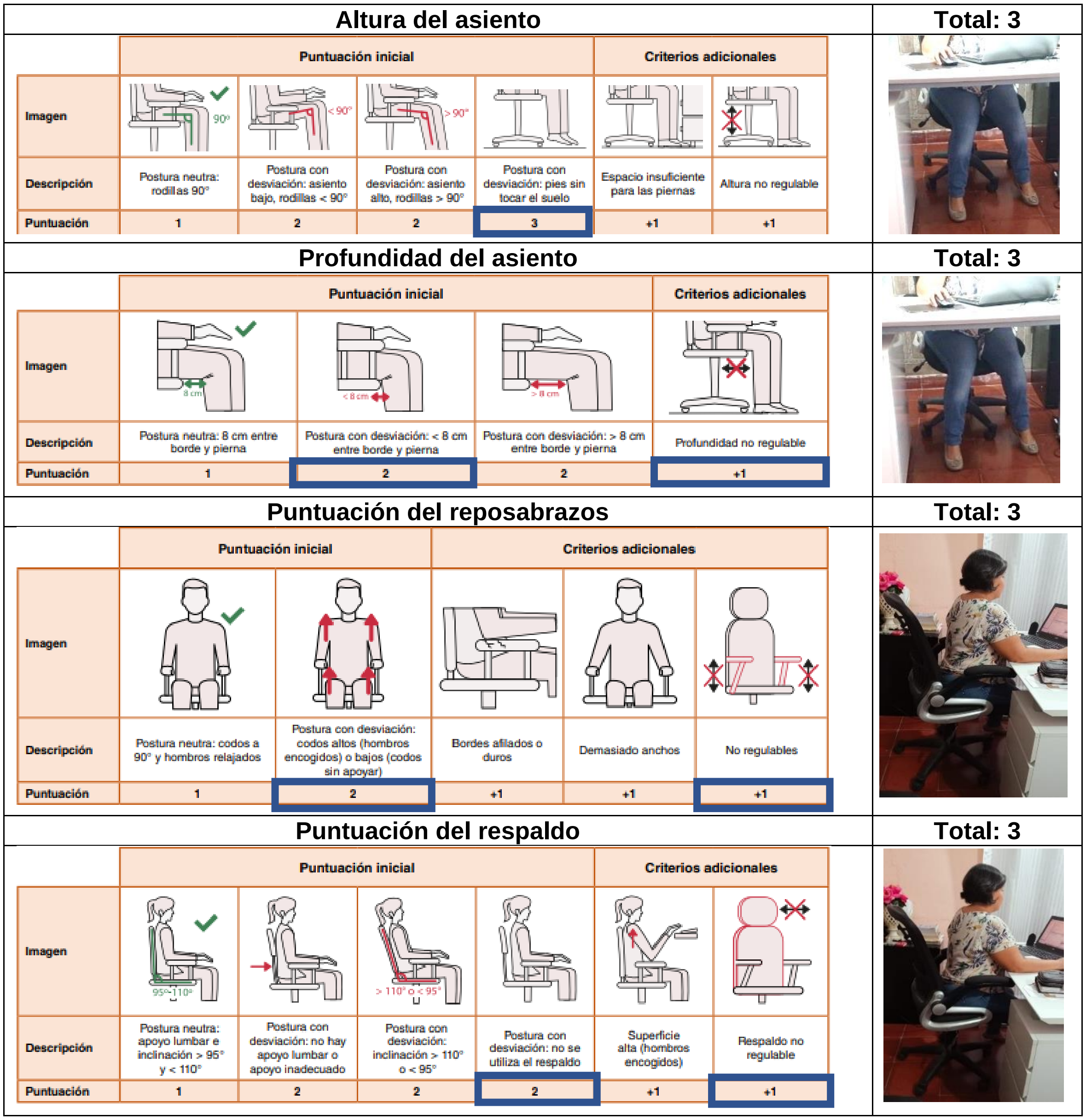


Figure 1. Work chair

Table 1. Chair rating

		Reposabrazos + respaldo (A-3 + A-4)							
		2	3	4	5	6	7	8	9
Asiento: altura + profundidad (A-1 + A-2)	2	2	2	3	4	5	6	7	8
	3	2	2	3	4	5	6	7	8
	4	3	3	3	4	5	6	7	8
	5	4	4	4	4	5	6	7	8
	6	5	5	5	5	6	7	8	9
	7	6	6	6	7	7	8	8	9
	8	7	7	7	8	8	9	9	9

Table 2. Time of daily use

Tiempo de uso diario	Puntuación
Uso continuo durante más de una hora, o durante más de 4 horas diarias.	+1
Uso continuo durante menos de 30 minutos, o menos de una hora de trabajo diario.	-1

Puntuación del teléfono — **Total: 3**

	Puntuación inicial		Criterios adicionales		
Imagen		> 30 cm			
Descripción	Postura neutra: cuello recto (1 mano, manos libres)	Postura con desviación: teléfono alejado > 30 cm	Sujeción con el hombro/cuello	No existe opción de manos libres	Tiempo de uso diario (tabla F)
Puntuación	1	2	+2	+1	+1 / -1

Puntuación de pantalla — **Total: 3**

	Puntuación inicial			Criterios adicionales				
Imagen	40-75 cm	30°		> 75 cm				
Descripción	Postura neutra: pantalla a 40-75 cm, y a la altura de los ojos	Postura con desviación: pantalla baja, por debajo de 30°	Postura con desviación: pantalla alta, extensión de cuello	Distancia > 75 cm	Giro de cuello	No hay porta-documentos y se necesita	Reflejos en pantalla	Tiempo de uso diario (tabla F)
Puntuación	1	2	3	+1	+1	+1	+1	+1 / -1

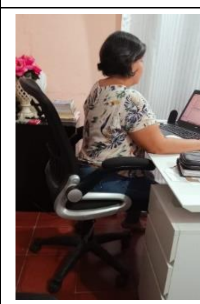


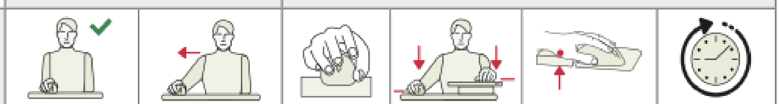
Figure 2. Phone and display scoring

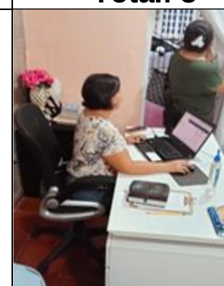
Table 3. Total phone and screen score

		Pantalla (B-2)								
		0	1	2	3	4	5	6	7	8
Teléfono (B-1)	0	1	1	1	2	3	4	5	6	6
	1	1	1	2	2	3	4	5	6	6
	2	1	2	2	3	3	4	6	7	7
	3	2	2	3	3	4	5	6	8	8
	4	3	3	4	4	5	6	7	8	8
	5	4	4	5	5	6	7	8	9	9
	6	5	5	6	7	8	8	9	9	9

Puntuación del ratón — **Total: 3**

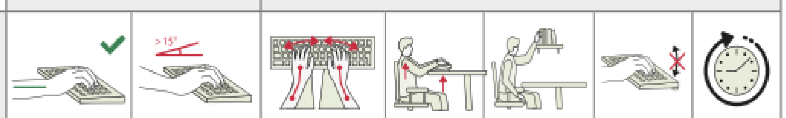
	Puntuación inicial		Criterios adicionales			
Imagen						
Descripción	Postura neutra: ratón alineado con el hombro.	Postura con desviación: ratón no alineado o fuera del alcance	Ratón pequeño agarre en pinza	Ratón y teclado a diferentes alturas	Reposamanos duro o puntos de presión	Tiempo de uso diario (tabla F)
Puntuación	1	2	+1	+2	+1	+1 / -1





Puntuación del teclado — **Total: 4**

	Puntuación inicial		Criterios adicionales				
Imagen							
Descripción	Postura neutra: muñeca recta, hombros relajados	Postura con desviación: extensión muñeca > 15°	Desviación al escribir	Teclado elevado, hombros encogidos	Alcance por encima de la cabeza	Soporte teclado no ajustable	Tiempo de uso diario (tabla F)
Puntuación	1	2	+1	+1	+1	+1	+1 / -1



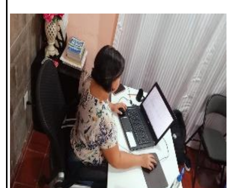


Figure 3. Mouse and keyboard scoring

Table 4. Mouse and keyboard total score

		Teclado (C-2)							
		0	1	2	3	4	5	6	7
Ratón (C-1)	0	1	1	1	2	3	4	5	6
	1	1	1	2	3	4	5	6	7
	2	1	2	2	3	4	5	6	7
	3	2	3	3	3	5	6	7	8
	4	3	4	4	5	5	6	7	8
	5	4	5	5	6	6	7	8	9
	6	5	6	6	7	7	8	8	9
	7	6	7	7	8	8	9	9	9

Table 5. Total score of display and peripherals

		Tabla C (ratón y teclado)								
		1	2	3	4	5	6	7	8	9
Tabla B (teléfono y pantalla)	1	1	2	3	4	5	6	7	8	9
	2	2	2	3	4	5	6	7	8	9
	3	3	3	3	4	5	6	7	8	9
	4	4	4	4	4	5	6	7	8	9
	5	5	5	5	5	5	6	7	8	9
	6	6	6	6	6	6	6	7	8	9
	7	7	7	7	7	7	7	7	8	9
	8	8	8	8	8	8	8	8	8	9
	9	9	9	9	9	9	9	9	9	9

Table 6. Final score of the ROSA method

		Tabla D (pantalla y periféricos)									
		1	2	3	4	5	6	7	8	9	10
Tabla A (silla) con factor tiempo	1	1	2	3	4	5	6	7	8	9	10
	2	2	2	3	4	5	6	7	8	9	10
	3	3	3	3	4	5	6	7	8	9	10
	4	4	4	4	4	5	6	7	8	9	10
	5	5	5	5	5	5	6	7	8	9	10
	6	6	6	6	6	6	6	7	8	9	10
	7	7	7	7	7	7	7	7	8	9	10
	8	8	8	8	8	8	8	8	8	9	10
	9	9	9	9	9	9	9	9	9	9	10
	10	10	10	10	10	10	10	10	10	10	10

The findings found were:

A). Regarding the chair:

1. Too high for the physical complexion of the worker.
2. The length of the seat is not long enough to maintain a correct posture, without the possibility of regulating this condition.
3. The armrests are not adjustable, which prevents them from being adjusted to more comfortable positions.
4. The backrest has a very marked backward inclination and it is not possible to adjust it, so it is not used during work, as this position is uncomfortable.

B). Regarding the use of the telephone and screen:

1. The telephone is located at a distance greater than 30 cm, which implies greater displacements to reach it (it is a mobile telephone).
2. The computer monitor is at a low level, so the worker has to bend his neck about 30 degrees.
3. In relation to the time of use of both devices, it is longer than one hour continuously throughout the workday.

C). Mouse and keyboard use:

1. To use the mouse, the worker, adopts a posture in which, it is not aligned to his shoulders, thus producing abduction of between 30 to 45 degrees of the shoulder for its manipulation.
2. When using the keyboard of your computer, you must adopt extension of the wrists, as well as adduction and abduction of the wrists to be able to type properly.
3. The time of use of these devices is more than one hour in your working day.

6. CONCLUSIONS

The administrative workstation evaluated presented a very high postural risk, so it is necessary to make immediate modifications in order to avoid the appearance of musculoskeletal disorders (MSD) in the worker.

Some of the proposed interventions for improvement in this workplace are related to the following points:

- Educate the personnel involved in the adoption of adequate working postures during their workday (postural hygiene).
- Perform active work breaks, thus limiting the permanence in sustained postures for prolonged periods of time, as well as adding variability of activities throughout the workday.
- Educate and train the worker to perform stretching exercises of the paravertebral musculature, of the muscles of the upper limb, particularly in elbows and wrists, with the purpose of producing adaptation to the effort to which these areas are subjected during the performance of this type of work.
- As far as possible, request the change of the furniture used (in particular the chair), taking into consideration anthropometric criteria of the personnel to whom it is addressed, as well as the possibility that these accessories have the means to regulate aspects such as height, depth of the chair, regulation of the armrest and backrest.

7. REFERENCES

Álvarez, A (2022) *Método para la evaluación de puestos de trabajo de oficinas: Método Rosa.* https://www.insst.es/documents/94886/566858/NTP+1173+Modelo+para+la+evaluaci%C3%B3n+de+puestos+de+trabajo+en+oficina.+M%C3%A9todo+ROSA.pdf/68d0d775-aeb9-598c-d4e2-8e102601a4d7?version=2.0&t=1653390736592

Bongers, P. et al. (2006). *Epidemiology of work related neck and upper limb problems: Psychosocial and personal risk factors (part I) and effective interventions from a bio-behavioural perspective (part II).* J Occup Rehabil. 16:279–302, http://dx.doi.org/10.1007/s10926-006-9044-1

Castro, M. (2022). *Evaluación ergonómica mediante la aplicación del método ROSA y propuesta de intervención en los trabajadores administrativos de la gerencia de planeamiento y desarrollo de la empresa Electro Sur este S.A.A., Cusco 2022.* [Tesis de licenciatura, Escuela Andina de Cusco]. Repositorio Digital Universidad Andina del Cusco. https://hdl.handle.net/20.500.12557/5048

Diego, J. (2019). *Evaluación de puestos de trabajo de oficinas mediante el método ROSA.* Ergonautas, Universidad Politécnica de Valencia. https://www.ergonautas.upv.es/metodos/rosa/rosa-ayuda.php

Instituto de Biomecánica (2024). *Método ROSA: aplicación y alcance para la evaluación ergonómica en oficinas.* https://www.ergoibv.com/es/posts/metodo-rosa-evaluacion-ergonomica-oficinas/

Instituto Mexicano del Seguro Social (s.f.). *Salud en el trabajo. Memoria estadística 2022*. https://www.imss.gob.mx/conoce-al-imss/memoria-estadistica-2022

Junta de Andalucía (s.f.). *Guía breve para la prevención de los trastornos musculo-esqueléticos en el trabajo.* https://www.sesst.org/wp-content/uploads/2020/05/1_2191_guia_tme.pdf

Organización Mundial de la Salud (2021). *Trastornos musculoesqueléticos. https://www.who.int/es/news-room/fact-sheets/detail/musculoskeletal-conditions*

Rojas, L. (2023, 1 junio). *Síndrome del oficinista, ¿cómo afecta a tu cuerpo? -* WeRemote. https://weremote.net/sindrome-oficinista/

Secretaría del Trabajo y Previsión Social (2018). *NORMA Oficial Mexicana NOM-036-1-STPS-2018, Factores de riesgo ergonómico en el Trabajo-Identificación, análisis, prevención y control. Parte 1: Manejo manual de cargas.* Diario Oficial de la Federación. https://www.dof.gob.mx/normasOficiales/7468/stps11_C/stps11_C.html

Sela, E. (2021). *Evaluación ergonómica aplicando el método ROSA en el área administrativa del GAD municipal de Cumandá*. [Tesis de licenciatura, Escuela Superior Politécnica de Chimborazo] http://dspace.espoch.edu.ec/handle/123456789/15701

Toro, R. (2020, 11 noviembre). *Los efectos sobre la salud del trabajo de oficina. Nueva ISO 45001.* https://www.nueva-iso-45001.com/2020/11/los-efectos-sobre-la-salud-del-trabajo-de-oficina/

Tremblay, M. et al. (2017). *Sedentary behavior research network (SBRN)–terminology consensus project process and outcome*. Int J Behav Nutr Phys Activity. 14(1):75.

SYSTEMATIC LITERATURE REVIEW: WORKING POSTURES AND MUSCULOSKELETAL DISCOMFORT ASSOCIATED WITH WORKSTATION CONDITIONS WHEN WORKING FROM HOME (WFH)

Miguel Angel Rodríguez-Orona[1], 0009-0008-5971-3300, Aide Aracely Maldonado-Macías, 0000-0002-4959-161X[1], Cesar Omar Balderrama Armendáriz[1], 0000-0001-8329-4988, Arturo Realyvásquez Vargas[2], 0000-0003-2825-2595, Mónica Gabriela Gutiérrez-Hernández[1], 0000-0003-4866-4933

[1] Department of Electrical Engineering
Universidad Autónoma de Ciudad Juárez
Avenida del Charro y C. Henry Dunant 450-Edificio I, Omega
Ciudad Juárez, Chihuahua 32320

[2] Department of Industrial Engineering
Instituto Tecnológico de Tijuana
Calzada del Tecnológico 12950, Tomas Aquino
Tijuana, Baja California 22414

Corresponding author's e-mail: amaldona@uacj.mx

Resumen: El teletrabajo en casa se ha convertido en una nueva forma de trabajo para muchas compañías, por este motivo, sus posturas de trabajo tienen que ser investigadas para entender cuáles son las molestias musculoesqueléticas asiciadas con el teletrabajo en casa. Se realizó una revisión sistemática de literatura en bases de datos electrónicas (Science Direct, MedLine, PubMed, EBSCOhost, Google Scholar, ProQuest) y un total de 15 estudios fueron incluidos en esta revisión. Esta revisión sistemática de literatura examina las posturas de trabajo y las molestias musculoesqueléticas asociadas con las condiciones de las estaciones de teletrabajo en casa. Los hallazgos indican que existen algunas posturas de trabajo asociadas con las condiciones del teletrabajo en casa que no están siendo adoptadas en un ambiente típico de una estación de trabajo en oficina. La revisión de literatura muestra que un alto porcentaje de personas está incrementando o desarrollando nuevas molestias musculoesqueléticas al adoptar estas posturas únicas de teletrabajo en casa. Estos hallazgos sugieren que existen factores de riesgos ergonómicos asociados con el teletrabajo en casa que podrían llevar a problemas de salud para los teletrabajadores. Entender estos riesgos es escencial para desarrollar una metodoligía que sea capaz de evaluar el nivel de riesgo ergonómico para realizar las correcciones y/o recomendaciones pertinentes.

Palabras clave: Teletrabajo en casa, Molestias, Musculoesquelético, Posturas de trabajo.

Relevancia para la ergonomía: Esta investiación contribuye a identificar las condiciones de las estaciones de trabajo, posturas de trabajo y las molestias

musculesqueléticas asociadas con el teletrabajo en casa. Los factores de riesgos ergonómicos asociados con el teletrabajo en casa deben ser estudiados para desarrollar una metodología que permitirá una evaluación apropiada y proporcionar correcciones y recomendaciones ergonómicas para cada condición de las estaciones de teletrabajo en casa.

Abstract: Working from home is becoming a new way of working for many companies. Hence, the working postures when WFH must be investigated to understand the associated musculoskeletal discomfort. A systematic literature review was conducted in electronic databases (Science Direct, MedLine, PubMed, EBSCOhost, Google Scholar, ProQuest), and 15 studies were included in this review. This systematic literature review examines the working postures and musculoskeletal discomfort associated with workstation conditions when working from home (WFH). The findings highlight that some working postures associated with WFH conditions are not adopted in a typical office environment. The literature review shows that many people are either increasing or developing new musculoskeletal discomfort when adopting these unique WFH postures. These findings suggest ergonomic risk factors associated with WFH could lead to health problems for teleworkers. Understanding these risks is essential to develop a methodology capable of evaluating the ergonomic risk level to make the appropriate corrections and/or recommendations.

Keywords: Working from home, Home office, Musculoskeletal, Discomfort, Working Postures.

Relevance to ergonomics: This research contributes to identifying the workstation conditions, working postures, and musculoskeletal discomfort associated with WFH. The ergonomic risk factors associated with WFH must be studied to develop a methodology that will allow for a proper evaluation and ergonomic corrections and recommendations for each WFH condition.

1. INTRODUCTION

Working from home (also known as home office or teleworking) has become a new way of working worldwide. Some studies show that teleworkers adopt unique working postures that differ from those in a typical office station, and these working postures negatively affect certain body areas. Studies show that some teleworkers have experienced increased pre-existing musculoskeletal symptoms, while others have developed new ones (McAllister et al., 2022). In addition, some teleworkers do not have office-related equipment at home and need to use whatever areas they have available. These areas include the living room, dining room, bedroom, and kitchen. Working from these house areas implies using inadequate or non-ergonomic chairs such as the couch, a dining room highchair, the bed, and a foldable chair (Radulović et al., 2021).

This research presents a systematic literature review to determine the state of the art regarding working postures and the musculoskeletal discomfort associated with WFH workstation conditions.

2. OBJECTIVES

2.1. General objecive

Conducting a systematic literature review on working postures and the musculoskeletal discomfort associated with WFH workstation conditions to determine a preliminary state of the art.

2.2. Specific objectives

1. Determining those working postures mostly adopted by teleworkers and related to working from home (WFH) in the literature.
2. Determining those musculoskeletal complaints associated with the WFH postures in the literature.
3. Determining those house areas mainly used for WFH in the literature.
4. Determining those types of chairs typically used during WFH in the literature found.
5. Summarize and report the results comprehensively.

3. METHODOLOGY

The PRISMA systematic literature review process was followed, and the research question was defined as follows:

- What are the working postures and the musculoskeletal discomfort associated with the WFH workstation conditions found in the literature?

Figure 1 shows the steps to answer the research question and summarize and report the literature findings.

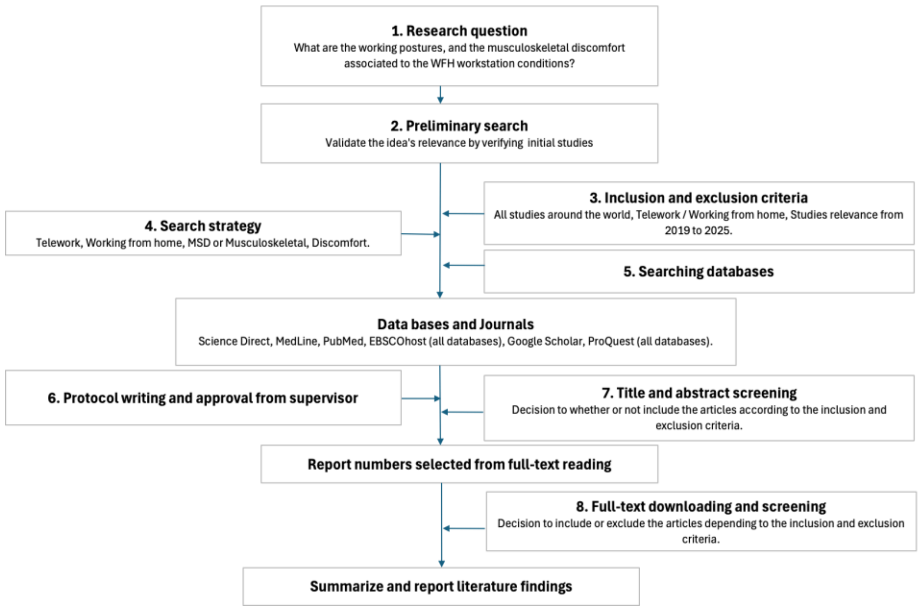


Figure 1. PRISMA systematic literature review process (Tawfik et al., 2019)

4. RESULTS

4.1. Preliminary search results

The preliminary search was conducted to verify that the research question is valid and that no work has already been done on any available journal or protocol. Science Direct and Google Scholar databases (Table 1) were considered for this initial search, and two main keywords (taken from the research question) were used.

Table 1. Preliminary search results

Databases	Preliminary search strategy (*according to the research question's nouns*)	Search results
Science Direct	Working from home, Musculoskeletal	4,964
Google Scholar		17,500

Based on the initial exploration of more than 22,000 articles in these two databases, the research question was defined as "valid and suitable" for further investigation through the systematic literature review.

4.2. Search strategy

The "inclusion-exclusion" criteria were defined so that all studies worldwide were considered, and the search results were also narrowed based on the relevance period from 2019 to 2025. In addition to the keyword combination for the search strategy in Figure 2, a complete search through multiple journal databases was completed.

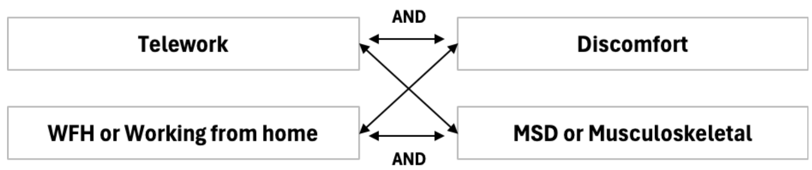


Figure 2. Keyword combination for the search strategy

The databases Science Direct, MedLine, PubMed, EBSCOhost (all databases), Google Scholar, and ProQuest (all databases) were selected to complete the article search. These databases align with the search strategy and contain the journals and articles necessary to include in this research. The search strategy had to be precisely adjusted based on each database's "Advanced Search" characteristics, but in the end, it remained the same throughout all databases. It is important to highlight that the database search remained consistent with the investigation's "research strategy" and "inclusion-exclusion" criteria.

4.3. Databases search results

The keyword combination significantly impacted the search results (Table 2). The databases Science Direct, Google Scholar, and ProQuest presented a noticeable difference in search percentage results when using the keywords "Telework" and "Working from home." The search percentage results in these databases, regardless of the usage of the keywords "Musculoskeletal" or "Discomfort," dropped as low as 2% when using the keyword "Telework." A similar behavior was observed for the PubMed database, except the search percentage results were slightly higher. When using the keyword "Musculoskeletal" in combination with "Working from home," the databases MedLine, PubMed, and EBSCOhost had search percentages of 67%, 61%, and 48%, respectively. On the contrary, the databases Science Direct (70%) and ProQuest (65%) had higher search percentages when using the "Working from home" and "Discomfort" combination. The Google Scholar database had an almost even search percentage of 49% and 50% when using the keywords "Musculoskeletal" and "Discomfort."

Table 2. Database search results when applying the keyword combination and "inclusion-exclusion" criteria

Search strategy	Keyword combination	Search results Qty of articles	Search results % of articles
Sceince Direct, 2019-2024	Telework AND Musculoskeletal	110	1%
Sceince Direct, 2019-2024	Telework AND Discomfort	202	1%
Sceince Direct, 2019-2024	Working from home AND Musculoskeletal	4,964	28%
Sceince Direct, 2019-2024	Working from home AND Discomfort	12,550	70%
MedLine, 2019-2024	Telework AND Musculoskeletal	51	11%
MedLine, 2019-2024	Telework, AND Discomfort	13	3%
MedLine, 2019-2024	Working from home AND Musculoskeletal	301	67%
MedLine, 2019-2024	Working from home AND Discomfort	86	19%
PubMed, 2019-2024	Telework AND Musculoskeletal	56	9%
PubMed, 2019-2024	Telework AND Discomfort	18	3%
PubMed, 2019-2024	Working from home AND Musculoskeletal	368	61%
PubMed, 2019-2024	Working from home AND Discomfort	158	26%
EBSCOhost (all databases), 2019-2024	Telework AND Musculoskeletal	241	20%
EBSCOhost (all databases), 2019-2024	Telework AND Discomfort	88	7%
EBSCOhost (all databases), 2019-2024	Working from home AND Musculoskeletal	591	48%
EBSCOhost (all databases), 2019-2024	Working from home AND Discomfort	309	25%
Google scholar, 2019-2024, Review articles	Telework AND Musculoskeletal	341	1%
Google scholar, 2019-2024, Review articles	Telework AND Discomfort	287	1%
Google scholar, 2019-2024, Review articles	Working from home AND Musculoskeletal	17,500	49%
Google scholar, 2019-2024, Review articles	Working from home AND Discomfort	17,800	50%
ProQuest (all databases), 2019-2024	Telework AND Musculoskeletal	67	1%
ProQuest (all databases), 2019-2024	Telework AND Discomfort	49	1%
ProQuest (all databases), 2019-2024	Working from home AND Musculoskeletal	1,822	33%
ProQuest (all databases), 2019-2024	Working from home AND Discomfort	3,554	65%

A total of 61,526 search records resulted when applying the keyword combination to each database search engine; the databases with the most search results were "Google Scholar" and "Science Direct," with a total of 35,928 and 17,826 records, respectively (Table 3). These databases presented various related case studies and contributed to most of the selected articles during the selection process. The remaining databases accounted for only 13% of the total searching records; most of the articles found in these databases were duplicated as the priority was to complete the screening process in the databases with the most searching records.

Table 3. Database search results summary when applying the keyword combination and "inclusion-exclusion" criteria.

Databases	Search strategy (*according to the "inclusion-exclusion" criteria*)	Search results (Quantity of articles)
Science Direct	Telework AND Musculoskeletal Telework AND Discomfort Working from home AND Musculoskeletal Working from home AND Musculoskeletal	17,826
MedLine		451
PubMed		600
EBSCOhost (all databases)		1,229
Google Scholar		35,928
ProQuest (all databases)		5,492

4.4. **Article selection**

Figure 3 presents the flowchart of selected studies after a total of 61,526 articles were found in databases when applying the search criteria. The selection process to exclude articles from this research was considered a verification using the following criteria: The duplicate articles and studies not related or partially related to this research's objectives. The selected articles (n=75) were considered after a title and abstract revision; these articles are not duplicated and are somehow related to the defined research question. After a full-text review, 49 articles were considered eligible, but only 15 were included in this systematic literature review.

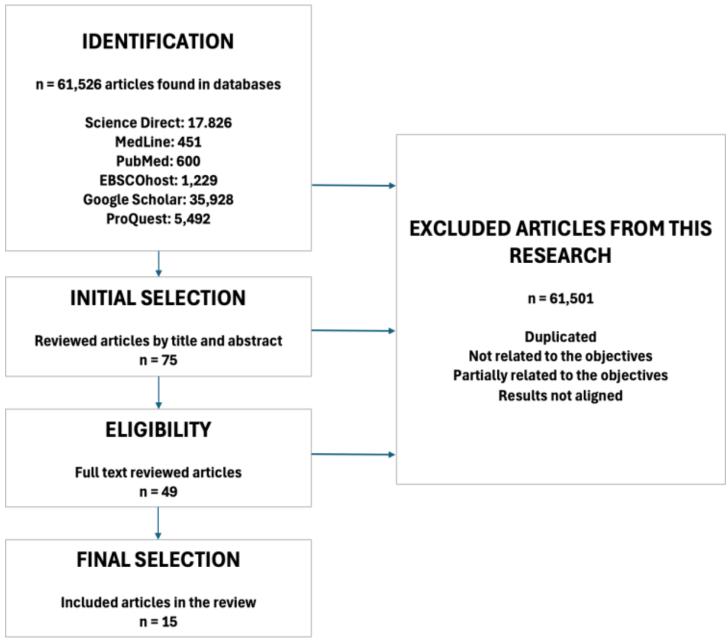


Figure 3. Article selection flowchart

According to the selection process results, less than 0.15% of the database search results (when applying the keyword combination and "inclusion-exclusion" criteria) comply with these criteria, which are related to the working postures and musculoskeletal discomfort associated with the WFH workstation conditions.

4.5. Literature review results

4.5.1. Adopted postures when working from home

The author Du et al. (2022) classified and presented in Figure 4 some of the different working postures experienced when using inadequate furniture in various WFH conditions. The sitting posture in C1 corresponds to an office setup, and C2 represents a low table. Lower back support is used when seated on the floor or the bed. C3 shows a person seated on a couch, and C4 is the most extreme position, represented whenever a person is working on a bed without back support and a low table. These authors found that the posture C4 represents the highest risk of musculoskeletal disorders. In addition, none of these postures can be effectively evaluated with actual postural methods.

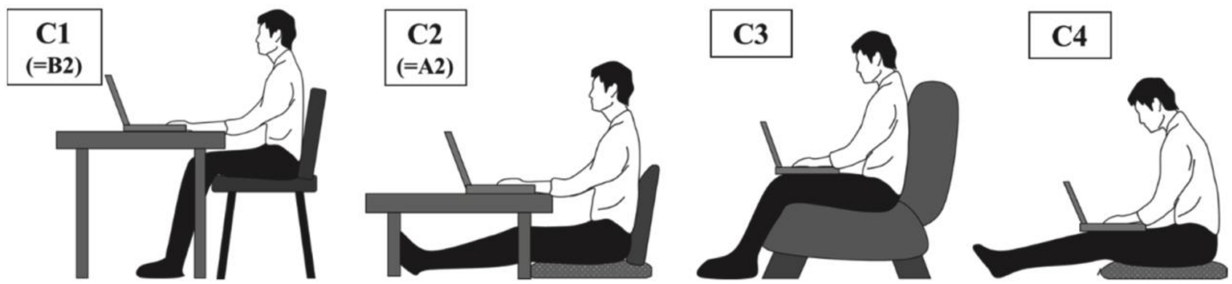


Figure 4. Images of experimental WFH conditions (Du et al., 2022)

Furthermore, in a study monitoring the sagittal inclination when seated, the backward (19%) and forward (13%) lean postures were observed when WFH. At the same time, 68% of people adopt an upright (neutral) posture (Black & St-Onge, 2022). In Table 4, the authors summarize people's different postures with their corresponding working-from-home conditions. The results show that as much as 75% of the people work with the head and neck tilted forward, while 40% adopt a working posture with the trunk slightly bent forward. This postural combination directly results from inadequate working conditions and an ergonomic workplace for teleworkers.

Table 4. Adopted postures when working from home (Snodgrass et al., 2022)

	(Snodgrass et al., 2022)		**(Gerding et al., 2021)**	
	N	**%**	**N**	**%**
Head/Neck being tilted sideways	---	---	234	28
Head/Neck being tilted forward	---	---	625	75
Head/Neck being tilted backwards	---	---	153	18
Trunk a little bent forward	202	39.5	323	40
Straight up, back against backrest	122	23.9	---	---
Straight up, back NOT against backrest	53	10.4	---	---
Bottom dropped, lower back not against backrest	50	9.8	---	---
Variable: alter at least once per 1/2 hr	84	16.4	---	---

4.5.2. Musculoskeletal discomfort associated with working from home

Studies have found increased musculoskeletal discomfort among home teleworkers in the reviewed literature. The author McAllister et al. (2022) reported in his study that up to 51% of them have experienced worsening discomfort in multiple body areas, with the neck (35%) being one of the most affected body regions. Similar results were observed by Gupta et al. (2023), where neck discomfort increased from 25% to 29% in the surveyed population working from home. Additionally, shoulder pain increased from 18% to 20%, upper back pain increased from 5% to 9%, and lower back pain increased from 17% to 19%. In their study, the author Radulović et al. (2021) found that 45.7% of people experienced more muscular pain in the upper back and neck body regions when working from home than in the office. Regarding lower back and hand pain, the surveyed people reported 39.1% and 27.2% stronger pain than in the office.

According to supporting results, the neck (19.1%), upper back (14.1%), and lower back (24.8%) body regions are among the most affected areas when investigating the discomfort associated with working from home (Ahmed et al., 2021). In similar results reported by Jajoo et al. (2021), El Kadri Filho & Roberto De Lucca (2022), and El Kadri Filho & De Lucca (2023), the body areas most frequently reported with discomfort when WFH are the neck, lower/upper back, and shoulder. Unfortunately, there are other body areas like the knee (48.74%), elbow (45.38%), and wrist/hand (71.43%) where people are experiencing pain when transitioning from a regular office to WFH (Figure 5).

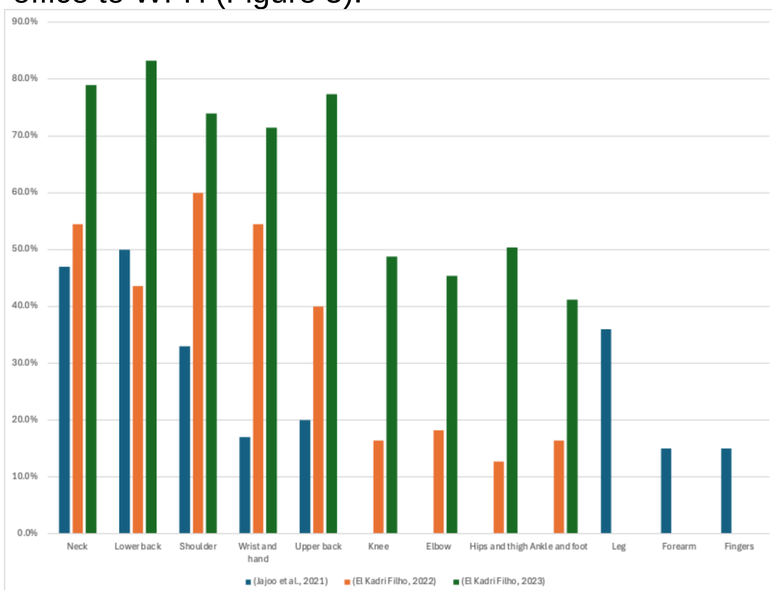


Figure 5. Frequency of body areas with reported discomfort associated with WFH

4.5.3. The main house areas used when WFH

According to Mayer & Boston (2022), 51.6% of people have a dedicated home office station throughout the working day, while a similar proportion of 46% was found by MacLean et al. (2022). Considering the complementary proportions, up to 54% of people use a variety of house areas whenever they are in working-from-home conditions. Among the main areas found by the authors are the living room, the dining room, the bedroom, and the kitchen (Figure 6). These areas' characteristics are unusual in a regular office. Other results by Radulović et al. (2021) indicate a higher percentage of people teleworking in different house areas than in a dedicated home office station. Hence, in this study, the proportions are as follows: Living room (40.2%), Dining room (34.5%), Kitchen (14.9%), and Bedroom (10.3%).

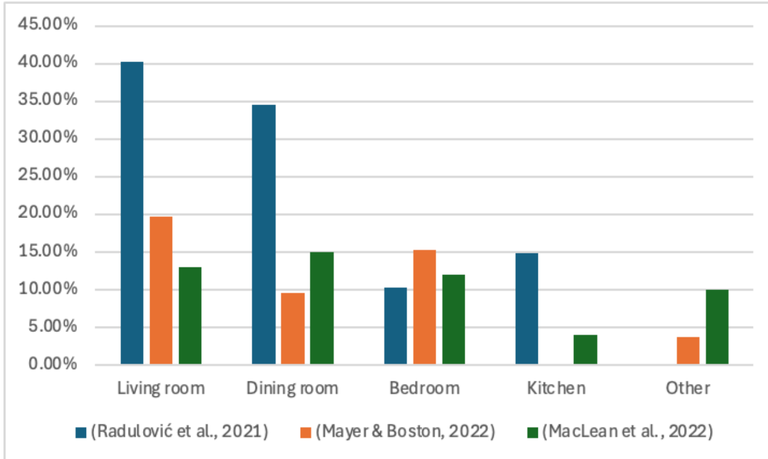


Figure 6. House locations often used during teleworking

4.5.4. Chair types used when working from home

Regarding chair types, findings show that teleworkers use a home office chair in a dedicated WFH station ranging from 55.7% to 79.7% (Figure 7). Gerding et al. (2021) reported that 56.6% of people use a dining chair to work, while 36.6% and 12% use a couch and a bed, respectively.

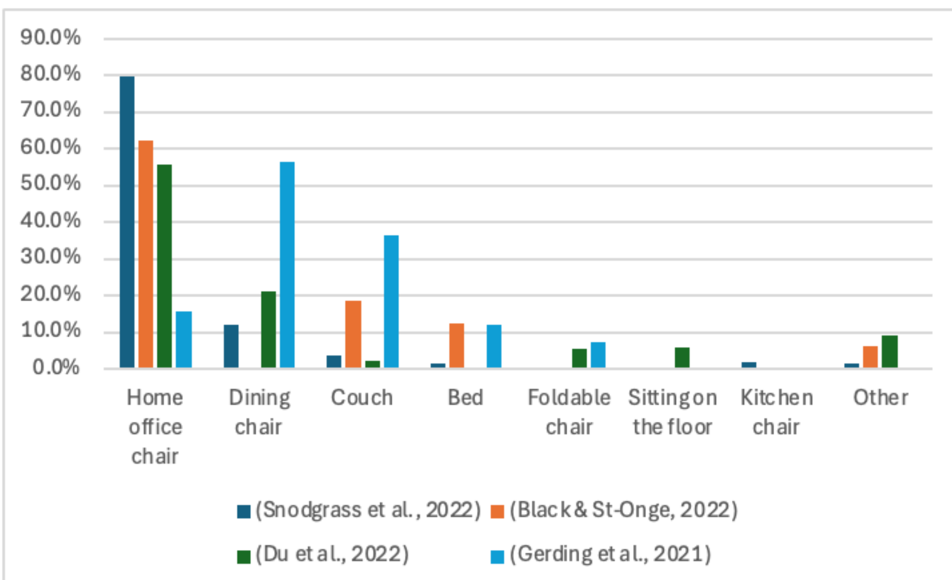


Figure 7. Chair type used under working-from-home conditions

5. DISCUSSION/CONCLUSIONS

The proposed research question for this systematic literature review was valid and suitable for further investigation. The WFH topic gained much relevance, especially from 2020 to 2023, mainly due to the COVID-19 pandemic. The proliferation of scientific articles, especially from 2021 to date, is a clear **indicator that WFH is a** relevant topic that remains in the scientific community's interest and must be further investigated.

The keyword “Working from home (WFH)” is the term better adopted by researchers to describe home office conditions as some of the most important databases presented a noticeable difference in search results percentage compared to when using the keyword “Telework”. Furthermore, the keyword “Working from home” is more often used than “Telework” in state-of-the-art literature. This is perhaps because “WFH” better represents a person actually working from home, while “Telework” is a more general term that can include working from other places than home or the office.

Additionally, evidence from literature shows that teleworkers have established their working stations in different areas of the house, such as the living room, dining room, bedroom, and kitchen. Working in these areas implies using non-ergonomic chairs and adopting bad postures that may increase or even cause new symptoms of musculoskeletal discomfort among teleworkers. These symptoms of musculoskeletal discomfort will result in diminished performance and health problems for teleworkers.

This systematic literature review found that working postures and workstation conditions are associated with musculoskeletal discomfort when working from home (WFH). The findings highlight that some working postures associated with WFH conditions are not adopted in a typical office environment. These findings suggest that ergonomic risk factors associated with WFH could lead to health problems for teleworkers.

Since working from home is becoming a new way of working for many companies, the working postures (when WFH) must be investigated to understand its associated musculoskeletal discomfort. The ergonomic risk factors associated with WFH must be studied to develop a methodology for a proper evaluation that will result in ergonomic corrections and recommendations for each WFH condition.

6. **REFERENCES**

Ahmed, S., Akter, R., Islam, M. J., Muthalib, A. A., & Sadia, A. A. (2021). Impact of lockdown on musculoskeletal health due to COVID-19 outbreak in Bangladesh: A cross sectional survey study. *Heliyon*, *7*(6), e07335. https://doi.org/10.1016/j.heliyon.2021.e07335

Black, N. L., & St-Onge, S. (2022). Measuring pandemic home-work conditions to determine ergonomic recommendation relevance. *Work*, *71*(2), 299–308. https://doi.org/10.3233/WOR-210726

Du, T., Iwakiri, K., Sotoyama, M., Tokizawa, K., & Oyama, F. (2022). Relationship between using tables, chairs, and computers and improper postures when doing VDT work in work from home. *Industrial Health*, *60*(4), 307–318. https://doi.org/10.2486/indhealth.2021-0222

El Kadri Filho, F., & De Lucca, S. R. (2023). Ergonomic and psychosocial risks related to musculoskeletal problems among Brazilian labor judges in telework during the COVID-19 pandemic. *International Journal of Occupational Safety* *and Ergonomics*, *29*(2), 837–846. https://doi.org/10.1080/10803548.2022.2085382

El Kadri Filho, F., & Roberto De Lucca, S. (2022). Telework during the COVID-19 pandemic: Ergonomic and psychosocial risks among Brazilian labor justice workers. *Work*, *71*(2), 395–405. https://doi.org/10.3233/WOR-210490

Gerding, T., Syck, M., Daniel, D., Naylor, J., Kotowski, S. E., Gillespie, G. L., Freeman, A. M., Huston, T. R., & Davis, K. G. (2021). An assessment of ergonomic issues in the home offices of university employees sent home due to the COVID-19 pandemic. *Work*, *68*(4), 981–992. https://doi.org/10.3233/WOR-205294

Gupta, G., Jadhav, R. A., Nataraj, M., & Maiya, G. A. (2023). Effect of Covid-19 lockdown/ compulsory work from home (WFH) situation on musculoskeletal disorders in India. *Journal of Bodywork and Movement Therapies*, *33*, 39–45. https://doi.org/10.1016/j.jbmt.2022.09.019

Jajoo, B., Bhatbolan, S., & Bhatbolan, S. (2021). Lifestyle behaviors and their influence on work-related musculoskeletal discomfort: A web-based survey during coronavirus disease 2019 pandemic. *The Indian Journal of Occupational Therapy*, *53*(3), 99. https://doi.org/10.4103/ijoth.ijoth_30_21

MacLean, K. F. E., Neyedli, H. F., Dewis, C., & Frayne, R. J. (2022). The role of at home workstation ergonomics and gender on musculoskeletal pain. *Work*, *71*(2), 309–318. https://doi.org/10.3233/WOR-210692

Mayer, B., & Boston, M. (2022). Residential built environment and working from home: A New Zealand perspective during COVID-19. *Cities*, *129*, 103844. https://doi.org/10.1016/j.cities.2022.103844

McAllister, M. J., Costigan, P. A., Davies, J. P., & Diesbourg, T. L. (2022). The effect of training and workstation adjustability on teleworker discomfort during the COVID-19 pandemic. *Applied Ergonomics*, *102*, 103749. https://doi.org/10.1016/j.apergo.2022.103749

Radulović, A. H., Žaja, R., Milošević, M., Radulović, B., Luketić, I., & Božić, T. (2021). Work from home and musculoskeletal pain in telecommunications workers during COVID-19 pandemic: A pilot study. *Archives of Industrial Hygiene and Toxicology*, *72*(3), 232–239. https://doi.org/10.2478/aiht-2021-72-3559

Snodgrass, S. J., Weerasekara, I., Edwards, S., Heneghan, N. R., Puentedura, E. J., & James, C. (2022). Relationships Between the Physical Work Environment, Postures and Musculoskeletal Pain During COVID-19: A Survey of Frequent Computer Users. *Journal of Occupational & Environmental Medicine*, *64*(11), e782–e791. https://doi.org/10.1097/JOM.0000000000002698

Tawfik, G. M., Dila, K. A. S., Mohamed, M. Y. F., Tam, D. N. H., Kien, N. D., Ahmed, A. M., & Huy, N. T. (2019). A step by step guide for conducting a systematic review and meta-analysis with simulation data. *Tropical Medicine and Health*, *47*(1), 46. https://doi.org/10.1186/s41182-019-0165-6

EVALUATION OF MANUAL HANDLING OF LOADS IN THE PROCESS OF FILING AND DISTRIBUTION OF WATER CRAFES UNDER STANDARD 036-1-STPS 2018

María Paz Guadalupe Acosta Quintana[1], 0000-0001-7115-9076[1], Rigoberto Zamora Alarcón[2], 0009-0006-3356-2239[2], Iván Francisco Rodríguez Gamez[3], 0000-0002-7713-4440[3]

[1 y 3]Department of Industrial Engineering
Instituto Tecnológico de Sonora
5 de Febrero 818 Sur, Colonia Centro
Ciudad Obregón, Sonora, 85000

[2]Department of Industrial Engineering
TecNM/Instituto Tecnológico de Mexicali
Av. Instituto Tecnológico s/n Plutarco Elías Calles
Mexicali, B.C, México. 21376

Corresponding author's e-mail: marypaz.acosta@itson.edu.mx

RESUMEN El presente estudio se enfocó en evaluar el manejo manual de carga en el proceso de llenado y distribución de garrafones de agua en la planta purificadora del Instituto Tecnológico de Sonora (ITSON), campus Náinari, con base en la Norma 036-1 STPS 2018. Se analizó la dinámica operativa de los trabajadores en la recolección, lavado y distribución de garrafones, identificando factores de riesgo ergonómico que podrían derivar en afectaciones a la salud y eficiencia del servicio. El proceso comienza con la recolección de garrafones vacíos, los cuales son trasladados a la zona de lavado y posteriormente a las áreas de llenado y distribución. Este flujo de trabajo implica recorridos dobles, dado que las distancias son significativas y se realizan en distintos momentos del día. Como herramienta de apoyo, los trabajadores utilizan un diablito pequeño y simple, diseñado para transportar hasta seis garrafones. El equipo actual presenta limitaciones ergonómicas que pueden generar posturas inadecuadas, afectando cuello, espalda, hombros, muñecas y extremidades en general. Las jornadas laborales se dividen en dos turnos de ocho horas, con un descanso de media hora para la comida. En este contexto, el manejo manual de carga resulta crítico, pues cualquier lesión en los trabajadores podría impactar negativamente en la distribución, al reducir la cantidad de personal disponible para abastecer la demanda. Dado que el número de trabajadores es limitado, la afectación en la productividad sería considerable si alguno de ellos presentara lesiones relacionadas con la carga y el transporte de los garrafones. El objetivo del estudio fue identificar y proponer mejoras ergonómicas en las actividades realizadas por los empleados de la planta purificadora para reducir los riesgos derivados del manejo manual de cargas. A partir del análisis del proceso de llenado y distribución, se aplicaron los criterios de la Norma 036-1 STPS 2018, estableciendo un diagnóstico de los niveles de riesgo y formulando estrategias de mitigación. La evaluación reveló que el mayor problema se encuentra en el medio de transporte utilizado para el traslado de los garrafones. Aunque el peso total de seis garrafones más el diablito se encuentra dentro de los límites recomendados, el diseño del equipo obliga a los trabajadores a adoptar posturas inadecuadas, aumentando el riesgo de lesiones musculoesqueléticas. Además, el uso repetitivo de fuerza y carga aplicada genera fatiga y puede contribuir a la aparición de trastornos musculares a largo plazo. Como propuesta principal, se recomendó la optimización del medio de transporte para mejorar la distribución de la carga y facilitar el manejo de los garrafones sin comprometer la postura del trabajador. Se sugiere el rediseño del diablito o la implementación de un equipo con mejor estabilidad y ergonomía, permitiendo una manipulación más segura. Con estas modificaciones, se espera minimizar los riesgos en cuello, espalda, hombros y extremidades, mejorando tanto la seguridad de los trabajadores como la eficiencia en el proceso de distribución.

Palabras clave: posturas, proceso de llenado y distribución, lesiones

Relevancia para la ergonomía: Este estudio contribuye mediante la evaluación de las actividades realizadas por el personal en el proceso de llenado y distribución de garrafones, identificando los niveles de riesgo asociados al manejo manual de carga. Dichos riesgos pueden provocar lesiones debido al peso de los garrafones, la repetitividad de los movimientos y las posturas inadecuadas al cargarlos y descargarlos. Además, el estudio propone soluciones ergonómicas para prevenir incapacidades laborales y evitar retrasos en la distribución. Estas mejoras se sustentan en la aplicación de métodos ergonómicos que permiten analizar la problemática y fundamentar las propuestas de intervención.

Abstract: This study focused on evaluating the manual handling of loads in the process of filling and distributing water jugs at the purification plant of the Instituto Tecnológico de Sonora (ITSON), Náinari campus, based on the Norma 036-1 STPS 2018. The operational dynamics of workers in the collection, washing, and distribution of water jugs were analyzed, identifying ergonomic risk factors that could affect both health and service efficiency. The process begins with the collection of empty water jugs, which are transported to the washing area and then to the filling and distribution sections. This workflow involves double trips due to significant distances, performed at various times throughout the day. As a support tool, workers use a small, simple hand truck designed to carry up to six water jugs. However, the current equipment presents ergonomic limitations that can lead to inadequate postures, affecting the neck, back, shoulders, wrists, and limbs. Work shifts are divided into two eight-hour periods, with a thirty-minute meal break. In this context, manual load handling is critical, as any worker injury could negatively impact distribution by reducing the available workforce. Since the number of workers is limited, productivity would be significantly affected if one of them suffered an injury related to carrying and transporting the water jugs. The study aimed to identify and propose ergonomic improvements in the activities carried out by employees at the water purification plant to reduce risks associated with manual load handling. Based on an analysis of the filling and distribution process, the criteria of Norma 036-1

STPS 2018 were applied, establishing a risk-level diagnosis and formulating mitigation strategies. The evaluation revealed that the main problem lies in the transport equipment used for moving the water jugs. Although the total weight of six jugs plus the hand truck falls within recommended limits, the equipment's design forces workers into improper postures, increasing the risk of musculoskeletal injuries. Additionally, repetitive force exertion and applied loads contribute to fatigue and may lead to long-term muscular disorders. As the primary proposal, optimizing the transport equipment was recommended to improve load distribution and facilitate jug handling without compromising workers' posture. Redesigning the hand truck or implementing a more stable and ergonomically efficient tool is suggested to ensure safer handling. With these modifications, the risks associated with the neck, back, shoulders, and limbs could be minimized, enhancing both worker safety and distribution efficiency.

Keywords. postures, filling process and distribution, injuries

Relevance to Ergonomics: This study adds value by evaluating the activities of personnel in the process of filling and distributing water jugs, identifying ergonomic risks associated with manual load handling. These risks, stemming from the weight of the jugs, repetitive movements, and improper postures, can cause injuries that affect both workers' health and operational efficiency. To mitigate these impacts, the study proposes ergonomic solutions aimed at preventing occupational disabilities and ensuring continuity in distribution. The suggested improvements are based on the application of ergonomic methods that allow for a thorough analysis of the issue and support the proposed interventions.

1. INTRODUCTION

Logistics plays a key role in the delivery of 19-liter demijohns, ranging from storage management to efficient distribution of the product to end consumers. This process involves planning routes, optimizing delivery times and reducing operating costs, ensuring that the product arrives in optimal conditions. However, the manual handling of these carafes presents significant ergonomic challenges for workers, highlighting the importance of adopting measures that minimize physical impact and improve operational efficiency.

Ergonomics applied to industrial and logistics processes aims to optimize human performance and reduce the physical impact on workers. In the bottled water industry, the filling and delivery of 19-liter jugs represents an ergonomic challenge due to the weight and frequency of handling these containers.

The filling process involves repetitive handling of empty and full jugs, which generates significant risks of musculoskeletal disorders (MSDs) due to awkward and non-neutral postures, especially in the lumbar region, upper limbs and other musculoskeletal problems (Brents, et al., 2021, Nadila & Suryadi (2024) and Kunar, et al., (2021). Studies such as Marras et al. (2006) have shown that frequent lifting of loads greater than 15 kg increases the risk of spinal injuries. Handling tasks, especially those involving lifting, pushing or pulling, are associated with a high risk of MSDs, especially affecting the spine, neck and upper extremities Russeng, et al., (2021) and Kunar, et al., (2021). Load handling position: the position in which loads are handled significantly affects trunk biomechanics, with higher load positions increasing the risk of back injuries (Ning, et al., 2014).

The International Labor Organization (ILO) recommends that manual lifting of objects should not exceed 25 kg under ideal conditions, making 19-liter demijohns a load close to the limit. Research in industrial ergonomics has proposed the implementation of mechanical systems, such as automatic conveyors or lift tables, to reduce the physical load on workers (Chaffin et al., 2019).

Delivery workers face additional ergonomic risks due to the transportation and delivery of demijohns to homes or businesses. Studies by the National Institute for Occupational Safety and Health (NIOSH) have identified that repetitive loading on ladders and uneven surfaces increases the likelihood of muscle injuries and falls.

To mitigate these risks, several companies have implemented ergonomic carts with improved wheels and adaptive restraint systems, reducing physical strain. In addition, trainings in safe lifting techniques and the design of efficient logistics routes have shown a decrease in the incidence of occupational injuries (Garg et al., 2018). Recent studies (Takala et al., 2020) suggest that the combination of technology and ergonomic training improves productivity and reduces injury-related absenteeism rates.

The Mexican Official Standard NOM-036-1-STPS-2018 (Secretaría del Trabajo y Previsión Social [STPS], 2018) establishes guidelines to identify, analyze, prevent and control ergonomic risk factors in workplaces, specifically those derived from manual handling of loads. Its objective is to prevent alterations in workers' health, such as musculoskeletal disorders, through the implementation of specific assessments that determine the magnitude of the risk associated with these activities. These evaluations use scientifically validated methods to assess working conditions in detail and propose appropriate control measures.

At the Technological Institute of Sonora (ITSON), due to the high demand for purified water consumption, a water purification plant was installed at the Nainari Campus, with the objective of supplying water to all areas of the same, This plant has staff, which has reported discomfort in the lower back, so the following question arises:

What is the level of risk that exists in the activities developed by the employees of the purification plant of ITSON in the filling and distribution of water bottles.

Objective of the study: was to identify and propose ergonomic improvements in the activities performed by the employees of the purification plant to reduce the risks derived from manual handling of loads.

METHODOLOGY

The steps that were carried out were the following:

Step 1. Identify the activities carried out in the process of filling, assortment and collection of empty jugs. For the identification, the activities performed by the operators were observed; we talked with them in order to obtain information on the areas that each one attends, how many demijohns they deliver daily. In order to be able to analyze the process and avoid interrupting activities, the process was recorded, from the collection, filling, delivery and collection of empty demijohns. From this step we obtained the activities, which are indicated in a format with a photograph and description, and also identified those that present risks and that will be the object of study.

Step 2. Evaluation of the activities through the STPS Standard 036-12018 to assess and estimate the level of risk by lifting and transporting loads and manual loading operations in the purification plant. Appendix I and II of Standard 036-1 2018 were used according to what it contemplates identifying the color and the value corresponding to the way in which the operator develops the activities, It is worth mentioning that the analysis was performed by activity, i.e.: lifting, transport, manual load operations and pushing loads with auxiliary equipment allowing at the end to obtain a score and according to what is established in the standard to determine the condition in which the activity is developed. The standard was applied only to those activities with the highest risk for the empl.

Step 3. Improvement actions. In this step, solution proposals were developed for the activity that resulted in a high risk level, contemplating several aspects that favor the activity's development and support the worker.

RESULTS

The number of areas served is 78 areas, which are distributed between the two workers according to the number of demijohns that are delivered, five days a week in two shifts, the two people who perform the activities of filling, delivering demijohns and collecting the empty ones. The demand in each season is different; in summer it is 80 demijohns per day and in winter it is 30 to 40 demijohns.

Figure 1 shows the map of the Náinari Campus showing the areas to which demijohns are delivered and the routes taken to supply demijohns to each one. The process begins by collecting the empty demijohns in each area and then moving to the plant for filling, and then returning to the areas to leave the full demijohns; this is how the process is defined because each demijohn has a label with the name of the area.

Figure 1. Map of the ITSON Nainari Campus

Table 1 shows the process that is followed from the arrival of the demijohns at the plant until they are delivered to each of the areas to which they are supplied:

Table 1. Filling and distribution process of demijohns

Phase	Photography	Description
Labeling		A label with the brand name, product information and filling date is affixed.
Reception and selection of demijohns		Empty demijohns are collected from each area, since the labels show the area, so they are not mixed.
Carafe washing	  	Pre-washing: A pressurized water rinse is performed to eliminate residues; it is done in pairs to optimize time. Washing with detergent: A disinfectant solution and automatic brushes are used to clean the interior and exterior. Final rinse: The bottles are rinsed again with purified water to avoid disinfectant residues.

Filling of demijohns		The jugs are passed to an automatic filling machine that doses 19 liters of purified water into each jug. Controlled flow systems are used to avoid spills and contamination. The operator controls the water flow to avoid spills, which requires him to monitor the filling process.
Sealing	 	The airtight lid is placed on the bottle. After placing the lid, the operator dries the demijohns with a flannel, placing it in the designated place.
Distribution	***Preparación para la entrega***   ***Entrega de garrafones a las áreas*** 	The demijohns are placed on the delivery diablitos and distributed to the corresponding areas. In the figure you can see how the operator bends his knees a little, but because he is a tall person, it is necessary to do so to place the demijohns at the bottom of the diablito. Subsequently, it moves to areas to deliver the demijohns, as shown in the photographs.

Based on the description of the process, the activities that are considered to present a risk in their development were identified. Table 2 shows those that were assessed as candidates for a risk level.

Table 2. Activities identified with a risk level

Stage of the process	Activities to be valued	Justification
Collection of empty jugs	Bottles are collected for filling	The weight of the empty bottle is 694 grams, so it is not considered a risk of manual handling of loads.
Bottles filling	• Lifting of water demijohns • Washing of demijohns • Filling, capping and drying	As a result of the analysis, and as part of the evaluation, this activity was divided and is not considered a risk for the operator.
Manual transfer	1. Loading of demijohn 2. Transfer of full demijohn to the diablito 3. Loading a full demijohn into the diablito	Based on the above, the three activities will be evaluated for the possible risk that may occur in the development of the activity.
Delivery of demijohns	4. Push diablito 5. Unload the carafe from the diablito 6. Move the carafe to the defined location 7. Unload carafe	No risk for the operator is visualized

For the activities previously identified, the evaluation of the work was carried out, being these: manual transfer and delivery of demijohns. The following are the results of the evaluation in accordance with the provisions of STPS Standard 036-01 2018.

Activity: Manual Transfer.

Job Description: The activity consists of handling a full bottle weighing 19 kg. For this purpose, 40 demijohns per employee are moved during each shift in the summer to cover the demand of the 78 areas of the institution. In this stage of the process, the following activities and frequencies are carried out: 1) Loading full demijohn (7 lifts per hour), 2) Transfer to the diablito (< 4 meters) and 3) Loading diablito for delivery to the different areas. The table 3 shows the results of the evaluation.

Table 3. Evaluation of the manual transfer activity

RISK FACTORS	Color (Green, Orange, Red and Purple)			Rating (Number)		
	Survey	Transportation	Survey	Survey	Transportation	Survey
Loaded weight and frequency of loading/ lifting	Green	Green	Green	0	0	0
Horizontal distance from hands to lower back	Orange	Green	Orange	3	0	3
Lifting vertical region	Green		Red	0		3
Torso twisting and lateral bending; Asymmetrical load on torso (carrying)	Green	Orange	Orange	0	1	1
Postural restrictions	Green	Green	Green	0	0	0
Hand-object coupling	Orange	Orange	Orange	1	1	1
Floor surface	Green	Green	Green	0	0	0
Other environmental factors	Green	Green	Green	0	0	0
Transport distance		Green			0	
Obstacles on the route		Green			0	
Communication, coordination and control						
Total Score:				**4**	**2**	**8**

Conclusion: a score of 4 was obtained in the lifting of the full garrafon, for its transfer to the diablito obtaining a score of 2 qualification in this activity; for both are considered a low risk. For the loading of the diablito, a medium risk level was determined, since the score was 8, so corrective actions should be considered in the short term.

Activity: Delivery of demijohns using diablito

Description of the task: The activity consists of delivering full demijohns to the different areas of the institution, for this purpose the worker pushes a small wheel, which has a weight of 21.6 kg, while the total load is estimated at 133 kg. The activity is not considered repetitive, which allows for breaks during the transfer and delivery of the demijohns. The maximum transfer distance is greater than 30 meters. The equipment does not have a preventive maintenance program, but it is in reasonable condition. The working surface (floor) in some sections of the transfer has cobblestones, which makes it difficult to push the load. In the summer there are average temperatures in the shade of 45 to 50 grades. The table 4 shows the results of the evaluation.

Table 4. Evaluation of the Delivery of demijohns using diablito

RISK FACTORS	Small equipment	
	Color	**Value**
Loaded weight		4
Posture		0
Hand-object coupling		0
Work pattern		1
Distance per trip		3
Condition of auxiliary equipment		4
Ground surface		1
Obstacles on the route		0
Other environmental factors		1
	Total Score:	**14**
	Risk Level:	**Alto**

Conclusion: A score of 14 was obtained in the transfer for the delivery of demijohns in the different areas, so it is considered a high-significant risk. Quick action is required as a control measure related to the risk factors of load weight, distance and condition of the auxiliary equipment

Activity: Unloading of demijohns from the diablito and in the assigned location

Description of the task: The activity consists of the delivery of full demijohns to the different areas of the institution, for this the worker once transferred the diablito with the full demijohns. He/she will: 1) lift the load (7 lifts per hour), 2) transport it inside the building (> 10 meters) and 3) place it on the side of the cooler (unloading). In the table 5 shows the results of the evaluation.

Table 5. Evaluation of the activity of unloading demijohns from the diablito and at the assigned location.

RISK FACTORS	Raise		Transport		Unload	
	Color	**Value**	**Color**	**Value**	**Color**	**Value**
Weight loaded and frequency of loading / lifting		0		4		0
Horizontal distance from hands to lower back		3		0		3
Lifting vertical region		3				1

Torso twisting and lateral bending / asymmetrical load on torso (carrying)		1		3		0
Postural restrictions		0		0		0
Hand-object coupling		1		2		2
Floor surface		0		0		
Other environmental factors		0		0		
Transport distance				3		
Obstacles on the route				1		
	Total Score:	**8**	**Total Score:**	**13**	**Total Score:**	**6**
	Risk Level	**Medio**	**Risk Level**	**Alto**	**Risk Level**	**Medio**

Conclusion: A score of 8 was obtained in the lifting of the bottle for its transfer to the interior of the building, in the case of unloading at the place of delivery a score of 6 was determined; for both it is considered a medium risk, so the tasks should be examined through a specific evaluation or establish control measures related to the risk factors of horizontal distance, vertical lifting, hand-object coupling, in both activities. In the particular case of lifting, the torso torsion and flexion condition should be improved. The evaluation of the transfer activity presented an overall score of 13 points, so the level of risk is high, for this reason it is necessary to establish a rapid action to reduce the risk, for which the risk factors of asymmetric load on the torso, as well as the hand-object coupling, transfer distance, obstacles on the route and the weight and frequency of the transfer of the jugs must be considered.

After the evaluation of the activities identified with a risk level, which confirmed the evaluation, we proceeded to analyze the activity with a high risk level, which is the delivery of demijohns, due to the weight of the filled demijohns and the diablito that is used, so the recommendation is a transport that facilitates the development of the activity. The figure shows a possible transport to be used, whose height is at the elbows of the worker that allows him to load and unload easily.

Improvement actions

After the evaluation of the activities identified with a risk level, which confirmed the evaluation, we proceeded to analyze the activity with a highrisk level, which is the delivery of demijohns, due to the weight of the filled demijohns and the diablito that is used, so the recommendation is a transport that facilitates the development of the activity. The Table 6 shows a possible transport to be used, whose height is at the elbows of the worker that allows him to load and unload easily.

Stage of the process	Activities to be valued	Risk Level	Improvement actions
Collection of empty jugs	Bottles are collected for filling	--------	--------
Bottles filling	• Lifting of water demijohns	--------	--------
	• Washing of demijohns		
	• Filling, capping and drying		
Manual transfer	• Lifting of water jugs	**Low**	No improvement actions are required
	8. Transfer of full demijohn to the diablito	**Low**	No improvement actions are required
	9. Loading a full demijohn into the diablito	**Medium**	1. Material handling equipment should be designed to have a minimum height above the knees to prevent personnel from lifting the bucket close to the ground.  2. Considering the above improvement, the worker shall be prevented from twisting his torso or leaning it sideways to load the work platform cart. 3. The trolley configuration will allow reducing the horizontal distance when loading the carafes. 4. The design shall be designed with a hinged railing or fence to facilitate loading.

			
Delivery of demijohns	5. Push diablito	**High**	1. A work platform trolley shall be designed for the transfer of the demijohns to prevent the personnel from bearing part of the total transfer load.  2. Además, deberá de contar con flat taires para facilitar 2. In addition, it should have flat taires to facilitate transportation, thus avoiding uneven floors and cobblestones. 3. Delivery routes should be analyzed to avoid inefficient routes or transfers with the intention of reducing delivery distances in the different areas. 4. Establish a preventive maintenance program for handling equipment. el traslado, evitando con ello los desniveles de piso y el adoquín.
	6. Unload the carafe from the diablito	**Medium**	1. The features of the suggested work platform cart will prevent the personnel from lifting the bucket close to the ground. In addition, it will prevent the worker from twisting his torso or tilting it sideways to unload the cart. 2. The cart configuration will reduce the horizontal distance when loading the demijohns, so they will be able to hold the demijohn and keep it symmetrically attached to the body.

			
	7. Move the carafe to the defined location	**High**	1. This activity should be avoided, since the equipment should enter the buildings with the equipment up to the unloading destination, thus avoiding the manual transfer of the demijohns.
	8. Unload carafe	**Medium**	1. La c The trolley configuration will reduce the horizontal distance when loading the demijohns, so they can hold the demijohn and keep it attached to the body in a symmetric way.  2. Considering the new position of the carafes this will allow a better grip of the carafes keeping the fingers at 90 degrees below the base of the carafe.  3. Another improvement action is to have a rack to avoid placing the bottles on the floor, thus avoiding a vertical discharge that is harmful to the operator. 

Table 6. Proposals for transportation solutions to be used

CONCLUSION

The analysis of manual load handling in the filling and distribution process of water jugs at the purification plant of the Instituto Tecnológico de Sonora identified significant ergonomic risks that can affect both workers' health and operational efficiency. It was found that the weight of the jugs, repetitive movements, and improper postures increase the likelihood of musculoskeletal injuries, which could lead to occupational disabilities and disrupt product distribution.

By applying Norma 036-1 STPS 2018, a detailed assessment was conducted, serving as the foundation for ergonomic improvement proposals. The main recommendation focuses on optimizing the transport equipment used, aiming to reduce physical strain and improve workers' posture, thereby minimizing the identified risk factors.

It is concluded that implementing these improvements would not only enhance the safety and well-being of employees but also contribute to a more efficient and sustainable operation within the plant. Furthermore, the findings of this study may be applicable to other environments where manual load handling poses an ergonomic challenge, promoting safer and more productive working conditions.

REFERENCES

Brents, C., Hischke, M., Reiser, R., & Rosecrance, J. (2021). Trunk Posture during Manual Materials Handling of Beer Kegs. International Journal of Environmental Research and Public Health, 18. https://doi.org/10.3390/ijerph18147380.

Chaffin, D. B., Andersson, G. B. J., & Martin, B. J. (2019). Occupational Biomechanics. Wiley.

Garg, A., Moore, J. S., & Kapellusch, J. M. (2018). Ergonomics in Material Handling. Human Factors and Ergonomics Society.

Kunar, B., Aruna, M., & Kar, M. (2021). Postural analysis of dumper operators and construction workers – a case study. , 69, 180-185. https://doi.org/10.18311/JMMF/2021/28525.

Marras, W. S., Granata, K. P., & Davis, K. G. (2006). Biomechanics of Manual Material Handling. Journal of Applied Ergonomics, 37(4), 451-456.

Nadila, F., & Suryadi, A. (2024). Analysis of Work Posture and Risk of Musculoskeletal Complaints of Loading-Unloading Workers Using the REBA Method at PT. XYZ. IJIEM - Indonesian Journal of Industrial Engineering and Management. https://doi.org/10.22441/ijiem.v5i1.21878.

National Institute for Occupational Safety and Health (NIOSH). (2021). Manual Material Handling Guidelines. U.S. Department of Health & Human Services.

Ning, X., Zhou, J., Dai, B., & Jaridi, M. (2014). The assessment of material handling strategies in dealing with sudden loading: the effects of load handling position on trunk biomechanics.. Applied ergonomics, 45 6, 1399-405 . https://doi.org/10.1016/j.apergo.2014.03.008

Russeng, S., Saleh, L., Wahyulianti, W., & Palutturi, S. (2021). The Effect of Age and Workload on Work Posture toward Musculoskeletal Disorders Complain on

Loading and Unloading Workers. Open Access Macedonian Journal of Medical Sciences. https://doi.org/10.3889/oamjms.2021.7277.

Secretaría del Trabajo y Previsión Social. (2018). Norma Oficial Mexicana NOM-036-1-STPS-2018, Factores de riesgo ergonómico en el trabajo – Identificación, análisis, prevención y control. Diario Oficial de la Federación. https://sidof.segob.gob.mx.

Takala, E. P., Pehkonen, I., Forsman, M., & Hansson, G. A. (2020). Ergonomics and Technological Advancements in Load Handling. Ergonomics Journal, 63(3), 375-390.

ERGONOMIC ASSESSMENT OF A WORKSTATION IN A GLASS INDUSTRY IN THE STATE OF VERACRUZ

Magdalena Hernández Cortez https://orcid.org/0000-0002-5997-573X; Viridiana Sánchez Vázquez https://orcid.org/0000-0003-0879-8929; Leticia Vázquez Tzitzihua https://orcid.org/0000-0002-3848-240X

Departamento de Ingeniería Industrial
Tecnológico Nacional de México, campus Tierra Blanca
Prolongación de Avenida Veracruz, S/N esq, C. héroes de Puebla
Colonia PEMEX, Tierra Blanca, Ver.,
cp. 95180, Veracruz, México.

Corresponding author's e-mail: magdalena.hernandez@itstb.edu.mx

Resumen: La industria decoradora de envases, es un sector que demanda altos niveles de precisión y resistencia física debido a la naturaleza de sus procesos productivos, los trabajadores están expuestos a condiciones ergonómicas deficientes, como posturas inadecuadas, movimientos repetitivos y cargas físicas excesivas, lo que puede generar trastornos musculoesqueléticos a mediano y largo plazo. Estas problemáticas suelen derivar de la falta de diseño ergonómico en los puestos de trabajo y de la planificación ineficiente de las jornadas laborales, lo que afecta tanto la salud de los empleados como la productividad de la empresa.
Ante este panorama, la metodología OCRA (Occupational Repetitive Actions) se presenta como una herramienta eficaz para la evaluación y prevención de los riesgos asociados a trabajos repetitivos.

Palaras clave: INDUSTRIA VIDRIERA, OCRA, EVALUACIÓN, ERGONOMIA

Relevancia para la Ergonomía: La ergonomía es un factor clave en la optimización de las condiciones laborales y en la prevención de trastornos musculoesqueléticos (TME), especialmente en industria vidriera donde las tareas son de alta exigencia física. En este contexto, el presente estudio sobre la aplicación del método OCRA (Occupational Repetitive Actions) resulta altamente relevante y proporcionará evidencia científica, así como recomendaciones prácticas para la mejora de las condiciones de trabajo promoviendo un entorno laboral más seguro, saludable y productivo.

Abstract: The packaging decorating industry is a sector that demands high levels of precision and physical endurance due to the nature of its production processes. Workers are exposed to poor ergonomic conditions, such as inadequate postures, repetitive movements and excessive physical loads, which can lead to musculoskeletal disorders in the medium and long term. These problems often arise from a lack of ergonomic design in the workplace and from inefficient planning of work days, which affects both the health of employees and the productivity of the company.

Given this scenario, the OCRA (Occupational Repetitive Actions) methodology is presented as an effective tool for the evaluation and prevention of risks associated with repetitive work.

Keywords: GLASS INDUSTRY, OCRA, EVALUATION, ERGONOMICS

Relevance for Ergonomics: Ergonomics is a key factor in the optimization of working conditions and in the prevention of musculoskeletal disorders (MSDs), especially in the glass industry where tasks are highly physically demanding. In this context, the present study on the application of the OCRA (Occupational Repetitive Actions) method is highly relevant and will provide scientific evidence as well as practical recommendations for the improvement of working conditions by promoting a safer, healthier and more productive work environment.

INTRODUCTION

The following research work was developed in a glass industry, which within all its processes were identified some that currently may in the future cause MSDs to workers, this due to repetitive activities, inadequate postures, lack of breaks during the work day, in such a way that these activities can cause short, medium and long term injuries among those who do not modify or attend to these recommendations of the study.

The present study aims to evaluate ergonomic risk factors in a glass industry using the OCRA methodology, in order to identify the most critical tasks and propose improvement strategies that promote the health and well-being of workers. Through this analysis, it is hoped to contribute to the optimization of the work environment, promoting safety and efficiency in production processes.

METHODOLOGY:

The application of the method aims to determine and evaluate the risk factors in jobs with repetitive activities, inadequate or static postures, forces, forced movements and the lack of rest or recovery periods, using the OCRA Check List Index (ICKL) value and, based on this value, classify the risk as Optimal, Acceptable, Very Light, Light, Medium or High. The ICKL is calculated using the following equation:

$$ICKL = (FR + FF + FFz + FP + FC)\,.MD$$

OCRA Check List Index (ICKL)

1.-Task Identification: The work stations in the production line were analyzed, identifying activities with high repetitiveness and physical load. In this analysis, through direct observation, it was possible to identify the task performed within the department and the real process times in the activities.

The evaluation was carried out in the final product area, in which the workers in that area, their main function is to assemble cardboard boxes, so that in a later process they can be filled with empty bottles to deliver to the final customer. A non-experimental, longitudinal, quantitative and retrospective evaluation was carried out. The study participants were explained the procedure to be carried out in their workplace.

2.- Risk Factor Record: The frequency of movements per minute, the use of force and the posture adopted during each task were recorded. These will be considered in the following calculations.
As a previous step to the calculation of the different factors and multipliers to obtain the OCRA Check List Index, it is necessary to calculate the Net Repetitive Work Time (TNTR) and the Net Work Cycle Time (TNC) under the following equation.

$$.TNTR \equiv DT - \lfloor TNR + P + A \rfloor$$

Net Repetitive Work Time (NRT)

In this equation, DT is the shift duration in minutes or the time the worker occupies the position during the shift. TNR is the non-repetitive work time in minutes. This time is the time spent by the worker on non-repetitive tasks such as cleaning, restocking, etc. P is the duration in minutes of the breaks the worker takes while occupying the position. A is the duration of the lunch break in minutes. Substituting these values, the TNTR is:

$$TNTR = 420 - \lfloor 10 - 0 + 60 \rfloor = 350\,Minutes$$

Once the TNTR is known, it is possible to calculate the Net Work Cycle Time. The **TNC** could be defined as the work cycle time if only the repetitive tasks performed at the station were considered

$$.TNC = 60 * TNTR/NC$$

Net Duty Cycle Time (NCT)

Substituting these values:

$$TNC = 60 * \frac{350}{8400} = 2.5\,minutes$$

Once **TNTR** and **TNC** are known, the factors and multipliers of the **ICKL** calculation equation will be calculated.

3.- **Calculation of the OCRA Index:** The ICKL formula was applied, classifying the tasks according to their risk level. The following is a breakdown.

Recovery factor: In this section, all the activities carried out by the worker and the average number of scheduled breaks, as well as those that are not considered, were analyzed. This factor of the equation assesses whether the recovery periods at the evaluated position are sufficient and are conveniently distributed.

Situación de los periodos de recuperación	Puntuación
- Existe una interrupción de al menos 8 minutos cada hora de trabajo (contando el descanso del almuerzo). - El periodo de recuperación está incluido en el ciclo de trabajo (al menos 10 segundos consecutivos de cada 60, en todos los ciclos de todo el turno)	0
- Existen al menos 4 interrupciones (además del descanso del almuerzo) de al menos 8 minutos en un turno de 7-8 horas. - Existen 4 interrupciones de al menos 8 minutos en un turno de 6 horas (sin descanso para el almuerzo).	2
- Existen 3 pausas, de al menos 8 minutos, además del descanso para el almuerzo, en un turno de 7-8 horas. - Existen 2 pausas, de al menos 8 minutos, en un turno de 6 horas (sin descanso para el almuerzo).	3
- Existen 2 pausas, de al menos 8 minutos, además del descanso para el almuerzo, en un turno de 7-8 horas. - Existen 3 pausas (sin descanso para el almuerzo), de al menos 8 minutos, en un turno de 7-8 horas. - Existe 1 pausa, de al menos 8 minutos, en un turno de 6 horas.	4
- Existe 1 pausa, de al menos 8 minutos, en un turno de 7 horas sin descanso para almorzar. - En 8 horas sólo existe el descanso para almorzar (el descanso del almuerzo se incluye en las horas de trabajo).	6
- No existen pausas reales, excepto de unos poco minutos (menos de 5) en 7-8 horas de turno.	10

Tabla 1: Puntuación del Factor de Recuperación (FR).

Performing the analysis, it was observed that there is no recovery factor in the work day, therefore, the Recovery Factor has a rating of 10

Frequency factor: The actual cycles and consecutive movements are considered. For this point, it is necessary to identify the type of technical action carried out at the position. This can be static or dynamic, and is defined according to the periodicity and duration, comparing the activities with the following tables.

Acciones técnicas dinámicas	ATD
Los movimientos del brazo son lentos (20 acciones/minuto). Se permiten pequeñas pausas frecuentes.	0
Los movimientos del brazo no son demasiado rápidos (30 acciones/minuto). Se permiten pequeñas pausas.	1
Los movimientos del brazo son bastante rápidos (más de 40 acciones/minuto). Se permiten pequeñas pausas.	3
Los movimientos del brazo son bastante rápidos (más de 40 acciones/minuto). Sólo se permiten pequeñas pausas ocasionales e irregulares.	4
Los movimientos del brazo son rápidos (más de 50 acciones/minuto). Sólo se permiten pequeñas pausas ocasionales e irregulares.	6
Los movimientos del brazo son rápidos (más de 60 acciones/minuto). La carencia de pausas dificulta el mantenimiento del ritmo.	8
Los movimientos del brazo se realizan con una frecuencia muy alta (70 acciones/minuto o más). No se permiten las pausas.	10

Acciones técnicas estáticas	ATE
Se sostiene un objeto durante al menos 5 segundos consecutivos realizándose una o más acciones estáticas durante 2/3 del tiempo de ciclo (o de observación).	2,5
Se sostiene un objeto durante al menos 5 segundos consecutivos, realizándose una o más acciones estáticas durante 3/3 del tiempo de ciclo (o de observación).	4,5

Factor de Frecuencia (FF)

Substituting the observed values in the following equation.

$$FF = Max\ (ATD; ATE)$$

$$FF = Max\ (4; 2{,}5) = 4$$

Therefore, FF corresponds to a score of 4.

Force Factor: The calculation of the Force Factor is based on quantifying the effort required to carry out the technical actions in the position. To do this, firstly, the actions that require the use of force will be identified, as well as the effort required, based on the following tables.

- Empujar o tirar de palancas.
- Pulsar botones.
- Cerrar o abrir.
- Manejar o apretar componentes.
- Utilizar herramientas.
- Elevar o sujetar objetos.

Force Factor: The calculation of the Force Factor is based on quantifying the effort required to carry out the technical actions in the position. To do this, firstly, the actions that require the use of force will be identified, as well as the effort required, based on the following tables.

Required effort:

Acciones técnicas dinámicas	ATD
Los movimientos del brazo son lentos (20 acciones/minuto). Se permiten pequeñas pausas frecuentes.	0
Los movimientos del brazo no son demasiado rápidos (30 acciones/minuto). Se permiten pequeñas pausas.	1
Los movimientos del brazo son bastante rápidos (más de 40 acciones/minuto). Se permiten pequeñas pausas.	3
Los movimientos del brazo son bastante rápidos (más de 40 acciones/minuto). Sólo se permiten pequeñas pausas ocasionales e irregulares.	4
Los movimientos del brazo son rápidos (más de 50 acciones/minuto). Sólo se permiten pequeñas pausas ocasionales e irregulares.	6
Los movimientos del brazo son rápidos (más de 60 acciones/minuto). La carencia de pausas dificulta el mantenimiento del ritmo.	8
Los movimientos del brazo se realizan con una frecuencia muy alta (70 acciones/minuto o más). No se permiten las pausas.	10

Esfuerzo	Puntuación	OCRA FFz
Nulo	0	No se considera
Muy débil	1	
Débil	2	
Moderado	3	Fuerza moderada
	4	
Fuerte	5	Fuerza intensa
	6	
Muy fuerte	7	
Cercano al máximo	8	Fuerza casi máxima
	9	
	10	

Escala de esfuerzo percibido CR-10 de Borg

A score will then be obtained for each of the detected actions based on the intensity of the effort (moderate, intense, almost maximum), and the percentage of the work cycle time in which the effort is made.

Fuerza moderada		Fuerza Intensa		Fuerza casi Máxima	
Duración	Puntos	Duración	Puntos	Duración	Puntos
1/3 del tiempo	2	2 seg. cada 10 min.	4	2 seg. cada 10 min.	6
50% del tiempo	4	1% del tiempo	8	1% del tiempo	12
> 50% del tiempo	6	5% del tiempo	16	5% del tiempo	24
Casi todo el tiempo	8	> 10% del tiempo	24	> 10% del tiempo	32

Scoring actions that require effort

The activity in this case does not require effort because it only opens and closes boxes, therefore the effort is not considered or its score is 0.

<u>Postures and movements factor:</u> The postures that the worker takes considering shoulder, hand, elbow and wrist were evaluated and given a score, using the following formula:

$$FP = Max\ (PHo; PCo; PMu; PMa + PEs)$$

Postures and Movements Factor (FP)

Substituting the values the result is:

$$FP = Max\ (24; 8; 4; 8 + 3) = 27$$

<u>Additional risk factors:</u> Additional factors are grouped into two types: physical-mechanical factors and those derived from socio-organizational aspects of work. For this assessment, tables and the following formula will be used:

$$FC = Ffm + Fso$$

Replacing the values:

$$FC = 3 + 2 = 5$$

Additional Risk Factor (CF)

These data were taken into account the speed of the machine that transports the boxes, the height and/or position of the lids that the worker takes. The result of the additional risk factor is 5.

<u>Duration multiplier:</u> To obtain the risk level considering the exposure time, the duration multiplier **(DM)** must be calculated. This is calculated using **the Net Repetitive Work Time (NRTT)** table calculated previously. The duration of the work day, compared to the net repetitive work time.

Tiempo Neto de Trabajo Repetitivo (TNTR) en minutos	MD
60-120	0.5
121-180	0.65
181-240	0.75
241-300	0.85
301-360	0.925
361-420	0.95
421-480	1
481-539	1.2
540-599	1.5
600-659	2
660-719	2.8
≥720	4

Therefore, the duration multiplier factor is 0.925.

Once the evaluation has been carried out, each of the previously calculated values is replaced, in order to be able to compare them with the risk level proposed by the method.

$$ICKL = (FR + FF + FFz + FP + FC) * MD$$

Replacing the values:

$$ICKL = (10 + 4 + 0 + 27 + 5) * \ 0.925 = 42.55$$

With the calculated value of the OCRA Check List Index, the Risk Level and the Recommended Action can be obtained using the following table.

Índice Check List OCRA	Nivel de Riesgo	Acción recomendada	Índice OCRA equivalente
≤ 5	Óptimo	No se requiere	≤ 1.5
5.1 - 7.5	Aceptable	No se requiere	1.6 - 2.2
7.6 - 11	Incierto	Se recomienda un nuevo análisis o mejora del puesto	2.3 - 3.5
11.1 - 14	Inaceptable Leve	Se recomienda mejora del puesto, supervisión médica y entrenamiento	3.6 - 4.5
14.1 - 22.5	Inaceptable Medio	Se recomienda mejora del puesto, supervisión médica y entrenamiento	4.6 - 9
> 22.5	Inaceptable Alto	Se recomienda mejora del puesto, supervisión médica y entrenamiento	> 9

Risk Level, Recommended Action and Equivalent OCRA Index

Once the assessment was completed, it was compared with the risk level proposed by the method. It was possible to identify that the activity carried out repetitively, although it does not require great effort, the fact of being repetitive and for 8 consecutive hours, in a long-term period the worker will present musculoskeletal injuries.

Results

Once the assessment was completed, it was possible to determine that the risk level is unacceptably high, so improvement actions must be carried out in the position, as well as medical supervision of the workers and training for said modifications to the workplace.

In addition, the results obtained highlight the importance of carrying out a more detailed evaluation of the work station, with the objective of identifying possible improvements in the design and organization of tasks. Adjustments in the height of work surfaces, variation in repetitive movements and the implementation of active breaks can significantly contribute to reducing the impact of these risk factors.

Conclusions

The analysis carried out using the OCRA method has proven to be a valuable tool, revealing the presence of significant ergonomic risks due to task repetitiveness and excessive workloads. The implementation of active breaks, task rotation and redesign of workstations is recommended to mitigate these risks.

The systematic application of the OCRA method can contribute to the prevention of MSDs and improve the quality of working life of operators.

The implementation of active breaks, task rotation and redesign of workstations is recommended to mitigate these risks. The systematic application of the OCRA method can contribute to the prevention of MSDs and improve the quality of working life of operators.

References:

Colombini, D., Occhipinti, E., & Grieco, A. (2017). Risk assessment and prevention of work-related musculoskeletal disorders: Ergonomic approaches. CRC Press.

Diego-Mas, Jose Antonio. Risk assessment due to repetitive movements using the Ocra Check List. Ergonautas, Polytechnic University of Valencia, 2015. Available online: https://www.ergonautas.upv.es/metodos/niosh/niosh-ayuda.php

Neumann, W. P., Wells, R. P., & Norman, R. W. (2020). Ergonomics and musculoskeletal disorder risk assessment using OCRA in industrial environments. International Journal of Industrial Ergonomics, 76, 102921.

Occhipinti, E., & Colombini, D. (2019). OCRA: A concise index for evaluating exposure to repetitive movements of the upper limbs. Applied Ergonomics, 75, 29-40.

Takala, E.-P., Pehkonen, I., Forsman, M., Hansson, G.-A., & Mathiassen, S. E. (2019). Analysis of repetitive work: A review of ergonomic risk assessment methods. Journal of Occupational Health, 61(2), 151-164.

TRUNK KINEMATICS IN TWO LOAD-LIFTING TASKS: APPLICATION OF AN OPEN-SOURCE MARKERLESS TOOL

Jhon A. Quiñones[1], https://orcid.org/0000-0001-8084-0883 1, José J. Guevara[2], https://orcid.org/0009-0003-0816-3162 2, Lina M. Melo 3[3], https://orcid.org/0009-0009-3971-7766 3, and Lessby Gomez Salazar[4],https://orcid.org/0000-0001-8084-0883 4

1Department of Morphology-2Faculty of Engineering-3,4School of Human Rehabilitation-
University of Valle
Cl. 4B #36-00
Cali, Valle del Cauca, Colombia

Corresponding author's e-mail: quinones.jhon@correounivalle.edu.co

Resumen: **Introducción**: La manipulación manual de cargas es un factor de riesgo para desórdenes musculoesqueléticos en la región lumbar, especialmente por la combinación de movimientos de tronco que son complejos de valorar. El uso de herramientas biomecánicas de código libre abre oportunidades para realizar evaluaciones objetivas. **Objetivo:** Establecer la cinemática del tronco en los planos sagital, frontal y transversal al levantar un ladrillo de 3 kg con y sin flexión de rodilla. **Metodología:** Estudio descriptivo con 10 adultos jóvenes normopeso (27.7 ± 5.3 años, IMC 23.32). Cada participante realizó tres repeticiones de ambos gestos; se analizó la mejor ejecución. La captura se realizó con dispositivos iOS (60 fps) y procesamiento en OpenCap para obtener rangos de movimiento (ROM) y variabilidad**. Resultados:** El levantamiento con flexión de rodilla presentó un ROM de tronco máximo sagital de 51.6°, frontal de 10.7° y transversal de 31.3°, mostrando menor exigencia lumbar. Sin flexión de rodillas, el ROM en el plano sagital fue de 56.2°, con mayor inclinación lateral (12.1°) y rotación (37.5°), lo que indica mayor carga sobre la columna. La flexión de rodilla redujo compensaciones posturales y mejoró la estabilidad**. Conclusiones:** OpenCap es una herramienta eficaz para la evaluación ergonómica sin marcadores, permitiendo valorar, en este caso, la movilidad de columna al ejecutar los Aportaciones a la ergonomía: Los hallazgos refuerzan la importancia de la flexión de rodilla en la prevención de lesiones y validan el uso de OpenCap en la evaluación biomecánica laboral

Palabras clave: Biomecánica, Levantamiento de carga, OpenCap, Cinemática del tronco, Ergonomía ocupacional

Relevancia para la ergonomía: Este artículo aporta evidencia sobre el análisis tridimensional del tronco durante el levantamiento de carga, resaltando el valor de la flexión de rodilla como estrategia protectora. Además, valida el uso de OpenCap como herramienta accesible para la evaluación biomecánica en entornos laborales reales, facilitando intervenciones preventivas basadas en evidencia.

Abstract: Introduction: Manual material handling is a recognized risk factor for musculoskeletal disorders in the lumbar region, especially due to the combination of trunk movements, which are complex to assess. The use of open-source biomechanical tools opens new opportunities for objective evaluations.
Objective: To determine the trunk kinematics in the sagittal, frontal, and transverse planes when lifting a 3 kg brick, comparing two techniques: with and without knee flexion. **Methodology:** Descriptive study with 10 young normoweight adults (27.7 ± 5.3 years, BMI 23.32). Each participant performed three repetitions of both lifting techniques; the best execution was selected for analysis. Motion capture was performed using iOS devices (60 fps), and data processing was carried out in OpenCap to obtain ranges of motion (ROM) and variability. **Results:** The lifting with knee flexion showed a largest trunk ROM of 51.6° in the sagittal plane, 10.7° in the frontal plane, and 31.3° in the transverse plane, showing lower lumbar demand. In contrast, the lifting without knee flexion resulted in a sagittal ROM of 56.2°, with greater lateral inclination (12.1°) and rotation (37.5°), showing higher load on the spine. Knee flexion reduced postural compensations and improved stability. **Conclusions:** OpenCap proved to be an effective tool for markerless ergonomic assessment, allowing for the evaluation of spinal mobility during functional tasks, providing valuable information for occupational risk prevention.

Keywords: Biomechanics, Load lifting, OpenCap, Trunk kinematics, Occupational ergonomics

Relevance to ergonomics: This article provides evidence on the three-dimensional analysis of the trunk during load lifting, highlighting the protective role of knee flexion. It also validates OpenCap as an accessible tool for biomechanical assessment in real work environments, helping evidence-based preventive interventions.

1. INTRODUCCIÓN

La manipulación manual de cargas es una actividad común en diversos entornos laborales y constituye un factor de riesgo biomecánico considerable en la aparición de desórdenes musculoesqueléticos, especialmente en la región lumbar(Paola & Vallejo, 2021). Investigaciones previas han señalado que los movimientos de flexión y rotación del tronco durante estas tareas pueden inducir elevadas cargas sobre los discos intervertebrales, incrementando la susceptibilidad a lesiones, particularmente cuando la técnica de levantamiento no es óptima(Lomeli-Rivas & Larrinúa-Betancourt, 2019).

Dentro del campo de la ergonomía y la prevención de lesiones, la evaluación del movimiento humano se ha basado históricamente en análisis observacionales y en sistemas de captura de movimiento con marcadores(Nogareda & Canosa, 2016). No obstante, estos métodos presentan limitaciones en términos de disponibilidad, precisión y aplicabilidad en entornos dinámicos(Ghezelbash et al., 2020). En este contexto, OpenCap emerge como una alternativa innovadora de código abierto, realizando captura de movimiento sin marcadores basada en la web que estima la cinemática 3D a partir de vídeos grabados desde al menos dos dispositivos iOS(Uhlrich et al., 2023).

Este sistema ha demostrado ser válido ampliamente para analizar la cinemática de las extremidades inferiores, con errores entre 2.9° y 7° al compararse con sistemas ópticos tradicionales(Turner et al., 2024). Recientemente, su precisión también ha sido evaluada para estudiar el movimiento del tronco durante tareas funcionales, de acuerdo con Lima(Lima et al., 2024), se han mostrado errores aceptables menores a 7° y niveles de fiabilidad de buenos a excelentes según la articulación analizada. Además, su aplicación se ha extendido al ámbito de la ergonomía ocupacional, combinándose con herramientas como REBA para la evaluación de posturas de trabajo(Bernabé Pardo, 2023). Esta evidencia respalda su uso como una herramienta accesible y válida para la evaluación biomecánica del tronco en tareas de manipulación manual de cargas.

El presente estudio tiene como finalidad la caracterización de la cinemática del tronco en los planos sagital, frontal y transversal durante la ejecución de levantamientos de carga en 10 individuos normopeso con IMC promedio de 23.32. Se analizaron 2 gestos de levantamiento de un ladrillo de 3 kg, considerando el hacerlo con y sin flexión de rodilla.

Los hallazgos de este estudio promoverán el uso de las tecnologías de captura de movimiento sin marcadores en la evaluación ergonómica, permitiendo una caracterización precisa de las demandas biomecánicas en la manipulación de cargas. Estos resultados contribuyen al análisis del riesgo musculoesquelético, facilitando la optimización de estrategias de levantamiento y su aplicación en entornos ocupacionales y clínicos

.

2. OBJETIVO

Establecer la cinemática tridimensional del tronco en los planos sagital, frontal y transversal durante el levantamiento de un ladrillo de 3 kg, comparando dos técnicas: con flexión y sin flexión de rodilla, mediante el uso de OpenCap como herramienta de análisis biomecánico.

3. METODOLOGIA

Estudio descriptivo, con un enfoque cuantitativo que analiza la cinemática tridimensional del tronco en dos tareas de levantamiento de carga, evaluando la aplicabilidad de OpenCap para estudios ergonómicos en entornos controlados.

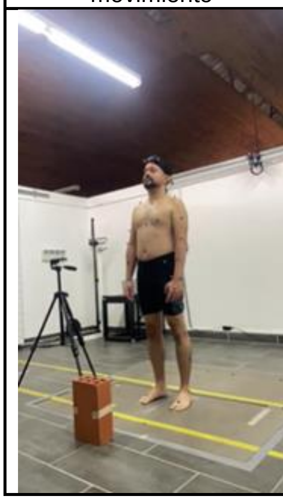
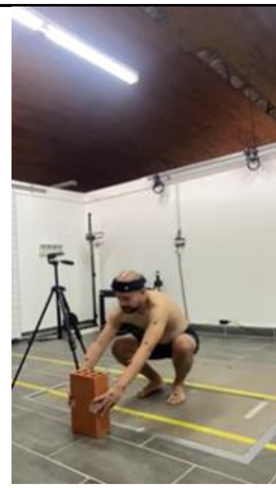
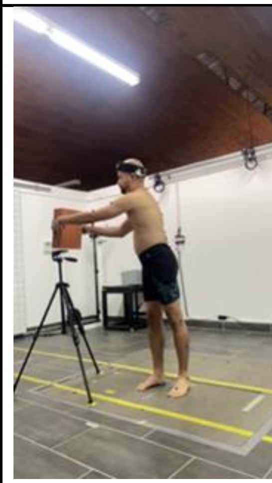
Tareas evaluadas

Las tareas seleccionadas incluyen el levantamiento de un ladrillo de 3 kg con y sin flexión de rodilla.

El levantamiento de ladrillo se realiza desde el piso, hasta una altura de 105 cm . y se dividió en 3 fases de ejecución del gesto :

- Fase de inicio: El sujeto se encuentra en posición erguida.
- Fase de agarre: Inicia en la posición inicial y culmina con la sujeción del ladrillo.
- Fase de posicionamiento: El ladrillo es llevado a la superficie

Tabla 1. Descripción de las fases de los gestos

Inicial: El sujeto se encuentra en posición erguida antes de iniciar la ejecución del movimiento	**Agarre/Sujeción:** El sujeto toma el ladrillo asegurándose de una sujeción firme.		**Posicionamiento:** El ladrillo se coloca sobre una superficie con control y estabilidad
			

Participantes

Se contó con la participación de 10 sujetos con características antropométricas homogéneas. La edad promedio fue de 27.7 años, con un rango de 20 a 37 años. El peso medio fue de 66.6 kg (rango: 63.4 - 71.0 kg) y la estatura promedio de 1.69 m (rango: 1.68 - 1.70 m). El índice de masa corporal (IMC) promedio fue de 23.32 kg/m^2, manteniéndose dentro del rango normopeso. Todos los participantes estaban libres de patologías patología que pudiera verse afectada por la realización de los gestos evaluados o que afectaran la ejecución de estos

Configuración experimental

Se utilizaron 3 dispositivos móviles IOS 12, filmando a 60 fps, posicionados en el plano frontal (0°) y oblicuos (45°) del sujeto para realizar la captura de movimiento. La sincronización y configuración de los dispositivos se realiza mediante la aplicación OpenCap, empleando la cuadrícula y la postura de cada sujeto, garantizando la estandarización del registro de datos cinemáticos.

Procesamiento de datos

Los videos obtenidos fueron procesados en la nube en la plataforma de OpenCap, generando modelos tridimensionales del movimiento de los participantes. Se extrajeron los datos cinemáticos del tronco en los tres planos de movimiento y se calcularon los rangos de movilidad articular (ROM) en cada fase del levantamiento, así como la variabilidad intersujeto.

Análisis estadístico

Se aplicó estadística descriptiva para caracterizar los parámetros cinemáticos de cada tarea. Se calcularon medias y desviaciones estándar de los rangos de movimiento. La variabilidad intersujeto fue evaluada mediante el coeficiente de variación (CV) para cada parámetro.

Consideraciones Éticas

El estudio fue aprobado por el Comité de Ética de la Universidad del Valle 009-024, y todos los participantes firmaron un consentimiento informado antes de la recolección de datos.

4. RESULTADOS

A continuación, se presentan los resultados de la evaluación cinemática tridimensional del tronco durante el levantamiento de un ladrillo de 3 kg, comparando las condiciones con y sin flexión de rodilla. Se describen los rangos de movimiento (ROM) en los planos sagital, frontal y transversal, así como la variabilidad intersujeto observada en cada fase del gesto. Los resultados se ilustran mediante figuras que representan los patrones de movimiento y las diferencias individuales

Durante el levantamiento de ladrillo con flexión de rodilla se mostró un patrón de movimiento uniforme (ver figura 2). Evidenciando en el plano sagital, un rango de movimiento (ROM) promedio de 44.8 y un valor máximo de alcanzado de 51.6°, con una reducción progresiva en la fase de posicionamiento final. En el plano frontal, se observaron inclinaciones laterales moderadas con un pico máximo de 10.7°. En el plano transversal, la rotación máxima registrada fue de 31.3°(Ver figura1)

Durante el levantamiento de ladrillo con flexión de rodilla se mostró un patrón de movimiento con mayores variaciones (ver figura 4). El levantamiento sin flexión de rodilla presentó un ROM más elevado en el plano sagital, alcanzando un pico máximo de 56.2°. En el plano frontal, el ROM máximo registrado fue de 12.1°,

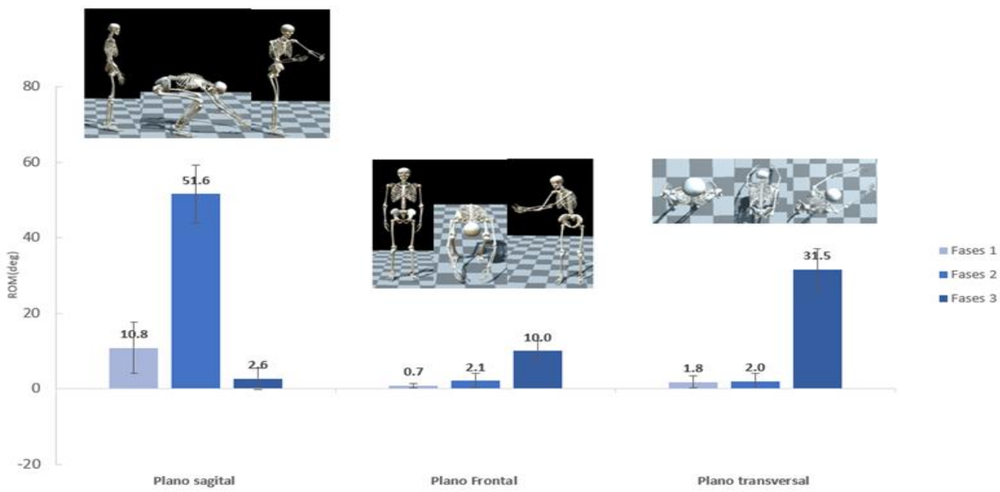


Figura 1. Cinemática 3D del tronco durante el levantamiento de ladrillo con flexión de rodilla

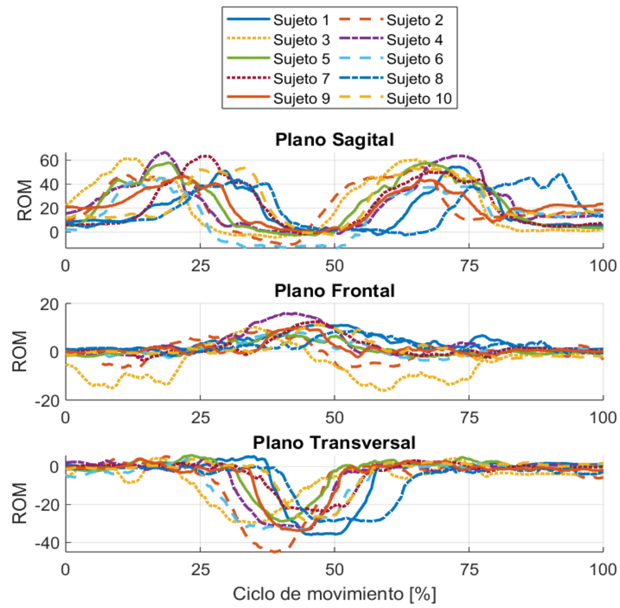


Figura 2. Diferencias individuales durante la ejecución del levantamiento de ladrillo con flexión de rodilla en los tres planos

.

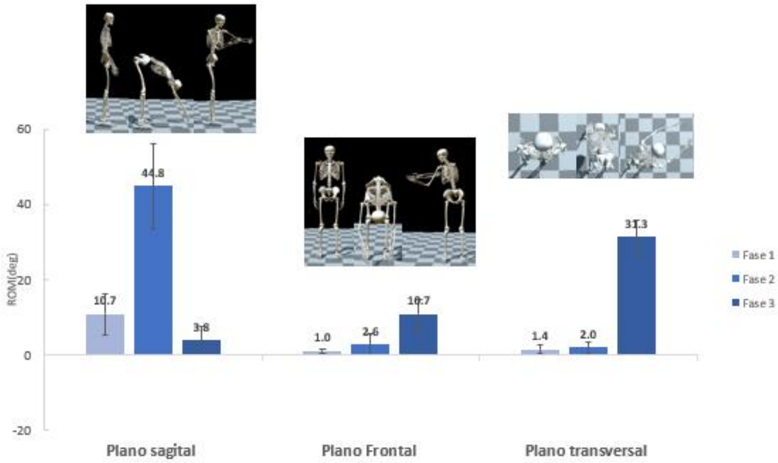


Figura 3. Cinemática 3D del tronco durante el levantamiento de ladrillo sin flexión de rodilla

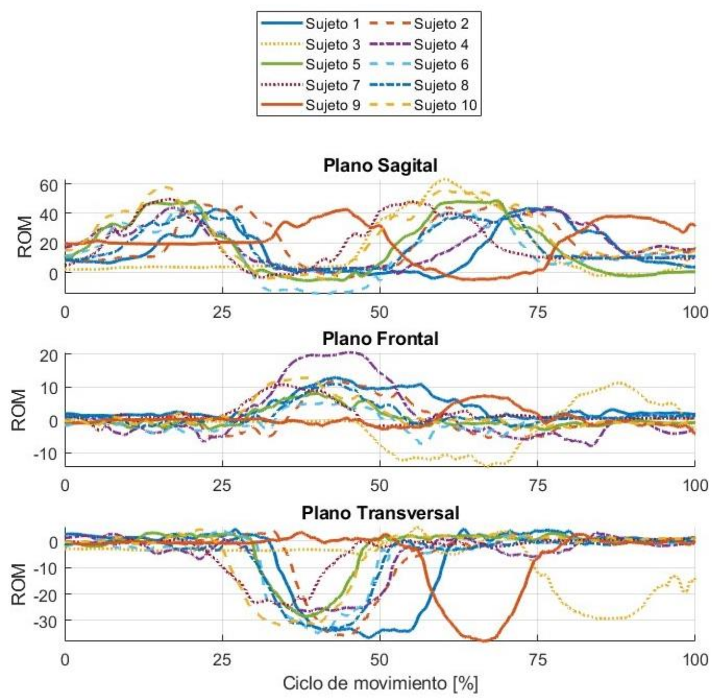


Figura 4. Diferencias individuales durante la ejecución del levantamiento de ladrillo sin flexión de rodilla en los tres planos

reflejando un incremento en la inclinación lateral. En el plano transversal, la rotación máxima registrada fue de 37.5°, lo que indica una mayor compensación rotacional.

Tabla 2. Promedio del ROM del tronco y variabilidad Inter sujeto

LEVANTAMIENTO DE LADRILLO (3kg) CON FLEXIÓN DE RODILLA									
	Fase 1			Fase 2			Fase 3		
	Plano Sagital	Plano Frontal	Plano Transverso	Plano Sagital	Plano Frontal	Plano Transverso	Plano Sagital	Plano Frontal	Plano Transverso
PROMEDIO	10.70	0.97	1.40	44.77	2.64	1.98	3.80	10.73	31.29
DS	5.41	0.64	1.01	11.36	2.80	1.51	3.80	3.91	4.52
CV	0.51	0.66	0.72	0.25	1.06	0.76	1.00	0.36	0.14
LEVANTAMIENTO DE LADRILLO (3kg) SIN FLEXIÓN DE RODILLA									
	Fase 1			Fase 2			Fase 3		
	Plano Sagital	Plano Frontal	Plano Transverso	Plano Sagital	Plano Frontal	Plano Transverso	Plano Sagital	Plano Frontal	Plano Transverso
PROMEDIO	10.84	0.75	1.80	51.56	2.08	2.00	2.64	9.99	31.52
DS	6.87	0.63	1.52	7.70	1.92	1.96	2.77	2.57	5.64
CV	0.63	0.84	0.84	0.15	0.92	0.98	1.05	0.26	0.18

Los resultados muestran que el levantamiento de un ladrillo de 3 kg con flexión de rodilla presentó menor variabilidad en la cinemática del tronco, especialmente en el plano sagital durante la fase central del gesto, mientras que el levantamiento sin flexión de rodilla mostró mayores rangos de movimiento y mayor variabilidad, particularmente en los planos frontal y transversa. Los CV Inter sujeto, oscilaron entre 0.14 y 1.06, siendo mayores en la fase inicial y de agarre, especialmente en la inclinación de tronco sin flexión de rodilla (0.84 y 1.06 respectivamente). En contraste, el menor CV se presentó en la fase final de la flexión de tronco con flexión de rodilla (0.14).

5. DISCUSIÓN Y CONCLUSIONES

Este estudio analizó la cinemática tridimensional del tronco durante el levantamiento de un ladrillo de 3 kg, comparando dos técnicas identificadas previamente en campo: con y sin flexión de rodilla. Posteriormente, los participantes replicaron estos gestos de forma estandarizada, lo que permitió comparar sus patrones de movimiento bajo un mismo protocolo. En ambos casos, el plano sagital presentó los mayores rangos de movimiento, mientras que los planos frontal y transversal mostraron mayor variabilidad intersujeto, especialmente al inicio del gesto, reflejando diferencias individuales en la preparación y alineación postural.

El levantamiento sin flexión generó mayores demandas sobre la columna lumbar, aumentando el ROM sagital y provocando compensaciones rotacionales en el plano transversal. Estos hallazgos coinciden con estudios previos (San Agustin et al., 2016) que señalan que la flexión de rodillas facilita la distribución de cargas y mejora la estabilidad postural (Granata & Marras, 1999; Tang, 2020).

Al comparar con investigaciones que validan OpenCap en tareas deportivas y controladas(Lima et al., 2024; Turner et al., 2024), este estudio evidencia una variabilidad moderada en los coeficientes de variación (CV), con valores entre 0.51 y 0.84 en las fases iniciales, y entre 0.14 y 0.36 en las fases finales. Aunque el gesto fue estandarizado, cada participante ajustó su postura según su experiencia previa y sus características físicas. En línea con Lima et al., el plano sagital mostró menor variabilidad (CV entre 0.15 y 0.25 en la fase 2), lo que reafirma la precisión de OpenCap para captar flexo-extensión de tronco.

En contraste, los planos frontal y transversal presentaron mayor variabilidad, alcanzando un CV de hasta 0.84 en el plano frontal sin flexión de rodilla, lo que refleja ajustes posturales espontáneos para mantener el equilibrio o redistribuir la carga. Este comportamiento es coherente con lo descrito por Bernabé Pardo(Bernabé Pardo, 2023), quien identificó patrones posturales irregulares al aplicar OpenCap con REBA en contextos laborales reales, resaltando que la variabilidad postural es un indicador clave en la evaluación ergonómica.

Desde el enfoque ergonómico y biomecánico, estos hallazgos subrayan la importancia de analizar no solo la postura final, sino también la dinámica completa del gesto y la variabilidad intersujeto. En el contexto laboral, esta variabilidad refleja cómo cada trabajador ajusta el movimiento según su experiencia, percepción de riesgo y condición física, lo que debe considerarse al diseñar programas de capacitación o estrategias preventivas adaptadas a las condiciones reales de trabajo.

Aportaciones a la ergonomía

Estos hallazgos destacan la importancia de la técnica en la prevención de lesiones musculoesqueléticas y respaldan la aplicabilidad de OpenCap en estudios ergonómicos. Se recomienda su uso para la evaluación biomecánica en contextos ocupacionales, con el fin de optimizar estrategias de levantamiento y reducir riesgos asociados a la manipulación manual de cargas.

6. REFERENCES

Bernabé Pardo, E. (2023). Uso de OpenCap para análisis ergonómicos en entornos de trabajo, empleando la herramienta de análisis postural REBA [Thesis Doctoral]. Universidad Politécnica de Valencia.

Ghezelbash, F., Shirazi-adl, A., Plamondon, A., & Arjmand, N. (2020). Comparison of different lifting analysis tools in estimating lower spinal loads – Evaluation of NIOSH criterion. Journal of Biomechanics, 112, 110024. https://doi.org/10.1016/j.jbiomech.2020.110024

Granata, K. P., & Marras, W. S. (1999). Relation between spinal load factors and the high-risk probability of occupational low-back disorder. Ergonomics, 42(9), 1187–1199.

Lima, Y. L., Collings, T., Hall, M., Bourne, M. N., & Diamond, L. E. (2024). Validity and reliability of trunk and lower-limb kinematics during squatting, hopping, jumping and side-stepping using OpenCap markerless motion capture application. Journal of Sports Sciences, 42(19), 1847–1858.

Lomeli-Rivas, A., & Larrinúa-Betancourt, J. E. (2019). Biomecánica de la columna lumbar: un enfoque clínico. Acta Ortopédica Mexicana, 33(3), 185–191.

Nogareda, S., & Canosa, M. d. (2016). Levantamiento manual de cargas: ecuación del NIOSH. Instituto Nacional de Seguridad e Higiene Del Trabajo, España.

Paola, M., & Vallejo, C. (2021). Medidas de prevención para riesgo biomecánico asociado a los desórdenes musculo esqueléticos generados en empresas expuestas a carga, dinámica por manipulación manual de cargas.

San Agustin, F. P., Mora, J. E., Castells, A. C., Armengol, T. P., Gomà, S. C., & Benasuly, A. E. L. (2016). Las lesiones por sobrecarga en las extremidades inferiores desde el punto de vista biomecánico. Revista Internacional de Ciencias Podológicas, 10(2), 106–121.

Tang, K. H. D. (2020). Abating biomechanical risks: A comparative review of ergonomic assessment tools. Journal of Engineering Research and Reports, 17(3), 41–51.

Turner, J. A., Chaaban, C. R., & Padua, D. A. (2024). Validation of OpenCap: A low-cost markerless motion capture system for lower-extremity kinematics during return-to-sport tasks. Journal of Biomechanics, 171, 112200.

Uhlrich, S. D., Falisse, A., Kidziński, Ł., Muccini, J., Ko, M., Chaudhari, A. S., Hicks, J. L., & Delp, S. L. (2023). OpenCap: Human movement dynamics from smartphone videos. PLOS Computational Biology, 19(10), e1011462. https://doi.org/10.1371/journal.pcbi.1011462

ERGONOMIC ANALYSIS IN THE QUALITY INSPECTION AREA IN MEXICALI TEXTILE INDUSTRY

Pedro Antonio Mendoza Rocha[1], 0009-0007-9115-2868, Olivia Yessenia Vargas Bernal[1], 0000-0001-8928-68822, Carlos Raúl Navarro Gonzalez[1], 0000-0003-3873-3800, Mildrend Ivett Montoya Reyes[1], 0000-0001-5575-8060, and Ismael Mendoza Muñoz[1], 0000-0002-0810-2090

[1]Department of Industrial Engineering
Autonomous University of Baja California
Av. Álvaro Obregón S/N
Mexicali, Baja California, México, 21100

Corresponding author's e-mail: pedro.mendoza16@uabc.edu.mx

Resumen: La ergonomía busca reducir los riesgos ocupacionales, trastornos musculoesqueléticos (TME) y la adecuación del entorno al trabajador. La evaluación ergonómica en el área de inspección de calidad, tuvo como objetivo identificar factores de riesgo, mejorar las condiciones laborales y promover el bienestar de los trabajadores, así como hacer más eficiente el proceso de inspección final. El análisis se centró en una estación de trabajo, del área de inspección de calidad en una industria textil de la Ciudad de Mexicali, donde la trabajadora realiza tareas repetitivas de revisión y medición. Se consideró el mobiliario, la iluminación, la postura de trabajo y los movimientos requeridos para la inspección. Se aplicó el método RULA para evaluar las posturas en la estación de inspección de calidad y se analizaron mediciones de iluminación y disposición del espacio. Los resultados indican que una estación de trabajo mal diseñada puede generar fatiga visual, TME y reducción de la precisión en la inspección. Se identificaron deficiencias en la iluminación y el diseño del mobiliario, lo que contribuye a posturas inadecuadas y estrés físico. La implementación de principios ergonómicos permite mejorar la postura de las inspectoras, reducir el estrés laboral y aumentar la eficiencia en la inspección. Es fundamental ajustar la estación de trabajo con sillas adecuadas, iluminación óptima y pausas activas para prevenir lesiones. Debido a la reciente reforma a la Ley Federal del Trabajo (LFT), conocida como Ley Silla, esta investigación representa un diagnóstico importante para su cumplimiento. Este estudio se realizó en el 2024.

Palabras clave: industria textil, condiciones de trabajo, inspección de calidad, TME, RULA.

Relevancia para la ergonomía: Contribuye al campo de la ergonomía al proporcionar un análisis detallado de los factores de riesgo en estaciones de inspección de calidad y ofrecer alternativas efectivas.

Abstract: Ergonomics seeks to reduce occupational risks, musculoskeletal disorders (MSDs) and the suitability of the environment for the worker. The ergonomic assessment in the quality inspection area aimed to identify risk factors, improve working conditions and promote worker well-being, as well as make the final inspection process more efficient. The analysis focused on a workstation, from the quality inspection area to a textile industry in the City of Mexicali, where the worker performs repetitive tasks of review and measurement. The furniture, lighting, work posture and movements required for inspection were considered. The RULA method was applied to evaluate the postures at the quality inspection station and lighting measurements and space arrangement were analyzed. The results indicate that a poorly designed workstation can generate visual fatigue, MSDs and reduced inspection accuracy. Deficiencies in lighting and furniture design were identified, which contribute to inadequate postures and physical stress. The implementation of ergonomic principles allows for improved posture of inspectors, reduced work stress, and increased inspection efficiency. It is essential to adjust the workstation with appropriate chairs, optimal lighting, and active breaks to prevent injuries. Due to the recent reform to the Federal Labor Law (LFT), known as the Silla Law, this research represents an important diagnosis for its compliance. This study was conducted in 2024.

Keywords: textile industry, working conditions, quality inspection, TME, RULA.

Relevance to Ergonomics: Contributes to the field of ergonomics by providing a detailed analysis of risk factors in quality inspection stations and offering effective alternatives.

1. INTRODUCTION

The present study was carried out in 2024, and was based on the ergonomic analysis of a workstation, of the quality inspection area in a textile industry located in Mexicali, Baja California.

Ergonomics in quality inspection activity within the textile industry is a crucial field to guarantee the health and well-being of workers, as well as to improve productivity. In this sector, workers perform repetitive tasks and often adopt uncomfortable postures for long periods, increasing the risk of musculoskeletal disorders (MSD). These disorders are common in jobs that require repetitive movements and fixed postures, as in quality inspection, where operatives must meticulously check each piece of fabric or product (López et al., 2021).

MSDs continue to be one of the main causes of incapacity for work worldwide, affecting millions of workers in various industries. These disorders include a wide range of conditions that impact muscles, bones, tendons, and nerves, and are commonly related to work factors such as repetitive movements, poor postures, excessive loads, and lack of adequate pauses. According to the World Health Organization (WHO, 2020), MSDs represent a significant burden on public health systems and are responsible for a high percentage of absenteeism, affecting the productivity and well-being of workers.

In recent years, various studies have shown that ergonomic factors, such as the arrangement of the workspace and the organization of tasks, play a crucial role in the appearance of these disorders. In particular, industries with repetitive jobs, such as manufacturing, textiles, and automotive, have reported high rates of musculoskeletal disruption among their employees (Bernard et al., 2021). According to a report by the European Agency for Safety and Health at Work (EU-OSHA, 2021), approximately 60% of European workers report having suffered muscle pain at some point in their working life, and the prevalence of These disorders increase with age and time of exposure to ergonomic risk factors.

The impact of MSDs is not only limited to the health of workers, but also has economic repercussions for companies, since musculoskeletal injuries can cause costly medical expenses and loss of productivity (López et al., 2020). For this reason, various investigations suggest that the implementation of adequate ergonomic measures, such as the redesign of workstations, can significantly reduce the incidence of MSDs and improve the quality of working life (Santos et al., 2022).

The RULA (Rapid Upper Limb Assessment method is an ergonomic tool widely used to assess the risk of work-related MSDs in the upper extremities, such as the neck, shoulders, arms, wrists, and hands. Developed by McAtamney and Corlett in 1993, the RULA method has become one of the main ergonomic assessment tools due to its ability to quickly identify the risks associated with workers' postures and movements. This method is mainly used to evaluate tasks that involve uncomfortable postures, repetitive movements and physical effort, which allows identifying areas for improvement in workplace design (Karhu et al., 2021).

In recent years, the RULA method has been validated and adapted to various industries, showing its usefulness in identifying ergonomic risk factors in manual and production work, among others (Galloway et al., 2020). In this sense, the method allows quick and effective evaluations without the need for complex equipment, making it an accessible and economical tool for most companies. Furthermore, its implementation in job evaluation has been shown to contribute to the prevention of musculoskeletal injuries by providing data that can guide changes in work organization and ergonomic design of spaces (Jovanović et al., 2020).

The RULA method classifies the body into two groups of segments. The first group includes the neck, torso, and legs, while the second group groups the arm, forearm, and wrist. A score is assigned to each body segment according to the posture adopted during the observed task. Using numerical tables, two scores are calculated that reflect the degree of musculoskeletal postural load. Scores A and B are determined considering factors such as grip type, load, and endurance, which are added to the initial score. Subsequently, a third table is used to calculate the C score, which is added to the previous value, resulting in the final grade or maximum score. This final score ranges from 1 to 15, and is compared to five established action levels and five risk levels (Cuautle Gutiérrez et al., 2021).

2. OBJETIVES

Identify risk factors, improve working conditions and promote the well-being of workers, as well as make the final inspection process more efficient.

3. METHODOLOGY

First, the workstation was selected considering the stressful postures, then the worker's postures were evaluated through the RULA method with the support of a video; then the results of the lighting measurements at the workstation were analyzed; Subsequently, the work area was analyzed and finally, recommendations were generated. Figure 1 illustrates the methodology used for ergonomic analysis in a quality inspection workstation.

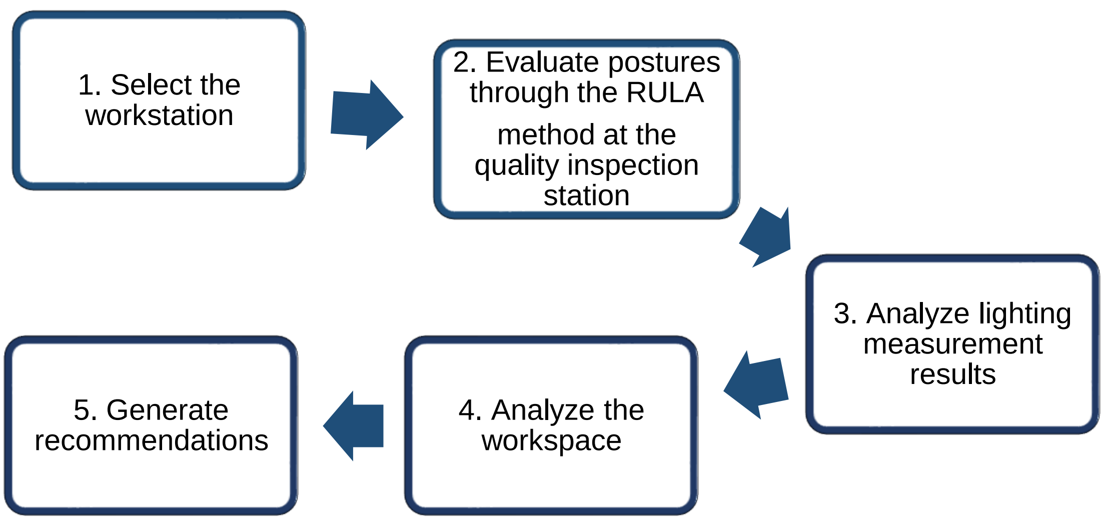


Figure 1. Methodology used for the analysis ergonomic of workstation.

4. RESULTS

Figure 2 shows the result of applying the RULA method, with a score of 7, which means that the positions and movements of the worker must be immediately studied and modified.

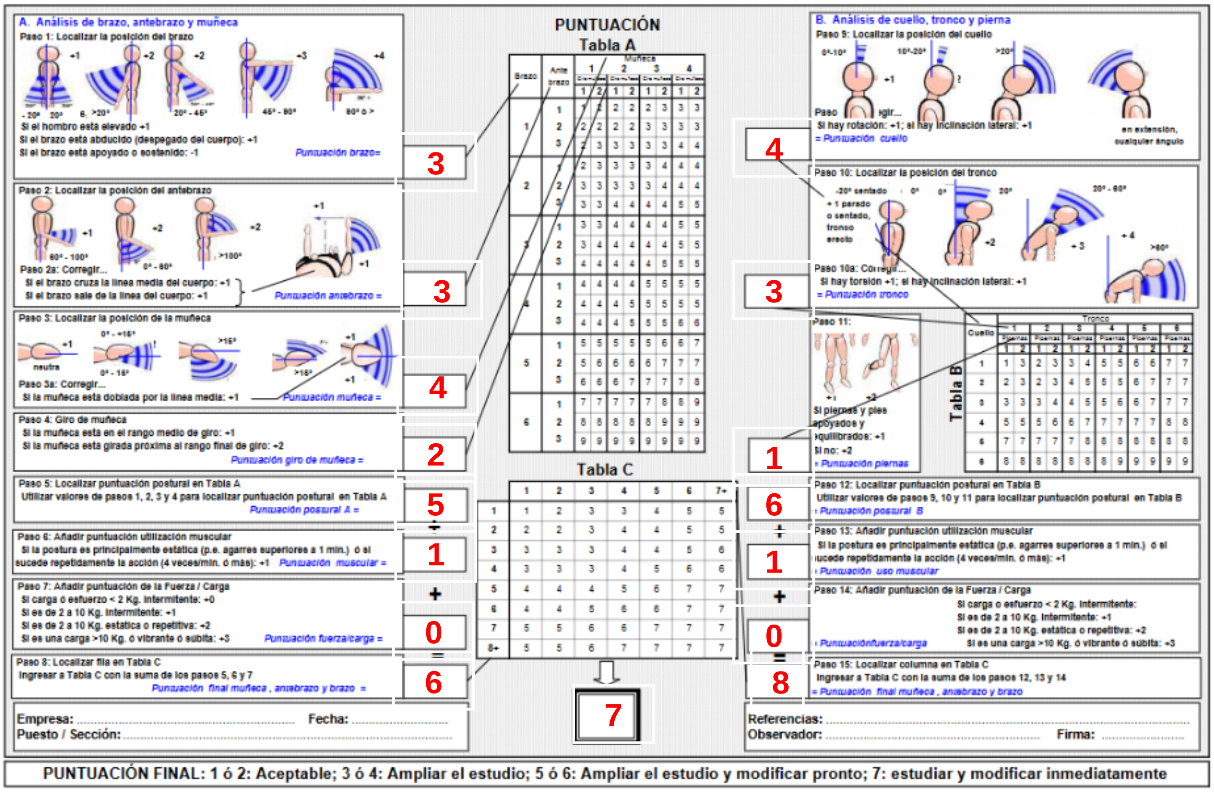


Figure 2. RULA method.

The measurement of lighting in the quality inspection workplace was carried out by an external company, based on NOM-025-STPS-2008 Lighting conditions in the work centers, lighting levels for visual tasks and work areas, it was found that the measured value was below the minimum level of lighting, as shown in Table 1.

Table 1. Lighting Measurement.

Area	Measurement location	Measurement value (Lux)	Minimum level of lighting (Lux)	Inside Norma (Yes/ No)
Quality	Inspection job	327.5	500	No

The work table has enough space to place the garments and has visual aids about the inspection process. As can be seen in Figure 3, there are no adjustable chairs or anti-fatigue mats.

Figure 3. Quality inspection table.

After analyzing the evaluation results of the worker's postures, lighting and workstation, recommendations grouped in Table 2 were generated.

Table 2. Recommendations.

Ergonomic analysis	Recommendation	Description	Benefits
Posture evaluation through the RULA method	Active breaks	They are short rest periods during the workday in which workers perform physical exercises or stretching activities. Generally, active breaks consist of stretching, gentle movements, or even short walks, lasting between 5 and 10 minutes, from time to time (for example, every 1-2 hours.	Relieves muscle tension, improves circulation, and reduces the risk of Musculoskeletal disorders.
		They are an essential component to guarantee the comfort, ergonomics and health of workers	

Workspace	Chairs for quality inspection stations	who perform repetitive tasks or who require staying long periods in the same posture. In the industry, especially in areas such as quality inspection, where operatives must examine products or parts often for hours, having an ergonomic chair is crucial to prevent musculoskeletal disorders and improve productivity.	Prevention of musculoskeletal disorders. Improved productivity. Fatigue reduction.
Workspace	Antifatigue mats	They are devices designed to improve the comfort and health of workers who stand for long periods of time. They are specially designed to reduce pressure on the legs, feet, and spine, helping to prevent fatigue-related musculoskeletal disorders in the workplace. These rugs are common in industrial settings, quality inspection workstations, offices, and other environments where people must stand for several hours.	Reduction of muscle fatigue. Prevention of musculoskeletal disorders. Improved posture and comfort. Increased productivity. Stress reduction.
		They are essential tools in environments where workers must perform precision tasks, such as product, component, or textile inspection. These lamps provide adequate lighting to allow a	Better visibility and precision. Reduction of eye fatigue.

Lighting measurement	Lamps for quality inspection tables	detailed evaluation of materials or products, which is crucial to detect defects, blemishes or irregularities during the inspection process.	Increased efficiency.

5. CONCLUSIONS

Ergonomic principles improve the posture of inspectors, reduce work stress and increase inspection efficiency. Adjusting your workstation with appropriate chairs, optimal lighting, and active breaks is essential to prevent injuries. Due to the recent reform to the Federal Labor Law (LFT), known as the Chair Law, where employers have the obligation to provide a sufficient number of seats or chairs with backrests for periodic rest during the work day, this research represents an important diagnosis for compliance.

Quality inspection table lamps not only provide adequate lighting for precision work, but also contribute to worker well-being by reducing eye fatigue and improving efficiency in inspection tasks.

The results indicate that a poorly designed workstation can lead to eye strain, MSDs, and reduced inspection accuracy.

6. REFERENCES

Bernard, B. P., Steckler, A., & Williams, J. S. (2021). *Work-related musculoskeletal disorders: A global view*. *Journal of Occupational Health and Safety*, 29(3), 12-18. https://doi.org/10.1002/jooh.12345

Cuautle Gutiérrez, L., Uribe Pacheco, L. A., & García Tepox, J. D. (2021). Identification and evaluation of postural risks in a process of finishing automotive parts. Revista Ciencias de La Salud, 19(1), 1–14. https://doi.org/10.12804/revistas.urosario.edu.co/revsalud/a.10053

European Agency for Safety and Health at Work (EU-OSHA). (2021). *Musculoskeletal disorders in the workplace: Current trends and preventive measures*. https://osha.europa.eu/en/publications

Galloway, J., Singh, K., & Smith, T. (2020). *Application of the RULA method in evaluating upper limb disorders in manufacturing environments*. *International Journal of Industrial Ergonomics*, 74, 102936. https://doi.org/10.1016/j.ergon.2020.102936

Jovanović, A., Tatomir, M., & Marinković, M. (2020). *Ergonomic assessment of risk factors using RULA: A case study in an automotive production environment*. *Applied Ergonomics*, 87, 103159. https://doi.org/10.1016/j.apergo.2020.103159

Karhu, O., Kansi, P., & Kuorinka, I. (2021). *The RULA method: A tool for ergonomic evaluation in the workplace*. *Ergonomics*, 64(1), 23-34. https://doi.org/10.1080/00140139.2020.1802703

López, M., González, C., & Pérez, R. (2020). *Impact of musculoskeletal disorders on labor productivity in Spain*. *Occupational Medicine Journal*, 72(4), 247-255. https://doi.org/10.1136/omj.2020.000345

López, M., González, C., & Pérez, R. (2021). *Impacto de la ergonomía en la mejora de la salud y productividad en la inspección de calidad en la industria textil*. *Journal of Textile Industry Safety*, 28(2), 45-57. https://doi.org/10.1016/j.jtis.2021.03.012

Organización Mundial de la Salud (OMS). (2020). *Trastornos musculoesqueléticos: una amenaza para la salud pública mundial*. Recuperado de https://www.who.int/news-room/fact-sheets/detail/musculoskeletal-disorders

Santos, G., Martins, P., & Almeida, T. (2022). *Ergonomic interventions for musculoskeletal disorder prevention in the workplace: A systematic review*. *International Journal of Industrial Ergonomics*, 85, 103255. https://doi.org/10.1016/j.ergon.2022.103255

ERGONOMIC STUDY ON THE LABELING TASK OF IMPORTED MISCELLANEOUS PRODUCTS IN CIUDAD JUAREZ

Juan Carlos Gómez Olguín, Edgar Antonio Martínez Romero, Dulce María Rodríguez Bosques, Víctor Aarón Solorio Frías, Aidé Aracely Maldonado Macías (0000-0002-4959-161X).

Department of Industrial Engineering and Logistics
Technological Institute of Ciudad Juárez
Av. Tecnológico 1340, Fuentes del Valle
Juárez, Chih., México, CP 32500

Corresponding author's email: L22110705@cdjuarez.tecnm.mx,

Resumen: En Ciudad Juárez, es común encontrar empresas que realizan el re-empaquetado de productos misceláneos importados para su venta. Este estudio se centra en el proceso de etiquetado de productos, donde los trabajadores enfrentan condiciones ergonómicas deficientes que pueden derivar en molestias musculoesqueléticas, fatiga y disminución del rendimiento. El estudio se enfoca en aplicar principios ergonómicos y antropométricos para rediseñar el área de trabajo, reduciendo riesgos y mejorando el bienestar y rendimiento laboral. El análisis incluye el estudio del trabajo mediante videograbación, el mapa del cuerpo de Marley y Kumar para la determinación de molestias musculoesqueléticas, el análisis de tareas con GOMPLAYER© y el uso de herramientas como el método RULA (Rapid Entire Body Assessment) para evaluar posturas y determinar el nivel de riesgo. Finalmente, se presenta una propuesta de rediseño de estación de trabajo más ergonómica y funcional, adaptada a las capacidades y limitaciones de los usuarios, con ajustes en dimensiones, mobiliario y distribución del área. Como resultados, las partes del cuerpo con mayor nivel de acción por su frecuencia e intensidad fueron espalda alta, espalda baja y cuello. En cuanto al análisis del trabajo se analizaron tres posturas que ocuparon más del 10% del tiempo observado y presentan factores de riesgo relevante. El método RULA detecta niveles de riesgo entre moderado y alto en las tres posturas evaluadas. En la propuesta se incluyen cambios de altura de la mesa de trabajo y una nueva distribución del lugar de trabajo.

Palabras clave: Ergonomía, etiquetado, rediseño, RULA, condiciones laborales.

Relevancia para la ergonomía: Este estudio es un ejemplo de cómo los principios ergonómicos pueden ser aplicados en sectores que comúnmente no reciben atención en este ámbito. A través de un análisis detallado de las posturas, movimientos, herramientas y el espacio de trabajo, se demuestra el impacto positivo que la ergonomía puede tener en la salud y seguridad de los empleados. En este sentido, el trabajo contribuye a mejorar las condiciones laborales, estableciendo un modelo para aplicar la ergonomía en microempresas y fomentando un enfoque preventivo en la gestión de riesgos ocupacionales.

Abstract: In Ciudad Juárez, it is common to find companies engaged in the repackaging of imported miscellaneous products for sale. This study focuses on the product labeling process, where workers face poor ergonomic conditions that may lead to musculoskeletal discomfort, fatigue, and decreased performance. The study applies ergonomic and anthropometric principles to redesign the workspace, reducing risks and improving worker well-being and productivity.The analysis includes work studies through video recording, the Marley and Kumar body map to identify musculoskeletal discomfort, task analysis using GOMPLAYER©, and ergonomic tools such as the RULA (Rapid Entire Body Assessment) method to evaluate postures and determine risk levels. Finally, an improved workstation design is proposed, optimizing dimensions, furniture, and layout to better fit workers' capabilities and limitations.Results indicate that the most affected body regions, based on frequency and intensity, were the upper back, lower back, and neck. Three postures were identified, each accounting for more than 10% of the observed time and presenting significant risk factors. The RULA method detected moderate to high risk levels in all three postures. The proposed redesign includes adjustments to the worktable height and a new workstation layout to enhance ergonomics and functionality.

Keywords: Ergonomics, labeling, redesign, RULA, work conditions.

Relevance to Ergonomics: This study demonstrates how ergonomic principles can be applied in sectors often overlooked in this field. A detailed analysis of postures, movements, tools, and the work environment shows the positive impact of ergonomics on employees' health and safety. In this sense, the work helps improve working conditions, establishing a model for applying ergonomics in microenterprises and promoting a preventive approach to managing occupational risks.

1. INTRODUCTION

In Ciudad Juárez, it is common to find microenterprises that generally lack trained personnel to evaluate the design of their work areas and the tasks performed by employees. This project focuses on one such company and, more precisely, the product labeling task, which is part of the purified water distribution process. The labeling operation, which is the focus of this study, involves repetitive movements and inadequate postures that have led to complaints from workers, such as wrist pain, fatigue, and physical discomfort due to suboptimal working conditions. Although these complaints exist, there is no official record of related incidents.

1.1 Description of the Process

In a manual labeling task performed while seated on a non-ergonomic chair, the worker is responsible for attaching labels to products using a tagging gun, typically repetitively. This activity involves constant hand and arm movements, primarily pressing the gun's trigger to release the label and position it correctly on the product. The worker needs to keep the items within their reach, which can lead to awkward postures if the workstation is poorly designed or the materials are not correctly arranged. The non-ergonomic chair may contribute to uncomfortable and prolonged postures, such as improper spinal alignment or lack of lumbar support, increasing strain on the lower back and shoulders. Additionally, the repetitive motion of using the tagging gun can cause muscle fatigue in the hands, wrists, and arms, raising the risk of injuries like tendonitis or carpal tunnel syndrome.

2. OBJECTIVES

2.1 General Objectives

The objectives are to identify and analyze the musculoskeletal discomfort experienced by employees in their work areas, evaluate the risks associated with tasks using ergonomic analysis tools, and recommend improvements in workplace quality of life by applying ergonomic principles and anthropometric design to enhance efficiency at the workstation. Proposals, methods, and strategies will also be developed to create a renewed design that helps reduce occupational risks. This includes reorganizing and improving the workspace to minimize injuries, optimize worker performance, and ensure physical well-being.

2.1. 1 Specific Objectives

- Identify current ergonomic risks by evaluating operators' postures, repetitive movements, and physical efforts at the labeling workstation.
- Assess the workstation design to identify potential improvements in the physical space that optimize workflow, accessibility, and operator comfort.
- Redesign the workstation by proposing an updated design that incorporates ergonomic improvements and facilitates a neutral posture for operators.

3. DELIMITATIONS

- **Implementation of Solutions:** The suggested improvements will be theoretical and unlikely to be implemented but will focus on accessible changes, always adhering to solutions that do not require significant investments.
- **Project Scope:** The project will focus solely on a supermarket's product labeling area. It will not include other work areas within the supermarket or additional activities.
- **Technological Limitations:** The ergonomic analysis will be conducted using direct observations and simple methods without advanced measurement or technological analysis tools due to technological limitations.

4. METHODOLOGY

4.1 Ergonomic Analysis

We conducted a detailed analysis of the product labeling task to identify and mitigate associated ergonomic risks. For this purpose, we used the MARLEY and KUMAR maps, key tools for detecting potential problem areas related to posture, repetitive movements, and environmental factors that could affect workers' health and performance.

During the analysis, we carefully evaluated the workspace dimensions, ensuring that the areas designated for the labeling task were adequate regarding accessibility, comfort, and safety. This evaluation allowed us to identify opportunities for improvement in the workspace design.

4.2 Design of Interventions.

The labeling area exhibits serious ergonomic issues as the person performing this activity must remain uncomfortable, risking musculoskeletal problems. Additionally, this task is not assigned to a specific area, prompting the need for proposed changes. Currently, the worker only has an inadequate stool for the labeling task and uses a tool for labeling products, which could also contribute to musculoskeletal problems. Improper grip, excessive wrist extension, and repetitive wrist flexions may lead to long-term injuries in this body area. Below, the two aforementioned items available to the worker are detailed.

One such resource is the *Anthropometric Data Table VIA-2: Anthropometric Data in Centimeters* (adapted from P. C. Champney, 1979, and B. Muller-Borer, 1981, Eastman Kodak Company; NASA, 1978), which provides percentile data for men and women. By calculating the appropriate percentiles for each situation, the labeling area can be redesigned using anthropometric principles.

4.3 Evaluation Methods

4.3.1 Frame Analysis in the Ergonomic Evaluation

For the ergonomic evaluation of the labeling task, frame analysis was used as the primary tool to study the postures adopted by workers during their workday. This method provided a detailed and accurate view of body positions at key moments of the activity, identifying potential areas of ergonomic risk.

The process involved recording videos of the worker performing the task at their usual workstation. These recordings extracted representative frames of critical postures, particularly those involving repetitive movements or forced positions. The frames were analyzed using specialized ergonomic tools, such as the RULA method, to assess the level of physical stress in different body parts, including the neck, shoulders, arms, and back.

4.3.2 The RULA method (Rapid Upper Limb Assessment)

The RULA method (Rapid Upper Limb Assessment) is an ergonomic tool designed to assess the risk associated with upper limb postures during work tasks. This method is essential for identifying work situations involving repetitive movements, improper postures, and physical effort that could lead to musculoskeletal disorders (MSDs). The analysis using the RULA method allows for the determination of ergonomic risks through a scoring system based on various factors, such as posture, physical effort, task frequency, and the duration of exposure. This provides valuable insights into identifying critical areas where ergonomic interventions are necessary.

The procedure for applying the RULA method consists of several steps. First, direct observation is carried out to monitor the worker performing the task and identify the most critical postures. Next, movements and positions adopted by the neck, arms, wrists, and back are recorded to assess risk factors. Following this, scores are assigned to each posture and evaluated factor according to the RULA system, allowing the calculation of the overall risk level for the task.

4.3.3 Methodology: Application of the Evaluation Matrix

Within the framework of this study, a matrix will be used as the primary tool to assess and select the optimal postures to be adopted during the labeling task. This matrix will allow the analysis of various ergonomic factors, such as the type of posture, the level of physical effort, the risk of musculoskeletal injuries, and other key elements within the work environment.

The methodology is based on the systematic application of this matrix to identify critical variables that affect posture, such as inclination, arm extension, work angles, and the repetitiveness of movements. From this analysis, it will be possible to determine which postures generate the highest levels of risk and establish recommendations to avoid unsafe practices. Additionally, the matrix will evaluate environmental factors and the worker's interaction with the work environment, identifying the best adjustment conditions to prevent fatigue, muscular strain, and long-term injuries. The results will allow the development of intervention strategies, the redesign of workspaces, and adjustments to furniture and tools used.

Table 1. Application of the Evaluation Matrix. (Eastman Kodak, 1983)

Parameters	Heavy Load of forces	Intermitternt work	Extended workenv elope	Variable tasks	Variable Surface height	Repititive Movements	Visual Attention	Fine Manioulation	Duration>4 hrs
Heavy Load of forces		ST	ST	ST	ST	ST	ST	ST	ST/C
Intermitternt work			ST	ST	ST	S or ST	S or ST	S or ST	S or ST
Extended work envelope				ST	ST	ST	ST	ST	ST/C
Variable tasks					ST	ST	ST	ST	ST/C
Variable Surface height						S	S	S	S
Repititive Movements							S	S	S
Visual Attention								S	S
Fine Manioulation									S
Duration>4 hrs									

Note: S=sitting; ST=standing; ST/C=standing with chair available

4.4 Health Considerations

The analysis of musculoskeletal disorders (MSDs) is essential to prevent injuries in the workplace. The leading causes of MSDs include repetitive movements and poor postures. Repetitive movements, such as typing for hours or performing continuous actions with the hands, wrists, or shoulders, can cause muscle tension, tendons, and ligaments, leading to injuries or inflammation. On the other hand, maintaining improper postures, such as slouching or sitting for long periods without rest, creates stress on the spine, joints, and muscles, increasing the risk of MSDs.

To prevent these disorders, strategies should be implemented to improve workplace ergonomics. For example, the height of desks, chairs, and screens should be adjusted to encourage a neutral and comfortable posture. Ergonomic support for wrists, knees, and the back are also crucial. Additionally, task rotation is essential to avoid prolonged repetitive movements, and active breaks or stretches should be incorporated every 30 to 60 minutes.

5. RESULTS

5.1 Ergonomic Analysis Using the Marley and Kumar Map

The ergonomic risk assessment based on the Marley and Kumar Map identifies different levels of biomechanical stress across body regions. The results indicate that most upper limbs and the upper back show a low-risk frequency (green), suggesting minimal exposure to ergonomic hazards. However, moderate risk (yellow) is observed in the wrists and some joints, indicating repetitive movements or sustained postures that could lead to muscle fatigue.

High-risk areas (red) include the left shoulder, lower back, and, to a lesser extent, the neck. These findings suggest excessive strain or poor posture, potentially leading to musculoskeletal disorders. Hand involvement also indicates repetitive gripping or force application under unfavorable conditions.

To mitigate these risks, workstation design should be optimized, task rotation implemented, and active breaks encouraged. Training in posture ergonomics and adjusting tools and furniture can further reduce exposure. Addressing high-risk areas is essential to prevent injuries and improve workplace conditions.

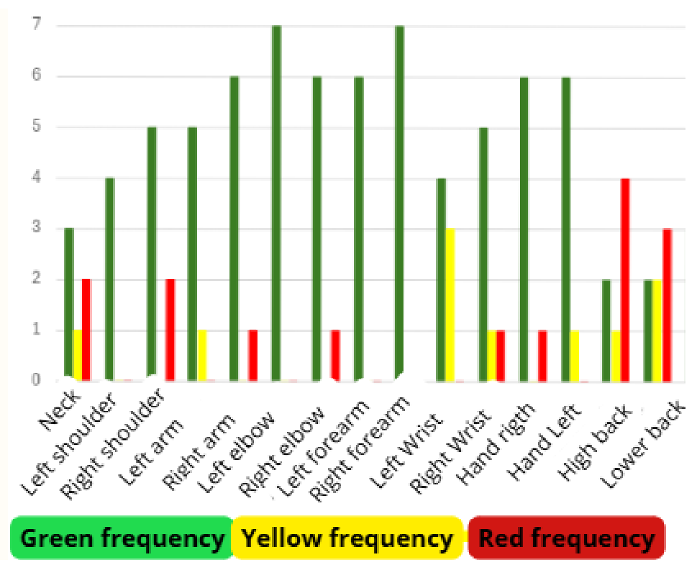


Figure 1. Evaluation with Marley and Kumar map.

5.2 Design of Interventions.

According to anthropometric principles, measurements were calculated for the 95th percentile of the population so that most people can use these spaces without any issues, thereby reducing musculoskeletal discomfort in the product labeling area. The following table shows how the dimensions for the table and chair were defined.

5.2.1 Anthropometric Redesign

The following table summarizes the key anthropometric measurements used for redesigning the workstation, ensuring adjustability and ergonomic suitability for a wide range of users:

Table 2. Anthropometric redesign data

Component	Measurement	Description	Percentile
Seat Height	Min:38.6 cm Max:47.8 cm	Height from seat to the back of the knee.	5th percentile women to the 95th percentile men.
Seat Depth	Max:53.12 cm	Thigh length, ensuring adequate support without restricting movement.	95th percentile women.
Seat Width	Max:48.52 cm	Hip width to provide sufficient space for comfort.	95th percentile women.
Backrest Height	Min:46.7 cm Max:58.44 cm	Height from the seat to the shoulder when seated.	5th percentile women to 95th percentile men.
Armrest Height	Max:18.16 cm	Height of the elbow when seated,	5th percentile of women.
Table Height	Min:62.2 cm Max:76.7 cm	Adjustable to fit elbow height when seated.	5th percentile women to 95th percentile men.
Table Width	Max:122.3 cm	Based on the 95th percentile shoulder width and arm reach to	95th percentile men.

		ensure spacious working conditions.	
Table Depth	Max:60 cm	Arm reach for the most petite women to minimize overextension.	5th percentile of women.

5.2.2. Work Area Organization

It was decided to propose removing the handheld tool and implementing a machine fixed to the workstation table. This machine will streamline the labeling task, allowing the worker to take and apply the label to the product. This adjustment eliminates reliance on the handheld tool, which, as previously mentioned, can cause ulnar nerve issues and musculoskeletal discomfort in the employee's hand. With this solution, the worker will use their hands in a natural and neutral position, reducing strain and improving overall ergonomics.

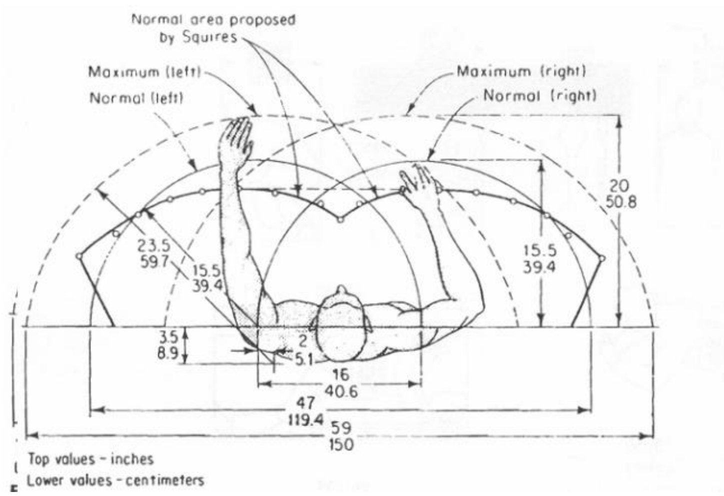


Figure 2. Dimensions of typical and maximum working areas in horizontal plane (Barnes,1963)

Based on all the considerations above, it was decided to eliminate the initial labeling tool and replace it with a labeling machine designed to prevent musculoskeletal discomfort. Another reason for choosing a seated workstation was that the new machine would be fixed to the worktable, allowing for a more straightforward operation. Considering this, the layout and distances for each element are determined based on the following image, which includes all the relevant anthropometric data.

With the data from the previous image and considering that the work is repetitive, it was decided that all tasks will be performed within the normal working area, approximately 40 cm. The worker will be positioned at the center of the proposed table, with the product labeled 35 cm to both the left and right sides, at a 45-degree angle. The labeling machine will be directly in front of the worker at a distance of 35 cm.

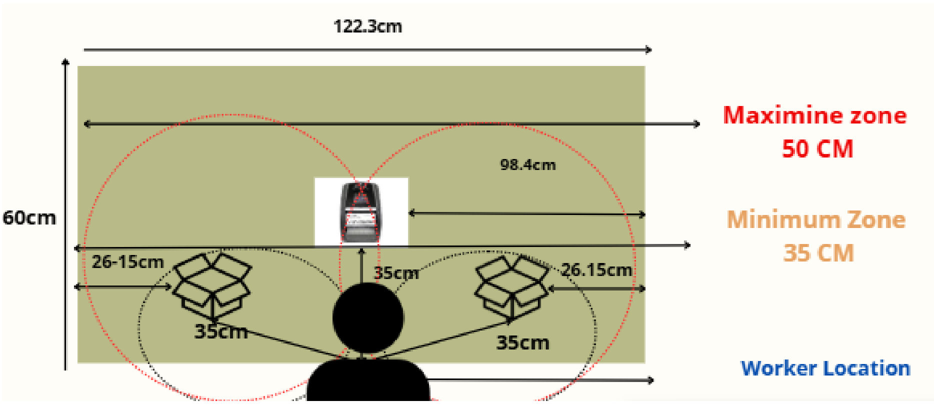


Figure 3 Workspace Distribution (Reach Zones)

5.3 Evaluation Methods

5.3.1 Frame Analysis in the Ergonomic Evaluation

The table of results obtained from the frame analysis of the postures adopted by workers during the labeling task is presented below. These data reflect the frequencies of the various assessed postures, their occurrence percentage, and the accumulation level throughout the work process. This information is crucial for identifying the most repetitive postures and evaluating the associated ergonomic risk levels.

The most relevant activities are those with a percentage greater than 10%, such as labeling, arranging, and reorganizing. These tasks are key in the work process as they represent the most frequent postures workers adopt during the labeling task. Identifying these activities is essential for implementing intervention strategies that optimize the work environment, improve ergonomics, and reduce the risk of musculoskeletal injuries.

Table 3. Frequency Table

Postures	Photo	Frequency	%Frequency	Accumulated
1. Reaching box		6,63,69,95,123,156	%6	%6
2. Pulling (bringing) box		4,18,35,61,64,100,101,110,130	%9	%15

3. Labeling		3,8,13,30,36,37, 38,70,71,72,73,7 4,75,80,106,127, 139,167,168,172 ,174,177,178,17 9,181,183,185,1 86187,199	%30	%45
4. Arranging		34,46,81,117,12 5,134,163,170,1 73,176,180,189, 190,192,195,198	%17	%62
5.Reorganizing		20,21,22,24,26,2 9,49,52,54,56,57 ,76,84,89,90,93, 94,114,118,119, 135,140,142,150 ,151,162,164,19 4,196	%29	%91
6. Leaving		14,15,25,28,47,5 9,98,122,141,17 1	%09	%100

5.3.2 <u>The RULA method (Rapid Upper Limb Assessment)</u>

The three most relevant postures, identified with the highest percentage of occurrence, were used as the basis for evaluation with the RULA method. These postures include labeling, arranging, and reorganizing, which were key in the analysis as they represent the most frequent postures adopted by workers during the labeling task.

1. Using the labeling posture, which has the highest percentage at 30%, the RULA method was applied to evaluate the ergonomic risk levels associated with the labeling task. The results showed a score of 4, indicating a moderate risk level. The obtained score suggests that the analyzed posture presents critical factors, such as spinal inclination, repetitive use of the upper limbs, and constant muscular overload due to repetitive movements during the task.
2. Using the arranging posture, which has the highest percentage at 17%, the method was applied to evaluate the ergonomic risk levels associated with the labeling task. The results showed a score of 4, indicating a moderate risk level.

3. The reorganizing task has the highest percentage, at 29%, so the RULA method was applied to evaluate the ergonomic risk levels associated with it. The results yielded a score of 5, indicating a high-risk level and the need for immediate corrective actions.

5.3.3 Methodology: Application of the Evaluation Matrix

Based on the analysis conducted using the evaluation matrix, it was determined that the task is performed in a seated position. This conclusion stems from the specific characteristics of the activity, which include repetitive movements and an intermittent work pattern. The seated posture is ideal for this type of task as it provides greater stability to the worker, reduces fatigue in the lower limbs, and facilitates the precision needed to carry out the activities efficiently.

Furthermore, since the task does not require constant movement, the seated position allows the worker to maintain a fixed posture during activity, resulting in less physical strain. However, despite its advantages, it is important to consider that this posture can also pose ergonomic risks if the work environment is not correctly adjusted, such as the height of the surface, the position of the seat, and lumbar support.

5.4 Health Considerations

Based on the Marley Kumar map results, we can observe in the graph that the following are the main issues identified. These problems have the potential to cause various musculoskeletal injuries, including:

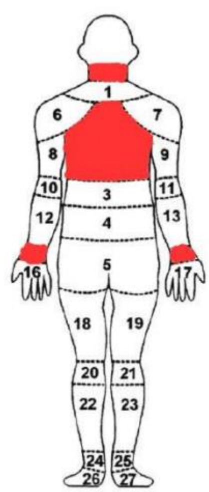


Figure 4. Areas with the most significant discomfort

- Reduction of musculoskeletal injuries: By improving ergonomics in the workspace, the risk of musculoskeletal disorders, such as injuries to muscles, tendons, and ligaments caused by repetitive movements or poor postures, is reduced.

- Improvement of employee well-being: Proper posture, along with active breaks and task rotation, helps reduce fatigue and stress, promoting greater comfort in the workplace.
- Increase in productivity: An ergonomic work environment enhances concentration and reduces physical discomfort, leading to better performance and greater efficiency in daily tasks.
- Prevention of vision problems and eye fatigue: Adjusting the lighting and avoiding glare prevents eye strain and discomfort in the neck and shoulders, improving comfort and reducing the risk of visual fatigue.
- Reduction of noise-induced fatigue: Controlling noise levels in the workplace helps decrease stress and auditory fatigue, creating a calmer and more productive environment.

6. CONCLUSIONS

This study highlights the importance of ergonomics in designing and improving workspaces, particularly in tasks such as product labeling, where risks associated with awkward postures, repetitive movements, and unfavorable environmental conditions, such as inadequate lighting and excessive noise, have been identified. These conditions negatively affect workers' health, causing musculoskeletal discomfort, stress, and visual fatigue, and directly impacting their productivity and overall performance. Implementing ergonomic and anthropometric principles, along with tools such as the RULA method and Marley and Kumar maps, allows for a detailed assessment of risks to redesign the workspace functionally, tailored to employees' capabilities and limitations.

This approach includes adjustments to furniture dimensions, space organization, and environmental improvements, fostering a safer, healthier, and more efficient work environment. Ultimately, this project underscores the importance of preventing injuries and optimizing work performance, demonstrating how proper ergonomic planning can benefit employees and the organization.

7. REFERENCES

Alférez Padron, C. R. *Video analysis of study with GOM Player.* Autonomous University of Ciudad Juárez, Master's in Industrial Engineering.

Cigna. *Ergonomics in the office.* Available at https://www.cigna.com/es-us/knowledge-center/hw/temas-de-salud/ergonoma-en-la-oficina-tr5915

Ely, E. A., Thomson, W. C., & Orlansky, A. L. (1963). *Ergonomic Design for People at Work.* Table 3.1: Choice of Workplace by Task Variables.

Ergonautas. *RULA (Rapid Upper Limb Assessment) method.* Polytechnic University of Valencia. Available at https://www.ergonautas.upv.es/metodos/rula/rula-ayuda.php

Kroemer, K. H. E., & Pheasant, S. *Ergonomics and Workplace Design: Ergonomics: How to Design for Ease and Efficiency* and *Bodyspace: Anthropometry, Ergonomics and the Design of Work.*

International Training Centre of the ILO. *Ergonomics.* Available at https://training.itcilo.org/actrav_cdrom2/es/osh/ergo/ergonomi.htm

Kromer, K. *Anthropometric data, in centimeters.* (Adapted from P. C. Champney, 1979, and B. Muller-Borer, 1981, Eastman Kodak Company; NASA, 1978).

Marley, R. J., & Kumar, N. (1996). *An improved musculoskeletal discomfort assessment tool. International Journal of Industrial Ergonomics, 17*, 21–27.

Medical Assistant. *Musculoskeletal disorders: Prevention and treatment.* Available at https://ma.com.pe/trastornos-musculoesqueléticos-prevención-y-tratamiento/

Secretariat of Labor and Social Welfare (STPS). (2008). *NOM-025-STPS-2008, lighting conditions in the workplace.* Official Gazette of the Federation. Available at https://www.gob.mx/stps

Uplift. (2023). *Anthropometry in ergonomics.* Uplift.cl. Available at https://uplift.cl/blogs/noticias/antropometria-en-ergonomia

ERGONOMIC ANALYSIS OF THE FLOWER BOUQUET ASSEMBLY TASK

Itzel Iyari Candelario Jimenez, Aidé Aracely Maldonado Macías 0000-0002-4959-161X, Rey David Molina Arredondo, 0000-0001-8482-4186 , Roberto Romero Lopez 0000-0003-0859-327X

Department of Industrial Engineering and Manufacturing
Autonomous University of Ciudad Juarez
Del Charro Ave. 450N
Ciudad Juarez, Chihuahua, Chihuahua, 32310

Corresponding author's e-mail: al216350@alumnos.uacj.mx

Resumen: Este artículo presenta un análisis ergonómico de las actividades realizadas en una floristería, con el objetivo de identificar los factores de riesgo que pueden afectar a la salud de los trabajadores y también de identificar mejoras en el área de trabajo para el bienestar de los trabajadores. La evaluación se centra en el análisis del trabajo, la aplicación de la antropometría y la evaluación postural durante la realización de tareas para la preparación de arreglos florales, el corte y la manipulación de flores, la determinación de las molestias musculoesqueléticas y la organización del espacio de trabajo. Se analizó el malestar musculoesquelético en una muestra de tres trabajadores y se analizó el trabajo grabándolo en vídeo y se utilizó el software Tumeke en versión de prueba para determinar el riesgo. En esta evaluación se aplican métodos como el mapa corporal de Marley y Kumar para determinar el malestar musculoesquelético, además se utilizó el método REBA para analizar las posturas adoptadas durante las tareas. Para el estudio de caso, se consideran las actividades y posturas adoptadas y las dimensiones reales del espacio de trabajo. Como resultado, las partes del cuerpo con mayor riesgo de lesión son la mano izquierda, la mano y el hombro derechos.

En cuanto a REBA, existe un riesgo en 4 de las 6 posturas evaluadas; por lo tanto, se presentan recomendaciones para reducir o incluso eliminar estos riesgos y rediseñar el área de trabajo para que sea más cómodo realizar esta tarea.

Palabras clave: Ergonomía, Malestar, REBA, Métodos, Herramientas

Relevancia para la ergonomía: El análisis ergonómico en una floristería es relevante porque muestra e identifica tareas repetitivas, posturas inadecuadas, manejo de herramientas y materiales que pueden afectar la salud de los trabajadores en este tipo de entornos.

La publicación de este artículo es importante porque proporciona datos específicos sobre los riesgos ergonómicos en las pequeñas empresas y ofrece soluciones aplicables no solo a las floristerías, sino también a otras pequeñas y medianas empresas con características similares. Esto aumenta la concienciación sobre la necesidad de aplicar principios ergonómicos en todos los sectores laborales, promoviendo la salud, la seguridad y la productividad de los empleados.

Abstract This article presents an ergonomic analysis of the activities carried out in a flower shop, with the aim of identifying risk factors that may affect the health of workers and also to identify improvements in the work area for worker well-being. The evaluation is focused on the analysis of work, application of anthropometry and postural assessment during the performance of tasks for the preparation of floral arrangements, cutting and handling of flowers, the determination of musculoskeletal discomfort and the organization of the workspace. Musculoskeletal discomfort was analyzed in a sample of three workers and the work was analyzed by video recording and the Tumeke software was used in a trial version for the determination of risk. In this evaluation, methods such as the Marley and Kumar body map are applied to determine musculoskeletal discomfort, in addition the REBA method was used to analyze the postures adopted during the tasks. For the case study, the activities and postures adopted and the current dimensions of the workspace are considered. As a result, the body parts with the highest risk of injury are the Left Hand, Right Hand and Right Shoulder.

Regarding REBA, there is a risk in 4 of the 6 evaluated postures, therefore recommendations are presented that can reduce these risks or even eliminate them, as well as a redesign of the work area to make it more comfortable to perform this task.

Keywords: Ergonomics, Discomfort, REBA, Methods, Tools.

Relevance to ergonomics: The ergonomic analysis in a flower shop is relevant because it shows and identifies repetitive tasks, inadequate postures, and handling of tools and materials that can affect workers' health in this type of environment.

This article's publication is important because it provides specific data on ergonomic risks in small businesses and offers solutions applicable not only to flower shops but also to other small and medium-sized companies with similar characteristics. This raises awareness of the need to apply ergonomic principles in all work sectors, promoting employee health, safety, and productivity.

1. INTRODUCTION

This study is carried out in a flower shop, an environment where manual and repetitive tasks, handling of tools, and postures maintained for long periods can generate fatigue and potential musculoskeletal injuries, because flower shops, being dedicated to the development of floral arrangements, require workers to perform activities that can generate discomfort if proper ergonomic practices are not applied, The objective is to develop an ergonomic analysis through the evaluation of the postures adopted, the use of tools and the layout of the space, applying the REBA ergonomic method to measure the physical impact of the tasks.

1.2 Problem statement

In a competitive and constantly changing market, small businesses, such as flower shops, face unique challenges related to the management of their daily routine, because they have limited resources and not enough training and personnel to optimize their production. In addition, task planning, role distribution and workspace are critical aspects that must be taken into account because if there is no solution, it can lead to inefficiencies, excessive workload, low production, occupational illnesses, etc.

Ergonomic problems can be varied due to the nature of the work that involves constant handling of flowers, plants, tools and other materials. the most common problems are:

- Repetitive movements: Constant repetition of movements when cutting stems, preparing flower arrangements and handling tools (scissors, knives, wires) can cause muscle fatigue and conditions such as tendonitis or carpal tunnel syndrome.
- Awkward postures: Prolonged standing can cause pain in the legs, feet and lower back; working in a stooped position can lead to back, neck and shoulder pain.
- Handling heavy loads: Moving large amounts of water, pots or flowers can result in strain injuries to the back, shoulders and arms and pose a risk to the spine and joints if not handled properly.
- Hand and Wrist Stress: The use of hand tools can cause pain in the hands and wrists, and over time can lead to repetitive strain injuries.
- Chemical exposure: If chemicals are used in cleaning or plant care, repeated exposure without adequate protection may cause skin irritation or respiratory problems.
- Thermal conditions: Exposure to cold or humidity to preserve flowers or in humid environments can cause discomfort and joint problems if proper precautions are not taken.

The tasks performed in the business are:

- Reception: Oversee the arrival or purchase of fresh flowers, plants, and other supplies such as ribbons, vases, floral sponges, etc.
- Storage: Flowers are stored in refrigerated chambers or in designated areas to preserve their quality.
- Inventory: Keep a record of the quantities of each type of flower and other materials, and place orders with suppliers according to needs and demand.
- Preparation: Flower selection, stem cutting, arrangement design, bouquet and centerpiece preparation.

- Maintenance: Watering and plant care: Ensure that plants are watered and cared for according to their specific needs.
- Elimination of wilted flowers: Remove flowers and plants regularly.
- Packaging and deliveries: Organize and schedule home deliveries to ensure that arrangements arrive in good condition and on time.
- Cleanliness: Keeping the store clean and tidy, which includes cleaning floors, display cases and work areas.

Detected shortcomings of the current design

- Task roles: The absence of designated areas for specific tasks can lead to confusion and unnecessary movement.
- Multitasking: Employees often have to perform multiple tasks simultaneously, due to lack of personnel.
- Waiting times: If queues or orders are not properly managed, customers may experience long waiting times.
- Insufficient training: Resulting in differences in skills and knowledge among employees.
- Space allocation: It can make it difficult to prepare arrangements, store flowers and access tools and materials.

Workplace risk factors detected:

- Flower handling and constant use of cutting tools can lead to repetitive strain injuries.
- Lifting heavy boxes up to 10 kg with flowers or supplies can cause muscle strain and back problems.
- The use of pesticides on flowers and contact with cleaning products can expose employees to chemicals.
- Long hours of work in a standing position and tasks that require detailed visual attention can cause visual fatigue and postural problems.
- Wet floors or material clutter can increase the risk of falls.
- Handling sharp tools can lead to low or high risk cuts and injuries.
- Use of inadequate protection for different tasks can lead to injuries.

1.2.2 Justification

The benefits that this ergonomic analysis will provide to the flower shop is to be able to know and increase the knowledge about the risk factors present in the business, propose changes that can potentially help reduce discomfort and disorders in the work collaborators, lower the costs that may cause occupational hazards, increase productivity in the realization of orders, in daily activities, among others.

1.2.3 Delimitations

The purpose of this work is to provide improvement proposals to a flower shop business in order to reduce the symptoms caused by the lack of ergonomics in the workplace.

2. OBJECTIVES

Apply ergonomic and anthropometric principles within a flower shop business to propose changes or redesign a workplace that can reduce awkward positions, aches and pains, as well as excessive fatigue.

2.1 Specific Objectives

- To determine the musculoskeletal discomforts and risk factors that occur when working in a flower shop, as well as to apply anthropometry within the same business.
- Determine the risk involved in working in a flower shop using ergonomic assessment methods.
- Propose changes to the workstation, methods or tools used within a flower shop.

3. METHODOLOGY

3.1 Stage 1. Analysis of musculoskeletal complaints.

In this stage, the Marley and Kumar method was applied to analyze musculoskeletal discomfort in three workers of a flower shop, two women and one man. This method focuses on the identification of pain or discomfort in different parts of the body, evaluating the frequency, intensity and level of action or risk, represented by a color system in the resulting graphs.

Frequency: It is measured on a scale of 0 to 3, where 0 indicates that no discomfort is experienced, and 3 indicates a high frequency of discomfort in the low back region. Frequency reflects how often a worker experiences pain or discomfort in a certain area of the body during the workday.

Intensity: Pain intensity is measured on a scale that varies according to the severity of the discomfort, and can range from mild to severe pain. This scale is applied subjectively, with workers indicating the level of pain experienced in different parts of the body.

Level of action or risk: This level is represented by a color chart that indicates the degree of urgency to take corrective action. The most commonly used colors are:

- Green: Low risk, indicates that treatment is not likely.
- Yellow: Moderate risk, moderate likelihood of treatment, which suggests that improvements should be evaluated and considered.
- Red: High risk, requires urgent intervention to avoid permanent damage.

Therefore, Kumar's analysis allowed to identify the areas of the body most affected during the creation of branches, and provide a basis for applying corrective ergonomic measures at the level of action or Riesco with the colors shown in the graph.

3.2 Stage 2. Analysis of the work and application of anthropometry.

For the analysis of the work and the application of anthropometry, a video was taken of one of the workers while she was performing the tasks of creating bouquets, so GOM Player software was used to visualize and stop the video at key moments, thus allowing the analysis of each posture of the workers during the process.

The analysis focused on identifying postural frequencies, observing how often workers adopt awkward or non-ergonomic postures. Postures were recorded at different stages of the work, such as cutting flowers, handling wires and the arrangement of hands in the bunches. These postures were analyzed using anthropometric data, which allow us to evaluate whether the workstations and tools are adjusted to the body dimensions of the workers.

In summary, the analysis provided valuable information on how the physical characteristics of the work environment affect workers' postures, and how they could be improved to better adapt.

3.4 Stage 4. Evaluation with the REBA Method and Tumeke (Rapid Entire Body Assessment).

The REBA (Rapid Whole Body Assessment) method was applied to evaluate ergonomic risks derived from work postures. This method allows evaluating posture, strength, movements and repetition of the tasks performed, assigning a risk score that indicates whether improvements are required.

In this evaluation, several key postures were selected during the creation of bunches, which were 6 postures, of which only 4 showed increased risk. The postures evaluated included those involving trunk flexion, arm extension and repetitive wrist movements.

In addition, Tumeke software, an ergonomic evaluation tool, was used to complement the results of the REBA method and to graphically visualize the points of greatest risk in the postures analyzed.

3.5 Step 5. Proposed workstation improvements

Finally, a workstation improvement proposal was formulated to reduce the ergonomic risks identified in the previous stages. This proposal focused on adjusting the heights of the work tables, repositioning the tools closer together to reduce repetitive strain, and adjusting the dimensions of the workstations to better suit the anthropometry of the workers.

In addition, changes in the organization of the space were proposed to improve access to materials and minimize the time workers spend in awkward postures or fall risks, so the implementation of these improvements is aimed at reducing fatigue, avoiding muscle overload and improving the efficiency of the work process in the flower shop.

4. RESULTS

4.1 Results of the Musculoskeletal Discomfort analysis

The results of the analysis of musculoskeletal complaints with the Marley and Kumar (1996) Body Map are presented below.

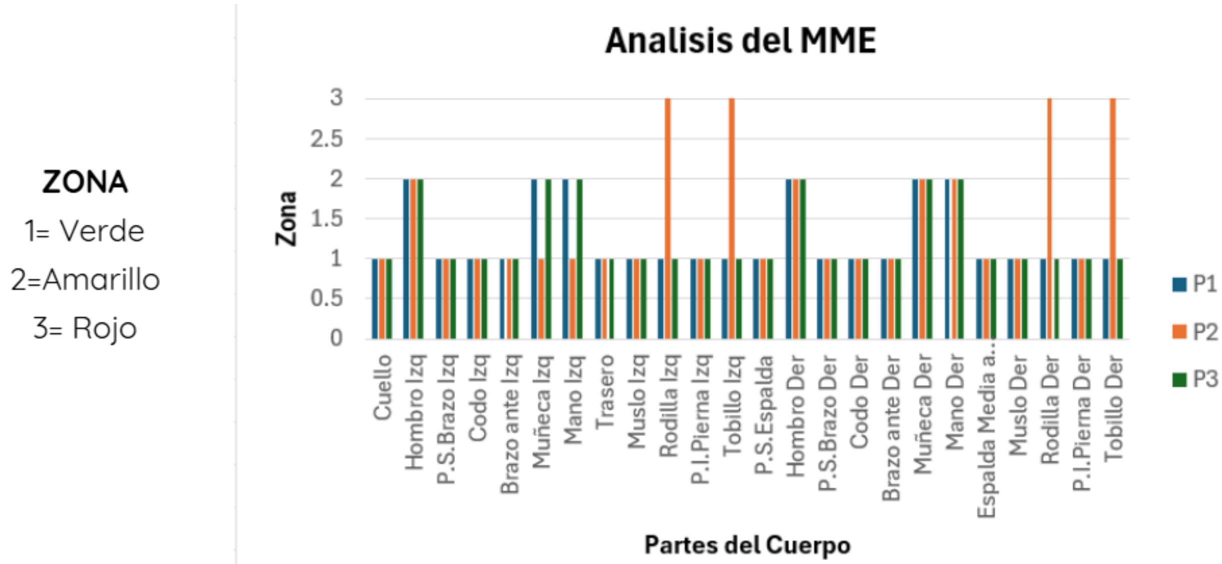


Figure 1. Analysis of the Marley and Kumar (1996) Body Map.

Where it can be seen that the most affected parts are:
1st Person: Left and Right Shoulder, Left and Right Hand, Right Shoulder, Both Feet
2nd person: Both hands, left elbow and back.
3rd person: Both hands, Right shoulder, and both feet

4.2 Application of Anthropometry

In this stage we seek to apply anthropometric principles within a local flower shop, it is essential to understand the importance of the physical characteristics and dimensions of the human body in the design and adaptation of work spaces. In the context of a flower shop, where activities include flower preparation and arrangement, handling of tools and materials, and customer service, it is essential to design a space that accommodates the physical needs of employees. A mismatch between the dimensions of the workplace and the physical characteristics of workers can result in discomfort, fatigue and, in the long term, health problems such as musculoskeletal disorders.

Sources of anthropometric information to be used in its design
American anthropometric tables of Champney & Muller-Borer (1979-1981)
Anthropometric chart, among which the following stand out:

- Height
- Arm length

- Hand grip circumference
- Height at elbows
- Functional overhead reach

Some key areas of application of anthropometry in a flower shop are as follows:

- Height of work tables: Work tables should be adjusted to a height that allows employees to make flower arrangements without having to bend over constantly. This avoids back and neck strain. For example, a table that is too low could force workers to bend over, while one that is too high could strain the shoulders and arms.
- Layout of tools and materials: Tools such as scissors, knives, wires and tape should be within easy reach of workers, without the need for repeated stretching or bending. By designing the layout of tools and inventory according to anthropometric measurements, physical strain is reduced and efficiency is improved.
- Storage at appropriate height: Shelves and storage spaces for vases, pots, and other materials should be at a height that allows easy access. Lower shelves should be high enough to prevent repetitive bending by employees, and higher shelves should be within comfortable arm's reach to avoid unnecessary stretching.
- Customer service counter design: The customer service counter should be of a height that allows for comfortable posture for both employees and customers.
- Organization of work spaces: The space for circulation within the flower shop, both in work and customer service areas, must be designed considering the width of the aisles and movement areas. This is essential to avoid collisions and facilitate the transport of heavy vases and floral arrangements, improving safety and efficiency.

4.2.1 Job analysis

For this analysis, it was necessary to examine each of the tasks, identify potential ergonomic hazards and propose solutions that could improve employee efficiency, comfort and safety. The following is a detailed analysis of the work, from material preparation to customer service.

Description of tasks in the flower shop

- Receiving materials and flowers: Consists of receiving and storing flowers, tools, and other supplies. This involves loading and unloading heavy boxes and vases, handling materials and organizing inventory.
- Arrangement preparation: Includes cutting stems, assembling bouquets, handling floral foams and decorative materials, and packaging arrangements. This task requires precision and repetition of movements.
- Plant and flower maintenance: Watering plants, trimming wilted leaves and flowers, and keeping work stations clean. Involves bending, lifting, and using hand tools.

- Internal transportation of materials: Moving vases and arrangements within the facility.
- Customer service: Consists of advising customers, presenting floral arrangement options, performing collections and packaging. This may involve standing for extended periods of time and repetitive motions when packaging products.

Frame analysis using the GOM Player application ®
The following results were obtained from the analysis of 100 random frames:

Table 1. Job analysis

Photo frame	Frequency	% of frequency	Cumulative frequency
Take	15	15	15
Upright posture carrying	15	15	30
Inclination with	15	15	45
Forced posture with	15	15	60
Tilting with both hands	15	15	75
Poor placement	15	15	90
Body stretching to take	10	10	100

Figure 2. Examples of some frames captured by the GOM Player application.

<u>4.2.1.1. Identification of ergonomic risks encountered</u>

- Awkward postures: Flower arranging and plant maintenance activities can lead to awkward postures, such as repeated bending or stooping. Lack of work tables adjusted to the correct height can lead to lower back and neck pain.
- Repetitive movements: Cutting stems, handling cutting tools and assembling bunches are tasks that require repetitive movements, especially of the hands and wrists, which can lead to muscle fatigue and, in the long term, to injuries such as carpal tunnel syndrome.

- Handling heavy loads: When receiving flowers and arranging heavy vases, employees may carry and lift objects improperly, increasing the risk of back and shoulder injuries.
- Prolonged standing: Customer service and tasks in work areas can involve standing for long periods of time, leading to leg fatigue and circulatory problems without adequate flooring or periodic breaks.

4.2.1.2 Definition of design-relevant body dimensions

Proper use of these dimensions and percentiles in ergonomic design can improve the user experience and prevent injury. Consideration of percentiles in ergonomics is critical to developing effective solutions that address the needs of a diverse population.

1. Height: This dimension was important to evaluate what would be the perfect height of the work table to reduce discomfort, so the 5th and 95th percentiles of female height were calculated as a reference to confirm that the proposed changes were adequate.

Altura
$X_5 \Rightarrow 162.1 + 6.0(-1.645) = 152.23\ Cm$
$X_{95} \Rightarrow 174.5 + 6.6(1.645) = 185.35\ Cm$

2. Arm length with closed hand: This dimension was important to evaluate the distance from the end of the table to the grip of the work tools in order to make the appropriate changes.

Longitud de los brazos con la mano cerrada
$X_5 \Rightarrow 74.1 + 3.9(-1.645) = 67.68\ Cm$
$X_{95} \Rightarrow 74.1 + 3.9(1.645) = 80.51\ Cm$

3. Height at the elbows: This dimension was important to evaluate the appropriate height of the work tableso that the workers can perform their tasks without bending over or raising their arms too much.

Altura a los Codos
$X_5 \Rightarrow 102.6 + 4.8(-1.645) = 94.70\ Cm$
$X_{95} \Rightarrow 110.5 + 4.5(1.645) = 117.90\ Cm$

4. Functional overhead reach It was used to assess the worker's ability to reach objects located in an elevated position, above his or her head, while standing, to avoid overexertion.

Alcance Funcional por encima de la cabeza

$$X_5 \Rightarrow 199.2 + 8.6(-1.645) = 185.05\ Cm$$

$$X_{95} \Rightarrow 209.5 + 8.5(1.645) = 223.58\ Cm$$

5. Grip diameter: This dimension was important for the design of the workstations and hand tools where the worker needs to grip them, in order to verify the dimensions.

Ancho de agarre, diametro interior

$$X_5 \Rightarrow 4.3 + 0.3(-1.645) = 3.86\ Cm$$

$$X_{95} \Rightarrow 4.9 + 0.6(1.645) = 5.97\ Cm$$

This is the current design of the workstation in which it can be seen that it is a piece of furniture made of wood material that does not have the correct dimensions, space and location for both the worker and the tools.

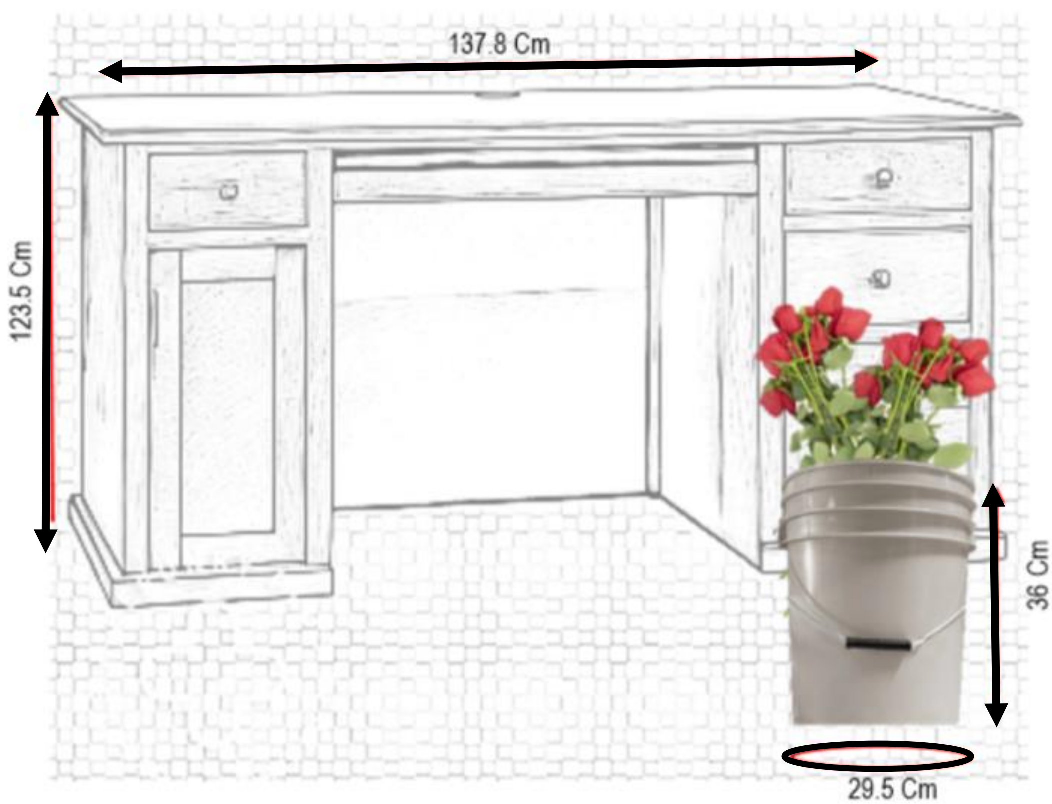


Figure 3 . Current workstation design

3.4 Evaluation with the REBA Method (Rapid Entire Body Assessment)

For this work analysis, the REBA tool was used since most of the causes and risks that are presented are forced postures, so the main postures with the highest risks are analyzed and identified with the Tumeke Software©

Figure 4. Posture 1

The description of this task is based on a stooping posture when performing the action of picking more flowers to finish the bouquet, so it is a posture with a high risk because it shows the arm very bent, the trunk leaning too far down, the legs too bent and the shoulder far away from its original part, so is necessary to take measures.

Figure 5. Result of Posture 1

Figure 5 shows that the risk level is 9, which is very high risk and therefore measures must be taken.

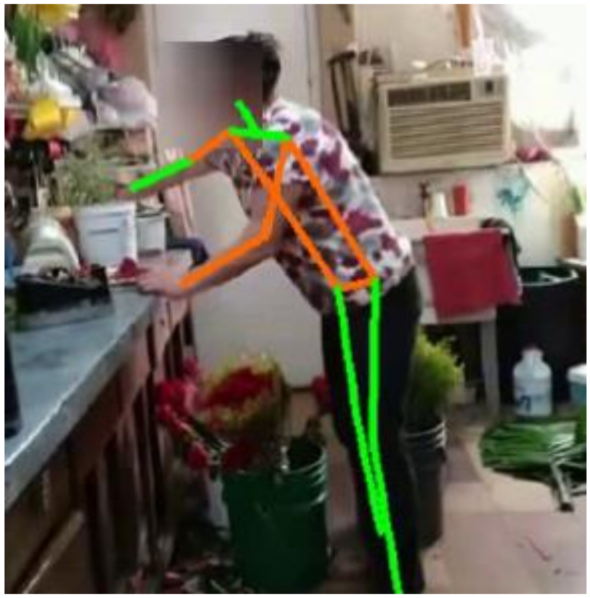


Figure 6. Posture 2

The description of this task is based on a forward leaning posture when grabbing a tool, which generates a bending posture in the trunk, also the arms are extended far forward which causes tension, so it is a posture with a medium high risk because it shows physical overexertion, so is necessary to take measures.

Figure 7 shows that the risk level is 4, which is a medium risk level, so measures should be considered before the risk rises.

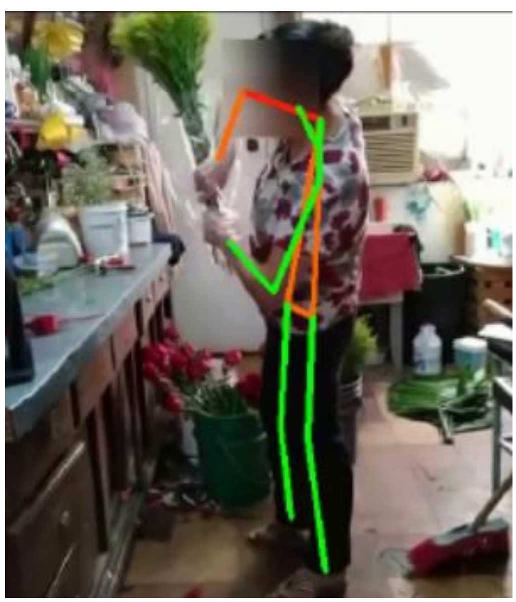


Figure 7. Result of Posture 2

Figure 8. Posture 3

The description of this task is based on a standing posture holding a bouquet with your arms bent at chest height. Although your trunk is upright, the raised arms can generate tension in the shoulders and neck if held for a prolonged period of time. In addition, straight legs can cause muscle fatigue if the posture is not alternated.

Figure 9 shows that the risk level is 5, which is a medium risk level, so measures should be considered before the risk increases in the arm area.

Figure 9. Results of Posture 3

Figure 10. Posture 4

The description of this task is based on a posture with a high forward bending of the trunk to manipulate a bunch inside a bucket on the floor. This excessive bending generates a significant load on the lower back, which increases the risk of low back pain and injury. In addition, the arms are extended forward, which adds stress to the shoulders and upper back. Figure 11 shows that the risk level is 3, being a low risk level because it does not maintain that posture for more than 3 seconds, since it only places the finished bouquet.

Figure 11. Results of Posture 4

Figure 12 shows the overall results of all postures that were analyzed in the Tumeke software, which shows that postures can be improved before more serious risks occur.

Figure 12. General Results

3.4 Recommendations and proposed improvement

Regarding the choice of working posture, the following recommendations are made:

- The worker must stand upright, making sure to keep the spine straight and relaxed, the feet must be fully supported on the floor, separated at shoulder height for a balanced weight distribution.
- The arms should be relaxed, with the elbows close to the body and forming an angle of 90° to 120°.
- The head should be in a neutral position, aligned with the spine, avoiding prolonged forward or downward leaning. If it is necessary to observe details of the bouquet, elevate the object to a comfortable height rather than leaning toward it

This position is considered appropriate for the following reasons

- Minimizes stress on the spine by keeping it aligned and avoiding tilting or twisting
- Reduces muscle strain by keeping arms and wrists in neutral positions, avoiding static or repetitive postures that may cause fatigue or injury.
- Prevents eyestrain and neck fatigue by keeping the head and neck in a neutral position
- Increases productivity and accuracy, as a comfortable posture allows for more controlled and effective movements

The workplace in a flower shop is usually a multifunctional space that combines areas dedicated to the preparation of floral arrangements, storage of flowers and plants, and customer service, within this flower shop the distribution or organization of the premises is divided into 4 parts which are:

1. Area
    - Work tables: Large surfaces where florists prepare and assemble floral arrangements
    - Tool storage: Frequently used tools, such as scissors, knives, tapes and floral wires, are organized in shelves or drawers near work tables for easy access
    - Floral foam and decorative materials: There are specific areas to store floral foam, ribbons, decorative papers, bows and other materials that are used in the arrangements
    - Water buckets for flowers: Fresh flowers are often placed in buckets of water near the tables so that workers can quickly select fresh stems

2. Flower and Storage Area

Flower coolers: This is a critical area for storing fresh flowers that require controlled temperatures to maintain optimal conditions. Refrigerators have adjustable shelves to accommodate different types of flowers and tub sizes. This is usually also in the same room, but set apart

Buckets and containers with water: Flowers that are not refrigerated but must be in water are kept here.

3. Area

It is a part located at the back of the outside where they are located

- Additional supplies: The warehouse is an area where bulk materials such as pots, soil, fertilizers, ribbons, floral foam and spare tools are stored.
- Chemicals: If fertilizers or pesticides are used, they are stored safely in a specific area, usually ventilated and separated from other materials to avoid risks

Exhibition and Area

- Sales counter: Where customers are attended to place their orders or receive their arrangements. Here there is a showcase that displays gift items and what they use for the accounts is a calculator, also has a space where florists can prepare quick presentations for customers
- Arrangement and plant display: An area near the entrance or counter where ready-made bouquets, centerpieces and plants are displayed for sale.
- Wrapping and packaging materials: Near the counter there is usually a space dedicated to packaging bouquets and plants for customers. It includes gift wrap, ribbons, bags and other items to prepare orders properly

Regarding Verification and modification of vertical and scopes

Worker reaches where they must reach objects at table or counter level, as well as the organization of tools and materials along workstations. A poorly designed horizontal reach can lead to awkward postures, shoulder and back strain, and repetitive strain

Scope

Maximum Reach Zones: If there are items that are not used frequently, they can be placed beyond the comfortable reach range (e.g., on shelves or in drawers), but never beyond a reach that requires excessive or awkward movements, such as twisting or stretching beyond what is recommended.

Efficient workspace layout: In a flower shop, space should be arranged so that the most frequently used items (such as flowers, stem cutters, ribbons, and scissors) are located within this comfortable reach range. This reduces the need for unnecessary movement and improves task efficiency

Reach

Avoid exertion at height: Avoid workers needing to raise their arms above their shoulders constantly. If work above shoulder height is required, it is important to use a platform or bench to reduce repetitive strain and muscle strains

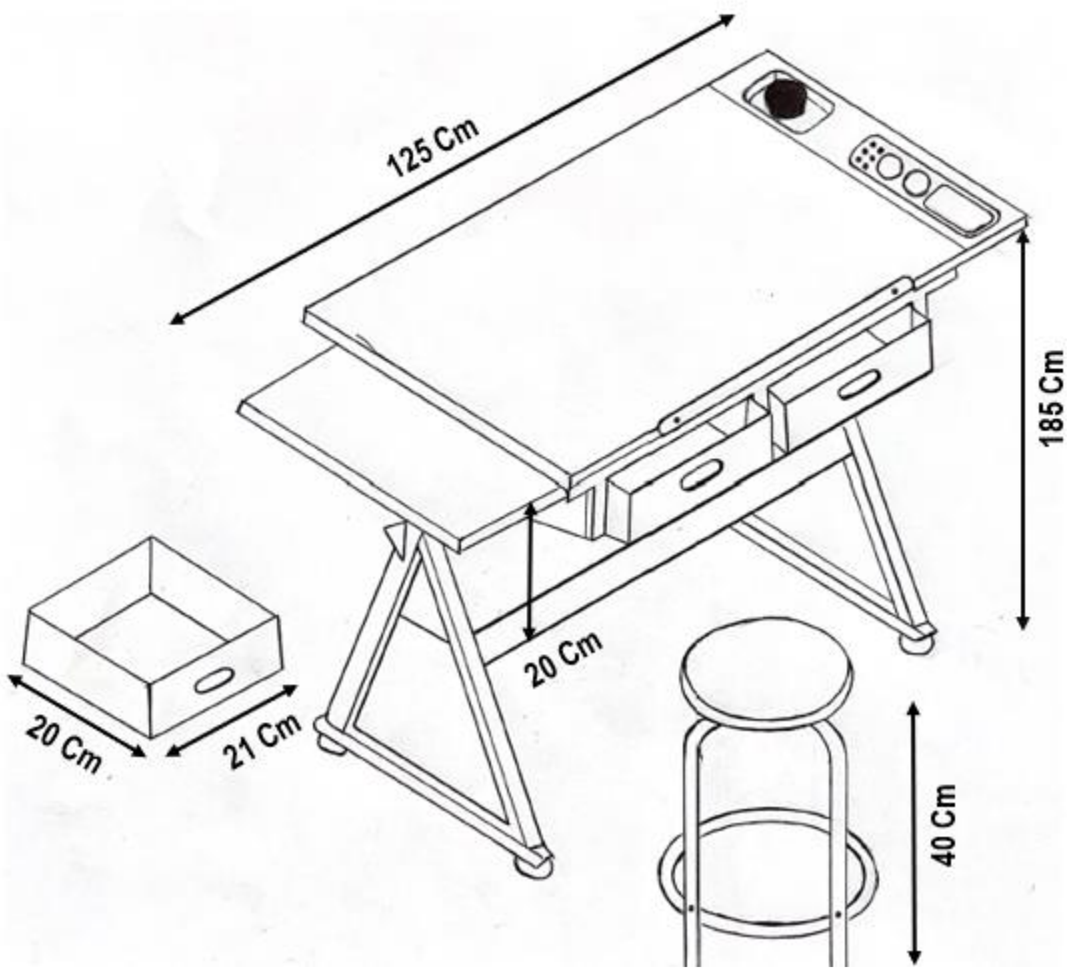
Adjustable surfaces: The use of height-adjustable work tables can be effective ergonomic solution, allowing employees to adjust the work level according to their height and the task they are performing.

In the flower shop, bouquet creation is one of the most repetitive and demanding tasks in terms of worker posture, so it is essential to have a table design that optimizes employee comfort, efficiency and health. A well thought-out ergonomic design can prevent musculoskeletal pain and improve productivity by reducing physical strain

By analyzing the posture they can propose the following changes improvements that can be applied, which are

- Explore ways to maintain a neutral posture throughout the work
- Consider acquiring equipment to maintain a posture.
- Change the position of the material to improve posture
- Table height adjustment: Ensure that work tables are adjustable or at an ergonomic height
- Use of adjustable stools: Provide high stools or ergonomic seating to allow for alternating between standing and sitting during prolonged tasks
- Ergonomic scissors: Use scissors with ergonomic handles and springs to reduce the effort required for each cut
- Task rotation: Implement a system of task rotation among employees so that they do not perform the same activities
- Organization of materials to fit and be within comfortable reach.
- Place anti-fatigue surfaces for those who work standing for long periods, improving comfort and reducing leg fatigue.

Proposal on the new dimensions of the workspace



Other recommendations are:

- Workstation adjustment: Workstations should be height adjustable to avoid the need to bend or stretch when working with floral arrangements. This will allow employees to maintain a neutral posture.
- Arrangement of tools and materials: Arranging tools and work materials within easy reach will reduce the need for repetitive movements and reduce muscle fatigue. Cutting tools and wire should be ergonomic and adjusted to reduce strain.
- Loading and transport equipment: Providing carts for transporting vases and heavy boxes will help reduce the physical burden on employees. In addition, it is important to train workers in safe lifting techniques to avoid injury.
- Anti-fatigue flooring and appropriate footwear: Installing anti-fatigue surfaces and encouraging the use of comfortable, appropriate footwear can reduce fatigue from prolonged standing. This helps improve circulation and reduces impact on joints.

- Task rotation: Implementing a task rotation system will allow employees to alternate between activities that involve standing, sitting and moving. This reduces the risk of repetitive motion injuries and reduces the load on certain muscle groups.
- Adequate workspaces: It is important that spaces are wide enough for employees to move freely without the risk of tripping. This is especially relevant for transporting vases and materials within the store.

NOTE:
If you cannot modify the work or posture and cannot purchase equipment to help you, consider reducing the duration of work by rotating workers or scheduling breaks

4.4 Conclusion

Finally, these studies helped to gather accurate information on the areas and postures that needed improvement such as the workstation, the adjustment of the height of the work surfaces, the incorporation of appropriate tools and the adoption of ergonomic techniques, which were adopted to the improvement proposals that the flower shop can implement to significantly reduce the physical loads on workers.

These results and options were evaluated and analyzed with the owners of the flower shop business to help the efficiency of the place, which they are implementing little by little and it has been improving a lot for both the place and its workers, thus reducing musculoskeletal discomfort.

Finally, this study highlights the importance of applying ergonomic principles to seemingly everyday activities, such as bouquet making, to improve working conditions, prevent injuries, and increase worker efficiency in the flower shop. Ergonomics should be considered an essential element to optimize both employee health and business productivity.

REFERENCES

Diego-Mas, J. A. (n. d.). Método REBA - rapid entire body assessment. Universidad Politécnica de Valencia. https://www.ergonautas.upv.es/metodos/reba/reba-ayuda.php

Grandjean, E. (1997). Manual de Ergonomía: Adaptación del trabajo al hombre. Editorial Paidós.

Marley, R. J., & Kumar, N. (1996). An improved musculoskeletal discomfort assessment tool. International Journal of Industrial Ergonomics, 17(1), 2127.

Champney, P. C., & Muller-Borer, B. (1979, 1981). Anthropometric data, centimeters. Eastman Kodak Company; NASA.

Moncada, S., Llorens, C., & Navarro, A. (2011). Participatory ergonomics in small businesses: A practical approach for intervention. Journal of Occupational Health, 28(1), 45-52.

Tumeke (n.d.). Productivity and time management software. https://www.tumeke.io/es-mx.

INFLUENCE OF INDIVIDUAL CHARACTERISTICS ON LEG VOLUME CHANGES IN STANDING WORKERS

Jonathan Osorio-Vasco[1] [0000-0002-3062-5736] Carlos Barrera-Causil[2] [0000-0001-7288-7710] Yordán Rodríguez[3] [0000-0002-0079-4336] Jessica Rojas-Mora[4] [0000-0003-1605-8584] and Juan Luis Hernández-Arellano[5] [0000-0001-7288-7710

[1, 2, 4]Instituto Tecnológico Metropolitano.
Vía al Volador, Calle. 73 # 76A – 354
Medellin, Colombia 050034.

[3]National School of Public Health, Universidad de Antioquia.
Calle 62 # 52 - 59
Medellín, Colombia 050010.

[5]Universidad Autónoma de Ciudad de Juárez. México
Av. Del Charro, núm. 450 norte A.P. 100
Ciudad Juárez, Chih., México 32310.

Corresponding author's e-mail: jonathanosorio296299@correo.itm.edu.co

Resumen. Trabajar de pie es común en muchas actividades laborales. En periodos prolongados de tiempo, tiene efectos negativos en las piernas, como el cambio de volumen. El cambio de volumen puede estar influenciado por las características individuales de los trabajadores. Este estudio analizó las características individuales de 177 trabajadores de tres sectores económicos y el cambio de volumen en las piernas a través de técnicas de aprendizaje de máquina. El algoritmo KNN fue el que mejor F1-score entregó para la pierna derecha (89.6%) y el algoritmo Random Forest que el que mejor F1-score entregó para la pierna izquierda (90.3%). El volumen de las piernas cambia durante la jornada de trabajo y puede estar asociado a las características individuales. Los resultados de este estudio son útiles para considerar las características individuales dentro de las labores de vigilancia y prevención de los desórdenes musculoesqueléticos en trabajadores que permanecen de pie durante la jornada de trabajo.

Palabras clave: Trabajo de Pie, Volumen en las Piernas, Salud Ocupacional, Aprendizaje de Máquina.

Relevancia para la ergonomía: Los resultados de este estudio son útiles para considerar las características individuales dentro de las labores de vigilancia y prevención de los desórdenes musculoesqueléticos en trabajadores que permanecen de pie durante la jornada de trabajo, especialmente en el cambio de volumen en las piernas. Adicionalmente, las técnicas de aprendizaje de máquina, entregan análisis profundos que pueden ser útiles para la toma de decisiones en la intervención ergonómica de puestos de trabajo.

Abstract. Standing work is common in many occupational activities. Over prolonged periods, it has negative effects on the legs, such as volume changes. These changes in leg volume may be influenced by individual worker characteristics. This study analyzed the individual characteristics of 177 workers from three economic sectors and the changes in leg volume using machine learning techniques. The KNN algorithm achieved the highest F1-score for the right leg (89.6%), while the Random Forest algorithm achieved the highest F1-score for the left leg (90.3%). Leg volume changes during the workday and may be associated with individual characteristics. The results of this study are useful for considering individual characteristics in the surveillance and prevention of musculoskeletal disorders among workers who stand for prolonged periods during their work shifts.

Keywords. Standing Work, Leg Volume, Occupational Health, Machine Learning.

Relevance to Ergonomics: The results of this study are useful for considering individual characteristics in the surveillance and prevention of musculoskeletal disorders among workers who remain standing throughout their workday, particularly regarding changes in leg volume. Additionally, machine-learning techniques provide in-depth analyses that can be useful for decision-making in the ergonomic intervention of workstations.

1. INTRODUCTION

Standing work is a common posture in multiple jobs and professions. According to the European Agency for Safety and Health at Work and various authors, some of the occupations that involve standing work include kitchen staff and waiters (both bar and table service), welders and cutters, retail workers, reception staff, electricians, pharmacists, teachers and childcare workers, physiotherapists (Kees & Nicolien, 2021), assembly line workers, machine operators, security personnel, engineers, library assistants, hairdressers, laboratory technicians, nurses and caregivers, and receptionists (Coenen et al., 2017; Konz, 2006).

In the European Union, as of 2019, an estimated 20% of workers performed their jobs standing. In 2010, 69% of individuals reported standing or walking for at least 25% of their workday (Kees & Nicolien, 2021). In countries such as Spain, Portugal, Romania, and North Macedonia, the proportion of workers who stand is higher than those who work seated (Kees & Nicolien, 2021). Outside the European Union, reports have also indicated significant numbers of standing workers. In Australia, 62% of a sample of workers stated that they worked standing (Coenen et al., 2016), while in Canada, 55.3% of the workforce reported working in a standing position (Antle et al., 2013).

In Colombia, as of 2016, no official statistics were available regarding the population that works standing (López Pabón & Osorio Vasco, 2016). However, studies have identified standing workers in the healthcare sector (Osorio-Vasco, Jonathan & Rodríguez Ruíz, 2021), among flower farmers (Rodríguez et al., 2021), and among workers at a health service provider company, who reported that standing was their primary work posture (Tolosa-Guzmán I, 2015).

Prolonged standing has been associated with reduced blood circulation in the lower legs, leading to symptoms of pain, discomfort, and general body fatigue (Antle et al., 2015, 2018; Zander et al., 2004). The decrease in blood circulation results in the accumulation of blood in the lower extremities due to a reduction in venous pumping, which relies on alternating muscle contractions in the lower leg to facilitate venous return to the heart (Antle et al., 2013, 2015, 2018). Reduced blood supply in static muscles accelerates muscle fatigue and pain due to the accumulation of metabolites, which may lead to muscle hypersensitivity (Waters & Dick, 2015; Zander et al., 2004).

Certain individual characteristics have been linked to the negative effects of standing work. Body Mass Index (BMI) has been associated with increased leg volume, highlighting a sociodemographic factor that may influence this effect (Zander et al., 2004). Additionally, a moderately strong correlation has been reported between demographic variables such as age, height, and weight and the effects of prolonged standing at the workplace (Orlando & King, 2004).

However, to date, few analyses have examined individual characteristics related to changes in leg volume among standing workers. Investigating these characteristics will provide evidence on their influence on leg volume increase. This study explores the impact of individual characteristics on leg volume increase during standing work through a computational machine learning analysis.

2. OBJECTIVE AND SCOPE

To analyze individual characteristics that may influence changes in leg volume during standing work using machine-learning techniques. This study considered workers who stood for at least 80% of their workday and voluntarily agreed to participate in the study.

3. METHODOLOGY

Machine learning techniques with unsupervised algorithms were used to analyze the data. Data were collected from 177 workers across 10 companies operating in the following economic sectors: industrial (52.54%) (chemical, textile, iron, and aluminum manufacturing), flower cultivation (20.9%), and healthcare (26.6%). The data were derived from a cross-sectional study in which workers' leg measurements were taken at the beginning and end of their work shift. Additional variables included posture, sex, age, height, weight, BMI, job tenure, dominant foot, and sleep duration.

Leg volume was calculated by measuring leg circumference. A wooden template with six 4 cm segments and a permanent marker was used to mark reference points on the leg for the second measurement. The template was placed from the lateral malleolus, starting from the ankle up to 20 cm along the longitudinal axis of the malleolus where the calf reaches its maximum circumference (Karimi et al., 2017; Lin et al., 2012; Zander et al., 2004).

The same procedure was applied to the left leg. Leg volume and percentage variation were calculated using the truncated cone formula, similar to previous studies (Karimi et al., 2016; Lin et al., 2012; Zander et al., 2004).

Individual characteristics were analyzed numerically, while leg volume was categorized as "increased volume" for differences greater than 0 cm³ and "no increased volume" for differences less than 0 cm³.

4. RESULTS

The machine learning algorithms used included K-NN (K Nearest Neighbors), Decision Tree, SVM (Support Vector Machine), Gradient Boosting, Random Forest, Neural Network, and Logistic Regression. Each algorithm was implemented using Python. The results for each algorithm for both the right and left legs are presented in Table 1

Table 1. Classification method with the highest accuracy in predicting leg volume changes.

Algorithms	Indicator					
	Right Leg			Left Leg		
	Accuracy	F1 Score	Observation	Accuracy	F1 Score	Observation
K-NN	79,16%	89.6%	5 estimator	75%	85.2%	5 estimator
Decision tree	80,50%	75.4%	Deep of 10	63.8%	77.1%	Deep of 10
SVM	75%	85.71%	-	77.7%	87.5%	-
Gradinet Boosting	66.6%	79.9%	Depth of 3 with estimator of 100	72.2%	83.3%	Depth of 3 with estimator of 100
Random Forest	72.2%	83.8%	Depth of 10 with estimator of 100	83.3%	90.3%	Depth of 10 with estimator of 100
Neuronal network	75%	85.24%		77.7%	87.5%	
Logistic regression	75%	85.71		77.7%	87.5%	

The best classification algorithm for the right leg was K-NN, with an F1-score of 89.3% and an accuracy of 79.16%, while for the left leg, the best algorithm was Random Forest, with an F1-score of 90.3% and an accuracy of 83.3%. Notably, in all models, the F1-score exceeded 70%, indicating that individual characteristics may influence at least 70% of leg volume changes in standing workers.

5. CONCLUSIONS

Leg volume changes during the workday across different economic sectors. This change may be associated with factors such as posture, sex, age, height, weight, BMI, job tenure, dominant foot, and sleep duration. Additionally, supervised machine learning algorithms can provide insights into factors influencing leg volume changes.

Future studies should explore additional variables such as workplace surface conditions, footwear types, and ergonomic interventions. The integration of real-time monitoring technologies could further enhance predictive models and support evidence-based occupational health recommendations.

6. REFERENCES

Antle, D. M., Cormier, L., Findlay, M., Miller, L. L., & Côté, J. N. (2018). Lower limb blood flow and mean arterial pressure during standing and seated work: Implications for workplace posture recommendations. Preventive Medicine Reports, 10(March), 117–122. https://doi.org/10.1016/j.pmedr.2018.02.016

Antle, D. M., Vézina, N., & Côté, J. N. (2015). Comparing standing posture and use of a sit-stand stool: Analysis of vascular, muscular and discomfort outcomes during simulated industrial work. International Journal of Industrial Ergonomics, 45, 98–106. https://doi.org/10.1016/j.ergon.2014.12.009

Antle, D. M., Vézina, N., Messing, K., & Côté, J. N. (2013). Development of discomfort and vascular and muscular changes during a prolonged standing task. Occupational Ergonomics, 11(1), 21–33. https://doi.org/10.3233/OER-130205

Coenen, P., Parry, S., Willenberg, L., Shi, J. W., Romero, L., Blackwood, D. M., Healy, G. N., Dunstan, D. W., & Straker, L. M. (2017). Associations of prolonged standing with musculoskeletal symptoms—A systematic review of laboratory studies. Gait & Posture, 58, 310–318. https://doi.org/10.1016/j.gaitpost.2017.08.024

Coenen, P., Willenberg, L., Parry, S., Shi, J. W., Romero, L., Blackwood, D. M., Maher, C. G., Healy, G. N., Dunstan, D. W., & Straker, L. M. (2016). Associations of occupational standing with musculoskeletal symptoms: a systematic review with meta-analysis. British Journal of Sports Medicine, 1–10. https://doi.org/10.1136/bjsports-2016-096795

Karimi, Z., Allahyari, T., Azghani, M. R., & Khalkhali, H. (2016). Influence of unstable footwear on lower leg muscle activity, volume change and subjective discomfort during prolonged standing. Applied Ergonomics, 53, 95–102. https://doi.org/10.1016/j.apergo.2015.09.003

Karimi, Z., Azghani, M. R., & Allahyari, T. (2017). Lower leg swelling and muscle co-contraction during prolonged standing: an unstable footwear evaluation. Footwear Science, 9(2), 103–110. https://doi.org/10.1080/19424280.2017.1342702

Kees, P., & Nicolien, de L. (2021). Prolonged constrained standing postures Health effects and good practice. European Agency for Safety and Health at Work. https://doi.org/10.2802/91149

Konz, S. (2006). Standing Work. International Encyclopedia of Ergonomics and Human Factors, 929–931.

Lin, Y. H., Chen, C. Y., & Cho, M. H. (2012). Effectiveness of leg movement in reducing leg swelling and discomfort in lower extremities. Applied Ergonomics, 43(6), 1033–1037. https://doi.org/10.1016/j.apergo.2012.03.002

López Pabón, L., & Osorio Vasco, J. (2016). Desarrollo inicial de herramienta para valorar el nivel de riesgo en trabajo de pie [Tesis de Especialización] [Universidad de Antioquia]. http://hdl.handle.net/10495/5537

Osorio-Vasco, Jonathan, & Rodríguez Ruíz, Y. (2021). Efectos del trabajo de pie en trabajadores del sector sanitario. Revista Cuidarte. https://doi.org/10.15649/cuidarte.1790

Osorio-Vasco, J., & Rodríguez, Y. (2021). Changes in Lower Leg Volume Among Health Care Workers During a Working Day. In Lecture Notes in Networks and Systems: Vol. 222 LNNS (Issue 2017). Springer International Publishing. https://doi.org/10.1007/978-3-030-74611-7_55

Rodríguez, Y., Osorio-Vasco, J., Zuluaga, I., & Múnera, A. (2021). Leg Swelling Among Colombian Florists. In Lecture Notes in Networks and Systems: Vol. 221 LNNS. Springer International Publishing. https://doi.org/10.1007/978-3-030-74608-7_33

Tolosa-Guzmán I, I. A. (2015). Riesgos biomecánicos asociados al desorden músculoesquelético en pacientes deTolosa-Guzmán I, I. A. (2015). Riesgos biomecánicos asociados al desorden músculoesquelético en pacientes del régimen contributivo que consultan a un centro ambulatorio en Madrid. Ciencias de La Salud, 13(1), 25–38. https://doi.org/10.12804/revsalud13.01.2015.02

Zander, J. E., King, P. M., & Ezenwa, B. N. (2004). Influence of flooring conditions on lower leg volume following prolonged standing. International Journal of Industrial Ergonomics, 34(4), 279–288. https://doi.org/10.1016/j.ergon.2004.04.014