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Prefacio

Para la Sociedad de Ergonomistas de México A.C. (SEMAC); la ergonomía se ha distinguido por ser una ciencia cada vez más comprometida con el bienestar humano, ampliando sus intereses y alcances en el estudio de las capacidades y limitaciones del hombre. Las reglamentaciones y normativas existentes en torno a la Ergonomía y Salud Ocupacional existentes en México y que se fraguan en Latinoamérica deben cubrirse por las organizaciones al desarrollar ambientes y espacios laborales confortables y saludables. Pero la Ergonomía debería incluirse en la búsqueda de la mejora en la productividad donde la inversión realizada es retornada para empresas con ergónomos comprometidos.

La Ergonomía también debe aplicarse en la informalidad laboral, donde también se tienen condiciones riesgosas y peligros laborales que vulneran la calidad de vida de quienes los realizan. Así, en México uno de cada dos trabajadores subsiste en la informalidad laboral y esta proporción parece estar aumentando en los últimos años, por lo que representa un desafío complejo con diversas perspectivas, económicas, sociales, ambientales, tecnológicas y de sostenibilidad que amerita un esfuerzo multidisciplinario para atender, reducir y mitigar sus efectos en la población laboral.

Los editores, árbitros y comité académico, a nombre de la Sociedad de Ergonomistas de México, A.C., agradecemos a los autores de los trabajos por compartir investigación en este libro que busca recapitular nuevos conocimientos y aplicaciones creativas. Reconociendo a los autores en su esfuerzo, compromiso y sacrificio al impulsar la ergonomía en su propio entorno social y sector de trabajo específico. Donde su valiosa aportación estamos seguros impulsa y contribuye en el avance de la ergonomía a nivel nacional y mundial en la mejora de entornos de trabajo, el aumento de la productividad organizacional y hacia el interior de las Instituciones de Educación Superior.

Considero que este nuevo libro editado por la SEMAC ha conseguido la meta de difundir y dar acceso libre a estos trabajos que buscan el bienestar de los miembros de empresas y organizaciones. Los invito a leerlos, compartirlos y difundirlos para que sean de utilidad a aquellos estudiosos y practicantes de la ergonomía en México y el mundo y así se consiga el objetivo y lema de SEMAC "TRABAJO PARA OPTIMIZAR EL TRABAJO"

Dr. Carlos Raúl Navarro González
Presidente SEMAC 2024-2026

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ANTHROPOMETRIC DIMENSIONS OF UNDERGRADUATES STUDENTS

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Resumen: Este estudio resalta el papel fundamental de la antropometría en el diseño ergonómico de mobiliario y espacios en entornos educativos. Su objetivo principal fue identificar y analizar las dimensiones antropométricas de 50 estudiantes de Ingeniería Industrial, conformados por 25 hombres y 25 mujeres, en la Universidad de Guadalajara. Se registraron dimensiones antropométricas como estatura, peso y diversas medidas en posición sentada, para construir una base de datos integral destinada a mejorar los estándares ergonómicos en el contexto universitario. Los hallazgos revelaron diferencias en las dimensiones corporales entre hombres y mujeres, lo que subraya la importancia de considerar las variaciones basadas en el género en el diseño. El estudio enfatiza que ignorar estas diferencias podría derivar en la adquisición de mobiliario inadecuado, lo que afectaría negativamente la comodidad y la salud de los estudiantes. La base de datos generada proporciona una referencia valiosa para diseñadores y fabricantes de mobiliario escolar, fomentando el desarrollo de diseños ergonómicos que mejoren el bienestar general de los usuarios en entornos educativos.

Palabras clave: Antropometría, Estudiantes Universitarios

Relevancia para la Ergonomía: Este estudio aporta datos cruciales para el campo de la ergonomía, destacando la importancia de considerar la diversidad antropométrica en el diseño de entornos educativos. Los resultados pueden

utilizarse para desarrollar estándares ergonómicos más inclusivos, mejorando así la comodidad y el bienestar de los estudiantes. Además, el estudio subraya la necesidad de realizar evaluaciones antropométricas regulares para mantener los diseños ergonómicos actualizados con las características físicas de la población estudiantil y ampliar la muestra estudiada.

Abstract: This study highlights the critical role of anthropometry in the ergonomic design of furniture and spaces in educational environments. Conducted at the University of Guadalajara, its primary objective was to identify and analyze the anthropometric dimensions of 50 Industrial Engineering students, comprising 25 males and 25 females. Key anthropometric dimensions such as height, weight, and various seated measurements were recorded to build a comprehensive database aimed at improving ergonomic standards within the university context. The findings revealed significant differences in body dimensions between male and female students, underscoring the importance of considering gender-based variations in design. The study emphasizes that overlooking these differences could result in the acquisition of inadequately sized furniture, which may negatively impact students' comfort and health. The database generated provides a valuable reference for designers and manufacturers of school furniture, encouraging the development of ergonomically sound designs that enhance the overall well-being of users in educational settings.

Keywords: Anthropometry, University Students

Relevance to Ergonomics: This study provides critical data for the field of ergonomics, highlighting the importance of considering anthropometric diversity in the design of educational environments. The results can be used to develop more inclusive ergonomic standards, thus improving the comfort and well-being of students. Furthermore, the study underlines the need for regular anthropometric assessments to keep ergonomic designs up to date with the physical characteristics of the student population, and to increase the student sample.

1.INTRODUCTION

Anthropometry plays a critical role in the design of ergonomic products and spaces (Prado-Leon & Ávila-Chaurand, 2006), particularly in educational environments. In universities, understanding the anthropometric dimensions of students is essential for optimizing the design of furniture and equipment, thereby promoting user comfort and health (Ben Ayed, Yaich, Trigui, Ben Hmida, Ben Jemaa, Ammar, Jedidi, Karray, Feki, Mejdoub, Kassis, & Damak, 2019). A lack of consideration for these measurements may result in the acquisition of furniture that does not meet ergonomic requirements, potentially leading to discomfort and health issues (Castellucci, Arezes, & Viviani, 2010). This study aims to assess the anthropometric dimensions of students at a public university, providing data to enhance ergonomic standards within educational settings.

At the University of Guadalajara, students spend a significant portion of their daily lives engaged in various academic tasks, including reading, writing, comprehension, and teamwork, all while seated on institutional furniture (Podrekar Loredan, Kastelic, Burnard, & Šarabon, 2022; Sherry, Pearson, & Clemes, 2016). The prolonged interaction with inadequately designed seating increases the risk of musculoskeletal disorders, discomfort, and cognitive impairments (Castellucci et al., 2010). In addition, inappropriate furniture design can limit the effectiveness of pedagogical strategies, thereby hindering the overall learning experience. Addressing the ergonomic suitability of school furniture is essential to ensuring the physical well-being and academic performance of students. By incorporating anthropometric data into design processes, educational institutions can create more supportive environments that enhance both comfort and learning outcomes (Ben Ayed, et al., 2019). The main objective of the study is to identify and analyze the anthropometric dimensions of students at a public university in Mexico. This includes the measurement of various body variables in order to create a database that can be used to improve the ergonomic design of furniture and equipment in the university environment.

2.MÉTODO

A study was conducted with a sample of 50 randomly selected students from the Engineering Division at the University of Guadalajara, 25 females and 25 males. The anthropometric dimensions were collected following the methodology proposed by Avila, Prado & Gonzalez (2007). Anthropometers -Martin type, U. de G. model-, scales, large calipers, large 900 mm calipers, variable height benches, and anthropometric charts were used. Variables measured included (1) weight, (2) height, (3) seated height, (4) seated shoulder height, (5) Height at elbow seated , (6) Knee height seated, (7) popliteal height, (8) buttock-popliteal length, (9) seated hip width (see table 2.1 and figures 2.1 and 2.2).

Table 1 Anthropometric dimensions

Post	Anthropometric Dimensions
Post 1	(1) Weight. (2) Height.
Post 2	(3) Seated height (4) Seated shoulder height (5) Height at elbow seated (6) Knee height seated (7) Popliteal height. (8) Buttock-popliteal length. (9) Seated hip width.

2.1 Description of Measurement Postures

2.1.1 Standing Posture

All subjects were positioned uniformly. They stood barefoot in the Frankfort plane, with their head facing forward, shoulders relaxed and level, arms resting naturally at the sides, and hands at ease. The heels were together, while the toes were slightly apart, forming an angle of approximately 45 degrees. See Figure 2.1.

2.1.2 Seated Posture

The subjects were seated on an adjustable-height bench, adopting the following posture: the torso upright, maintaining the natural curves of the spine, especially in the lumbar region, with the head aligned in the Frankfort plane. The thighs formed a right angle with the torso, and the popliteal area did not contact the bench. The legs formed a 90-degree angle with the thighs, and the feet were flat on the floor, maintaining proper alignment between the torso, thighs, legs, and feet. See Figure 2.2. The subjects were barefoot and wore form-fitting clothing.

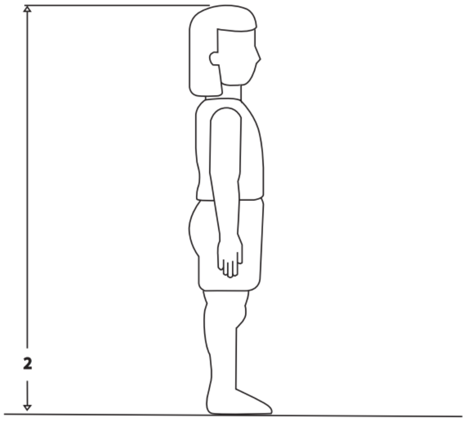

Figure 2.1 Standing posture

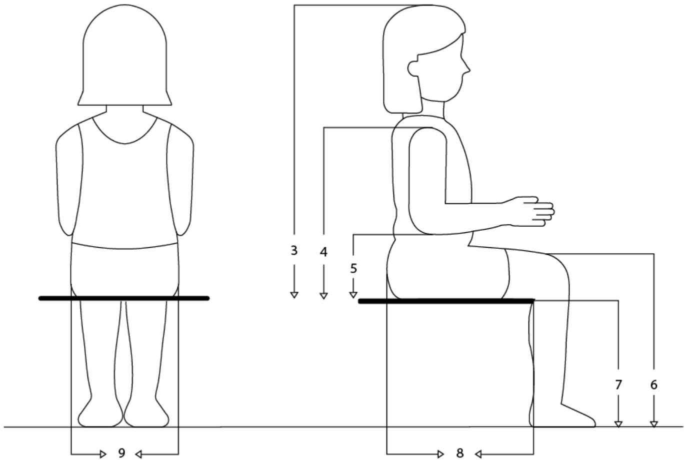

Figure 2.2 Seated posture

3.RESULTS

Descriptive statistics were obtained for the 9 measurements of the university students, including the average, standard deviation and the 5th, 50th and 95th percentiles. Findings were divided into males and females.

The descriptive statistics of the 9 measurements for female university students, including the mean (x), standard deviation (S.D.), and the 5th, 50th, and 95th percentiles, are presented in Tables 3.1 and 3.2. The data obtained in station 1 are shown in Table 3.1, and the data from station 2 are shown in Table 3.2. All anthropometric dimensions are provided in millimeters, except for weight, which is given in kilograms.

Table 2. Anthropometric data University students

		19 - 25 years (n=25)				
Dimensions				Percentiles		
		X	**D.E.**	**5**	**50**	**95**
1	Weight (kg)	59.196	36.78	46	58	72
2	Height	15836	42.47	1501	1581	1648

Table 3. Anthropometric data for female university students

	19 - 25 years (n=25)				
Dimensions			Percentiles		
	X	**D.E.**	**5**	**50**	**95**

3	Seated height	842	26.21	800	842	884
4	Seated shoulder height	573	21.42	548	574	615
5	Height at elbow seated	250	67.20	205	241	270
6	Knee height seated	484	22.82	456	485	523
7	Popliteal height.	384	19.68	351	384	412
8	Buttock-popliteal length	453	29.62	397	461	485
9	Seated hip width	392	26.60	356	395	437

The descriptive statistics for the 9 measurements of the university students, including the mean (x), standard deviation (S.D.), and the 5th, 50th, and 95th percentiles, are presented in Tables 3.3 and 3.4. The data obtained in station 1 are shown in Table 3.3, and the data from station 2 are shown in Table 3.4. All anthropometric dimensions are provided in millimeters, except for weight, which is given in kilograms.

Table 4. Anthropometric data University students

		19 - 25 years (n=25)				
Dimensions				Percentiles		
		X	**D.E.**	**5**	**50**	**95**
1	Weight (kg)	78	22.05	55	72	123
2	Height	1738	30.53	1624	1726	1836

Table 5. Anthropometric data for female university students

		19 - 25 years (n=25)				
Dimensions				Percentiles		
		X	**D.E.**	**5**	**50**	**95**
3	Seated height	854	13.03	827	857	871
4	Seated shoulder height	570	14.99	539	575	585
5	Height at elbow seated	209	12.64	183	211	223
6	Knee height seated	497	14.83	459	502	510
7	Popliteal height.	402	9.92	388	402	414
8	Buttock-popliteal length	442	16.31	419	445	461
9	Seated hip width	344	15.22	317	347	360

Significant differences in body dimensions were identified between women and men. These results suggest the need to take anthropometric diversity into account in the design of university furniture and equipment and to check for compatibility.

4.CONCLUSIONS

The study concludes that there are differences in anthropometric dimensions between female university students and male university students, which has important implications for the ergonomic design of furniture and equipment in the educational environment. The database generated constitutes a valuable reference for designers and manufacturers of school furniture and avoids mismatches between students' anthropometric characteristics and anthropometric dimensions. Mismatches between the anthropometric characteristics of students and the dimensions of furniture can result in improper postures (Batistão, Sentanin, Moriguchi, Hansson, Coury, & de Oliveira Sato, 2012), negatively affecting essential classroom activities such as writing and reading. These misalignments can lead to discomfort and musculoskeletal pain, particularly in the back, shoulders, neck, and legs, as well as cause visual strain (Ben Ayed et al., 2019). Furthermore, such discomfort can impair cognitive functions crucial for learning, including attention and creativity (Podrekar et al., 2020). In the field of ergonomics, it is well established that a lack of alignment between human anthropometric data and equipment dimensions contributes to reduced productivity, fatigue, injury, and accidents (Mandahawi et al., 2008).

Research in ergonomics has highlighted significant mismatches between the dimensions of university furniture and the anthropometric characteristics of students (Podrekar Loredan et al., 2022). However, the University of Guadalajara currently lacks specific data to assess whether its school furniture is compatible with the needs of its users, their tasks, and the environment. Adapting school furniture to meet the anthropometric needs of students is critical not only to enhance academic performance but also to mitigate the risk of musculoskeletal disorders (Savanur, Altekar & De A, 2007; Adeyemi, Lasisi, Ojile & Abdulkadir, 2020). This study helps to establish and encourage the development of a larger database of Mexican students, aimed at making evidence-based decisions for purchasing school furniture for universities in Mexico, with the end-users at the core of the process.

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ANTHROPOMETRIC DATA OF PEOPLE WORKING IN THE CUTTING OF ASPARAGUS (sparagus) ON THE COAST OF CABORCA, SONORA MEXICO.

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RESUMEN: El presente trabajo forma parte de un estudio que se está iniciando en el área agrícola de la costa de Caborca, Sonora, México. Como primer paso para el estudio, se registraron algunas dimensiones antropométricas de los trabajadores agrícolas que laboran en la cosecha del corte del esparrago, donde la antropometría con fines ergonómicos busca proporcionar datos importantes antropométricos que sirvan como base para dimensionar herramientas y estaciones de trabajo que se adapten a las verdaderas necesidades de los trabajadores en el corte del espárrago.

El presente trabajo tiene como objetivo identificar las medidas antropométricas de los trabajadores del corte del espárrago de la costa de Caborca, Sonora, México. En un estudio posterior al registro se identificará cómo éstas influyen en su desempeño laboral.

Los registros de las medidas antropométricas en el corte del espárrago son importantes debido a que se puede evitar que el trabajador se vea en la obligación de adaptarse a las condiciones de la estación o área de trabajo como comúnmente sucede, es decir, permiten adaptar el entorno laboral y las herramientas a las características y alcance físico de los trabajadores.

Esta investigación busca en su primera etapa registrar los datos antropométricos de las personas que participan en el corte del espárrago y en una segunda y tercera etapa garantizar que los trabajadores estén cómodos y ergonómicamente adaptados para realizar su trabajo de manera eficiente y segura.

Palabras claves: antropometría, ergonomía, trabajadores, corte de espárrago, agricultura**.**

Aportaciones a la Ergonomía: Estos estudios marcan la pauta para formar una base de datos antropométricos, que contengan las dimensiones de la población que participa en la cosecha y corte del espárrago en la costa de Caborca, Sonora, México y que puede ser una aportación para el resto del Estado y País.

Abstrac: The present work is part of a study that is being initiated in the agricultural area of the coast of Caborca, Sonora, Mexico. As a first step for the study, some anthropometric dimensions of agricultural workers who work in the asparagus cutting harvest were recorded, where anthropometry for ergonomic purposes seeks to provide important anthropometric data that serve as a basis for sizing tools and workstations that are adapted to the real needs of workers in asparagus cutting.

The present work aims to identify the anthropometric measurements of asparagus cutting workers on the coast of Caborca, Sonora, Mexico. A subsequent study will identify how these measurements influence their work performance.

The objective of this work is to identify the anthropometric measurements of asparagus cutting workers from the coast of Caborca, Sonora, Mexico. A post-registration study will identify how these influence their work performance.

The records of anthropometric measurements in asparagus cutting are important because they can prevent the worker from having to adapt to the conditions of the work station or work area as commonly happens, that is, they allow adapting the work environment and the tools to the characteristics and physical reach of the workers.

This research seeks in its first stage to record the anthropometric data of the people involved in asparagus cutting and in a second and third stage to ensure that workers are comfortable and ergonomically adapted to perform their work efficiently and safely.

Key words: anthropometry, ergonomics, workers, asparagus cutting, agriculture.

Contributions to Ergonomics: These studies set the standard to form an anthropometric database containing the dimensions of the population that participates in the harvesting and cutting of asparagus on the coast of Caborca, Sonora, Mexico, and that can be a contribution for the rest of the State and Country.

1. INTRODUCTION

Asparagus is one of the main crops in the region of Caborca, Sonora, Mexico, since it has a good position in the national and international market. In addition, the production and export of asparagus is a great economic benefit and generates employment for the region throughout the year, but mainly during the harvest stage.

According to Sagarhpa (Secretaria de Agricultura, Ganadería, Recursos Hidráulicos, Pesca y Acuacultura), in 2023 the Caborca region had approximately 13,188 hectares planted with asparagus and a harvest of 135,797 tons, making it the most productive area for this crop in Mexico.

There are studies of different types of asparagus cultivation, such as the study developed by Maticorena (2024), which shows the concern for the care of the crop and the continuous improvement in its harvest and the challenges of the coming years. Similarly, Huallanca, C.A. (2024) in his study of agronomic techniques to reduce heavy metals in the asparagus crop, which indicates prevention in the health of consumers.

Vásquez, B. M., & Cesar, K. (2024), found that temperature control does influence the growth of the asparagus plant by developing an experiment in a greenhouse with controlled temperatures where the plant maintained significant growth during their research.

In his article published by Quichiz-Ramírez, J. M., Gómez-Oscorima, R. M., Diez-Matallana, R. A., & Vásquez-Quispe, C. Z. (2024), he writes that asparagus in Peru generates important foreign currency, but depends on the demand from the United States, so it is important to look for new markets such as Switzerland, Norway, among others.

The aim of recording anthropometric measurements is to prevent the development of musculoskeletal disorders due to non-ergonomic postures adopted during the asparagus cutting process. In addition, the measurement of anthropometric data of the users will make it possible to identify how important their physical capacities and reach are when performing their work.

On the other hand, the tools and equipment used in asparagus cutting may need to be adjusted to fit the body dimensions of the workers, which can significantly affect the efficiency of the work.

For these and many other reasons, it is important to record anthropometric data of the people who cut asparagus in the coastal region of Caborca, Sonora, Mexico.

2. OBJECTIVE

To develop an investigation with the necessary ergonomic elements in the field of anthropometry, seeking to build a first stage database of agricultural workers involved in the harvesting and cutting of asparagus on the coast of Caborca, Sonora, Mexico. With this, we are looking for a second stage of the study with the proposal of tools according to their anthropometric dimensions and with this the possible reduction of musculoskeletal disorders for the work of harvesting asparagus and an increase in their productivity.

3. DELIMITATION

The study has certain limitations due to the production dates of the asparagus crop, which is a short period; in the case of Caborca, depending on the climate, it has a duration of 4 months regularly from December to March, which makes data collection difficult and the cost required for transportation to the place of harvest.

4. METHODOLOGY

4.1 Introduction.

For the recording of anthropometric data of the asparagus cutting workers in the coastal region of 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 made in a cross-sectional observational manner from a convenience sample of 100 asparagus harvesting and cutting workers on the coast 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:

To obtain data, the workers who were finishing their work shift and arrived at the dining room were taken at random, for the realization of this study the participation of two teams composed of two people each was needed, while one took the measurements, the other noted the data in the anthropometric chart of each team.

During the data collection, the workers were passing by once they had finished eating their meals and were resting from the workday.

The 24 measurements shown in Table 1 are those recorded for the case study of this work, where the worker was standing, the procedure followed for each of the measurements is the one shown in the book published by NASA (National Aeronautics and Space Administration), 1978. 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 from the investigation of the anthropometric measurements of the agricultural population of asparagus cutting and harvesting in the region of Caborca, Sonora, Mexico are shown in Table 2. The table shows the calculations of the 5th, 50th, and 95% percentiles, as well as the maximum and minimum of the measurements. The calculations were analyzed in the Excel spreadsheet. The calculation of weight is given in kilograms, the rest of the measurements are in centimeters.

The State of origin of the study subjects, the 100 workers who participated in the asparagus cutting on the coast of Caborca, Sonora, Mexico, is represented according to data provided by them, 72% from the State of Chiapas and 28% from Oaxaca, see Figure 1.

On the other hand, the average age of the workers registered in the study is 25 years, with a minimum of 18 years and a maximum of 55 years.

Table 2. Results obtained from the study of 100 asparagus cutters on the coast of Caborca, Sonora, Mexico.

		Percentiles				
Code	Size name	**5%**	**50%**	**95%**	**Mínimo**	**Máximo**
N920	Weight	47	56	73	44	84

N805	Height	150	158	164	147	172
N328	Height at standing eye	139	146	153	136	159
N23	Height at shoulder standing	124	130	137	119	141
N309	Height at elbow standing	92	99	104	87	105
N949	Height at waist standing	78	87	94	69	99
N398	Height at buttock standing	63	72	81	60	85
N973	Height at wrist stationary	69	74	80	68	81
N265	Height at middle finger standing	53	60	65	52	67
N797	Width of outstretched arms	147	160	173	100	179
N798	Width of elbows to center of chest	39	50	87	37	90
N80	Arm length to wall	65	75	85	43	87
N122	Width of shoulders standing	38	42	46	33	48
N223	Standing chest width	25	29	33	25	39
N457	Standing hip width	28	32	35	27	39
N144	Distance from ear to ear above the head	16	18	20	16	50
N427	Head width	10	12	17	9	18
N441	Length of head	22	24	26	21	27
N420	Length of hand	16	17	19	15	20
N656	Longitud de la palma de la mano	9	10	11	8	85
N411	Ancho de la palma de la mano	8	9	9	8	10
N402	Diámetro de agarre(interior)	3	4	5	3	9
N529	Altura del suelo a la rodilla	39	44	48	36	53
N381	Longitud del codo al dedo medio	40	44	48	37	48

6. CONCLUSIONS AND RECOMMENDATIONS

Anthropometry has many practical uses and some of them are just beginning. For example, it is used to assess nutritional status, monitor the growth of people, assist in the design of work environments and objects of daily use, etc.

The values resulting from this study are of fundamental importance for the design of elements to be used when assigning people to cut asparagus, as well as the tools they use to develop their work

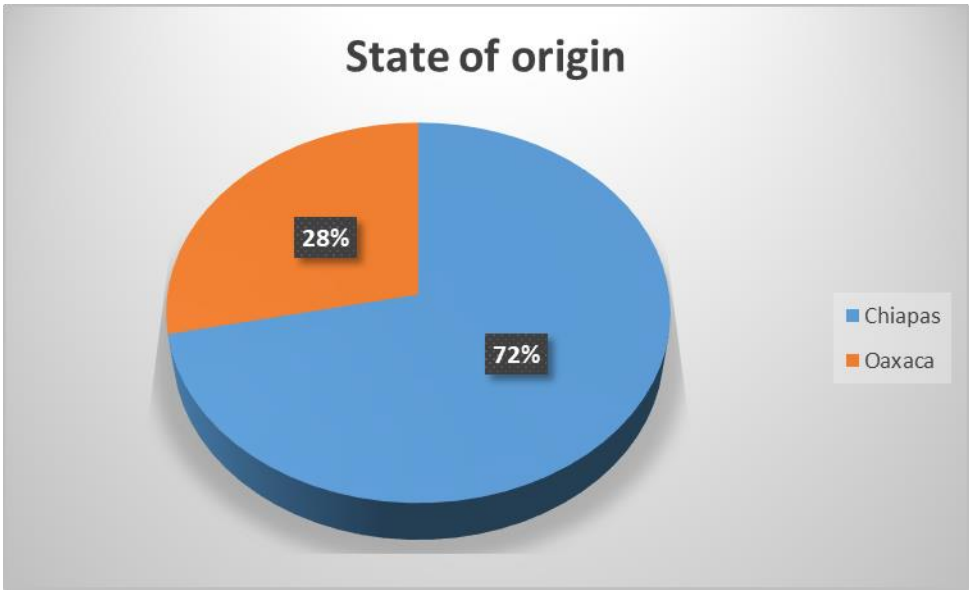

Figure 1. State of origin of the 100 workers registered in the asparagus cutting study on the coast of Caborca, Sonora, Mexico.

With these records we can begin what could be the study of the population that participates in agricultural activities as stated by Daniel Vergara Lope (1910), who recommends that studies be carried out with the Mexican population, because products and machinery were imported that did not fit the dimensions of the Mexicans.

The data obtained in this study could be taken as a basis for further research, which will serve to detect changes in the physical development of workers in the field of agriculture, the variants that exist in weight, and the different anthropometric data recorded for the workers, as well as for the design of workstations, tools, etc.

Future research will seek to use this data to compare the measurements of people from different states and to be able to propose designs of stations and tools used in the harvesting of asparagus in the field and to be able to reduce the possible injuries caused by the development of their work.

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EVALUATION OF THE ERGONOMIC REDESIGN OF THE TIRE DEMOUNTING BAR

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Resumen: En las llanteras se realizan diversas actividades las cuales requieren de bastante fuerza, por lo que los trabajadores están propensos a diversos daños musculares por las posiciones y agarres que realizan. El montar y desmontar llantas es el trabajo principal que se lleva a cabo en las llanteras el cual es muy pesado ya que se requiere de bastante fuerza para la carga de neumáticos, y las posiciones al igual que los agarres antiergonómicos que realizan algunos trabajadores de manera repetitiva por el uso de la barra desmontadora. Esto puede llevar a que el trabajador padezca de daños físicos, psicológicos y psicosociales los cuales si no se tratan a tiempo puede llegar a ser un daño irreversible. En el presente informe se evaluará el rediseño de herramienta del artículo de publicación de acuerdo a Armenta I. y Col, (2023), “Ergonomic redesign of a tire demounting bar 2023” mediante 2 métodos para poder analizar si la barra desmontadora rediseñada tiene un aporte ergonómico para las personas que la usan.

Palabras claves: Barra desmontadora, Evaluación, Riesgos ergonómicos, neumático.

Relevancia para la ergonomía: en base al rediseño retomado se pudo observar que el montar y desmontar una llanta por la barra desmontadora original genera problemas a la salud como cansancio, dolores lumbares, irritación de ojos, dolor de articulaciones, hernias, y entre muchos más. El rediseño de la barra desmontadora esta realizado para aportar mejor manipulación al momento de ser usada por los trabajadores y generar mayor eficiencia al igual que reducir daños a la salud. Por lo tanto, en este artículo la evaluación de este rediseño se abordará para analizar si la herramienta rediseñada es apta para realizar las actividades de montaje y desmontaje de llantas de manera positiva para el trabajador, tomando en cuenta los agarres y posturas adecuadas para disminuir daños a la salud tanto físicos, psicológicos y psicosociales.

Abstract: In tire workshops, various activities are carried out that require a great deal of strength, so workers are prone to various muscular injuries due to the positions and grips they perform. Tire mounting and demounting is the main work carried out at tire workshops, which is very heavy, as it requires a lot of strength to load tires, and the positions as the anti-ergonomic grips that some of the workers perform repetitively due to the use of the tire demounting bar. This can cause the worker to suffer of physical, psychological and psychosocial damages which, if not treated in time, can become irreversible. This report will evaluate the tool redesign from the public article, according to Armenta I. y Col, (2023), “Ergonomic redesign of a tire demounting bar 2023” using 2 methods to analyze whether the redesigned tool has an ergonomic contribution for the people who use it.

Key words: Tire demounting bar, Evaluation, Ergonomic Risks, Tire.

Contribution to ergonomics: Based on the redesign it was observed that mounting and demounting tires with the original demounting bar generates health problems such as fatigue, lumbar pain, eye irritation, joint pain, hernias and more. The demounting bar redesign is made to provide better handling at the time of being used by the workers and generate greater efficiency as well as reduce damage to health.

1. INTRODUCTION

According to Armenta I. y Col, (2023), “The muscle injuries in operators are caused by the mishandling of tools or because of the bad design of them, in a tire workshop the operators are exposed to a variety of risks because of the activities they perform, which are considered of high risk because they require a lot of muscle strength in some cases, and to adopt unsuitable postures because of these activities. Mounting and demounting tires is one of the most frequent activities they perform, therefore, there is a high percentage that the operator is unsafe and that this may affect the operator´s health later, from aches, some injury or maybe even a disease.” This Project is a continuation of the Redesign of a tire demounting bar, with the goal of making changes that will improve the ergonomics of the operators.

According to Menéndez Mansilla R. (2020), in a “Ergonomic study of the tire mounting and demounting job in the area of mechanic maintenance the tire workshop operators do not take into account both workplace safety and health”. The LEST method was used in the mentioned article, where the results of the different evaluations of the conditions in which the operators are exposed show that because of these conditions, they are exposed to several consequences, such as high probability of fatigue, and lumbar and dorsal afflictions. In addition, through the NIOSH lifting equation, it was noted that the equivalent index to the lifting activities was rated a 10, which shows that the activities that they practice are considered of high risk and can cause alterations in both muscle and bones.

Moreover, considering the public article by Gómez Rangel R, (2011), “Health and work on the employees of a tire workshop in the city of Mexico” chapter 3. The risks that the operator of a tire workshop is faced against are physical, psychological and psychosocial, which will severely affect the operator´s health over time, some of these risks are fatigue, eye redness, joint pain, injuries, lumbago, hernias, among others. Preventive measures are proposed to avoid the presence of these risks, some of them are the use of back belts, ear plugs, bait or suede gloves and safety shoes.

Based on this, this document displays the evaluation of the tool redesign of the public article according to Armenta I. y Col, (2023), “Ergonomic redesign of a tire demounting bar 2023”. In a tire workshop, the operator´s job consists of heavy loads and generally the tools are not suitable for the operator´s health, or the operator adopts anti-ergonomic positions when using them. When mounting and demounting tires, the tool that is usually used is the original tire demounting bar, with which the operator´s effort increases and his wrists, legs and back positions are anti-ergonomic, which consequently provokes physical, psychological and psychosocial risks, risks that, over time, can cause severe health damage for the operator. That is why we chose to use and evaluate the redesigned tool, which was made considering the positions that the operator does when mounting and demounting tires, so it can facilitate his duties and correct his handling and positioning when using the tool.

2. EQUATIONS

Through the method applied the results were significant for the redesigned demounting bar, since, by means of the NIOSH checklist, the traditional bar got only 1 positive affirmation and 6 negative responses, among which the following stand out; Do you feel comfortable with the tool, Is the tool handle covered with soft material, are you able to use the tool while keeping your wrist straight? This translates into a compliance of 14.3% of the evaluated criteria (1 of 7).
Suppose that:

- Nc is the number of criteria met.
- Nt is the total number of criteria evaluated.
- P is the percentage of compliance.

The equation for the percentage compliance would be:

$$P = \left(\frac{Nc}{Nt}\right) \times 100 \qquad (1)$$

For the data provided:

- Nc= 1
- Nt= 7

Substituting these values into the equation, we have:

$$P = \left(\frac{5}{7}\right) \times 100 \qquad (4)$$

We calculate this:

$$P = \left(\frac{5}{7}\right) \times 100 = 71.4\% \qquad (5)$$

These results indicate that the redesigned bar is significantly better in compliance terms with NIOSH criteria list for hand tools compared to the original demounting bar. Now, with the help of the Ergotec method it was possible to avoid different risks when using the improved bar while demounting a tire, by performing an analysis certain improvement changes were observed during tire demounting for the benefit of the operator.

By means of this method it was possible to analyze the results of the improved bar, the scale of work characteristics was 33% since a total score of 76 was obtained, which indicates that this bar is within a medium tabulation, on the other hand, with the original demounting bar a scale of work characteristics of 67% was obtained since a total score of 115 was reached, which indicates that the original bar is in a high tabulation.

Risk of injurie due to DTA’s
Total score for risk of DTA injuries before ergonomic redesign= 115
Total score for risk of DTA injuries after ergonomic redesign= 76
NPS= 38
Tabulation

- High 60%-100%
- Medium 21%-59%
- Low 0%-20%

Scale of work characteristics= $\frac{(P.T-NPS)}{NPS*3}(100) \qquad (6)$

P.T= Total score.
NPS= Number of significant questions.
ECT= Scale of work characteristics.
ECT for DTA injuries before ergonomic redesign:

$$\frac{(115-38)}{(38*3)}(100)=67\% \qquad (7)$$

67%= High.
ECT for DTA injuries after ergonomic redesign:

$$\frac{(76-38)}{(38*3)}(100)=33\% \qquad (8)$$

33%= Medium.

3. FIGURES AND TABLES

4.

It can be seen in figure 1 that the operator does not have an ergonomic grip and therefore this can cause long-term illnesses due to the fact that he works 8 hours a day and the tire demounting activity is occasional during his work. However, figure 2 shows a better grip, which allows adding force to the bar in a proper way without hurting the wrist or palm of the hand.

Figure 1. Original Bar

Figure 2. Redesigned bar.

Figure 1 shows that when the operator generates force to dismount the tire, he opts for comfort and tilts his back to perform his work quicker. It can be observed that in figure 2 it is easier to apply the force because the bar has an anti-slip protection for hands and this main point is considered as one of the most common problems in tire operators.

Being these the two main problems of the operator, it was detected that some changes that were made to the bar could be improved to the level of being able to consider it ergonomic with a higher percentage. Therefore, two evaluations were carried out using the Ergotec and NIOSH methods to obtain a better result for the improved bar. The results will be announced below.

Activity evaluation of tire demounting with redesigned tire demounting bar.

Table 1. Ergotec evaluation

ERGOTEC

ANALYSIS DATE _19/06/2024________ POSITION ______________________________

DEPT/UNIT _______________________ SERVICE AREA ____________________

PART/UNIT ______TIRE DEMOUNTING__________________________________

DURATION CICLE JOB* ___OCCASIONAL_ NO. OF PEOPLE EXPOSED ___1____

JOB DESCRIPTION: DEMOUNTING TIRES

* CONTINUOUS > 4 HOURS FREQUENT = 1 TO 4 HOURS OCCASIONAL < 1 HOUR

B.- RISK OF INJURY DUE TO DTA

	BEFORE					**AFTER**				
	NA	**N**	**O**	**F**	**S**	**NA**	**N**	**O**	**F**	**S**

1. THE WORKER REPEATS THE SAME MOTION AT HIGH SPEED			X					X		

REPETITION IS CAUSED BY:

2. INCENTIVE PROGRAMS			X					X		
3. HIGH PRODUCTION REQUIREMENTS.	X					X				
4. HIGH SPEED ASSEMBLY LINES	X					X				

THE WORKER´S POSTURE REQUIRES:

5. TURN OR TILT THE TORSO			X					X		
6. BEND					X			X		
7. REACHING AND/OR STRETCHING					X				X	
8. WRIST IN NON NEUTRAL POSITION					X			X		
9. EXTENSION OF THE ARM(S)				X			X			
10. ELEVATION OF THE ELBOWS				X			X			
11. SQUEEZING ACTION OF THE WRISTS			X				X			

CONTROL AND/OR WORK OBJECTS

12. REQUIRES EXCESSIVE STRETCHING				X				X		
13. REQUIRES EXCESSIVE STRENGTH					X				X	

WORK CAUSES FATIGUE DUE TO

14. WALKING, CLIMBING AND/OR STOOPING					X				X	
15. ONE LEG SUPPORTS THE WEIGHT OF THE BODY					X					X
16. CHANGES IN WORK DISTANCE			X					X		
17. MATERIAL WEIGHT			X					X		

THE WORK SURFACE

18. IS TOO HIGH OR TOO LOW					X					X
19. IS AT AN ANGLE THAT DOES NOT ALLOW FOR A NEUTRAL POSITION					X		X			
20. GLOVES ARE NECESSARY					X		X			

21. GLOVE SIZE IS INAPPROPRIATE FOR THE JOB					X					X

JOB AREA

22. CAUSES STRETCHING AND/OR TURNING TO REACH					X			X		
23. CAUSES THE NECK TO BE IN A NON-NEUTRAL POSITION					X				X	
24. FOOT, ELBOW, WRIST AND/OR ARM RESTS ARE NECESSARY			X					X		
25. REQUIRES STANDING OR WALKING FOR LONG PERIODS		X					X			
26. CONTRIBUTES TO A NON-NEUTRAL WAIST					X			X		
27. INSUFFICIENT LEG, FOOT OR ARM CLEARANCE		X					X			
28. REQUIRES STRETCHING OVER OR ACROSS THE WORK SURFACE				X						X
29. NO ANTI-FATIGUE MATS, INSOLE OR FOOT SUPPORTS					X		X			
30. CAUSES A KNEE ANGLE OF MORE THAN 100° OR LESS THAN 60°					X					X
31. JOB ROTATION IS NECESSARY				X					X	

HAND TOOLS

32. CAUSES THE HAND-WRIST TO BE IN A NON-NEUTRAL POSITION					X			X		
33. CAUSES A NON NEUTRAL WAIST POSITION					X		X			
34. CAUSES THE ELBOWS TO BE EXTENDED ON THE OUTSIDE, AND/OR IN FRONT OF THE BODY					X		X			
35. CAUSES THE ARM TO BE RAISED TO HOLD THE TOOL ABOVE THE SHOULDER		X					X			
36. HAS UNEQUAL (UNBALANCED) AND/OR EXCESSIVE WEIGHT					X		X			

37. THE HANDLE´S DIAMETER IS TOO SHORT OR TOO LONG		X					X			
38. IT REQUIRES GRABBING WITH FINGERS		X					X			
39. GRIP OF THE HAND WRENCH (PINCER TYPE) TOO LONG OR TOO SHORT		X					X			
40. POORLY DESIGNED FOR THE TASK					X			X		

USE OF COMPUTERS

41. THE HEIGHT OF THE KEYBOARD IS AT A NON-ADJUSTABLE ANGLE	X					X				
42. TYPING REQUIRES EXCESSIVE FORCE	X					X				
43. WRISTS REST ON THE WORK SURFACE DURING TYPING	X					X				
44. INCENTIVE PROGRAMS ARE PROMOTED TO INCREASE THE TYPING RATE	X					X				
45. THE MOUSE IS USED FOR VERY LONG PERIODS	X					X				

TOTALS _6_ _7__ _5__ _20__ _15 _13_ _5_ _5_

_ _

X1 X_2 X_3 X_4 X1 X_2 X_3 X_4

- _14_ _15_ _80_ 15_ _26_ _15 +_20_
_6_ + + + + _
+

TOTAL SCORE = _115_ = _76_

TABULATION

HIGH **60%-100%**
MEDIUM **21%-59%**
LOW **0%-20%**

SCALE OF WORK CHARACTERISTICS=(P.T. - NPS) X 100 = _67%_ _33%_
(NPS)(3)

NPS= NUMBER OF SIGNIFICANT QUESTIONS

TABULATION = __HIGH__ = __MEDIUM__ **(B)**

Through the Ergotec applied method, it was possible to analyze the comparison of the traditional tire demounting bar with the improved demounting bar taking into account different efforts made by the operator during his work, the results of this method were significant for the improvement since it was possible to avoid different risks when using the improved bar while removing a tire, “through the analysis certain changes of improvement were observed during the tire demounting for the benefit of the operator both in back postures, wrists and applied force, a great difference was observed between the two types of bars due to the fact that the traditional bar generates increased efforts during the demounting process; however, with the use of the new bar, the application of force during the operation was facilitated”, by means of the result of the improved bar method, its work characteristics scale was 33%, since a total score of 76 was obtained, which indicates that this bar is within a medium tabulation, whereas with the original demounting bar, a work characteristics scale of 67% was obtained, since it got a total score of 115, which indicates that the original bar is in a high tabulation.

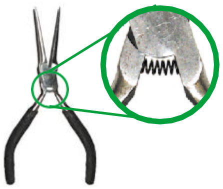
In conclusion, favorable results were obtained for the application of the tire demounting bar; however, it is important to mention that improvements can still be made to the bar in order to obtain a low tabulation which ranges from 0% to 20% to consider the bar as a fully ergonomic tool.

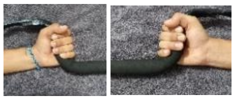
To improve the conventional bar, it is proposed to widen the ends of the bar and change the position of the paddles, placing them on opposite sides. This will allow a more efficient and effective work during tire demounting. It is also suggested the implementation of a platform with a pneumatic piston to prevent non-ergonomic postures of the operator. This platform, driven by air compression, can be adjusted to the most convenient height for the operator, thus optimizing comfort and work efficiency.

Evaluation of tire demounting activity with redesigned tire demounting bar.

Table 2. NIOSH evaluation.

Tips for selecting hand tools.

			Mark if the answer is "Yes"			
Checklist for selecting hand tools Select the tools with the most "Yes" answers		**Examples**	One handle tools		Two handle tools	
			1	2	1	2
1	Single-handled tools used for power work: Do you feel comfortable with the tool? Does the handle of the tool have a diameter between 1 ¼ to 2 inches? (Page 8)		NO	YES		
2	Single-handled tools used for precision work: Does the handle of the tool have a diameter between ¼ to ½ inch? (Page 8)					
3	Two-handled tools used for power work: Is the distance between the handles at least 2 inches when the tool is closed and no more than 3 ½ inches when open? (Page 8)					
4	Two-handled tools used for precision work: Is the distance between the handles less than 1 inch when the tool is closed and no more than 3 ½ inches when open? (Page 8).					
5	Two-handled tolos: Do the handles open automatically by spring? (Page 9).					

Checklist for selecting hand tools Select the tools with the most "Yes" answers		**Examples**	*Mark if the answer is "Yes"*	
			1	2
6	Does the handle of the tool have sharp edges or finger impressions? (Page 9).		NO	NO
7	Is the handle of the tool coated with a soft material? (Page 9)		NO	YES
8	Can you use the tool while keeping your wrist straight? (Page 10)		NO	YES
9	Can this tool be used with your dominant hand or any of your hands?		YES	YES
10	For Jobs that require a lot of force: Is the handle of the tool longer than the widest part of the palm of your hand? (Usually 4 to 6 inches) (Page 11)		NO	NO
11	Does the handle of the tool have an anti-slip surface? (Page 11)		NO	YES

Symbology:

1. = Traditional bar.

■ = Redesigned bar.

3. No aplica o no es el caso.

TOTAL:	YES=	1	5
	NO=	6	2

A comparison was made between the traditional tire demounting bar and a redesigned bar using a NIOSH checklist. The results obtained showed significant differences in compliance with the criteria established in the checklist.

The traditional bar obtained only 1 positive affirmation and 6 negative responses. This translates into a 14.3% compliance with the criteria evaluated (1 of 7). On the other hand, the redesigned bar achieved 5 positive affirmations and only 2 negative responses, which translates into 71.4% compliance with the criteria (5 out of 7).

These results indicate that the redesigned bar is significantly better in terms of compliance with NIOSH criteria for hand tools compared with the traditional bar. The improved design contributes to greater safety, efficiency and ergonomics during use, which is crucial for injury prevention and improved performance when working with tires.

In conclusion, the redesigned tire demounting bar is presented as the superior option, with 71.4% compliance with the criteria established by NIOSH, compared to 14.3% for the traditional bar. This percentage difference highlights the importance of considering redesigned tools that improve both safety and efficiency in tire demounting operations.

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ANALYSIS OF THE INTERACTION OF ADULTS OVER 60 YEARS OLD WITH THE INFOTAINMENT INTERFACE WITHIN VEHICLES WHILE DRIVING.

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Resumen. Desde sus inicios, el automóvil ha estado acompañado de elementos informativos que ayudan a comunicar al usuario el estado del vehículo, tales como tacómetros y velocímetros, pasando después por dispositivos de entretenimiento como la radio y reproductores de *cassette y CDs*, hasta llegar al uso de sistemas de geolocalización para facilitar la navegación. Todos estos elementos se lograron conglomerar en los primeros sistemas de Infoentretenimiento a principios del siglo XXI. Durante las últimas dos décadas las tecnologías como las interfaces computacionales en los *displays*, la comunicación móvil y el internet de las cosas (IoT) han inundado gran parte de los dispositivos que usamos y las interfaces de infoentretenimiento de los vehículos no son la excepción.

Las interfaces de infoentretenimiento se han convertido en elementos fundamentales dentro de los vehículos, que permiten controlar diversas tareas; generalmente a través de las pantallas ubicadas en la parte central del tablero del vehículo, ocupando una importante parte de la atención al conducir.

Usuarios de un amplio rango de edades interactúan con estas interfaces, siendo los adultos mayores uno de los más vulnerables debido a la degeneración de sus capacidades, principalmente la visión, siendo así más complicada la interacción con las interfaces computacionales.

Esta investigación busca conocer las capacidades de este grupo etario para así conocer sus limitaciones sensoriales, perceptuales y cognitivas; y generar datos que puedan aportar *insights* para el desarrollo de interfaces de infoentretenimiento. El trabajo se llevó a cabo en dos etapas, donde la primera se trata de la revisión de literatura y posteriormente la aplicación de un cuestionario a usuarios adultos mayores que conducen habitualmente. Los datos arrojados por esta investigación aportan información acerca de la percepción de las interfaces de infoentretenimiento de este grupo vulnerable y las tareas que llevan a cabo mientras conducen.

Palabras clave: Interfaz, usabilidad, adultos mayores, interacción, conducción.

Relevancia para la ergonomía: Esta investigación aporta a la ergonomía información relevante y actual para el diseño de interfaces de infoentretenimiento.

Contribuye a considerar las características de los adultos mayores que, a pesar de los cambios en sus capacidades, son una población que requiere mantener una vida activa e independiente. Es de suma importancia tener en cuenta las limitantes y condiciones de este grupo etario, al momento de diseñar y evaluar dispositivos tecnológicos y de comunicación; para así ofrecer productos con una usabilidad apropiada no solo para los adultos mayores, si no para otros grupos vulnerables y así beneficiar con estas mejoras a los demás usuarios de estos sistemas.

Abstract. From the beginning, the automobile has been accompanied by information elements that help communicate the status of the vehicle to the user, such as tachometers and speedometers, then through entertainment devices such as radio cassettes, and CD players, to the use of geolocation systems to facilitate navigation. All these elements were successfully combined in the first infotainment systems in the first years of the 21st century. During the last two decades, technologies such as computer interfaces on displays, mobile communication, and the Internet have flooded many of the devices we use and vehicle infotainment interfaces are no exception.

These interfaces have become fundamental elements within vehicles, allowing various tasks to be controlled; generally, through the screens in the central part of the vehicle's dashboard, occupying a significant part of the attention when driving.

Users across various age groups interact with these interfaces, with older adults being particularly vulnerable due to age-related declines in abilities, especially in vision, which can complicate their interaction with the computer interfaces.

This research aims to assess this age group’s sensory, perceptual, and cognitive limitations and to gather data that can offer insights for developing infotainment interfaces. The work was carried out in two stages, where the first is a literature review and then the application of a questionnaire to older adult users who drive regularly. The data obtained from this research provides information about this vulnerable group's perception of infotainment interfaces, and the tasks they perform while driving.

Keywords. Interface, usability, older adults, interaction, driving.

Relevance to Ergonomics: This research provides ergonomics with relevant and current information for the design of infotainment interfaces. It contributes to considering the characteristics of older adults who, despite changes in their abilities, are a very active population that requires maintaining an active and independent life. It is extremely important to take into account the limitations and conditions of this age group when designing and evaluating technological and communication devices; to offer products with appropriate usability not only for older adults but also for other vulnerable groups and thus benefit other users of these computer systems with these improvements.

1. INTRODUCCIÓN

Over the past two decades, display technology, mobile communication, and the Internet of Things (IoT) have permeated much of the devices we use; and cars are no exception. GPS-based navigation systems and other advanced technology features have existed in vehicles since the early 1990s (Greengard, S. 2015).

Driving becomes more complex with the integration of a large number of secondary tasks such as entertainment, communication, or assistance in the navigation process, these three being the most recurrent. Around 2007 a new era in automotive infotainment systems began when Ford Motors Company (FOMOCO) announced the first integrated in-vehicle communications and entertainment system, SYNC (Greengard, S. 2015).

The vehicle cabin has become increasingly sophisticated and complex due to the number of indicators and displays that provide information about the vehicle's status, communication, and entertainment for users. All of this has been brought together in what we now know as In-Vehicle Information Systems (IVI's). They often consist of a screen in the vehicle's center console accompanied by some input devices (Bolder et al. 2018).

In Mexico, there are more than 18 million adults over 60 years old, representing 14% of the national population (INEGI 2022). According to United Nations studies, it is expected that by 2050, one in every 6 people in the world will be over 65 years old, which will represent 16% of the global population. Older people face an age-related decline in capabilities, such as loss of vision, hearing, memory, and mobility, which can interfere with the use of interactive systems and make it difficult to carry out daily life activities.

With the increasing use of digital technologies in daily life activities, these changes can become factors that increasingly impact essential aspects of the users, such as independence and autonomy. In this sense, some authors such as McLaughlin et al. (2020) have highlighted the difficulties in interacting with new technologies with the elderly population. This makes clear the importance of designing considering the changes in the capacities that older adults may have, due to the effects of age on their cognitive, visual, and motor skills (D. Hawthorn 2000), to adjust new technologies to this population group as well.

Driving as one of the aspects of daily life that is increasingly related to computer interfaces, it is of utmost importance to analyze the interaction of the growing population of older adults with these devices and to identify the aspects that may affect them, also considering the implications that such interaction may have on driving, as a complex and risky task.

The development of automotive technology and interfaces is taking place in contexts that are different from those in Latin America. This can constitute a barrier for users on this side of the world. Faced with this, it is important to analyze the implications that these interfaces have for users; and in particular, for populations whose characteristics may put them in greater difficulties in interaction, as is the case of older adults.

2. OBJECTIVES

2.1 General Objective

To analyze the use and interaction problems that older adults experience during the use of infotainment interfaces while driving.

2.2 Specific objectives

- Identify challenges that vehicle infotainment interfaces present for older adults while driving
- Find out the positive and negative aspects that users over 60 years old perceive about the Interface
- Understanding the frequency of interaction with infotainment interfaces
- Prioritize the tasks that are most frequently performed in the infotainment interface.

3. METHODOLOGY

This work is a cross-sectional, descriptive study. A questionnaire was designed to understand the experiences of older adults when interacting with infotainment screens in cars. The questionnaire applied consists of 16 open items and one multiple choice item that covers information on the visual capabilities of the users, frequency of driving, model of the vehicle they drive, the context in which the interface is used, opinion, and user experiences while interacting with the Infotainment interface.

This research was carried out with a population between 57 and 86 years old, with a mean of 69 (Fig. 1). 60% of the participants were male and 40% female. The selection of users is around 60 years of age, this being the point at which a subject is considered to enter old age, where the reduction in physical capabilities begins to be more noticeable. From the age of 60 onwards, the retina can receive two-thirds less light (Fig. 2) compared to a 20-year-old person (McLaughlin et al. 2020). Within this age group, they are more likely to present degenerative vision problems. Furthermore, its relationship with technology generates a relevant factor to analyze.

Due to the late interaction with the computing devices of this generation, limitations are added that make the interaction with these digital interfaces more complex. The research involves users of vehicles from 2008 models onwards, seeking that, as they are recent models, they are more likely to have an infotainment interface. This technology was commercially implemented in 2002 by the FOCOMO brand with its SYNC system (Greengard, S. 2015). The research is carried out in the Metropolitan Area of Guadalajara.

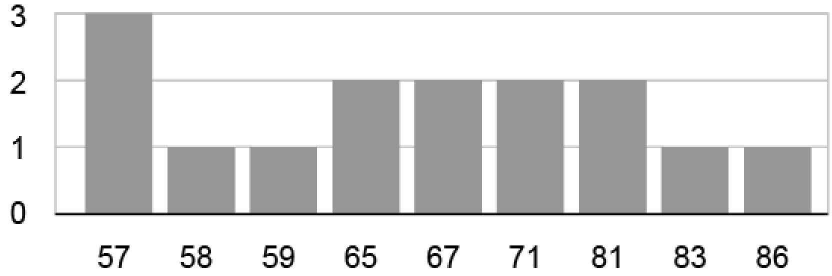

Figure 1. Ages range. Source: direct.

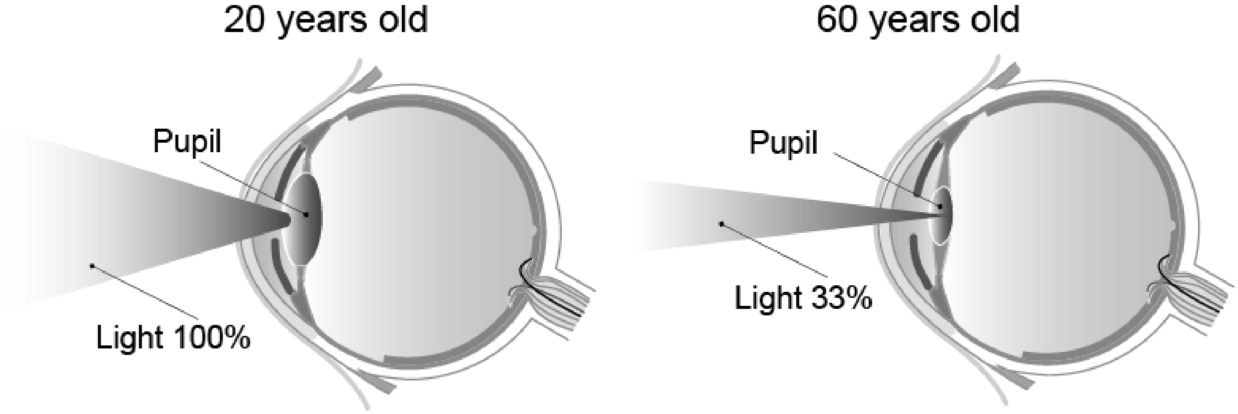

Figure 2. Comparison of visual capacities between young and older adults. Source: direct.

4. RESULTS

The questionnaire was applied to 15 subjects with an age range between 57 and 86 years, where 100% said they drive. 40% are retired while 60% continue with work activities and other routines. 50% claim to drive daily, their main destinations being family visits, medical appointments, and shopping, all of them within the urban area of Guadalajara.

In terms of visual abilities, 80% of the users analyzed wear glasses and only 20% do not use magnifying glasses for their daily activities. 66.5% have not undergone eye surgery, while 33.5% have had surgery. In the case of operations, 2 cases were for cataracts, 2 for myopia, and one for eyestrain (Figure 3).

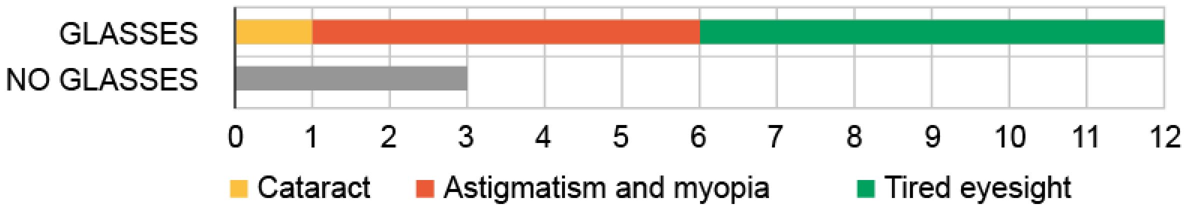

Figure 3. Comparison of the participants who used glasses for some visual issues. Source: direct.

The vehicles driven by the participants range from 2008 to 2024 from various brands, shows to KIA as the one that appears most frequently, in 20% of the cases (Fig. 4). Within the subjects' vehicles, 33% display the interface at the top of the dashboard, while the remaining 66% offer a lower location closer to the center of the dashboard.

Only 20% of the interfaces in the vehicles driven by the participants do not offer knobs to facilitate control of options and operation of the interface, while the remaining 80% have, in addition to knobs, buttons for predetermined functions and navigation in the interface.

Of the sample, 87% have this interface in their vehicle, while all subjects have interacted directly or indirectly with infotainment interfaces, either as a driver or co-driver. The perception of 30% of users is negative, for various reasons such as the difficulty when interacting with the menus and the distraction it generates when driving, while the remaining 70% affirm that the interface is quite useful for driving, as an aid to continue a route and facilitate communication when driving (Figure 5).

Regarding the use of the interface, the most common options are listening to the radio, seeing the time, answering calls, searching for directions, and listening to music when connecting to your cell phone (Figure 6). 30% of users express having had problems using the interface while driving, the main reason being the complexity of the menus and distraction, another factor that generates problems in interaction (Figure 7). Most users prefer to use the interface while the vehicle is stationary to avoid distractions and accidents when moving.

Aspects that they perceive positively are the connectivity and communication technology it offers, the location close to the steering wheel, the dimensions of the interface, and the information it displays. Negative aspects are the distraction it generates because it always shows information, in addition to the complexity of the menus and the order and structure in which the information is presented (Figure 8).

Users share the need for the interface to be accompanied by physical buttons that facilitate its operation; in addition to better compatibility with voice functions that also help interaction, without having to lose sight of the road.

Figure 4. Vehicle models and interfaces of participating users
Source: Motorpasion 2024.

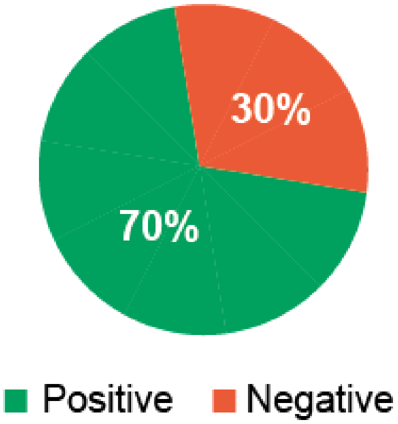

Figure 5. positive vs negative perception of the IVI's.
Source: direct.

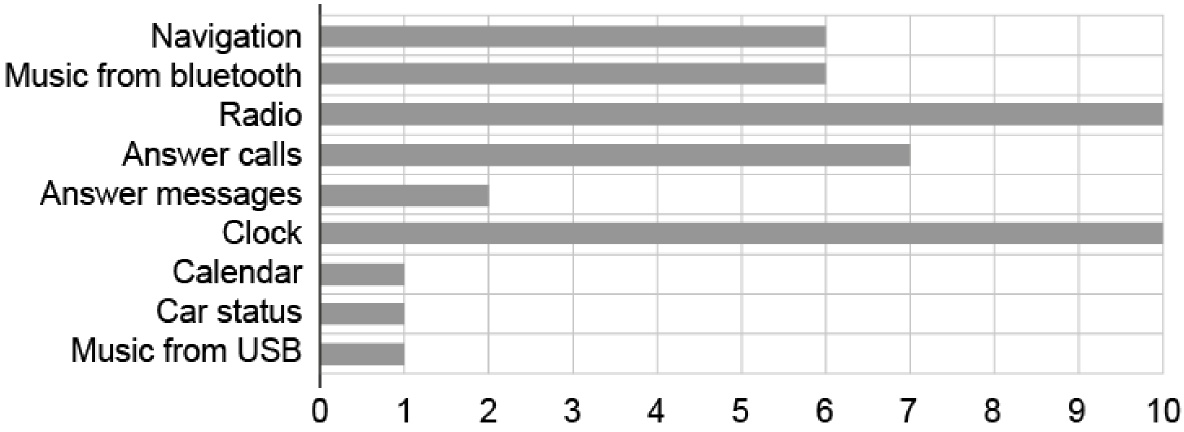

Figure 6. Main uses of the interface when driving. Source: direct.

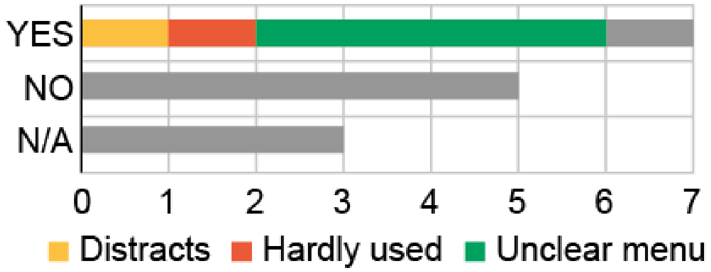

Figure 7. Perception of difficulties when interacting with the infotainment interface and the main reasons. Source: direct.

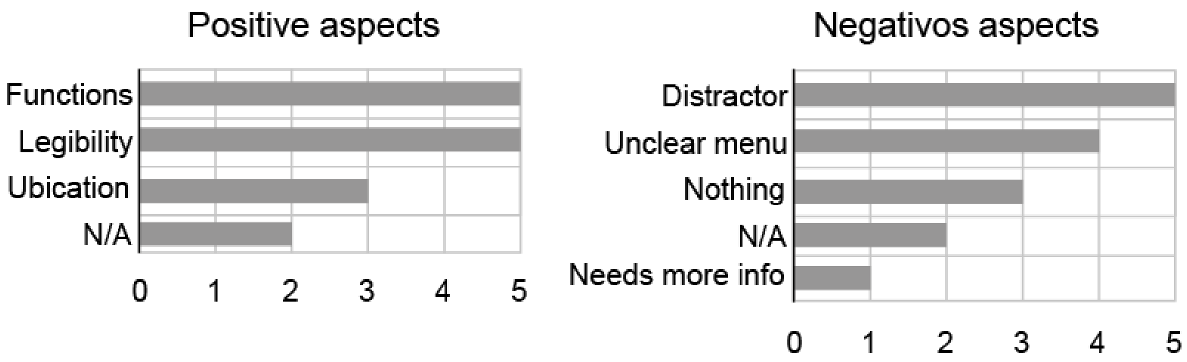

Figure 8. Positive and negative aspects perceived by users. Source: direct.

5. CONCLUSIONS

Users in this age group present difficulties when using the computer interfaces in their vehicles due to various factors, such as the degradation of their visual, cognitive, and physical abilities. Visual limitations make it necessary to offer greater adaptability in the way of presenting information to improve the readability of the elements. On the cognitive side, the continuous presence of many elements in the interface creates distractions for the user and detracts attention from the main task, which is driving. The lack of precision in the movements of older users means that the size of the buttons and controls on the interface is perceived as insufficient, making it difficult to make the correct contact without having to look at the screen while driving and limiting attention to the road. The large amount of options and information that these screens offer inside vehicles while driving is designed to help make the task of driving easier, but this information is perceived negatively, by generating distraction from the main task; which becomes even more relevant, considering the decrease in visual capacities reported by older adults.

This generation is aware that digital technology is here to stay and is open to learning about the new technologies offered by recent model vehicles. However, based on the data, it is identified that users only use the most familiar options of the interface and do not use some of the other resources that technology offers to facilitate their travels. This limitation in the use of the interface's capabilities is because how information is presented makes it difficult to locate the options within the menus, so older users prefer not to delve into these and use only the most obvious and familiar tasks such as playing music, radio, answering calls and navigation.

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ANALYSIS OF POSTURES IN A CARPENTRY WORKSHOP BY RULA AND REBA METHODS.

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Resumen: Cada vez es más demandado que las operaciones en las industrias sean evaluadas ergonómicamente, pero en muchos talleres esta actividad no es considerada. En este trabajo se presenta una evaluación ergonómica, por medio de RULA y REBA, de una operación en un taller de Carpintería ubicado en la localidad de Ciudad Juárez, México. Un análisis de la tarea permitió a los analistas seleccionar la actividad con mayor número de factores de riesgo ergonómico; dos análisis, en días diferentes, se realizaron para la evaluación por medio de RULA y REBA. Los resultados de ambos análisis fueron contrastados por medio del coeficiente de concordancia de Kendall y se encontró un alto nivel de concordancia en ambos análisis en el método utilizado, por lo que se puede asegurar que en ambos se tuvo un criterio parecido al evaluar la operación y que el marco temporal de la evaluación no influyo. Los resultados presentados por RULA y REBA muestran que la operación presenta un nivel alto de riesgo y se presentaron diversas propuestas para reducir el riesgo.

Palabras clave: Ergonomía, REBA, RULA, Posturas Musculoesqueléticas.

Relevancia para la ergonomía: Por medio de este trabajo se comparan dos métodos de evaluación (RUBA y REBA) por medio de dos analistas en diferentes periodos de tiempo en donde se puede comprobar que el marco temporal presenta un impacto bajo al momento de realizar la evaluación.

Abstract: Industrial operations are increasingly demanded to be ergonomically evaluated, but this activity is only considered in some workshops. This paper presents an ergonomic evaluation, using RULA and REBA, of an operation in a carpentry workshop in Ciudad Juarez, Mexico. A task analysis allowed the analysts to select the activity with the highest number of ergonomic risk factors; two analyses, on different days, were performed for the RULA and REBA evaluation. The results of both analyses were contrasted by means of Kendall's coefficient of concordance and a high level of concordance was found in both analyses in the method used, so it can be assured that both had a similar criterion when evaluating the operation and that the time frame of the evaluation did not influence. The results presented by REBA show that the operation presents a high level of risk, and several proposals were made to reduce the risk.

Keywords. Ergonomics, REBA, RULA, Musculoskeletal Postures.

Relevance to Ergonomics: The objective of this case study is to demonstrate the needs for a redesign of the work area for most work activities, especially jobs with high physical activity.

INTRODUCTION

In several countries, the existence of workshops or small industries is gradually gaining importance (Carrillo et al., 2024).In the field of ergonomics, the handling of loads in the workplace is of great importance today, in addition, there are more and more norms or standards that address the issue of load handling. For example, in Mexico there is NOM-036-1-STPS-2018, while at the international level there is ISO 11228-1:2003.

However, such evaluations are not as frequent for small companies. Ciudad Juarez is a city with a significant number of small businesses in which there is no evidence of evaluating the risk factors present. If the conditions of the workstations are not verified, musculoskeletal injuries can occur that have a great impact on workers' health (Ogedengbe et al., 2023; Sirikasemsuk et al., 2024; Stanton et al., 2013).

The objective of this case study is to demonstrate the need to redesign the work area in a woodworking shop for tasks with high physical activity. According to Stanton (Stanton et al., 2013), various methods must be used when performing an ergonomic intervention. Therefore, for this work, the RULA and REBA evaluation methods were selected, which, according to several authors, are the best known and most widely used (Ogedengbe et al., 2023; Ortiz Solis et al., 2018; Sirikasemsuk et al., 2024).

Additionally, it is also intended to check if there is any significant difference in the evaluations performed by two different analysts on different days to verify if the same evaluation criteria are used regardless of the time of execution.

Background

The word ergonomics derives from the Greek ἔργον (ergon, 'work') and νόμος (nomos, 'law'). Is understood that ergonomics is the set of techniques and scientific knowledge applied so that work, systems, products and environments adapt to the person's physical and mental capabilities and limitations (Asociación Española de Ergonomía, 2024). Also, according to the International Ergonomics Association (2024), Ergonomics can be defined as the scientific discipline that deals with the understanding of the interactions between humans and other system elements and is the discipline responsible for applying theories, principles, data and methods to design to optimize human well-being and overall system performance. In some countries, for example, in the United States of America, ergonomics is mainly known as human factors (Cañas and Waerns, 2001).

Ergonomics has always been present in human history, although it has not been defined as such; for example, in ancient Greece, around the 5th century B.C., its use in the design of tools was already present (Marmaras et al., 1999). In the middle of the 19th century, according to Leirós (2009), the word ergonomics was used for the first time in the philosophical treatise "Compendium of Ergonomics, or the Science of Work Based on Truths Taken from Nature" written by the natural philosopher Wojciech Bogumil Jastrzebowsk in 1857. At the beginning of the 20th century, Frederick W. Taylor began to work with aspects related to the analysis of the movements performed by workers during their tasks; thus, it was intended to reduce inefficient movements and thus perform the work more quickly (Taylor, 1911), in this way, it began to adapt the movement of the person to the work.

Currently, the field of action of ergonomics can be divided into three aspects: on the one hand, there are physical aspects (body posture when working, arrangement of tools, among others), environmental aspects (lighting, noise, thermal sensation, among others) and those related to human behavior and its perceptions or elements called non-physical or cognitive (decision making, perception, attention, motivation, among others) (Asociación Española de Ergonomía, 2024; Leirós, 2009). In the case of the study of physical elements, physical ergonomics oversees physical ergonomics, environmental ergonomics oversees environmental elements, and cognitive ergonomics oversees non-physical and cognitive elements. Within physical ergonomics, there are many ergonomic evaluation methods; some are REBA, RULA, NIOSH Equation, OWAS, among others.

RULA (Rapid upper-limb assessment) was developed by McAtamney and Nigel Corlett (1993) to provide an easy-to-perform assessment of musculoskeletal loading in tasks where people are at risk of loading the neck and upper extremities. This method provides a single "snapshot" score of the task, which rates posture, strength, and movement. Risk is calculated on a score from 1 (low) to 7 (high). These scores are grouped into four action levels that provide an indication of the time frame in which it is reasonable to expect risk control to be initiated (McAtamney & Corlett, 2004). The four levels of action are listed in Table 1.

On the other hand, REBA (Rapid Entire Body Assessment) was developed by Hignett and McAtamney, (2000). The assessment focuses on analyzing body postures, applied forces, types of movements, and task repetitiveness to identify potential risks and suggest improvements in work design. It follows a risk assessment very similar to the RULA method, presenting five risk levels shown in Table 2.

Table 1. RULA risk levels

Score	Level	Action
1 o 2	1	Acceptable Risk
3 o 4	2	Changes to the task may be required; further study is desirable
5 o 6	3	Redesign of the task required
7	4	Urgent changes to the task required

Table 2. REBA risk levels

Score	Level	Risk	Action
1	0	Insignificant	No action is required
2 o 3	1	Low	Action may be necessary
4 a 7	2	Medium	Action is necessary
8 a 10	3	High	Action is required as soon as possible
11 a 15	4	Very High	Action is needed immediately

Musculoskeletal disorders (MSDs) are conditions that impact the muscles, bones, joints, tendons, ligaments, and other connective tissues (World Health Organization, 2024). They can cause pain, stiffness, swelling, and reduced mobility (Morales et al., 2021).

Some common types of musculoskeletal disorders include (Fernandes et al., 2018; LeBlanc and LeBlanc, 2010):

- Osteoarthritis: A degenerative joint disease that causes pain and stiffness.
- Rheumatoid arthritis: An autoimmune disorder that causes inflammation in the joints.
- Tendonitis: Inflammation of the tendons, often due to repetitive strain.
- Bursitis: Inflammation of the bursae, which are fluid-filled sacs that cushion the joints.
- Osteoporosis: A condition in which bones become weak and brittle.

- Fibromyalgia: A disorder characterized by widespread musculoskeletal pain, fatigue, and tenderness in localized areas.

METHODOLOGY

The methodology used to carry out this case study was divided into three parts. The first was the selection of the task, where a quick analysis of the tasks performed in the workshop allowed the analysts to select the activity with the highest number of ergonomic risk factors: stressful postures, extreme efforts, static postures, mechanical stress, and vibration. The second part of the methodology involved the evaluation of the task by the RULA and REBA methods on different days and schedules, and, finally, analyzing the results and determining the level of agreement of the criteria used in the evaluation by both analysts and generate the recommendations. This methodology is illustrated in Figure 1.

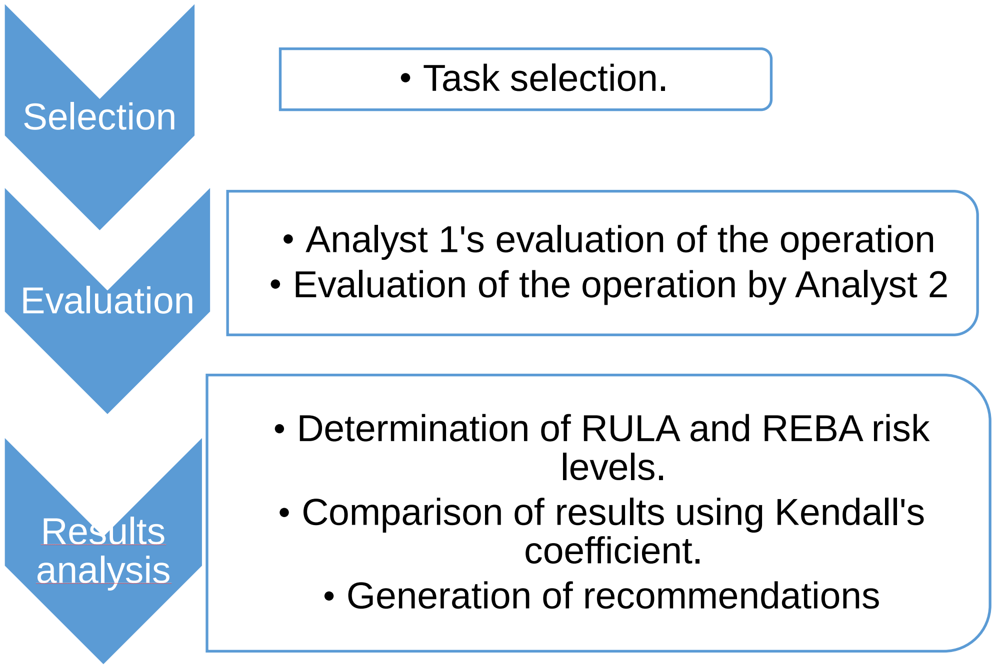

Figure 1. Methodology used in this work.

RESULTS

The operations carried out in the workshop for the different products manufactured are as follows:

- Edging: This operation, performed with precision by our edging machine, ensures the wood has an even surface on one of the edges, serving as a reliable reference for subsequent operations.
- Plane: The wood is given the appropriate thickness for use.

- Length dimensioning: The wood is dimensioned lengthwise, using the even side resulting from edging.
- Width dimensioning: The wood is dimensioned in width.
- Assembly: The furniture is assembled.
- Finishing: The final finish is given, which can be natural, solid color, or varnished.

Considering that the edging operation involves a series of repetitive tasks, this is the operation that began to be analyzed using RUBA and REBA. This operation is performed by a standing operator (Figure 2), using an edging machine (Figure 3).

Figure 2. Operator edging a wooden board.

The first analyst performed the analysis during the first hour of work. The second analyst evaluated the operation two days later, at the end of the work shift.

The RULA results are reported in Table 3.

As seen in the above results, the result, 7 in both analysts and based on Table 1, indicates that the operation should be studied and modified immediately.

Regarding REBA, whose results are presented in Table 4, the final results, 11 and 10, indicate that the operation should be studied and modified immediately.

Figure 3. Edging machine.

Table 3. RULA results

RULA scores			
	Step	Analyst 1	Analyst 2
Section A. Posture	1	3	3
	2	3	2
	3	3	3
	4	1	1
	5	4	4
	6	0	1
	7	3	3
Score Section A	8	7	8
Section B Neck, trunk and leg	9	4	3
	10	3	3
	11	2	2
	12	7	5
	13	0	1
	14	0	2
Score Section B	15	7	8
Final Score		7	7

Table 4. REBA results

REBA scores			
Section		Analyst 1	Analyst 2
Group A	Step 1	3	2
	Step 2	2	2
	Step 3	3	3
	Step 4	6	5
	Step 5	2	2
Score A		8	7
Group B	Step 1	2	2
	Step 2	3	3
	Step 3	4	3
	Step 4	7	5
	Step 5	3	3
Score B		10	8
Final Score		11	10

To determine whether the criteria of the two analysts' evaluations differed, their evaluations were analyzed using Kendall's Coefficient of Concordance. It was found that both analysts used similar criteria in both methods. These results are shown in Table 5.

Table 5. Kendall's Coefficient of Concordance

Method	Kendall’s Coefficient
RULA	0.923
REBA	0.888

CONCLUSIONS

According to the results of this work, the following can be concluded:

- The operation, as it is currently performed, represents a high risk to the health of workers, both methods confirm this.
- The analysts use very similar criteria when evaluating the operation, thus confirming the risk posed by it.

Regarding recommendations, it's suggested to place the edging machine on a platform where the machine's height can be adjusted. This will help the operator perform the operation without excessive leaning. Furthermore, the use of an anti-fatigue mat in the work area is strongly recommended to enhance worker comfort and safety.

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ERGONOMIC EVALUATION AT THE MAIN LINE 42 WORKSTATIONS

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Resumen: El presente proyecto presenta los resultados obtenidos de la aplicación de evaluaciones en los puestos de trabajo de la línea M42 de una empresa, para determinar el nivel de riesgo presente en las estaciones de trabajo, implementando mejoras, rediseño de métodos de trabajo y sugerencias que eliminen los posibles daños a la salud de los trabajadores de raíz.

Con este proyecto se pretende identificar las estaciones de trabajo con mayor probabilidad de provocar lesiones en los operadores, utilizando formatos de evaluación ergonómica para identificar factores de riesgo presentes en cada tarea y modificar los métodos de trabajo para reducir el nivel de riesgo asociado a cada tarea.

Para la aplicación de los métodos de evaluación ergonómica se identificaron los factores de riesgo predominantes en cada tarea, (posturas inadecuadas, movimientos repetitivos y manipulación de carga), para cada uno de estos factores de riesgo existen diversos métodos de evaluación ergonómica, por lo cual, se seleccionó el método que mejor se adapta a las características de la tarea analizada y en función del análisis que se pretende llevar a cabo, se seleccionaron los métodos REBA, JSI y las tablas de Snook y Ciriello respectivamente.

Palabras clave: Ergonomía, trastornos musculoesqueléticos, factores de riesgo, carga postural.

Relevancia para la ergonomía: Mejora en puestos de trabajo y en condiciones laborales, aumento de la producción.

Abstract: This project presents the results obtained from the application of evaluations in the workplaces of the M42 line of a company, to determine the level of risk present in the workstations, implementing improvements, redesign of work methods and suggestions that eliminate possible damage to the health of workers at the root.

This project aims to identify the workstations most likely to cause operator injuries, using ergonomic assessment formats to identify risk factors present in each task and modify working methods to reduce the level of risk associated with each task.

For the application of the ergonomic evaluation methods, the predominant risk factors in each task were identified (inappropriate postures, repetitive movements and load handling), for each of these risk factors there are various ergonomic evaluation methods, for which the method that best adapts to the characteristics of the analyzed task and depending on the analysis that is intended to be carried out was selected. the REBA, JSI and Snook and Ciriello tables were selected, respectively.

Keywords: Ergonomics, musculoskeletal disorders, risk factors, postural load.

Relevance for ergonomics: Improvement in jobs and working conditions, increased production.

1. INTRODUCTION

Ergonomics is the discipline that studies the adaptation of work to man and machine, to improve safety, well-being, efficiency and effectiveness in the performance of the task. The benefits of the e(Fajardo Bautista, y otros, 2024)Ergonomic functions go beyond improving people's comfort and reducing costs, but allow them to have a better posture and perform their activities with greater comfort, which is reflected in the quality of work and an increase in productivity. Ergonomics can renew efficiency and safety in the work environment, its role in improving the value-added service of professional insurance agents, and the identification of related musculoskeletal disorders.(Mamani Hualpa, 2021).

Ergonomics is a science where work is evaluated and the different conditions that workers can suffer due to exposure to risks at work, one of these conditions is musculoskeletal disorders, which are one of the most reported conditions in medical centers, caused by multiple situations such as social problems, psychic, physical and environmental factors. Ergonomics provides methodologies to detect possible problems that are affecting the worker through ergonomic assessments. (Díaz Tenesaca, Rivera Chacón, Oñate Haro, & Garay Cisneros , 2022)

This project carried out in an electronics company presents the results obtained from an ergonomic evaluation carried out in the packaging area in the M42 line, which is specialized in the manufacture of large inch televisions, to determine if its facilities and work processes are safe and adapt to operators, through the application of ergonomic evaluation methods for the risk factors present in the area.

2. OBJECTIVE

Evaluate the M42 line workstations using ergonomic assessment methods to reduce the level of ergonomic risk to which operators are exposed when manufacturing the 85-inch television models in-house.

3. DELIMITATION

The project is carried out in an electronic business company in the manufacture of televisions located in the city of Tijuana, Baja California, in the packaging area of the M42 line.

4. METHODOLOGY

Ergonomic evaluation methods make it possible to identify and assess the risk factors present in the workplaces and, subsequently, based on the results obtained, propose redesign options that reduce the risk and place it at acceptable levels of exposure for the worker. A worker's exposure to risk in a workplace depends on the extent of the risk to which he or she is exposed, the frequency of the risk and its duration. This information can be obtained through ergonomic evaluation methods, which are easy to apply, compared to other more complex techniques or techniques that require more specific knowledge or measuring instruments that are not always within the reach of ergonomists.

Ergonomic assessment methods allow the identification of forced postures, repetitive movements and work-related ergonomic risk factors and are complemented by technological analyses based on ergonomic assessment software that allow the results of an assessment to be optimised. (Arriola & Chávez, 2023)Depending on the activity to be evaluated and the ergonomic risk observed in it, various methods are developed for its analysis and estimation based on the needs and conditions of the workplace. These methods propose options capable of reducing the risk by placing it at acceptable levels for the worker based on the results obtained.(Rodríguez Sánchez, Guzmán Álvarez, Almanza Ojeda, & Rocha Ibarra, 2021)

4.1 Selection of the evaluation method.

A major difficulty when performing the ergonomic evaluation of a job to prevent musculoskeletal disorders is the large number of risk factors that must be considered, such as repetitive movements, lifting loads, maintaining forced postures. To determine the ergonomic evaluation methods that were used, a questionnaire was applied that allowed the selection of the most appropriate evaluation method for the risk factors identified in the packaging area of the M42 line.(Ergonautas, 2024)

4.2 REBA Method.

For the evaluation of posture, the REBA method was used, which is an ergonomic evaluation method aimed at the postural load and the different postures adopted by the worker during the development of his function, it is a special method for musculoskeletal risks and divides the body into segments to be individually coded, and evaluates both the upper limbs, as well as the trunk, neck and legs.(Prieto Muñoz, 2021)

4.3 JSI method (Job Strain Index method).

To evaluate the repetitiveness of the operation, the JSI method will be used, which is a method of evaluating jobs that allows assessing whether the workers who occupy them are exposed to developing cumulative traumatic disorders in the distal part of the upper limbs due to repetitive movements.(Catacora Leon, 2021)

4.4 Survey application.

Many of the processes on the line are automated, therefore, the operators are forced to follow the work rhythm of the machines, which are programmed to work in the shortest possible cycle time, there are a few seconds of rest between each manufactured television and the working day lasts 10.18 hours with 3 breaks for breakfast, lunch and snack, with a duration of 20, 30 and 10 minutes respectively; Many of the workstations were not thought or designed in an ergonomic way, which causes operators to adopt inappropriate postures when performing their work that could have repercussions on their health, in addition to this design makes it difficult and hinders the handling of loads to supply materials, in addition to the excessive repetitive work due to very short-term operations.

Due to this situation, a risk check survey was carried out on the line due to the multiple complaints presented by some operators who have presented discomfort and pain when producing the models, in figure 1 where it is shown that all operators have presented some type of pain or discomfort at least in some area of their body, the neck, shoulders and back being the most frequent.

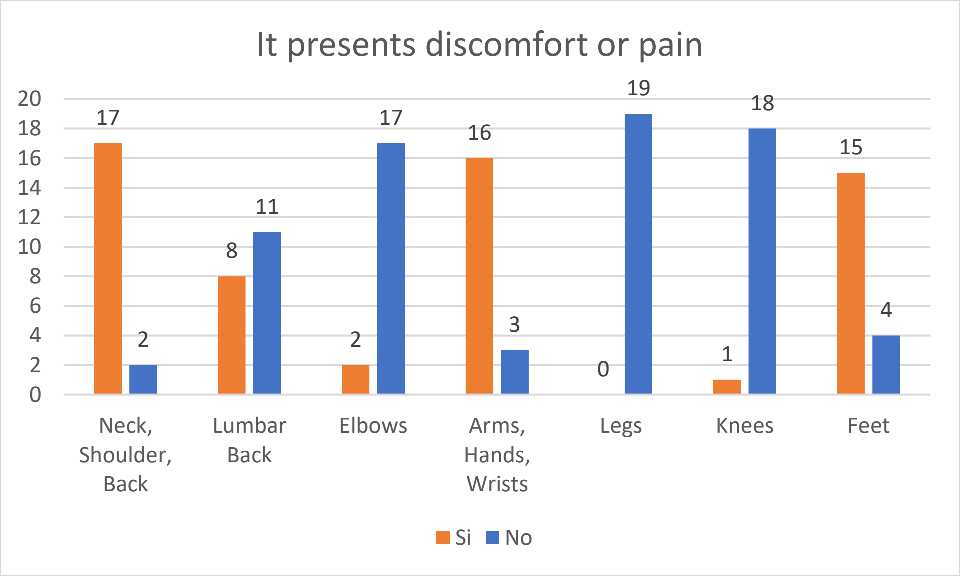

Figure 1. Graph of aches and pains in the areas of the body. Source: Authors.

We can see in Figure 2 that the pain or discomfort suffered by operators in the neck, shoulders and back occurs very frequently 58% of the time, on the other hand, pain in the arms, hands and wrists occurs very frequently 75% of the time and, finally, foot pain occurs very frequently 60% of the time.

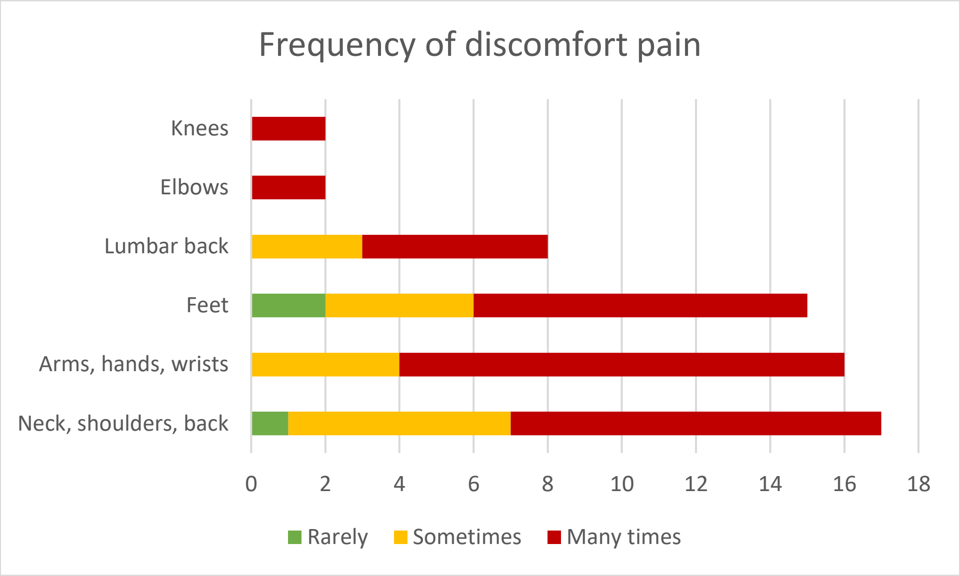

Figure 2. Graph of how often aches or pains occur. Source: Authors.

5. RESULTS

The results obtained previously applied to the evaluation methods in the packaging area of the M42 line, which has 8 workstations, are shown.

Table 1 shows the summary of the results of the REBA method of the evaluations applied in 5 workstations in which the operators maintained forced postures and of which the cushion bottom supply stations, box supply present a high level of risk and action is necessary.

Table 1. REBA method results matrix. Source: Authors.

REBA METHOD RESULTS MATRIX				
Activity	**REBA Score**	**Performance Level**	**Risk**	**Performance**
Cushion Bottom Supply	10	3	High	Action is needed as soon as possible
Placement of Cushion Top and Air Cushion	5	2	Middle	Action is needed

Fitting Accessories	6	2	Middle	Action is needed
Placement of Base Stand	6	2	Middle	Action is needed
Box Supply	9	3	High	Action is needed as soon as possible

Table 2. The matrix with the results of the evaluations in 7 workstations of the packaging area is shown, in which, due to the cycle time of less than 11.7 seconds, it was necessary to perform an evaluation of the repetitiveness of movements. It is shown that the cushion bottom supply station, box supply and box placement have a JSI (risk of appearance of disorders in the upper extremities) with a high value and greater than 7, so the task is high risk for workers, who have a high probability of suffering from musculoskeletal disorders in the upper extremities.

Table 2. JSI method results matrix. Source: Authors.

RESULTS MATRIX JSI METHOD			
Activity	**JSI Task**	**No. average of efforts/minute**	**Risk level**
Cushion Bottom Supply	20.25	7.83	High-risk task for the worker
Placement of Cushion Top and Air Cushion	4.50	5	It is not possible to say that the task is safe
Cushion Side Insert	4.50	6	It is not possible to say that the task is safe
Fitting Accessories	4.50	4.8	It is not possible to say that the task is safe
Placement of Base Stand	4.50	5	It is not possible to say that the task is safe
Box Supply	13.50	7	High-risk task for the worker

Box Placement	13.50	5.57	High-risk task for the worker

Table 3 shows the result of the application of the Snook and Ciriello tables at the Stand Base supply station, where load lifting is carried out with transport. The results of the application of this method indicate that this activity is harmful to the health of the worker since the ratio is greater than 1 due to the fact that the operator handles the load of 18.1 kg away from the body, with 7 kg being the maximum acceptable limit in those specific lifting conditions.

Table 3. Snook and Ciriello method results matrix. Source: Authors.

RESULTS MATRIX SNOOK AND CIRIELLO METHOD				
Activity	**Load Weight/Force**	**Maximum Acceptable Weight/Force**	**Ratio**	**Risk level**
Supply of Stand Base	18.1 Kg	7 Kg	2.59	Task detrimental to health

Redesigns were made in the methods and workstations and some processes were automated by implementing robot prototypes, which will significantly facilitate and simplify the work of the operators, thus reducing the level of risk associated with each task.

Figure 3 shows the proposed design for the cushion bottom supply station, which is substantially improved by increasing the height of the belts where the operator places the cushion bottom to feed the robot that places the television on the cushion.

For this modification it was necessary to change the base of the robot which did not allow to increase the height of the conveyor belts causing the operator to flex his trunk more than 60° and flex his knees every time he supplies the cushion bottom, being a posture too harmful to his health and a high-risk task. for which it was necessary to act as soon as possible.

Figure 3. Redesign of the Cushion Bottom Supply Station" **Source:** Company 2023.

6. CONCLUSIONS AND RECOMMENDATIONS

It can be concluded that the objectives of the project were satisfactorily met since the workstations with the highest probability of causing injuries to workers were determined, thanks to the ergonomic evaluations applied, 3 risk factors were identified present in the workstations of the packaging area in the M42 line, predominating inappropriate postures and repetitiveness of movements mainly, and improper handling of loads present only at the base stand supply station.

Once the highest risk workstations were identified, they needed to be modified to reduce the likelihood that the task would be harmful to the health of operators. For this redesign of the stations, robots were placed that do heavy and unergonomic work, ensuring the health of the operators by significantly facilitating their work, thus reducing the level of risk associated with each task by 30%.

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INFORMATION BEHAVIOR IN THE PROCUREMENT AREA

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Resumen: Este proyecto se enfoca en el comportamiento informativo de los usuarios o participantes del área de *procurement,* la cual es un área administrativa que se encarga de validar proyectos de materiales en referencia al cambio de proveedores, tener opciones de proveedores y cambios en los procesos donde estos materiales son utilizados. Particularmente, los usuarios tienen relaciones con las cadenas de suministros y areas de ingeniería, manufactura y calidad para lograr sus objetivos organizacionales. De ahí que, en la búsqueda y uso de la información, fueron descubiertas tres problemáticas respecto a los tiempos requeridos en la búsqueda y uso de la información, los errores en la búsqueda y uso de la información y la satisfacción en la búsqueda y uso de la información. Por ello, el objetivo fue señalado como mejorar el comportamiento informativo mediante técnicas de Ergonomía Cognitiva para incrementar la productividad. Este indicador fue compuesto de las problemáticas señaladas anteriormente delineando una metodología compuesta por 10 actividades, que, a su vez, contenía cuatro etapas enfocadas a diversas actividades que son realizadas exclusivamente en el área de *procurement*. Los resultados principales se mencionan que el tiempo promedio de las etapas en los proyectos decreció en promedio 48.75%, los errores cometidos en la búsqueda y uso de información promedio una reducción de 71.09% y la satisfacción de los usuarios fue incrementada 5 puntos de satisfacción. Esto permitió concluir que el objetivo planeado fue logrado exhibiendo, además, oportunidades para posibles mejoras teniendo como elemento principal el comportamiento informativo dentro de contextos considerados dinámicos como la empresa participante y que los usuarios de información puedan acceder a ésta acorde a sus necesidades de información en la realización de sus actividades rutinarias.

Palabras clave: Comportamiento informativo, área de *procurement*, proveedores, satisfacción informativa

Relevancia para la ergonomía: El proyecto permitió probar las teorías y argumentar las mejoras deseadas, que posteriormente fueron confirmadas permitiendo así, diseñar herramientas de trabajo con el objetivo de aumentar la productividad y el bienestar de los usuarios de éstas. Las competencias fueron adquiridas y aplicadas para argumentar mejoras en el comportamiento informativo y de esta forma dimensionar su aplicación en ambientes laborales reforzando y creando conocimientos en contextos o ambientes naturales, como lo fue la empresa participante y logrando objetivos organizacionales y generando conocimiento en la aplicación de éste a través de la investigación del comportamiento informativo.

Abstract: This project focuses on the information behavior of the users or participants of the procurement area, which is an administrative area that is responsible for validating material projects in reference to the change of suppliers, having supplier options and changes in the processes where these materials are used. Particularly, users have relationships with supply chains and engineering, manufacturing and quality areas to achieve their organizational objectives. Hence, in the search and use of information, three problems were discovered regarding the times required in the search and use of information, the errors in the search and use of information and the satisfaction in the search and use of information. Therefore, the objective was indicated as improving information behavior through Cognitive Ergonomics techniques to increase productivity. This indicator was composed of the problems indicated above, outlining a methodology composed of 10 activities, which, in turn, contained four stages focused on various activities that are carried out exclusively in the procurement area. The main results mention that the average time of the stages in the projects decreased on average by 48.75%, the errors made in the search and use of information averaged a reduction of 71.09% and user satisfaction was increased by 5 satisfaction points. This allowed to conclude that the planned objective was achieved, also exhibiting opportunities for possible improvements, with the main element being information behavior within contexts considered dynamic such as the participating company and that information users can access it according to their information needs in carrying out their routine activities.

Keywords. Information behavior, procurement area, suppliers, informational satisfaction

Relevance to Ergonomics: The project allowed to test the theories and to argue the desired improvements, which were subsequently confirmed, thus allowing the design of work tools with the aim to increase the productivity and well-being of their users. The competencies were acquired and applied to argue for improvements of the information behavior and in this way, the dimension of their application in work environments, reinforcing and creating knowledge in contexts or natural environments, such as the participating company, and achieving organizational objectives and generating knowledge in the application of this research on information behavior.

1. INTRODUCTION

Note: the name of the participating company, the processes, products, and tools used within it and its processes have been modified for ethical and confidential reasons.

Since the beginning of time, human beings have sought to satisfy their needs for information to carry out daily activities; this is called information behavior (Spink and Currier, 2006). The information search process can be direct or indirect (Calva Gonzalez, 1998). The indirect form is understood as one that satisfies the need of information by chance, such as finding information that was needed in an advertisement, in a publication, on social networks, on television, etc. On the other hand, there is direct search, which implies that the user consciously seeks to satisfy their needs for information, and takes actions to achieve this by accessing various sources within their reach, including documentation, programs, other users, etc.

Although humanity has always carried out information behavior, it is not a topic that is frequently studied in Latin America, in the cases in which this behavior is studied they are in projects applied to students (Vásquez-Velázquez, 2006). On the other hand, work activities such as administrative processes are considered. Since although engineering skills can be carried out in any field, it is usual to focus them on the industry, specifically on the operational areas of production companies, which have a greater monetary impact on them.

Considering the aforementioned, this project aims to demonstrate the importance of bringing Ergonomics knowledge to areas where it is not common to know applied projects, but thus, highlight the importance of cognitive ergonomics on them (Albert and Tullis, 2013). This is, particularly, as the various improvements that can be observed in users and subsequently in the performance of their activities with the use of abstract and physical tools that are intended to facilitate their responsibilities and support their competencies at work.

Therefore, this project was carried out within the procurement area, which is linked to various departments of the company, such as the supply chain, engineering, manufacturing and quality areas. Among the mentioned areas, there are 10 users who use of the information generated in the area to carry out their pertinent activities. In particular, in the procurement area, they are in charge of validating projects related to materials and these can be divided into three areas, which are:

- Change of supplier (COS). Its objectives are to minimize the minimum purchase quantity and storage space, the investment per raw material and unit cost.

- Two sources (Dual source). Its objectives are to have validated suppliers of raw materials and materials to increase supply options in cases of urgent needs.
- Change Engineering (QBE). Its objective is to make improvements in the various activities of the processes, considering the mentioned items.

In addition, within the projects that are in charge of the procurement department, there are activities that were considered such as (the names were changed for confidential reasons):

- Project Idea. These activities are carried out by project managers.
- PO's. These activities refer to purchase orders based on samples delivered by supplier candidates.
- MRBR. These activities are aimed to monitor purchase orders in consideration of price, quantity, or receipt discrepancies in warehouses, to avoid shortages of raw materials and materials in the processes.
- Q2C. They are the activities necessary to monitor products through formats, catalogs and systems.
- 3F. These are the activities necessary to validate products in the assembly process and ensure product performance and design specifications.
- eDerogation. These activities refer to the testing of products that will be used as product samples and sent to potential customers.
- PPAP. These activities are concerned with creating evidence to show the robustness and repeatability of the process.
- Workflow. These activities are aimed to create flow charts considering various aspects of the process, including suppliers, part numbers, process times, specifications or other systemically relevant data for the company.

The procurement area is in charge of projects for validation of materials and the activities mentioned above are developed; this requires a large amount of data, documents and procedures to be specifically followed. All the essential information is difficult to find since it is found in various sources of information, such as the server, and it is even necessary to contact different colleagues to collect the necessary data to satisfy the user's information needs. Due to this, there have been delays in completing the activities in a timely manner. This has caused delays in the completion of these projects, as well as errors that stop the progress of activities on them. Therefore, here it was discovered that the users have not been able to access the information required to carry out their daily activities that directly impact their responsibilities. The above was visualized by measuring the times required to carry out each of the stages of the procurement area projects and these were:

  - Stage 1, 54.5 minutes
  - Stage 2, 31.9 minutes
  - Stage 3, 65.7 minutes
  - Stage 4, 43.6 minutes

Average time spent in the four stages: 48.9 minutes

Regarding the accounting of errors committed by each of the users, these were:

- User 1, 32 errors
- User 2, 40 errors
- User 3, 44 errors
- User 4, 34 errors
- User 5, 46 errors
- User 6, 31 errors
- User 7, 33 errors
- User 8, 41 errors
- User 9, 42 errors
- User 10, 45 errors

Average number of errors committed 38.8

Finally, the measurement of user satisfaction in the search and use of information processes averaged a score of 4, with 1 being dissatisfied and 10 being completely satisfied.

That is, information behavior was affected by the sources of information, the forms in which it is presented and its use within the activities carried out within the commented area. This was observed in the increase in the time required in the information search process, the increase in user error when interpreting the information provided during the aforementioned activities, and primarily, the reduction in user satisfaction in the search and use of information. Information within the indicated activities, as noted above. Hence, the objective of the project is to improve the information behavior of users in the procurement area to increase productivity through the use of Cognitive Ergonomics tools. In addition, it is expected to reduce the information search time, to decrease the error on the part of the information user and finally, to increase user satisfaction in the search and use of information within the indicated context. The importance of the project exhibits the impact it has on the company's production area, mainly in the search for reliable suppliers in the environment.

In general terms, the background, the methodology used in the project, the results and the conclusions obtained in the project are presented below.

2. BACKGROUND

In this section, information behavior, information sources, databases, user productivity, usability and errors are presented.

2.1 Information Behavior

Information behavior can be pointed out as that manifestation of the information needs of a user or users, originated from the insufficiency of information and knowledge about a phenomenon, object, or event. (Calva González, 1998). This behavior has been treated in various areas of knowledge, it is being seen as a need for information where patterns are visualized for certain populations in economic, social and cultural aspects (Vásquez-Velázquez, 2006). Here, the aspects of art are also relevant in how the relationship between information and human behavior exists in its search and use (Spink and Currier, 2006). Additionally, Wilson (1999) and Case (2006) have carried out various studies on information behavior in various contexts as well as synthesizing them in such a way that they show the advantages of this to support activities where information is important for them.

2.2 Information Sources, Database and User Productivity

There are various definitions of information sources and their use is according to the context of use, and may be in consideration of the materials or products that allow access to knowledge (Carrizo, 2000); It may be a document or institution that provides the opportunity to respond to requests for information (Fuentes i Pujol, 1992); It can be any documentary that contains information that allows it to be shown (Puig, 1987), and it can be means to make the information possible to whoever requires it (Meira, 1997).

Besides, databases are sets of data stored in external memory organized by a structure and designed to satisfy information requirements. For this, end users hope to integrate data sharing, redundancy control, data consistency, improved data standards, better data security, better data accessibility, and economies of scale to support the activities using information. On the other hand, user productivity can be seen as the ability to direct efforts to the management of a system based on the resources that can be objectively used. That is, finding a relationship between resources used in the production of products or services, combining them for their effectiveness and efficiency for the benefit of organizations (Arraut, 2010). These are two components to indicate the achievement of objectives, on the one hand, and the resources used to achieve the objectives (Gutiérrez, 2009), on the other.

2.3 Usability and Error

Usability is the search for the satisfaction of the potential user of the products or services generated to satisfy their needs and desires (Reyes and Libreros, 2011). For its evaluation, various techniques can be used, ranging from heuristic evaluation and cognitive review (Reyes and Libreros, 2011), and can be used in software development processes or in other environments seeking to obtain better results (Nielsen, 1993). Moreover, this process is in itself a challenge that must be built in such a way that there is quality in its process to ensure that usability is evaluated according to what is expected in terms of user satisfaction.

Furthermore, error is seen as actions or activities that exceed the limits of acceptance or those that are placed outside the limits of performance (Swain, 1998). That is, error is considered an action that can be identified causing an unexpected or undesired result (Hollnagel, 2005). This can be combined with improving the user's perception in order to meet the stated objectives and the expected functionality to change in case of deviations (Nielsen, 1993).

3. METHODOLOGY

The project's development was divided into nine essential activities to achieve the general and specific objectives, which were focused on the user due to the improvement of information behavior. The activities were:

1. To divide the activities of the procurement area into stages according to the needs of the area, such as the idea of the project. There were four stages that were considered within this project called stage 1 (project idea, PO and MRBR), stage 2 (Q2C and 3F), stage 3 (deviation/pilot run) and stage 4 (PPAP and WORKFLOW), indicated in the section of introduction.
2. To development of questions to evaluate information satisfaction. This was to understand the users and their satisfaction for searching and using information.
3. The application of the survey to users. Its application was online to mainly discover the degree of access to information required for its activities.
4. The time recording of the stages of the procurement area. Here, the time required to search for information, interpret information, fill out forms, and correct erroneous information were considered.
5. The registration of user errors in the stages of the procurement area. These were mainly by using wrong information, entering wrong information, requesting wrong information, and adding missing information to perform their activities.
6. The development of a database. Here, the idea is to look for the software that could facilitate the access to users and its use in search, interpretation, filling out forms, and correcting information. The Excel software was chosen.
7. The database application. In this phase, training was provided in the use of the database through its presentation and implementation within the activities required in the area.
8. The second application of the survey to users. The survey developed was used to evaluate the usability of the information tools developed, including the database.
9. The second time taking of the stages of the procurement area. The times were taken again according to the use of the developed tools.
10. The second record of user errors in the stages of the procurement area. The errors presented in the use of the developed tools were recorded.

Also, evaluations were carried out on the 10 users who are within the procurement area in charge of the aforementioned activities; here, all the users and their perceptions were considered because they were a smaller number of users and were willing to participate in the entire project. Moreover, ethical and confidentiality aspects were taking into account, when people were involved.

4. RESULTS

The results of the study were according to the stages indicated above. Therefore, with respect to the times required to carry out the considered activities, before and after comparisons were made, the results of the different stages were obtained as follows:

- In stage one, the time decreased from 54.5 minutes to 26.1 minutes, representing a 52% reduction.
- In stage two, the time decreased from 31.9 minutes to 18.8 minutes, representing a 41% reduction
- In stage three, the time decreased from 65.7 minutes to 30.5 minutes, representing a 54% reduction.
- In stage four, the time decreased from 43.6 minutes to 22.8 minutes, representing a 48% reduction.

In this section, the results indicate that there was a general decrease in the times required in each stage. Hence, it could be visualized that in stage one there was a decrease of 52%; in the second, 41%; in the third, 54%, and in the fourth, 48%, averaging 48.75% of the time required in all stages.

Regarding the registration of errors made by users before and after in the implemented database and tools, the following results were obtained in the evaluations of the complete cycle per user:

- User 1 went from 32 to eight errors, reducing 75%.
- User 2 went from 40 to 11 errors, reducing 72.5%.
- User 3 went from 44 to nine errors, reducing 79.5%.
- User 4 went from 34 to nine errors, reducing 73.5%.
- User 5 went from 46 to 13 errors, reducing 71.7%.
- User 6 went from 31 to 12 errors, reducing 64%.
- User 7 went from 33 to eight errors, reducing 75.7%.
- User 8 went from 41 to 13 errors, reducing 68.2%.
- User 9 went from 42 to 15 errors, reducing 64.2%.
- User 10 went from 45 to 16 errors, reducing 66.6%.

It was noted that the reduction in error in the search and use of information. it is notable since the user with the lowest percentage reduced was 64% and the user with the highest percentage was 79.5%, averaging a reduction in the error of 71.09%. for this it was concluded that the results obtained are satisfactory in terms of fewer errors when carrying out the activities.

Regarding information satisfaction evaluated through the survey of users in the procurement area, users on average perceive their information satisfaction with a rating of “4” during the initial of the project, on a scale of 1 to 10, with 1 being dissatisfied, and 10 being completely satisfied, and a “9” after the implementation of the tools. That is, at the beginning of the project, satisfaction was 4 and at the end of the project, satisfaction was 9, increasing 5 units.

In general, the results obtained showed that the average time of the stages in the projects decreased 48.75%, the errors made in the search and use of information declined 71.09% and user satisfaction increased 5 points.

5. CONCLUSIONS

In the research, the stated objective was achieved through the reduction of complaints by the project managers, pointing out that their satisfaction was increased. Similarly, they indicated reduction of stress by delivering the required reports on time and by reducing errors in their processes. This is due to having the required information and making use of it when they required it. Also, it was shown that the creation of databases directly impacts the information behavior of users by facilitating access to information, by facilitating its interpretation, by reducing project completion times, and by accessing to information with a simple and quick form, among others benefits.

It is relevant to note that the procurement area is identified as an administrative area, in which access to the use of new knowledge and skills is sporadically allowed in such a way that, they directly impact its operation. Therefore, this facilitated their activities by reducing costs for rework, by project completion on time, and reducing costs for fines for late product delivery. Particularly, users spent long times searching for information and this was reduced as a result of the development and implementation of technological tools for improving these activities.

The above allowed it to confirm that the knowledge of Cognitive Ergonomics and Information Behavior created the bases for improving administrative activities in the procurement area. In the same way, this allowed it to visualize the benefits that arise when creating knowledge from the application of theories in natural environments, different from those previously indicated in the literature consulted.

Besides, during the project, other areas of opportunity were discovered, among which the following can be mentioned: to generate a database for each of the company's departments focused on satisfying the information needs of users; to use of production tests to train the use of information through the production processes; to create of a database for the entire company by employing an exclusively programmer; to train administrative users in the search and use of existing information by creating better options in the development of new tools for searching and using information, and to create appropriate techniques to evaluate the times required in the search and use of information according to the context in use.

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VALIDATION OF COMPUTER VISION SYSTEM FOR SPEED MEASUREMENT IN MANUAL WORK.

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Resumen: Hoy en día la implementación de la tecnología en las empresas de producción resulta crucial en su operación, la inteligencia artificial juega un papel fundamental en ello, una rama fundamental de esta ciencia es la visión por computadora, la cual por su definición busca analizar y procesar todo lo que podemos observar, brindando información valiosa para entender el contexto que nos rodea, en la industria manufacturera comúnmente se usa para la inspección de la calidad de producción. Si bien hay que decir que esta tecnología está presente en la industria, aún no ha desarrollado todo su potencial para el análisis y diseño del trabajo. Este documento describe la validación de un sistema de visión por computadora con el objetivo medir la velocidad con la cual los empleados realizan sus actividades de trabajo, enfocándose únicamente en operaciones manuales, lo que permitirá ser una herramienta en la determinación del tiempo normal y el tiempo estándar. Este sistema se basa en el lenguaje de programación Python y el uso de sus librerías de captura de movimientos como lo es media pipe, la cual permite la captura de determinados puntos del cuerpo. La importancia de este sistema radica en que puede constituirse como una herramienta que permita realizar análisis de los tiempos en un proceso productivo. Para poder validar la implementación de este tipo de sistemas en el análisis del trabajo participaron 30 alumnos de universidad, a los cuales se les tomo su distancia, tiempo y velocidad basándose en su mano y se comparó con una banda de trabajo (Rotary) a una velocidad constante. El experimento se llevó a cabo tomando cinco muestras por cada persona, en total se tomaron 150 muestras distribuidas en la colocación del sistema en dos diferentes posiciones verticales descritas en este artículo, con el fin de validar la eficiencia del sistema teniendo en cuenta que en un ambiente real se tiene que adaptar el sistema a la estación de trabajo. El análisis estadístico realizado con un software especializado permitió evaluar el desempeño y la precisión del sistema propuesto. Los resultados muestran que el sistema de visión desarrollado en Python y la velocidad constante del rotary arrojan la misma velocidad de las personas al mover un objeto. En conclusión, los resultados descritos en este articulo no solo demuestran la utilidad de estos sistemas de visión en la detección de la calidad en la industria manufacturera, sino que el uso de estos sistemas basados en el seguimiento corporal puede resultar útiles en el proceso de toma de tiempos. Con ello proveer una herramienta que de manera automática brinde soluciones al diseño y análisis del trabajo.

Palabras clave: Manufactura; Medición de Velocidad de la Tarea; Inteligencia Artificial; Visión por computadora.

Relevancia para la Ergonomía: Este artículo presenta un sistema automatizado basado en visión por computadora que permite medir y analizar la velocidad de las operaciones manuales, lo cual es crucial para diseñar estaciones de trabajo más eficientes y seguras. Además, demuestra la viabilidad de integrar tecnologías avanzadas en la evaluación del trabajo.

Abstract: Today the implementation of technology in production companies is crucial in its operation, artificial intelligence plays a key role in this, a fundamental branch of this science is computer vision, which by its definition seeks to analyze and process everything we can observe, providing valuable information to understand the context around us, in the manufacturing industry is commonly used for the inspection of production quality. Although it must be said that this technology is present in the industry, it has not yet developed its full potential for work analysis and design. This paper describes the validation of a computer vision system with the objective of measuring the speed with which employees perform their work activities, focusing only on manual operations, which will allow it to be a tool in the determination of normal and standard time. This system is based on the Python programming language and the use of its motion capture libraries such as media pipe, which allows the capture of certain points of the body. The importance of this system lies in the fact that it can be used as a tool for time analysis in a production process. In order to validate the implementation of this type of system in the analysis of work, 30 university students participated, whose distance, time and speed were taken based on their hand and compared with a work band (Rotary) at a constant speed. The experiment was carried out taking five samples for each person, in total 150 samples were taken distributed in the placement of the system in two different vertical positions described in this article, in order to validate the efficiency of the system taking into account that in a real environment the system has to be adapted to the workstation. The statistical analysis performed with specialized software allowed to evaluate the performance and accuracy of the proposed system. The results show that the vision system developed in Python and the constant speed of the rotary display the same speed of people moving an object. In conclusion, the results described in this paper not only demonstrate the usefulness of these vision systems in quality detection in the manufacturing industry, but also that the use of these systems based on body tracking can be useful in the time-taking process. With this providing a tool that automatically provides solutions to the design and analysis of the work.

Keywords: Manufacturing; Task Speed Measurement; Artificial Intelligence; Computer Vision.

Relevance to Ergonomics: This paper presents an automated computer vision-based system for measuring and analyzing the speed of manual operations, which is crucial for designing more efficient and safer workstations. It also demonstrates the feasibility of integrating advanced technologies into work evaluation.

1.INTRODUCTION

Computer vision has been used in different areas including medicine, in the health sector, computer vision is used for applications such as medical image analysis, including early detection of diseases through X-ray images, MRI or CT scans (Cronin et al. 2023). These systems can identify patterns and anomalies that might go unnoticed by radiologists, allowing for more accurate and faster diagnosis (Galán & Portero, 2022).

Furthermore, in precision agriculture, computer vision systems are used for crop classification and selection, detection of pests and diseases in plants, and monitoring crop growth and health (Yu et al., 2023). These systems help farmers optimize resource use, improve productivity, and reduce environmental impact (Rai et al., 2023). In the field of security, computer vision is used for intrusion detection in video surveillance systems, facial recognition in access control systems, and identification of suspicious behavior in public environments. These systems are essential for prevention and rapid response to security threats.

In manufacturing, these systems are used for product quality inspection, where cameras can identify defects or imperfections in manufacturing parts with an accuracy and speed that surpasses human inspection (Kassahun et al., 2024). These are implemented in automotive, electronics, food and beverage production lines, among other sectors, improving efficiency and reducing the risk of defective products (SaifI et al., 2023). Continuing with this area, the monitoring of production processes is a fundamental part of quality management and efficiency optimization in companies and production lines. Time measurement has traditionally used manual methods or specialized sensor technologies, which are often costly and complex to implement, but increasingly technology has been adopted in time measurement. Optimizing production times brings advantages in cost reduction and quality, allowing companies to compete in today's globalized market (Valencia et al., 2013). That is why we can increasingly observe the incursion of automated systems oriented in production.

The measurement of standard and normal time is an essential component in the efficient management of industrial and organizational processes. These methods offer in a structured way the evaluation and establishment of optimal working times in the execution of tasks and operations (Mor et al, 2018). Time measurement standardizes work activities by establishing a reference standard for the amount of time it is expected to take to complete a specific task, considering ideal conditions and average worker skills. Although traditionally the use of the stopwatch has been the method of choice, the incorporation of computer vision methods should be a priority for agencies dedicated to improving these procedures.

While measuring the production speed of a product can be crucial for assessing the efficiency of the manufacturing process and detecting areas for improvement, this task represents a significant challenge for computer vision systems. The complexity lies in the need to capture and analyze real-time data accurately and reliably in dynamic and variable environments. Computer vision systems must be able to distinguish and track moving objects, accurately calculate speeds, and adapt to changes in environmental conditions or in the production line itself. In addition, the diversity of product shapes, sizes and colors, along with possible visual obstructions or image distortions, add an additional layer of difficulty. Despite these challenges, the continued development of algorithms and increased computational power are enabling major advances in the ability of computer vision systems to measure production speed with greater accuracy and reliability, with this area having a great opportunity for research and development.

2. THEORETICAL FRAMEWORK

The use of vision systems has been growing in the market, the incursion of various cameras and technology to acquire digitally what humans can observe has been implemented in different types of research such as monitoring natural ecosystems, where vision systems are used to study the behavior of fauna and flora, as well as the evolution of landscapes (Speaker et al., 2021). Furthermore, in medical research, vision systems are used to analyze medical images and diagnose diseases, as well as to monitor and guide high-precision surgical procedures (Tang et al., 2022). In the field of robotics, vision systems are used to provide robots with autonomous perception and navigation capabilities, enabling them to interact safely and efficiently with their environment. These are just a few examples that demonstrate the growing scope and versatility of vision systems in various research and application areas (Friedrich et al., 2024).

There are different technologies to work with these systems, such as Kinect in its versions v1, v2 and Azure, Intel's RealSense (Kurillo et al., 2022). These devices are 3D perception cameras that use a variety of sensors, such as RGB cameras, infrared sensors, and lasers, to capture three-dimensional images of the environment (Gunawan et al., 2017). These technologies enable not only the capture of high-resolution images and videos, but also the detection and tracking of moving objects, depth estimation, and three-dimensional reconstruction of scenes, making them ideal for a wide range of applications in research, product development, and process automation (Yeung et al., 2020).

These 3D vision devices, in addition to their diversity in functionalities, also present a variety of costs, making them accessible to a wide range of users, from independent researchers to large companies (Cóias et al., 2023). For example, Microsoft's Kinect cameras have been widely adopted in entertainment, academic research, and product development applications due to their relatively low cost and ease of use (Amadeus et al., 2020). On the other hand, more advanced technologies, such as cameras featuring time-of-flight or structured light technology, offer higher accuracy and resolution, but often come with a higher price tag, making them more suitable for specialized applications in areas such as mapping, autonomous navigation, and underwater archaeology. This diversity in cost and capabilities allows users to select the technology that best suits their needs and budget, which contributes to their widespread adoption in a variety of industries and applications (Buarque et al., 2022).

Currently, there are libraries for working with vision systems, such as mediapipe, which is an open source platform developed by Google that provides tools and pre-trained models for real-time visual data processing. This library offers a wide range of functionalities, ranging from detection and tracking of human gestures and poses to segmentation and facial recognition, facilitating the development of interactive applications and immersive experiences (Kusunose et al., 2023). Another popular library is OpenCV (Open Source Computer Vision Library), which offers a wide variety of algorithms and functions for image processing and computer vision, including edge detection, object recognition, camera calibration, and more. These libraries, along with other development tools and platforms, have democratized access to computer vision, enabling developers and data scientists to create innovative solutions across a wide range of applications and industries (Grillo et al., 2024).

These libraries are highly versatile and can be integrated with a variety of programming languages, such as Python, C++, and others, allowing the creation of a wide range of applications in the field of real-time visual data acquisition. Speaking specifically about programming languages, these are formal systems that allow developers to write code to create applications in various areas (Chen et al., 2016). Among the most popular languages today is Python, which stands out for its simplicity, flexibility, and a large community of users and open source libraries that facilitate the development of computer vision applications and other fields of computer science (Munnalalal et al., 2023).

Python, a high-level programming language, has emerged as a versatile and powerful tool in a wide range of fields and disciplines. Its popularity is largely due to its clear and readable syntax, which makes it accessible to both beginners and expert programmers (Saabith et al., 2019). Python has been adopted in diverse areas, from data science and artificial intelligence to web development and task automation. Its extensive standard library and the availability of numerous specialized libraries, such as NumPy that allows working with numerical arrays, pandas for working with databases and mathematics, Tkinter that provides a user interface, os which serves to use operating system functions, there are endless libraries for each domain, make it a preferred choice for research, data analysis, prototyping and high-performance application development. (Sabo et al., 2023) In addition, the active Python community constantly contributes new tools, resources, and tutorials, which fosters its growth and adoption worldwide (Chi Ling et al., 2021).

3.METHOD

The objective of this validation is to verify that the system for measuring the working speed of a person is the same regardless of where the camera is placed. For which the following materials were used.

- A conveyor belt
- A Web Logic Pomya camera (generic).
- A dell precision 7540 laptop
- Legos used as speed reference
- Hand speed measurement system
- IDE Pycharm 2024.1 (Community Edition)
- Excel 2016
- Minitab 2021

For this experiment, 30 college students were selected to measure the speed with which they moved their hand during a moving band. They were separated into two parts: 15 for the capture positioning the camera at a height of one meter with respect to the band, and another 15 for the capture positioning the camera at 60 cm from the band, each student made 5 captures. That is, for positioning 1 of the camera, 75 samples were taken and for the second positioning, another 75 samples were taken. An image of the validation work area is shown in fig 1.

Regarding the system, it has a graphical interface with four buttons start and stop capture which allows to open the camera and start the data collection, verify that through this allows to send the data collection to terminal, export to Excel the same data shown in the terminal are sent to an Excel file for further analysis and finally the exit button. Another element of the system is the display of the camera which is positioned 1 meter above the work area, finally, the terminal captures the data of speed, distance and time which is done in real time. The following image shows the interface of the measurement system see fig 2.

Figure 1. Work Area

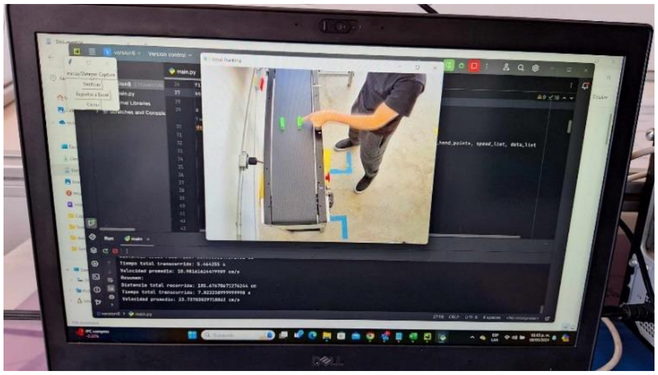


Figure 2. Measurement System

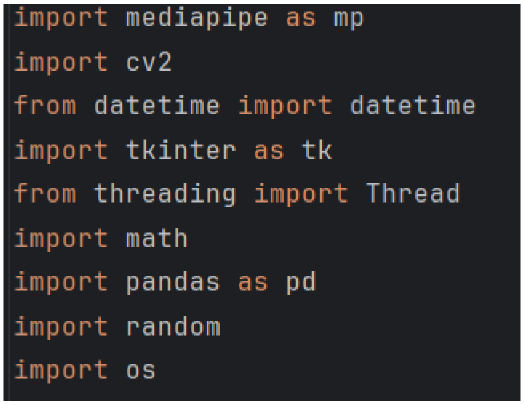
For the validation, the first thing that was done was to mark a distance of 60 cm from the total surface of the belt, which would serve as a reference for the measurements. The camera was placed at the corresponding height for its configuration.

Then, each student followed the movement of a piece of the lego, which served as a reference for the speed to be maintained. Once the student's measurements were finished, the system passed the captured data to Excel for further analysis. The figure 3 shows the reference lego against the capture of the right hand.

Figure 3. Sampling

This analysis consists of selecting only the measurements used to determine the velocity, eliminating the noise of some inconsistent data or that do not belong to the data of the distance and times. Being a linear motion, the system calculates the velocity of hand movement using the formula of v=d/t.

The measurement system was built using the Python language, in addition to the libraries mediapipe, cv2, datetime, tkinter, math, pandas, random, os. It consists of a camera at a distance of one meter which takes measurements using programming, displays them in real time on the terminal and stores them in Excel for later analysis. The figure 4 shows the libraries used in the system.



```
import mediapipe as mp
import cv2
from datetime import datetime
import tkinter as tk
from threading import Thread
import math
import pandas as pd
import random
import os
```

Figure 4. Python libraries used

A hypothesis test is also proposed in order to determine if there is a significant difference taking as a variable the average speed of placing the camera at a distance of 1 meter with respect to the band against the average speed of the captures when placing the camera at a distance of 60 cm with respect to the horizontal of the band.

H_0: $\mu_1=\mu_2$
H_1: $\mu_1 \neq \mu_2$

4. RESULTS

A total of 150 samples were captured, half for the distance called height 1 of the camera which corresponds to placing it 1 meter against the horizontal, and the other half of the total sample for height 2 which is 60 cm as mentioned above. A normality test was also performed using minitab software for each set of data which are shown in the following illustration fig 5.

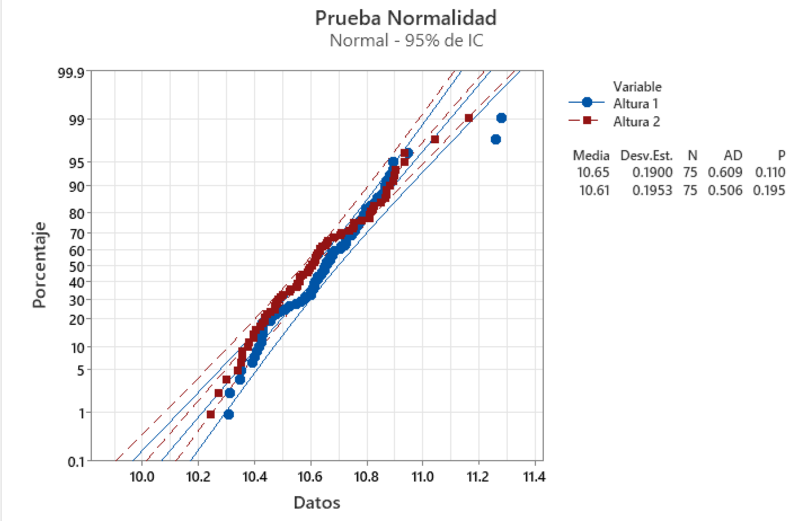
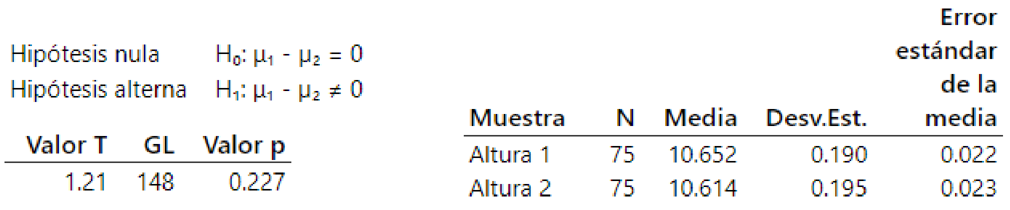


Figure 5. Normality Tests.

With a p_value of 0.110 and 0.195 is shown that there was normality in the data.

A student T test was also performed which yielded the statistics shown in the illustration below, in which obtained a mean of height 1 was 10.652 while the mean of height two was 10.614, see fig. 6.

Student T Test



Hipótesis nula H_0: $\mu_1 - \mu_2 = 0$
Hipótesis alterna H_1: $\mu_1 - \mu_2 \neq 0$

Valor T	GL	Valor p
1.21	148	0.227

Muestra	N	Media	Desv.Est.	Error estándar de la media
Altura 1	75	10.652	0.190	0.022
Altura 2	75	10.614	0.195	0.023

Figure 6. Student T Test

With respect to the hypothesis test previously mentioned, we can observe a p-value of 0.227, which indicates that there is not enough statistical evidence to reject the H_0, that means that both means are equal. Therefore, we can say that there is no difference in the positioning of 1 meter with respect to the positioning of

60 cm., Therefore, we verified that the program developed in mediapipe to measure hand speed when doing a task is reliable.

5.CONCLUSIONS

The use of computer vision technology is becoming increasingly common in the field of research, exploring all that this area of artificial intelligence offers is very stimulating for researchers, also being able to implement it in areas of engineering, medicine or agriculture gives it a greater demand. Although there are several alternatives to work with this technology, the simplicity of using Python and mediapipe allows applications to be built at very low cost, without the need to purchase expensive body tracking equipment.

The system that was built, which is based on the calculation of the speed of an operator, focuses on the tracking of his hands, it is an important challenge to develop an application that can measure the speed with which an employee performs his work. The purpose of this paper is to prove that this system can work even in different spaces, this was done with a measurement of 150 samples in total, divided into two heights mentioned throughout this paper, the results analyzed by the statistical software showed that there is no significant difference between the position that the camera is placed. Through this validation, it was proved that the speed measurement system can perform its function even if it is positioned at different heights, which is useful to be able to adapt it to different workspaces.

Although the system still needs to be able to automatically determine the speed of a worker, this project constitutes a great advance in time measurement, something that will undoubtedly help the industry in a great way, allowing it to optimize its most valuable resource, which is time. This has already specified at a low cost through the implementation of systems based on Python and its different libraries.

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INFORMATION BEHAVIOR IN THE PRODUCTION ORDERS

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Resumen: Esta investigación fue desarrollada con la finalidad de conocer el comportamiento de información en la liberación de órdenes de producción en el programa A220 de la empresa SC Tijuana. El comportamiento de información, es el proceso mediante el cual un sujeto adquiere información y hace uso de la misma. Por ello, en este proyecto se hace un mapeo el proceso en la liberación de órdenes de producción creando un diagrama de flujo tipo SIPOC para ayudar al usuario a su comprensión de forma visual. En el comportamiento informativo, uno de los usuarios de alto nivel dentro del Departamento de Planeación es el planificador, el cual realiza un plan de producción a tres semanas. El Planificador revisa si hay materiales en inventario para iniciar la producción, posteriormente, el comportamiento informativo entre el planificador y el comprador es la distribución de los mensajes para actuar y conseguir los materiales faltantes. De ahí la importancia del comportamiento informativo al evitar errores entre los departamentos involucrados, esto es principalmente cuando se genera el balanceo de la demanda, para, a su vez, se firma la demanda en el sistema para que el Departamento de Compras pueda obtener los mensajes de acción y así adquirir los materiales en el tiempo solicitado. Sin embargo, se descubrió que existen niveles de desempeño inferiores al esperado que es de 90%. Para ello, se desarrolló la metodología que tenía por objetivo mejorar el comportamiento informativo mediante el uso de mensajes de acción esperando disminuir los errores en el proceso de adquisición de materiales. Se encontró que fueron diversos usuarios los participantes dentro del proceso de compra de tal forma que al comprender cada uno de ellos el significado de los mensajes de acción se logró incrementar el nivel de desempeño al nivel esperado que es 90%. Esto trajo consigo, adicionalmente, la búsqueda de mejores costos en las transacciones al mejorar el comportamiento de los usuarios dentro del proceso involucrado y otros en los cuales participan activamente dentro de la organización.

Palabras clave: Comportamiento informativo, órdenes de producción,
herramientas abstractas, proceso de producción

Relevancia para la ergonomía: Esta investigación ayudó a exhibir que las teorías sirvieron de base para mejorar el comportamiento informativo de los colaboradors de varios departamentos en una empresa, particularmente en aquellos que se ven involucrados en el proceso de producción, siendo las áreas de planeación y de compra. De ahí que, comportamiento informativo situado dentro de la ergonomía cognitiva fue mejorado con la utilización de herramientas desarrolladas, Éstas fueron creadas para aumentar la productividad en el el proceso de liberación de órdenes de producción. Asimismo, esto aumentó la percepción del bienestar en el uso de las herramientas de tal forma que se equilibraron las cargas de trabajo para un mejor desempeño de los colaboradores dentro del ambiente natural que es la empresa participante en el proyecto.

Abstract: This research was developed with the purpose of knowing the information behavior in the release of production orders in the A220 program of the company SC Tijuana. Information behavior is the process by which a subject acquires information and makes use of it. Therefore, in this project the process in the release of production orders is mapped, creating a SIPOC-type flow diagram to help the user understand it visually. In information behavior, one of the high-level users within the Planning Department is the planner, who makes a three-week production plan. The Planner checks if there are materials in inventory to start production, subsequently, the informational behavior between the planner and the buyer is the distribution of messages to act and obtain the missing materials. Hence the importance of informative behavior in avoiding errors between the departments involved, this is mainly when the balancing of the demand is generated, and, in turn, the demand is signed in the system so that the Purchasing Department can obtain the messages. . of action and thus acquire the materials in the requested time. However, it was discovered that there are performance levels lower than expected, which is 90%. To this end, the methodology was developed that aimed to improve information behavior through the use of action messages hoping to reduce errors in the material acquisition process. It was found that there were diverse users participating in the purchasing process in such a way that by understanding each of them the meaning of the action messages, it was possible to increase the level of performance to the expected level, which is 90%. This additionally brought with it the search for better costs in transactions by improving the behavior of users within the process involved and others in which they actively participate within the organization.

Keywords. Information behavior, production orders, abstract tools, production process

Relevance to Ergonomics: This research helped to show that the theories served as a basis to improve the information behavior of collaborators in various departments in a company, particularly those involved in the production process, such as the planning and purchasing areas. Hence, informational behavior located within cognitive ergonomics was improved with the use of developed tools. These were created to increase productivity in the process of releasing production orders. Likewise, this increased the perception of well-being in the use of the tools in such a way that the workloads were balanced for better performance of the collaborators within the natural environment that is the company participating in the project.

1. INTRODUCTION

Note: the name of the participating company, the processes, products, and tools used within it and its processes have been modified for ethical and confidential reasons.

This project was developed in a company in the aeronautical industry, analyzing the informational behavior or information behavior (IB) within the production order release process, one of the company's programs or processes known as A220. It was in order to find how this process can be improved so that production orders should be started on time. It is because the performance indicators of the Planning Department showed that orders had not been generated at the time they were scheduled. In other words, production orders start late referring to the schedule time. These orders involved the Purchasing Department and the background of the problem to be addressed is based on communication and misinformation about material needs within the various areas involved within the company.

In order to start production on time, it is necessary that the materials are available for your disposal when they are required in mentioned processes. However, communication between supply chain departments did not have sufficient time to accept the requirements, and, furthermore, there is no fast response in the communication of the requirements. Hence, the first action messages used to acquire the requirements is through emails. Although one of the tools used by the departments is the *Infor Smart* system, it is limited but it did not clearly indicate what is required. It is suggested the system lacks of abstract tools that exhibit the action expected a consequence of the message. This generates a communication problem since these action messages are generally ignored by the system, saturating it due to the excessive amount of emails received and user did not enough time to pay attention to understand their importance.

Furthermore, in the Planning Department of the company SC Tijuana in the A220 program and its various product families, the following situation arises: production orders are not started on time in reference with their programmed schedule within the production plan causing a deviation on it. This situation is clearly noted in the goal of the performance indicator of the department or area by delays and errors in the production orders. For this reason, the objective was indicated to improve the information behavior of users or participants involved in the release of production orders through the use of action messages by the system in order to reduce delays and errors in the acquisition of materials. Hence, the indicator relating to the performance of orders initiated on time was 61% at the beginning of the project and it was proposed within the objective to increase this indicator by 29%.

Hence, this project was limited to the information behavior of users or participants involved in the release of production orders in a single product schedule, particularly the A220 production schedule, as described above. It is also delimited between the families belonging to this program, excluding one family from this program: the family of the A220 monuments, which is large and complex to be considered as a different program. This is despite the fact that the preparation of the products is similar to the other families in this program, the waiting times for the material can be months instead of days or weeks that is common with the rest of the families. Historically, firm demand times last at least half a year and sometimes extend up to a year instead of the 13 weeks, that is commonly the case with the rest of the product families. Here, the production plan is carried out considering two months instead of two weeks as in the rest of the other families. Furthermore, the production plan is segmented between the eight processes within the production process of this family, while in the rest of the other families they have two or three processes only. Moreover, releasing production orders is different and adds more variables to consider and the time required for release generally taking additional weeks.

Various departments are involved in the production order release process, and for the study of the information behavior of this research, two departments were particularly considered: Planning Department and Purchasing Department. The Planning Department, where this research is taking place, is the department responsible for planning production for certain days or periods of time and this generates material requirements. Also, this department is in charge of distributing action messages to acquire materials. On the other hand, the Purchasing Department, which once they have the material requirement messages, is in charge of acquiring the materials to start production within the time established by the Planning Department. However, as mentioned previously, the internal performance indicators of the Planning Department showed that production orders were not started on time, and/or are they completed in the scheduled time, generating additional costs.

Production orders are not started in the time they were planned, generating delays in production and the production plan being constantly changing to meet the delayed production. This is, generally, why production did not start on time due to lack of material and thus generate the scheduled production volume. It is relevant to note that the company does not allow, to the extent possible, the production plan to be modified since the dates agreed with the clients are strict and if they are modified, the company should be obliged to pay fines for non-compliance. This is despite the fact that the company, as a measure to meet the established dates or with minimum delays, considers adding days so that its expenses are small and within limit costs established by the management. For this reason, a change in the use of the tools used in the processes, they were considered hoping to impact the information behavior of the participants of the departments involved. Similarly, changes are expected in the channels through which information flows hoping to directly impact on that behavior.

In general terms, the background, the methodology used in the project, the results and the conclusions obtained in the project are presented below.

2. BACKGROUND

In this section, information behavior, performance indicators, process mapping and the SIPOC diagram are presented as theoretical background.

2.1 Information behavior

Calva (2004) points out that information behavior can be understood as the manifestation of the subject's information needs, originated from the insufficiency of information and knowledge about a phenomenon, object or event. That is, he mentions that when information is required about something in particular, information behavior is present to satisfy their needs for information or knowledge. Similarly, Wilson (2000) defines information behavior as the totality of human behavior in relation to information sources and channels, including the active and passive search for information and the use of information (p.2) and he is one of the precursors in the knowledge of this type of behavior in natural environments, as it is treated in this research. In the same way, other authors such as Fisher, Erdelez, McKechnie (2005) have an additional definition of information behavior after conducting research where a total of 70 theories and models used in the study of the different aspects of mentioned behavior are collected. Moreover, they defined as the area of documentation focused on investigating the way in which individuals need, search, manage, disseminate and use information in different contexts. Therefore, in this investigation, informational behavior is defined as a process through which a subject acquires information of any type using different sources and channels, makes use of the acquired information either for themselves or to broadcast it to a third party.

2.2 Performance indicators

Jackson (2009) mentions that KPIs (Key Performance Indicators), which are also known as performance indicators, are those indicators that help to validate the points that are failing within the organization and, in this way, increase consequently efforts on these points. The ultimate goal of any performance indicator system is to provide information about how the system achieve the goals. Similarly, it is important to make the distinction between information and data, So, for this an usual definition of information would be data that can be used for the purpose of making decisions, so that data is considered as raw facts and/or situations that were compiled in order to create particular and general understandings of them. Consequently, a system of performance indicators aims to provide the value of relationships between factors and the complementary elements (data quality, explanatory factors, context) necessary to make appropriate decisions. Consequently, a system of performance indicators is the result of considering all areas of interest, interested parties and factors that influence a certain environment (Alegre et al., 2017). Key performance indicators are defined as an industry term for a measure or metric that evaluates performance against some objectives. Furthermore, they are commonly used in organizations to measure both success and quality in meeting their objectives, enacting processes, or delivering products and services (Barone et al., 2011).

2.3 Process mapping

Starting with the definition of what a process is, the ISO 9000:2005 standard (ISO, 2005) in its foundations and vocabulary defines it as a set of mutually related activities that use inputs to provide an intended result. On the other hand, process mapping, Damelio (2011) points out that it is a methodology that is used to show in detail the activities that make up a process through a schematic representation called flow diagram, which is made up of a certain symbology. The activities that make up the process mapping must have a sequential and logical structure aimed at meeting a specific purpose. The main objective of process mapping is to graphically represent the main activities that are carried out within an organization, in such a way that everyone who reads it is able to understand it and carry out the activities indicated in the description. Also, the importance of process mapping lies in its implementation since it serves as a starting point for process operators to standardize their activities. It also provides the same level of service to all clients regardless of the person providing the mentioned service.

2.4 SIPOC diagram

Huerta (2016) mentions that process diagrams had started to emerge from the industrial revolution, through the creation of various machine diagrams and by using the scientific method with the objective to study work. The study of the work was initiated by Lilian and Frank Gilbreth and other collaborators who managed to create: flowcharts, operation diagrams, work diagrams, man-machine diagrams, among other abstract tools. Joyanes (2008) describes the flowchart as a diagram that uses standard symbols (boxes) and exhibits the steps of an algorithm written in those boxes joined by arrows, called flow lines, which indicates the sequence in which a process should be executed. While Damelio (2011) says that a flow chart is a graphic representation of the sequence of activities that must be followed within a process or procedure. Each step of the process is represented by a different symbol that contains a brief description of the process stage. The graphical process flow symbols are linked together with arrows indicating the direction of process flow. The flow chart offers a visual description of the activities involved in a process, showing the sequential relationship between them, and facilitating an easy understanding of each activity and the relationship between each other. The process map is a document with an attractive appearance and its presentation should be easy to read so that it can frequently facilitate its modification and consultation. Flowcharts help to make visible the work and operations carried out in a production system. Hence, the

SIPOC diagram is a derivation of process and flow diagrams in such a way that it is used specifically for information needs within the company in question and it would be an abstract tool expecting to facilitate the information behavior.

3. METHODOLOGY

Information behavior is the process by which a subject acquires information and use it influenced by the information distribution channel(s). Therefore, to identify the mentioned behavior within this project, which was carried out in the Planning department, it was required to separate the tools used, focusing in one of them. For research purposes, this was defined as a case study considering the process that is frequently used within the daily operation, which involves the largest number of users, being indicated as the A220 system. This is considered as the ideal tool that should be considered in this study.

It was because the participating company manufactures various products for different aircraft models, which generate complexity in the production process. From the above, it was seen that the information behavior of users is a crucial element within the planning processes since it is used to develop production plans. This is delimiting the family of products of the system indicated above and all those systems that support the activities required to develop commented plans. However, the A220 system, despite being the most used and housing the largest number of families, is too large. For this reason, the A220 Monuments family was not considered, as noted in the introduction section.

Hence, the project was divided into two phases. In the first phase, the process of releasing orders for the selected program was mapped, creating a flow diagram to help the reader to understand it. The second phase of the project consisted of finding how the information behavior is on releasing orders between the different levels within the Planning Department. Here, a survey was developed and applied considering the activities required within the process and aspects of productivity and user satisfaction. In order to obtain relevant information of the user, the following participants were considered: Planning Supervisor, Planner and Planning Administrator. Moreover, the survey contemplated the entire process of generating and using information within the production order release procedure. In the same way, the results allowed us to identify information needs, levels of information processing, information products, and information residues, that can be used in subsequent processes, or even within subsequent activities. The above was a challenge since this involved generating changes in the tools used. In addition, it was necessary to generate other tools for activities which lacked them.

To do this, it was also necessary to develop process mapping and the tools used in the commented processes, such as flow charts and the SIPOC diagram. The latter is a diagram of five steps, one for each letter of the aforementioned acronym. Here, the supplier and the process source were identified. Next, the process input was clarified, followed by the process itself. Subsequently, it was declared how the output takes the form of a product or service concluding with the form of delivery of the product or service to the customer. To do so, performance indicators were developed related to information behavior throughout the production order release procedure and its monitoring.

A way to carry out the research was developed starting with the mapping of the process specifically on the release of production orders and the SIPOC diagram. To have a complete vision of what is done, information satisfaction surveys were developed and applied in the aforementioned departments. The survey also served to identify sources, channels, application, distribution, and use of information within the indicated process. The results obtained showed those variables and considerations that were not previously indicated as relevant within the process, thus generating rules to create production plans and operation suggestions in mentioned creations. Below, it is showed the SIPOC diagram representing the release of production orders.

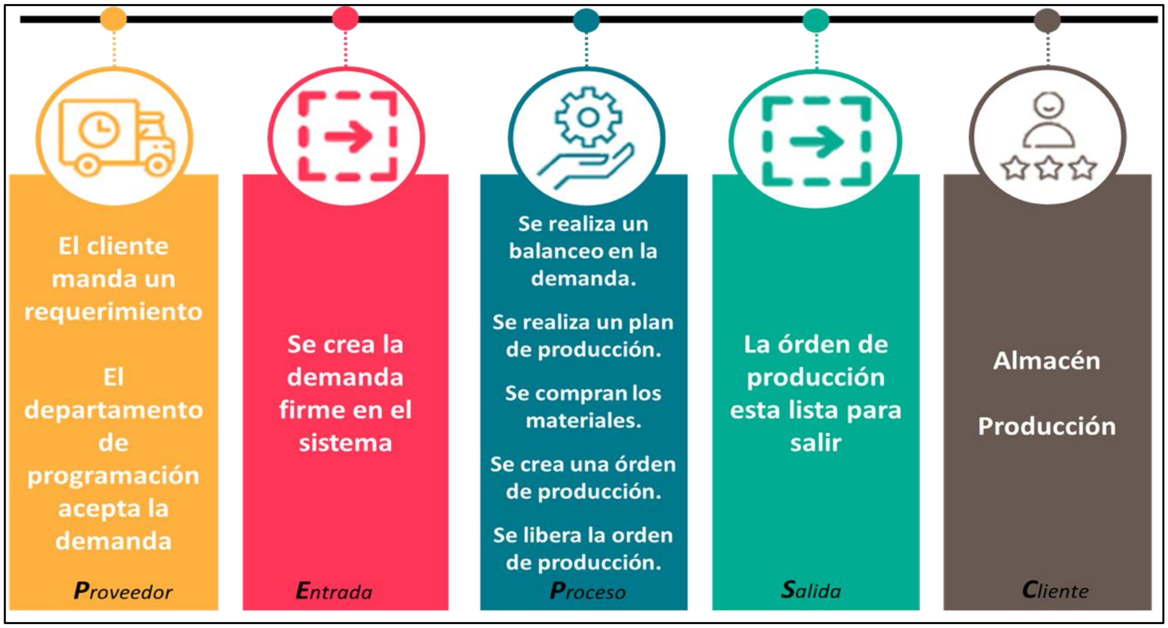

Figura 1. SIPOC diagram of releaese of production orders (Source: archive)

4. RESULTS

The results obtained were focused on achieving the stated objective. So, it was found that for the production order release process, it is relevant to accept the demand declared by customers and the first user should pay attention to its acceptance and understanding within the process. These are relevant activities within the information behavior of the users that should be understand correctly. Moreover, it was necessary to visualize and understand the available time to carry out the planning, which is generally 13 weeks. This is called firm or firm demand, and should be capable to adapt the production plan considered optimal and leveled within the existing production capacity of the system. However, it should note that for certain products of a given family, its planning time is 20 weeks of firm demand. This was because the existing differences were directly reflected in the way in how the product is grouped and stored, adding time margins to address potential problems in the production process.

Therefore, the programmer, who accepted the demand and defined the planning time, has considerations based on the information sourced from the manufacturing processes and standards developed for it, as well as the existing trends of production plans being executed. These were relevant considerations within the information behavior. Further, the creation of the production plan should include the indicated demand and should be carried out within the time considered for this, in this case were 13 weeks of the period considered. In addition, cycle times, leveling workloads, holidays and free days should be considered within the available weeks and days in which the production should be done. These should be included in the production plan and they should exhibit the history of demands and production levels achieved. In the same way, potential unusual demands should be pointed out during and after the commented planning in order to create contingency plans in reference to production. It was suggested to consider one or two additional weeks to those that were initially planned.

A key point in the production plan is the production levels considered to avoid labor overloads and to control them in order to make decisions considering the production system and its capacity. This should allow the evaluation of the performance of the system. To do this, the production supervisor should use the informational behavior to obtain information allowing them to make decisions for achieving the stipulated production plan. However, it does not make use of information from warehouses to corroborate the existing materials and this directly affects the production plans within the stipulated time. On the other hand, planners have to seek balances to consider the planning carried out by other planners to achieve the balance in the total production lines. Therefore, the initial work horizon is three weeks within the 13 weeks considered initially in the entire plan, and thus, the material inventories should be verified to subsequently make the pertinent adjustments. It is relevant to note that production plans are intertwined with each other according to product families and existing systems to control production processes. This allows the necessary adjustments, that should be made in reference to the times required to finalize the production plans, and according to the indicated demands.

From the above, the information behavior of the planners, according to the survey carried out and the information flow diagram, showed that variables or situations that directly affect the production system in strong relation with the indicated demand, which similarly should be considered in the production plan. The contemplated and indicated times showed a variable that is included within the information behavior and its limitations; so, it should be considered within its planned activities. For this, the indicator of production orders carried out within the indicated times was initially 61%. After the changes generated in the information behavior and in the development of abstract and physical tools, it increased to 90%. That is, the efficiency of activities increased 29%, achieving the planned index of 90%, which is the level considered adequate within planning and production system.

Furthermore, the Purchasing Department has a purchasing horizon of three weeks to meet the materials required to carry out the production plan. Hence, the first activity developed was the search and use of information related to existing inventories, which it is employed to start the production supplying the materials during the production process. So, if they did not have available information of inventories, the action messages are generated, which is an abstract tool developed to express the urgency of the demand of the materials. The delivery time is in accordance with that is commonly required by suppliers to meet the company's material needs. Other departments were involved in the mentioned purchase and sometimes, these delays in the delivery of materials produce consequently delays the production process. It was evident that there were other factors, which also delay the production process, but they were not considered in this study focusing on those related to information behavior only. Moreover, this increases the workload in the departments involved, supporting the activities, that should to be carried out in the production area.

5. CONCLUSIONS

The stated objective was achieved by making use of abstract and physical tools supporting activities of the participating departments. This was in consideration of the main responsibilities that each of them has, as: planning production plans and having materials available according to the developed production plan. This also includes the activities: to accept the demand, to carry out the production plan, to purchase the materials and to release the production orders. A very useful tool developed was the action message to acquire the missing materials in consideration of the existing inventories. This message should be carried out within the three weeks considered in the production plan.

Moreover, the use of flow charts within the release of production orders is another tool that contributes to the improvement of information behavior by clarifying how information should flow, where it can be accessed and how it can be used within the production process. This, in turn, highlights the need to develop additional tools that improve information behavior, especially, in the use of information in support activities in leveling workloads.

Therefore, it is relevant to point out that theoretical aspects are limited because they have commonly been generated in contexts different from the one used in this research. This opens the opportunity to continue applying and generating knowledge from new applications in contexts considered natural and those that scarcely have been considered in past studies. Hence, there are additional areas of opportunity in these types of contexts and where particular situations are changing for satisfying the demands indicated by internal and external clients.

6. ACKNOWLEDGMENTS

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ERGONOMIC ANALYSIS IN THE OFFICE AREA OF A MANUFACTURING COMPANY THROUGH THE ROSA METHOD

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Resumen: Actualmente en el área de oficinas laboran alrededor de 38 personas, las cuales cumplen una jornada de hasta 10 horas diarias, 5 días a la semana; así mismo suelen pasar el mayor tiempo sentados en sus escritorios generando una actividad demasiado sedentaria y duradera, trayendo como consecuencia una serie de malestares de carácter postural los cuales se reportan directamente en el área de enfermería que determinan como diagnostico general un nivel de estrés en algunos puntos del sistema musculo esquelético.

Se buscó evaluar aquellos puntos de estrés afectados directamente sobre ciertos factores de riesgo mediante el método ROSA (Valoración Rápida del Esfuerzo en Oficinas).

De acuerdo a la metodología utilizada, ésta se dividió en 4 fases y finalmente, con los resultados obtenidos se procedió a realizar una propuesta de mejora, misma que ayudará a reducir los puntos de estrés postural y permitirá por ende reducir las visitas a enfermería por malestares en el sistema músculo esquelético.

Palabras clave: Análisis, oficinas, empresa, método, ROSA

Relevancia ergonómica: El propósito de este proyecto es demostrar que el tener una estación de trabajo adecuada y segura permitirá generar un impacto en beneficio de la salud y productividad del personal, disminuyendo los posibles factores de riesgo de lesión a través de un rediseño en las estaciones de trabajo, derivado de los análisis posturales previos y adecuaciones en mobiliario y equipo.

Abstract: Currently around 38 people work in the office area, working up to 10 hours a day, 5 days a week; Likewise, they tend to spend most of their time sitting at their desks, generating excessively sedentary and long-lasting activity, resulting in a series of postural discomforts which are reported directly in the nursing area, which determine, as a general diagnosis, a level of stress in some. points of the musculoskeletal system.

We sought to evaluate those stress points directly affected by certain risk factors using the ROSA method.

According to the methodology used, it was divided into 4 phases and finally, with the results obtained, a proposal for improvement was made, which will help reduce postural stress points and therefore allow for a reduction in visits to the infirmary due to discomfort. in the musculoskeletal system.

Keywords: Analysis, offices, company, method, ROSA

Ergonomic relevance: The purpose of this project is to demonstrate that having an adequate and safe workstation will generate an impact that will benefit the health and productivity of staff, reducing possible risk factors for injury through a redesign of the stations. of work, derived from previous postural analyzes and adaptations in furniture and equipment.

1. INTRODUCTION

In recent decades, with the development of new technologies, an increase in opportunities and jobs has been generated, of which those of an administrative nature have been fundamentally necessary, which has resulted in the assignment of sedentary activity tasks with postures in long-term sitting position, as well as sitting in front of the computer. This project was developed in a manufacturing company in Tijuana Baja California, in the office area, where the staff works around 10 hours a day, 5 days a week. There, we seek to evaluate those injury risk factors that could harm the staff in their work day, using as the main support tool the application of the ergonomic evaluation method ROSA (Rapid Office Strain Assessment) which relates the worker's work environment in an office.

2. OBJETIVE

Analyze and diagnose the office area of a manufacturing company through the ROSA method in order to identify the possible risks that the workstations are generating to the health of the operators and propose a redesign that helps reduce or eliminate the factors that they provoke it.

3. DELIMITATION

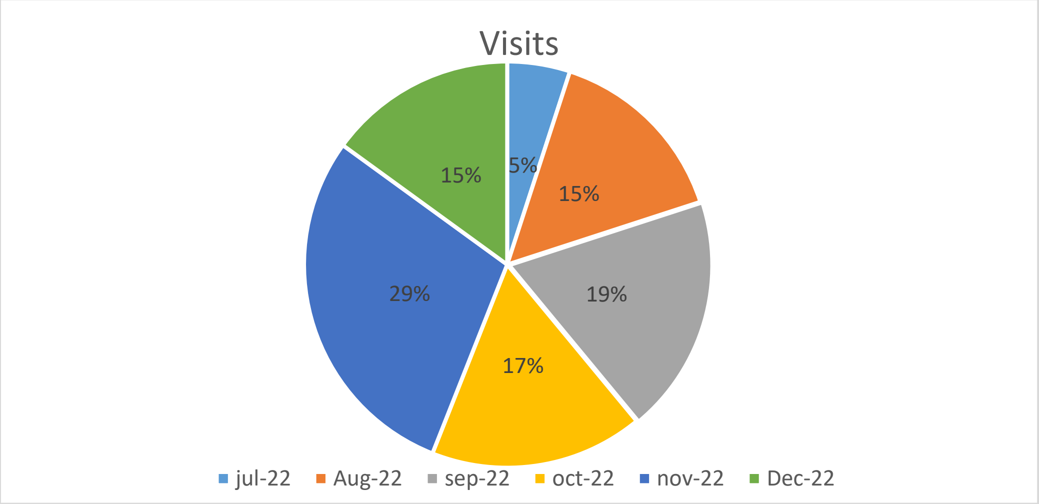
This research was developed in the city of Tijuana, Baja California, in a company in the manufacturing sector, specifically applied to the office area.

4. METHODOLOGY

This company located in Tijuana Baja California dedicated to the manufacturing of parts for electronic and automotive products, during its first period from January to

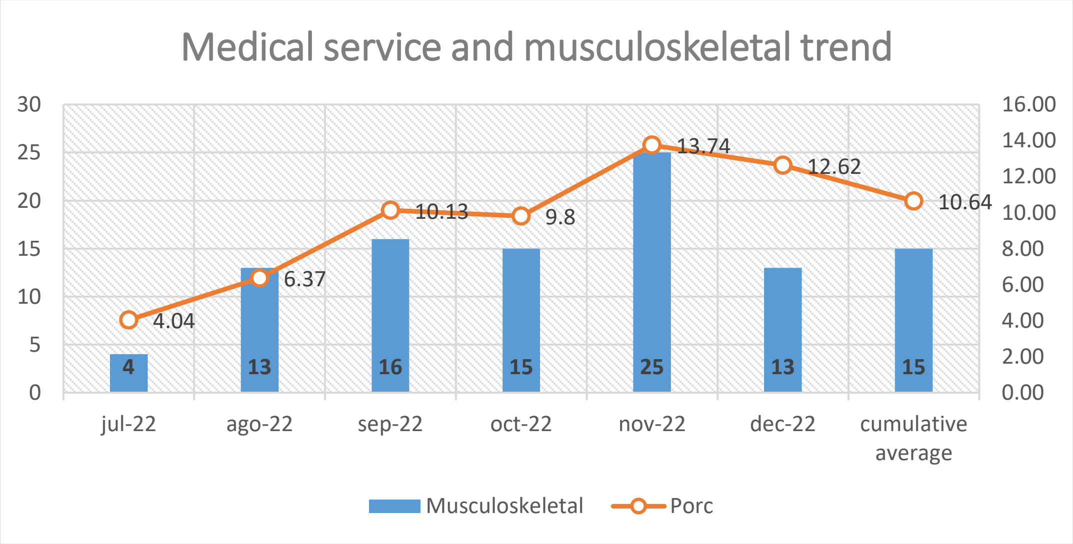
June 2022, there were a total of 427 nursing consultations and 59 cases derived from musculoskeletal problems, while that, during the period from July to December of the same year, there was an increase in visits to nursing for problems of the same nature by 14.77%.

Graph 4.1 shows the number of visits to nursing for musculoskeletal problems and the percentage they represent, with only 4 cases occurring in the month of July, or 5%, while in November there was an increase of 25. cases due to musculoskeletal problems representing 29% respectively.



Graph 1 Visits to nursing due to musculoskeletal problems
Source: Self made

Likewise, graph 4.2 shows the trend that has occurred in the period from July to December, with November being the one with the highest cases and percentage, in addition the KPI trend is found at 9.6%.



Graph 2 Medical service and musculoskeletal trend Source: Self made

At the same time, in the monthly reviews carried out by the safety and hygiene department, there were cases in the office area where the conditions of the desks and chairs were in poor condition, these continued month after month and no solution was given. as shown in picture 1

Graph 3 Chair in poor condition in a company Source: Self made

That is why it is intended to carry out an ergonomic analysis of the area and subsequently an evaluation in order to detect cases and propose improvements, and therefore reduce the cases of visits to nursing, given that there were no disabilities or absences due to these, the area The nursing department opted to purchase preventive equipment and anti-inflammatory gel, absorbing an extra cost for the company, as shown in table 1.

Table 1 Cost of medical equipment

Equipment	Quantity	Cost per Unit	Total Cost
Cervical collar	5	$500.00	$2,500.00
Anti-inflammatory gel	3	$350.00	$1,050.00
Thumb wristbands	9	$350.00	$3,150.00
Hand splint glove	9	$420.00	$3,780.00
Medical consultation (outside)	7	$300.00	$2,100.00
Therapies	4	$500.00	$2,000.00
Transportation	8	$200.00	$1,600.00
Total			$16,180.00

Source: Self made

In carrying out this project, different types of tools were used, which are: Camera, photographs of the study area, ergonomic software of the ROSA method, Microsoft packaging (Excel and Word), research referring to the application of ergonomics in offices, nursing area log.

ROSA Method

ROSA is the acronym for Rapid Office Strain Assessment. It is a checklist whose objective is to evaluate the level of risks commonly associated with office workplaces. The method is applicable to jobs in which the worker remains seated in a chair, in front of a table, and operating a computer equipment with a data display screen. 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 position to reduce the level of risk is obtained. (Ergonauts, 2015).

Below are the phases in which they are carried out during the project, as well as the description of the activities carried out in each phase chronologically:

Phase 1: Identify risk factors in the office area

In this phase it will be necessary to collect information from the records made in the log in the nursing area for musculoskeletal problems. In addition, with the help of Excel, a graph will be made to show the behavior from the moment in which visits to the nurse increased. to date, as well as the percentage of KPI it represents.

Phase 2: Analysis of the current risk level

According to the information collected in the nursing area log, the current risk level in the company's office area is determined with the help of the Software to apply the ROSA ergonomic method, where the evaluation is carried out. , in which according to the results the severity of the area will be determined, as well as the level of action and thereby know how quickly it is necessary to make the improvement in the area.

Phase 3: Identification of risk factors in workstations

In this phase, a survey is carried out in which the area personnel will be presented with the main problems due to MSDs that they present, as well as the frequency with which they feel said discomfort. Subsequently, photographs will be taken of the work area in which the causes that lead to physical and health problems of the personnel in the area will be identified.

Phase 4: Improvement proposal

Once the results of the previous phase have been obtained, the areas of improvement opportunities in the workstation will be pointed out, as well as a proposal to change the office furniture and equipment that is more ergonomically appropriate so that the staff can carry out their activities. without your health being affected, in which authorization will be necessary to carry out.
Some of the activities in this phase are the following:

4.1 Determine the ergonomic equipment necessary for the office area

In this part, research will be carried out on items necessary in offices to make them more ergonomic, in order to determine that equipment that can be added to current workstations.

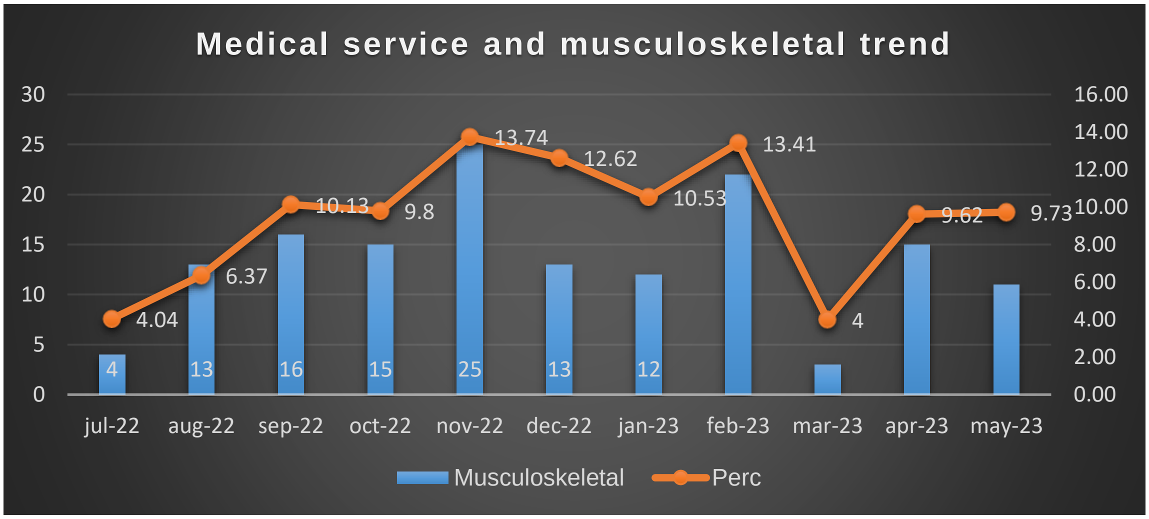
4.2 Make a budget for office equipment
Once the equipment that will need to be purchased or replaced has been identified, a budget will be made for the equipment where a comparison between different brands and prices will be made, in order to determine which is the best option either by price and/or brand.

4.3 Formal change request
Once the budget has been obtained, a formal letter will be made to the company's directors about the proposed ergonomic improvement in order for the implementation to be approved.

4.4 Implementation of improvements
Once the permit is obtained, the equipment is purchased and distributed to the workstations.

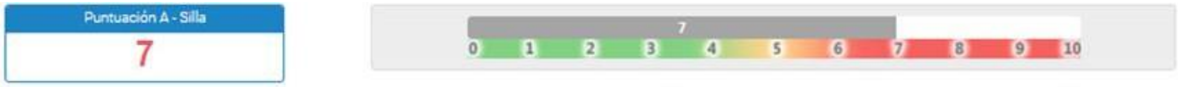
5. RESULTS

Phase 1: Identify risk factors in the office area
Graph 4 shows the behavior of the medical service and its trend for musculoskeletal problems, from the month of July 2022 to the month of May 2023, in which each bar shows the number of visits to the medical area, the orange line shows the percentage that represents the total number of visits for musculoskeletal problems with respect to medical care for other reasons and the line represents the KPI in which it maintained an average of 9.6%.



Graph 4 Skeletal muscle trend July 2022-May 2023.Source: Self made

Phase 2: Analysis of the current risk level
Below are the results obtained through the ROSA method, where the risk level in the chair is presented.



Graph 5 Risk level score in worker 1's chair. Source: Self made

Graph 6 Risk level score on the worker's screen and peripherals. Source: Self made

Table 2 shows the compilation of the results of the risk level score in chair, peripherals and ROSA of the 38 workers.

Table 2 Results of the risk level of workers in the office area

Worker	Chair	Peripherals	ROSA	Risk
1	7	5	7	3
2	9	5	9	4
3	9	5	9	4
4	7	5	7	3
5	7	7	7	3
6	7	6	7	4
7	7	5	7	3
8	9	5	9	4
9	9	5	9	4
10	9	5	9	4

Source: Self made

Subsequently, the results are shown in table 3, which determine the level of risk that exists in the workstations. These tables are referring to table E mentioned in the previous chapter, having five workers as a sample.

Table 3 Risk level in the work area

TABLE E		Punctuation Table C (screen and peripherals)									
		1	2	3	4	5	6	7	8	9	10
	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

Source: Self made

As shown in the previous tables, what would correspond to the final score and the level of action to be considered for the action to be carried out in order to support the health of the staff was obtained.

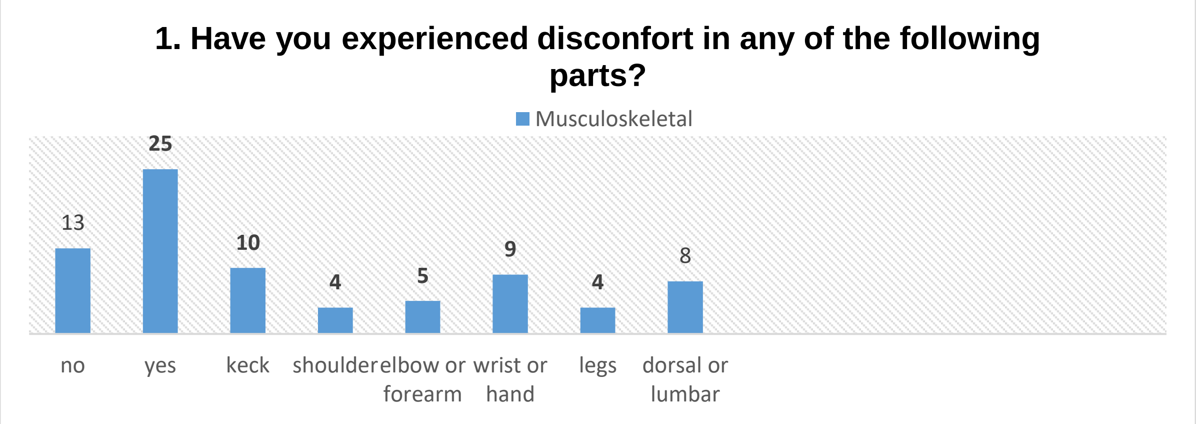
Table 4 Action levels

Punctuation	Risk	Level	Performance	Worker	Punctuation			Risk
					Chair	Peripherals	Work station	
1	Unacceptable	0	there's no need	1	7	5	7	3
2-3-4	Improvable	1	Some elements of the position can be improved	2	9	5	9	3
5	High	2	Action is necessary	3	9	5	9	3
6-7-8	Very High	3	Action is necessary as soon as possible	4	7	5	7	3
9-10	Extreme	4	Action is urgently needed	5	7	7	7	3

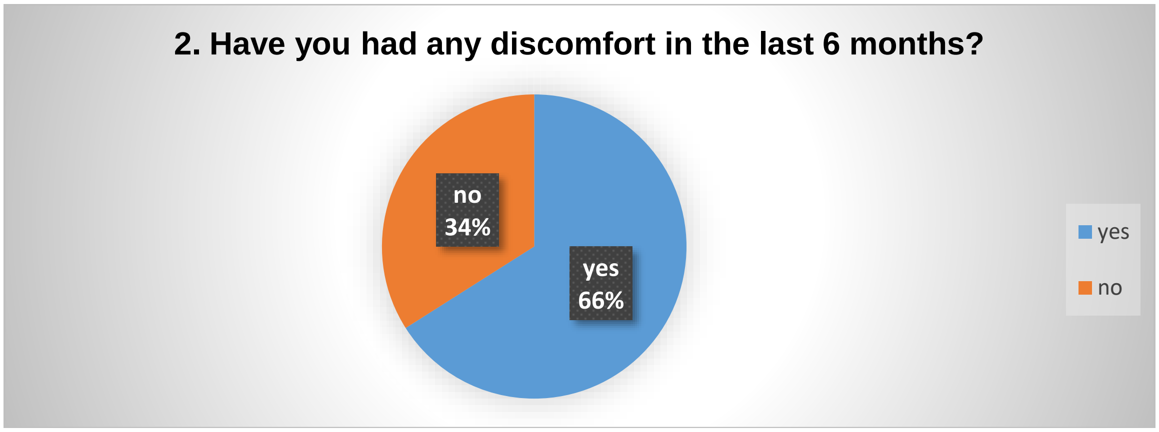
Source: Self made

Phase 3: Identification of risk factors in workstations

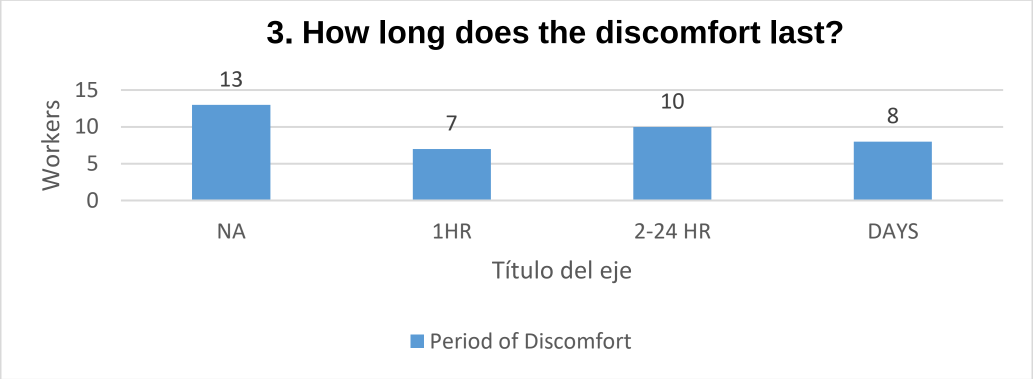
Below are the results obtained from the survey carried out on workers to detect discomfort that occurs in the body.



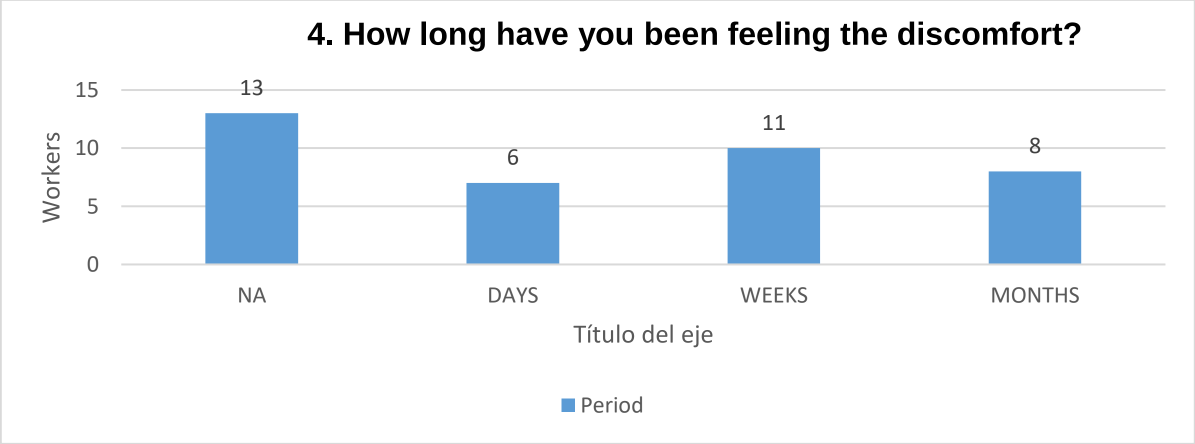
Graph 7 Results of the questionnaire, question .1Source: Self made



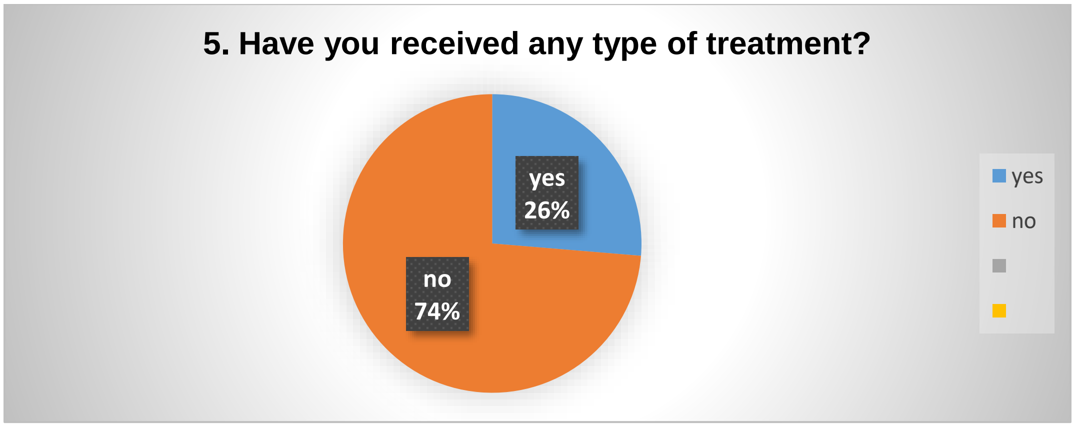
Graph 8 Results of the questionnaire, question 2. Source: Self made



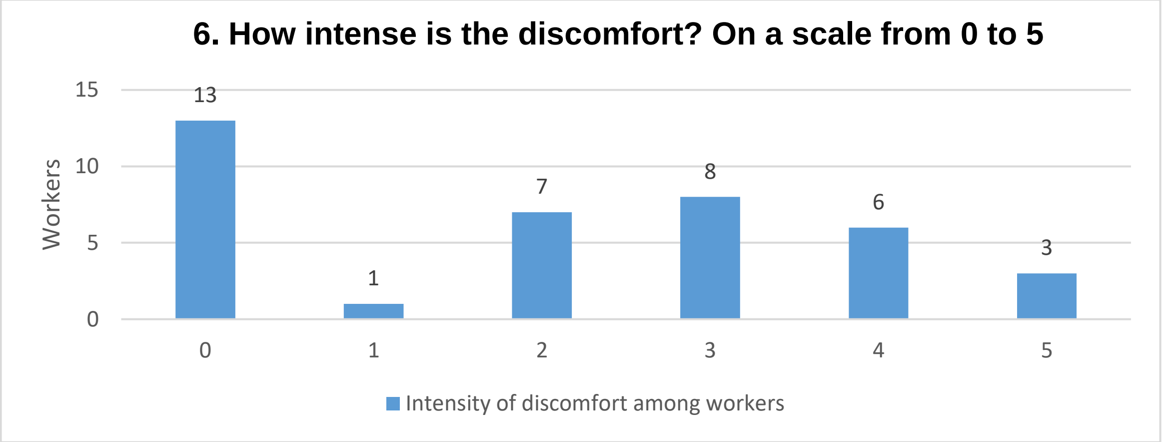
Graph 9. Results of the questionnaire, question 3.Source: Self made



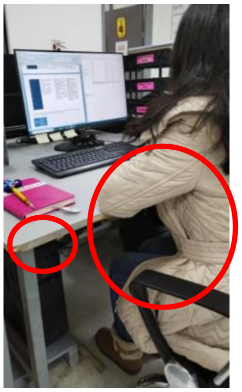
Graph 10 Results of the questionnaire, question 4. Source: Self made



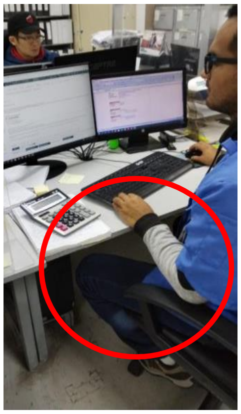
Graph 11. Results of the questionnaire, question 5. Source: Self made



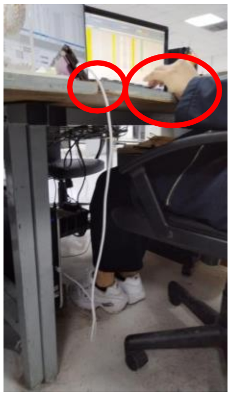
Graph 12. Results of the questionnaire, question 6. Source: Self made



Graph 13. Area results, worker 1. Source: Self made



Graph 14. Area results, worker 2. Source: Self made



Graph 15. Area results, worker 3Source: Self made

Graph 16. Area results, worker 4. Source: Self made

Phase 4: Improvement proposal

In this phase, redesign activities were carried out on furniture and equipment, and a comparison table of ergonomic equipment for offices was made, in order to find those that meet the conditions mentioned in the ROSA method, such as the adjustment in the height, backrest, armrests and seat depth, this in reference to chairs.

Table 5. Comparison of ergonomic equipment

Wrist rest			
Description	**Low**	**Medium**	**High**
Price	$169.00	$359.00	$609.00
Image			
Image			
Foot rest			
Description	**Low**	**Medium**	**High**
Price	$332.00	$653.00	$1,099.00
Image			
Desk			
Description	**Low**	**Medium**	**High**
Price	$1,754.00	$3,950.00	$7,299.00
Image			
Chair			
Description	**Low**	**Medium**	**High**
Price	$1,299.00	$2,629.00	$3,689.00
Image			
Compute			

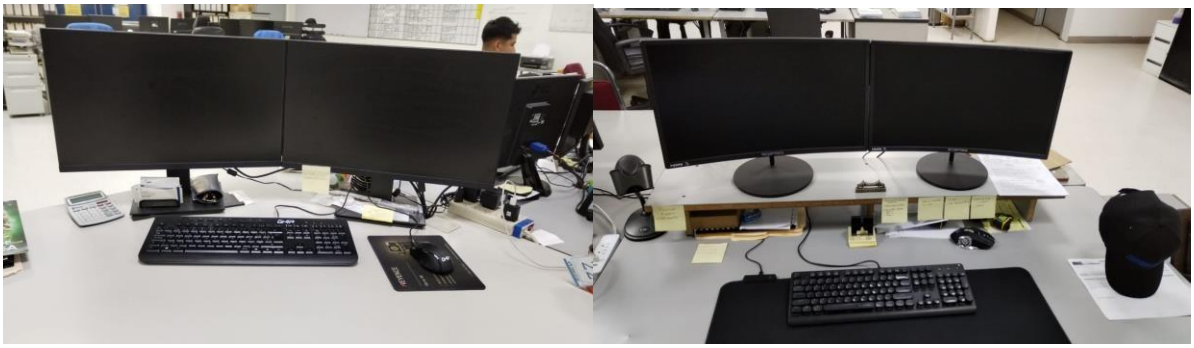
Description	Low	Medium	High
Price	$9,899.00	$11,799.00	$18,999.00
Image			

Source: Self made

Table 6. Ergonomic equipment budget

Description	Quantity	Unit Price
Wrist rest	1	$359.00
Footrest	1	$653.00
Desk	1	$3,950.00
Chair	1	$1,299.00
Compute	1	$11,799.00
Total		$18,060.00

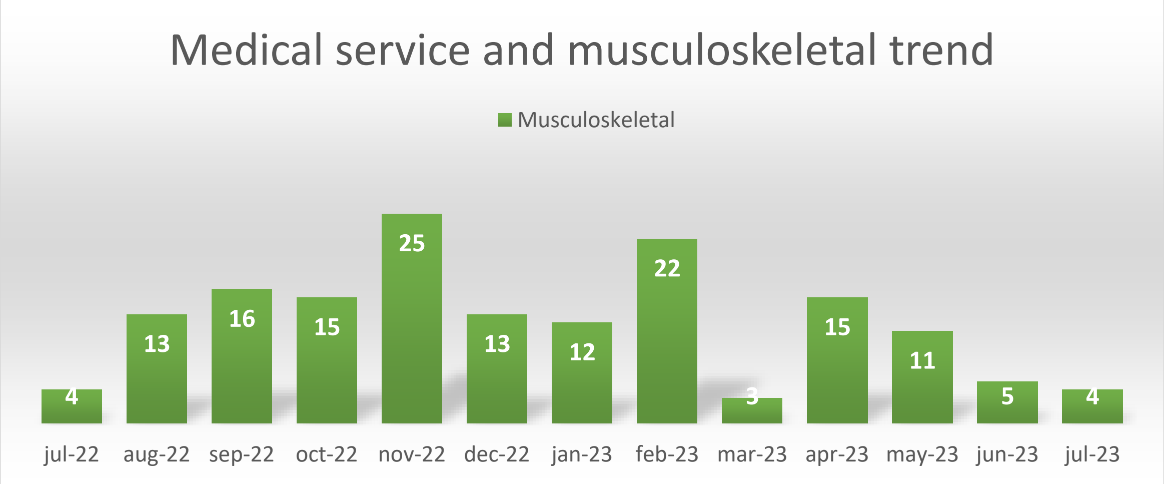
Source: Self made



Graph 17. Implementation of desktop, computer equipment and wrist rest Source: Self made

Graph 18 Implementation of footrests and chairs with armrests Source: Self made

Graph 19 shows the behavior of cases due to musculoskeletal problems for an entire year, after improvements were made from May to July 2023, where a decrease in cases can be seen compared to 2022.



Graph 19. Medical service and trend of complaints in the musculoskeletal system 2022-2023. Source: Self made

CONCLUSIONS AND RECOMMENDATIONS

The general objective of this project was to analyze and diagnose the administrative office areas of the company through the ROSA ergonomic method in order to identify the possible risks that are associated with the health of the workers, according to the reports presented by the nursing area of the various annex spaces.

At the same time, the general objective was met, which consisted of analyzing the exposed areas and personnel with the application of the method to diagnose risk level and present the diagnosis in the corresponding area for evaluation. All this was possible through questionnaires, which gave scores according to the level of risk detected.

Likewise, the proposal was generated and the implementation of new equipment was authorized for areas that had high levels of risk, since the health and economic impact that ergonomics has within workstations and related activities was demonstrated.

For the ergonomic adaptation within the office area to work, it is necessary to acquire the furniture and tools that help improve the health and comfort of the staff, so it will be necessary periodically, in order to have greater control, to periodically evaluate the workstations. , as well as supporting the results with the nursing area, to provide feedback and suggest solutions, once these risk levels have decreased, another type of implementation can be recommended that is in accordance with the new needs.

Additionally, make improvements in other areas using ergonomic evaluation methods that are appropriate according to the operation performed by the staff.

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MAN-MACHINE SYSTEM ERGONOMIC ANALYSIS OF CAR WASH WORKERS IN CUAUHTÉMOC, CHIHUAHUA

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Resumen La ergonomía es la parte de estudio del trabajo que se encarga de la optimización de condiciones laborales buscando establecer límites que no deben ser excedidos por las personas al realizar diversas actividades. En los sistemas hombre-máquinas correspondiente a lavado de carros se dan ciertas posturas que pueden llevar a lesiones musculoesqueléticas, por lo cual se decidió realizar un análisis ergonómico utilizando Art Tool y la medición de condiciones ambientales como son la temperatura, el ruido, la luminosidad y la humedad relativa. En base a ello, se propone un accesorio que reduce y ayuda con los resultados obtenidos.

Palabras clave: Análisis Ergonómico, Lavado de Carros, ART TOOL. Hidro Lavadora, Lesiones Laborales

Relevancia para la ergonomía: El proyecto HydroClean es un “Accesorio para pistola de una hidro lavadora industrial” que se va a fabricar con el propósito de ofrecerle a los trabajadores de autolavados realizar un trabajo más eficiente, rápido y cómodo. Esto en base al impacto físico que se está mostrando al momento de llevar a cabo las actividades. Asimismo, como la importancia ergonómica que se tiene, ya que son de gran nivel los daños que se obtienen.

Teniendo en cuenta que, dadas las condiciones en las que vivimos actualmente, también se buscó que dicho proyecto ayudara a la sustentabilidad de la comunidad buscando evitar contaminar en la mayor cantidad posible.

HydroClean consta de una estructura rectangular de plástico duro y rígido capaz de resistir a la presión del agua. Este mismo se une por medio de un acoplamiento adaptado a la punta de la pistola de una hidro lavadora industrial. Dicha estructura se encuentra forrada con tela de microfibra.

Abstract: Ergonomics is part of a work-study responsible for optimizing working conditions, seeking to establish limits that workers should not exceed when performing various activities. In the man-machine systems corresponding to car washing, certain postures and forces can lead to musculoskeletal injuries, so it was decided to perform an ergonomic analysis for which various methods were used, such as ART TOOL, as well as taking luminosity, humidity, noise, and temperature measurements. Based on this, an accessory is proposed that improves significantly actual working conditions.

Keywords. Ergonomics analysis, ART TOOL, Continuous Improvements, Work Injuries

Relevance to Ergonomics: The HydroClean Project is an “Industrial Hydro Washer Gun Accessory” that was designed to offer car wash workers a more efficient, fast, and comfortable working condition. This is based on the physical impact that is being shown at the time of carrying out their job.

Also, as well, an ergonomic impact is due to lowering the risk of a musculoskeletal injury. Furthermore, taking into account that, given the current conditions, it was also sought that this project would help the community sustainability by seeking to avoid polluting as much as possible.

HydroClean consists of a rectangular structure made of rigid plastic capable of resisting water pressure. This is joined employing coupling adapted to the tip of the gun of an industrial hydro washer, the structure is lined with microfiber fabric.

1. INTRODUCTION

Car washes represent a work environment where workers are exposed to a variety of ergonomic hazards due to repetitive tasks, awkward postures, and handling heavy equipment. In addition, the operational efficiency of the car wash workers can also be affected by poor ergonomics, resulting in decreased performance and poor service quality. However, a crucial aspect is a geography that we are analyzing since it was determined that Cuauhtémoc has a semi-dry temperate climate, which is characterized by strong winds, in addition to the fact that our economy does not allow 100% of the streets to be paved and leads to a problem of cleanliness in vehicles (INEGI, 2024)

Therefore, it is crucial to carry out an ergonomic analysis on car wash workers to identify areas for improvement in both working conditions and operational efficiency.

2. OBJECTIVES AND DELIMITATION

2.1 General Objective

Perform an ergonomic analysis of the man-machine system in the car washes of Cd. Cuauhtémoc, Chihuahua, identify and evaluate the ergonomic risks associated with the washing activity and determine their impact on the operational efficiency of the car washes. Likewise, it will promote the worker's well-being by reducing accidents, correcting harmful postures, and preventing ergonomic, physical, or mental injuries, through the implementation of corrective measures and working conditions improvement.

2.2 Specific Objectives:

1. Identify and classify ergonomic factors present in the man-machine system of car washes in Cd. Cuauhtémoc.
2. Assess ergonomic risks by applying ART TOOL ergonomic analysis in the washing activity.
3. Analyze the relationship between work environment ergonomic conditions and the operational efficiency of car washes, considering aspects such as productivity, safety, and the worker's well-being.
4. Examine the impact of ergonomic conditions on the service quality offered by car washes, exploring customer satisfaction and experience.
5. Propose specific ergonomic recommendations and solutions to optimize workplace's design, tools, and processes in car washes, to improve operational efficiency and ensure the safety and worker's well-being.

2.3 Delimitation

Car washes that are included in this article are based on those marked by Google Maps in the Cuauhtémoc, Chih region, in addition to those that met the research requirements, considering those that were in a position to support it.

3. METHODOLOGY

This research was carried out using a qualitative approach that will include the following stages:

1. Participant observation: the research team went to various car washes in the region on a given day, where an ART TOOL form was filled out, and various results were obtained.
2. Interviews: Interviews were conducted based on various questions that had a great impact on the relevant aspects, including environmental, ergonomic, and interest in improving their tools.
3. Data analysis: The data collected was analyzed using qualitative analysis techniques, such as content analysis, to identify relevant patterns, themes, and relationships (Hernández-Sampieri & Mendoza, 2018)

The Repetitive Task Assessment Tool (ART TOOL, for its acronym in English) is designed to help assess the risk of tasks that require upper extremities repetitive movement (arms and hands) (UK Health and Safety Executive, 2010).

It is a tool designed to assess some of the common risk factors in repetitive work that contribute to the development of upper extremity disorders (ULDs). ART is aimed at those responsible for designing, evaluating, managing, and inspecting repetitive jobs. It can help identify those tasks that involve significant risks and where to focus on risk reduction measures.

The evaluation is divided into four stages:
Stage A: Frequency and repetition of movements.
Stage B: Strength.
Stage C: Uncomfortable postures.
Stage D: Additional Factors (UK Health and Safety Executive, 2010)

4. RESULTS

4.1 ART TOOL Results

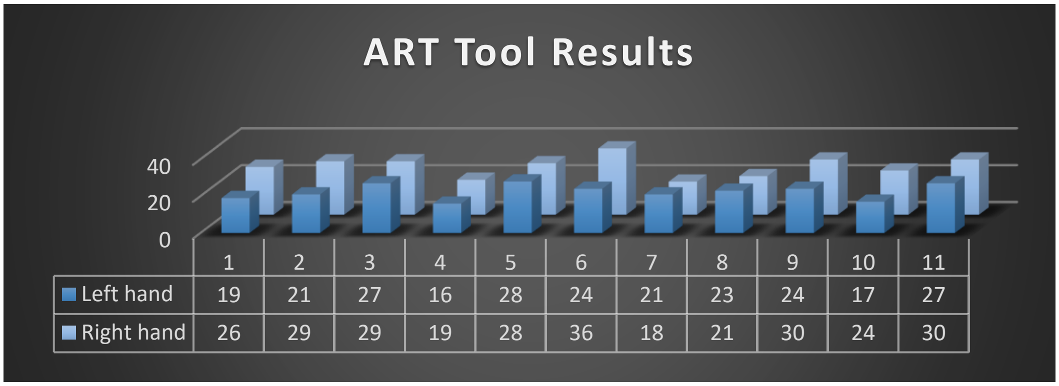
The work activities ergonomic analysis of eleven workers is carried out using the ART tool, obtaining the results that can be seen in Figure 1, which shows the ratings achieved by the workers by both the movements of the right and left hands. It was observed that most workers use their right hand more, even though there are workers who show a balance in the use of both hands (Subject 5), which results in greater efficiency in their work. On the other hand, subjects 7 and 8 work predominantly with their left hand.

Additionally, it can be determined that most workers obtained values higher than 22, considered high risk according to ART TOOL. Therefore, it is considered essential to implement measures or tools that reduce this value and thus reduce the associated risks.

4.2 Environmental Conditions Measurements

4.2.1 Noise

The measuring equipment involved in obtaining this environmental variable was a STEREN decibel meter, model HER-400, with a range of 30dB to 130dB.



	1	2	3	4	5	6	7	8	9	10	11
Left hand	19	21	27	16	28	24	21	23	24	17	27
Right hand	26	29	29	19	28	36	18	21	30	24	30

Figure 1. Results Ergonomic Analysis using ART TOOL.

Data obtained are shown in Figure 2, as can be seen only the measurement obtained in the car wash 8, does not comply with the maximum permissible exposure limits set by NOM-011-STPS-2011 which establishes a limit of 90dB (A) for 8 hours (STPS, 2002), however, it is important to clarify that the noise level was reached by the volume of the music that was played and the owner stated that the sound did not last for the 8 hours of the working day, the measurements were made following the protocol to measure the noise emission proposed by Echeverría & González (2011).

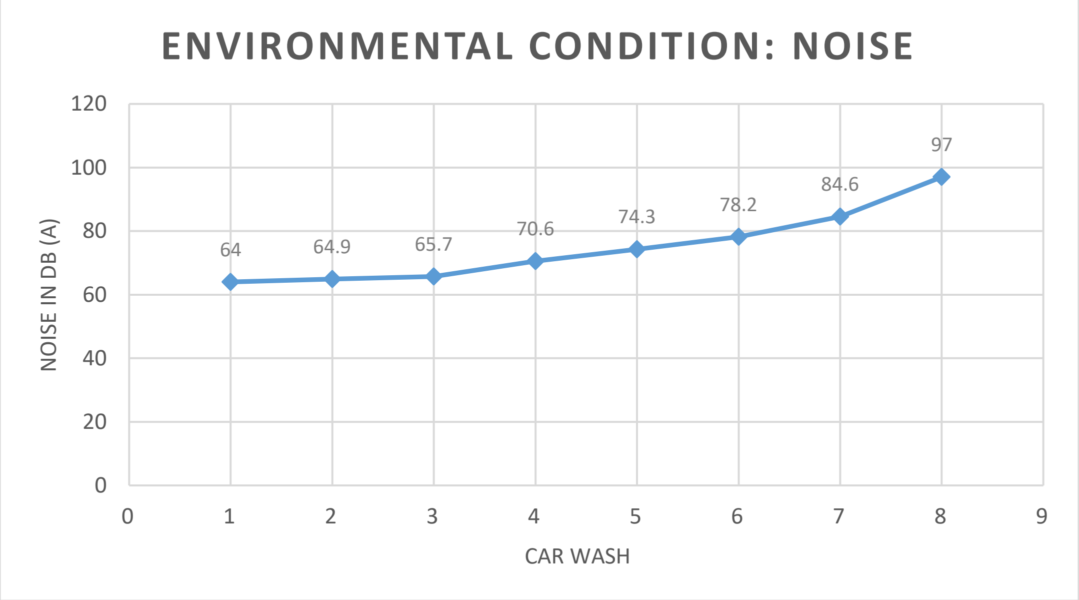


Figure 2. Sound conditions measurements.

4.2.2 Luminosity

For the luminosity measurements, a lux meter was used, brand URCERI®, model MT-912, It is important to note that some car washes had artificial shade for all or some of the tasks, while others are completely outdoors. The measurements were carried out according to the guidelines established in the NOM-025-STPS-2008 relating to workplace lighting conditions and can be determined under the afore mentioned regulations, and according to the data shown in Figure 3, all establishments comply with the classification of *Details Fine distinction* that marks as a minimum 750 luxes (STPS, 2008).

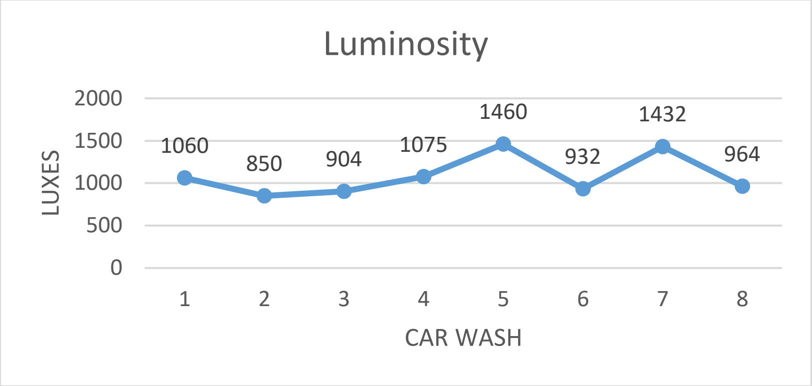


Figure 3. Light conditions measurements

4.3 Survey Results

A survey was carried out on thirteen workers, it is considered a significant sample since it includes 89% of the subjects engaged in manual car washing in 8 establishments in Cd. Cuauhtémoc, Chih.

The survey was focused on determining the perception of workers regarding their work environment, the injuries or accidents to which they have been exposed and the frequency of these, the environmental conditions, and the interest they may have in using an accessory for the hydro washer that could optimize their working conditions.

First, they were questioned concerning their perception of how heavy their work is, with 1 not being heavy and 10 being very heavy. 69% of workers gave a grade of 7 or higher. This leads us to infer that most operators consider their work very heavy due to the constant movements, postures, and vibrations caused by the hydro washer, the vacuum cleaner, the car exterior drying, and the interior cleaning. A significant variation can also be observed in the difficulty perception of the job, which depends on the number of cars they wash per day, the specific activities they must perform according to the customer's demands, and the fact that Saturday is the day with the highest workload.

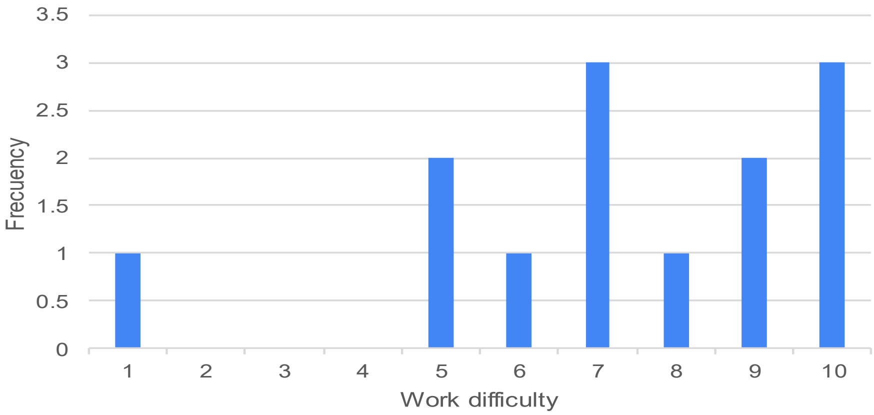


Figure 4. Difficulty in work task perception.

Through observation and analysis, it was determined that the activities carried out in this particular man-machine system can be divided into: Washing, Vacuuming, Drying, and interior Cleaning, based on this, the first question was related to determining what activities the subjects specifically performed during their working day. 100% of the workers stated that they carried out washing activities that involved using the pressure washer, and only one subject (7.69%) commented that they only carried out the washing activity.

The next question was about having suffered some type of injury, in graph 5, can be seen that most people have not suffered any injury. However, in answering the question, many considered only serious injuries. With a small deviation of one person, some did report injuries, highlighting that it is a heavy job that involves performing multiple activities. This causes muscle aches and physical fatigue, which, although not serious injuries, can negatively influence your health over time.

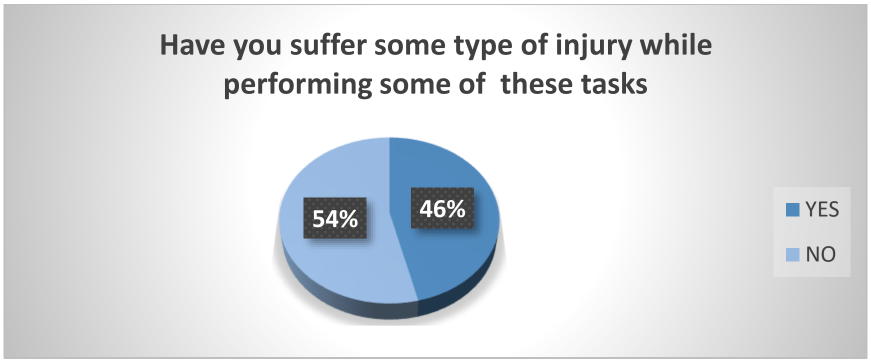


Figure 5. Work Injuries.

In graph 6, it can be seen that most people believe that climatic aspects do not affect their work. However, a slightly smaller number consider it, mainly due to the cold. In Ciudad Cuauhtémoc, the temperature drops significantly, and since this job involves constant contact with water, there is a higher chance of getting sick.

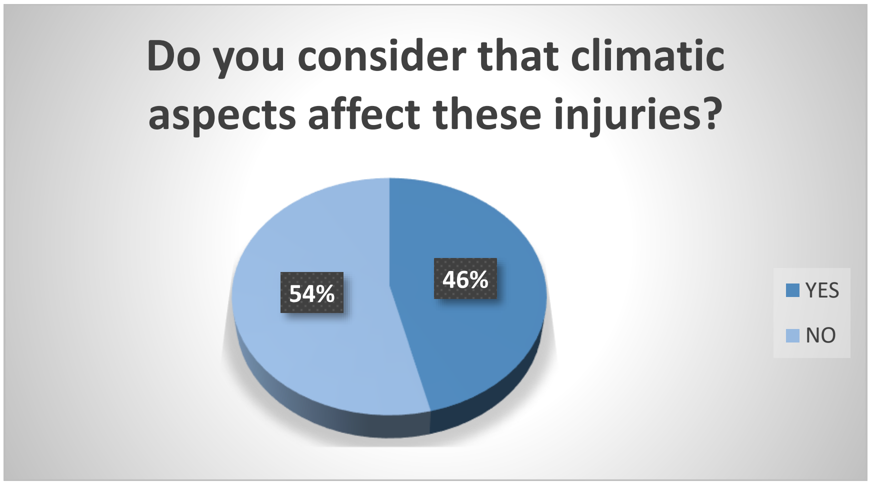


Figure 6. Weather vs Injury.

53.85% of those interviewed would consider acquiring a new accessory for their pressure washer to reduce fatigue and avoid injuries, as they seek to do their work less heavily and faster without losing quality. Those who would not buy it indicated that they already have similar accessories or are simply not interested. Regarding the price, 69.2% consider that less than $500.00 pesos would be a reasonable price, and 30.8% consider it in the range of between $500.00 and $1000.00 pesos (Figure 7).

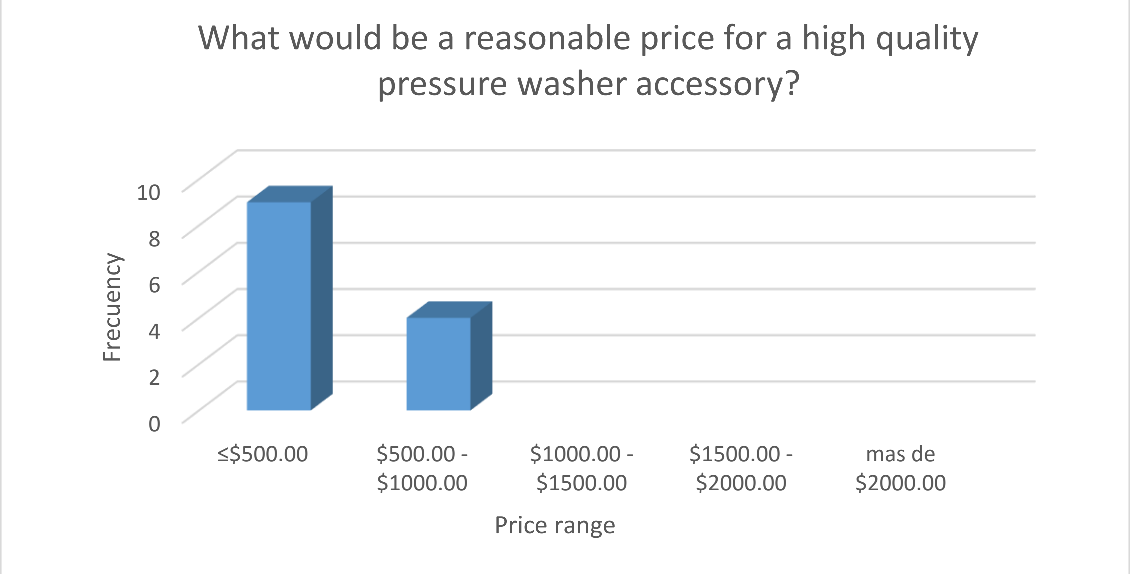


Figure 7. Price range to be considered

5. CONCLUSION

Finally, we determined that it is a fundamental step to evaluate the musculoskeletal damage caused by working in a car wash, based on the risk levels obtained with ART TOOL, although no previous research was found in this regard, it was found that performing work in a car wash can cause long-term injuries, although it is a very well-paid economic activity. Therefore, it is important to modify certain tools to avoid certain postures and reduce the force necessary to use the pressure washer. Hence, the HydroClean tool is designed.

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ERGONOMIC EVALUATION OF WORKSTATIONS ON DCI, ITHD AND SRX LINES

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Resumen: En el presente trabajo se realizaron evaluaciones ergonómicas en los puestos de trabajo de las líneas de producción de DCI, ITHD y SRX, esto con el propósito de conocer el factor de riesgo que interfiere en las estaciones de trabajo y los niveles de riesgo de las actividades que desempeña el trabajador durante la jornada laboral, utilizando primeramente una lista de análisis inicial de riesgos que esta arrojo que el factor de riesgo de las estaciones es la postura y la repetitividad, seguido de la selección del método RULA enfocado en la evaluación de las posturas de las extremidades superiores, donde dichas evaluaciones se aplicaron a un total de 12 trabajadores repartidos en las 3 líneas.

Palabras clave: Ergonomía, riesgo, Método RULA, seguridad.

Relevancia para la ergonomía: Contribuirá al cumplimento de las normas de seguridad y salud en el que rige la Secretaría del Trabajo y Previsión Social como la 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”.

Abstract: In this work, ergonomic evaluations were carried out at the work stations of the DCI, ITHD and SRX production lines, with the purpose of knowing the risk factor that interferes in the work stations and the risk levels of the activities that the worker performs during the working day, using first a list of initial risk analysis that showed that the risk factor of the stations is the posture and repetitiveness, followed by the selection of the RULA method focused on the evaluation of the postures of the upper extremities, where said evaluations were applied to a total of 12 workers distributed in the 3 lines.

Keywords: Ergonomics, risk, RULA Method, safety.

Relevance to ergonomics: It will contribute to compliance with the health and safety regulations governed by the Ministry of Labor and Social Welfare, such as the Mexican Official Standard NOM-036-1-STPS-2018, “Ergonomic risk factors at work: Identification, analysis, prevention and control. Part 1: Manual handling of loads”.

1. INTRODUCTION

Ergonomics is the science that seeks the adaptation between the worker, the machinery, the tools and the physical environment of the working day, with the purpose of adapting the jobs to the physical and psychological characteristics of the worker. The main objective of ergonomics is to prevent damage to the health of the individual considering its three dimensions: physical, mental and social (León-Duarte, Martínez-Cadena, & Olea-Miranda, 2021).

Ergonomic design within workstations prevents work-related injuries and illnesses, as well as having the ergonomic characteristics necessary to improve the workplace. If organizations choose to design and adapt workstations with an ergonomic approach, there will be more balance between the worker and the tools, benefiting them with better comfort in their workplace (Martelo Lora & Mercado Pérez, 2023). In the workplace, various problems of occupational disability with respect to health are occurring, motivating ergonomic risk factors, which has caused employees to suffer from certain problems during the years of greatest work productivity, leading in many cases to disability linked to this work activity (Morales Arrieta, 2020).

Knowing the risk factors surrounding workstations will always be useful in the company. Ergonomic risk refers to the probability of suffering an unwanted event at work, and among the most frequent associated factors are postural load, repetitive tasks, weight load, inadequate furniture, maintained postures, posture time, among others (Torres Ruiz, 2023).

Studies have suggested the creation of programs or strategies that can reduce the level of musculoskeletal injuries in staff. These strategies could have a positive impact on the company by reducing the number of work-related disabilities and thus maintaining a great healthy work environment that helps to have increasingly increasing work productivity (Clemente Hernández, Cruz Hernández, Arcos González, & Rocha Ibarra, 2021). Another study identified the most common musculoskeletal disorders associated with ergonomic risk factors in professionals in Latin America. It was found that the lower lumbar area and the neck are the body regions where professionals regularly experience intense pain and discomfort. These risks are also related to overweight, physical workload, high shift demands, repetitive movements, excessive loads, long standing shifts, and uncomfortable postures (Daza Fragozo, 2021).

2. OBJECTIVE

Conduct an ergonomic assessment at the work stations of the DCI, ITHD and SRX lines in the final assembly area of a company in order to obtain the level of ergonomic risk presented by the workers.

3. DELIMITATION

The project is carried out in a company located in the city of Tijuana, Baja California, responsible for the production of speakers and electronics that focuses mainly on the creation of professional audio and video controllers.

4. METHODOLOGY

The focus area of the evaluation is the electronics production area, in the DCI, ITHD and SRX lines.

4.1 Initial risk identification.

To begin with the ergonomic assessments, a superficial risk analysis was carried out. For this, a format was developed to identify the initial risks in the workplaces, which allowed to know the risk factor "Posture and repetitiveness" which affects the jobs.

Figure 1 shows the types of musculoskeletal injuries and the quantity of each of them produced in the controlled electronics room in 2023, where Upper limb myalgia is the most frequent injury of workers with 15 injuries, followed by non-specific low back pain with 13 injuries recorded.

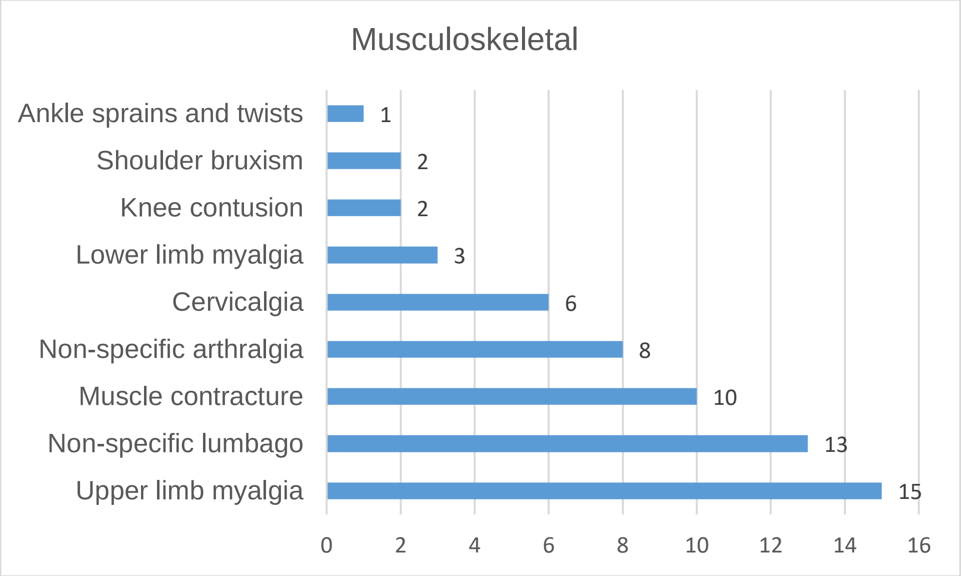

Figure 1. Consolidated musculoskeletal system. Source: Company Medical Service.

A survey was applied to all workers on the 3 production lines to find out the workers' perception of pain when carrying out their respective activities, thus obtaining that the part of the body with the highest percentage of pain and discomfort is the back and shoulders (which is part of the upper limbs of the body). The part of the body with the most pain or discomfort voted by the workers were the feet with a total of 14 votes, followed by the shoulders and spine with a total of 13 votes and with one vote difference the lower back with a total of 12 votes as shown in figure 2.

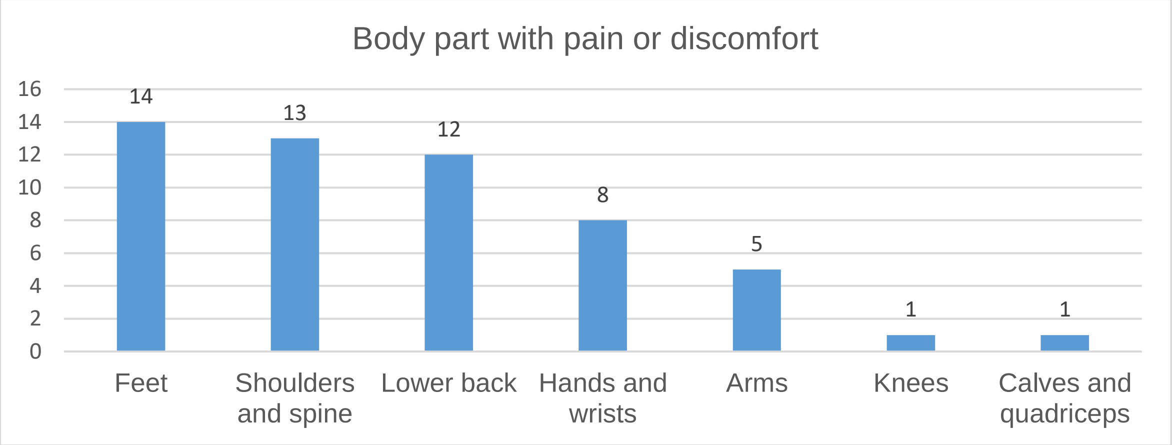

Figure 2. Body part with pain or discomfort. Source: Own elaboration.

4.2 RULA method.

The applied method will allow to evaluate the exposure of workers to risks due to the maintenance of inadequate postures that can cause disorders in the upper limbs of the body, for which the RULA (Rapid Upper Limb Assessment) method will be used (Monárrez Orona, Flores Sánchez, Gómez Zepeda, & Margarita Portillo Reyes, 2023).

The RULA methodology was applied as a method for risk assessment, from which a risk level and a level of action are obtained and based on these, a proposal for improvement is made for the mitigation of these (Durán Martínez, Marquez Gayosso, Flores Sánchez, Atay de Campos, & Portillo Reyes, 2024).

For the application of the RULA method, some stations were selected based on the type of activity they carry out (assembly, electrical testing and packaging), thus selecting 14 activities from the 3 different DCI, ITHD and SRX lines, as shown in table 1:

Table 1. Production line workstations.

Line	Station number	Activity	Description
DCI	**1**	Chassis pre-assembly	Place screws on the sides of the chassis and then place it in a vise.
	5	Closed chassis	Place the cover on the chassis and secure it with screws around the product.
	8	ATE electrical test	Unscrew and then insert the electrical test leads.
	10	Box assembly packaging	Assemble the packaging box for the finished product using a pneumatic stapler.
	10	Closed box packaging	Place the finished product with its foam inside the box and close it with the pneumatic stapler.

ITHD	**1**	Sub-assembly	Assemble screws, plates, brackets and connectors.
	5	Front panel assembly	A plate and a little silicone are placed.
	6	Closed chassis	Place the cover on the chassis and secure it with screws around the product.
	8	Electrical test	Cables are connected for testing and a manual test is performed.
	10	Clean and inspect unit	The final product is inspected and cleaned with a cloth and alcohol.
	10	Assembled and closed packaging of the box	A packaging box is assembled for the finished product with the help of a pneumatic stapler and the product with its foam is placed inside the box and finally closed with the same stapler.
SRX	**4**	Closed chassis	Place the cover on the chassis and secure it with screws around the product.
	6	Electrical test	The cables are connected to the back of the product and the electrical test is performed.
	8	Packing in the master box	A packaging box is assembled and the finished product is introduced.

5. RESULTS

Using the RULA method focused on the study of postures specifically in the upper extremities, it was possible to obtain the ergonomic risk levels of each activity that was decided to be evaluated. Table 2 shows the summary of scores and to which line and activity it belongs.

It can also be observed that 3 of the activities that make up packaging activities have the highest score, followed by 7 activities that have a risk level of 5 and 6, and finally 4 activities that have a level of 3 and 4 respectively (see Table 2).

Table 2. Summary of results of risk levels. Source: Prepared by the authors

Resumen de resultados de niveles de riesgo					
Line	**Station number**	**Activity**	**Level**	**Risk level**	**Action**
DCI	**1**	Chassis pre-assembly	Medium	6	Task redesign required.
	5	Chassis closure	Medium	6	Task redesign required.
	8	ATE electrical test	Medium	5	Task redesign required.
	10	Box assembly packaging	Medium	5	Task redesign required.
	10	Box closure packaging	High	7	Urgent changes to task.
ITHD	**1**	Sub-assembly	Low	3	Task changes required.

	5	Front panel assembly	Medium	6	Task redesign required.
	6	Chassis closure	Medium	6	Task redesign required.
	8	Electrical test	Low	4	Task changes required.
	10	Clean and inspect unit	High	7	Urgent changes to task.
	10	Box assembly and closure packaging	High	7	Urgent changes to task.
SRX	**4**	Chassis closure	Low	4	Task changes required.
	6	Electrical test	Low	4	Task redesign required.
	8	Packing in master box	Medium	6	Task redesign required.

At the end of the project, the objective of carrying out an ergonomic assessment and being able to know the level of risk that the worker faces in his/her workplace was achieved. The area of ergonomics is very extensive, therefore a specific analysis of each factor and condition that involves the worker would take more time to develop. In accordance with the priority taken with the initial risk assessment, it was possible to focus on a single factor and to start from there towards the safety and integrity of the worker.

The workers that make up the 3 evaluated lines are a total of 24 workers, where 4 workers were evaluated in the DCI line, 5 workers in the ITHD line and 3 workers in the SRX line, giving a total of 12 workers evaluated carrying out their own activities in their workplace, this being 50% of the workers that make up the 3 lines.

3. CONCLUSIONS AND RECOMMENDATIONS

After completing the ergonomic evaluations at the work stations and seeing the results obtained, it can be concluded that one of the stations with the highest level of risk is the packing station, in which not only the postural risk factor is involved, but also the manual handling of loads, which plays an important role in increasing the level of risk at said stations. The proper use of tools for each activity, which can cause that where there is normally no ergonomic risk or where the level of ergonomic risk is not so high, this risk increases due to this type of practices.

These results can be used to begin to develop improvements that help the previously evaluated activities to reduce their level of ergonomic risk until reaching a safe level for the worker, in addition to taking these results into account when designing a work station or implementing a new process in the area. Some of the recommendations for following up on this project or for future research are to reduce the level of risk and make certain modifications to the design or the work activity itself, such as:

- For repetitive tasks, specific tools will be used. Screwdrivers, knives, hammers, saws, pliers and other hand tools must be exactly the appropriate type, size, weight and power.
- Minimize the weight of tools (except for percussion tools).

- Place the most frequently used materials, tools and controls within easy reach.
- Allow workers to alternate sitting and standing during work as much as possible and use ergonomic mats.
- Reduce manual handling of materials using conveyor belts, cranes and other mechanical means of transport.
- When handling loads, eliminate tasks that require bending or turning.
- Develop visual aids, as well as training in handling materials when transported with the proper posture.

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Exploring and Analyzing User-Focused Characteristics for Designing and Implementing Lactation Rooms in Workplaces: A literature review.

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Resumen: Las salas de lactancia, definidas como espacios exclusivos y adecuados para la extracción de leche o amamantamiento, representan una de las estrategias más comunes que las organizaciones de trabajo a nivel global implementan para promover la lactancia materna. Dada la importancia crucial de la lactancia en el desarrollo saludable de los niños, es fundamental la identificación de condiciones óptimas para llevar a cabo esta actividad. Disponer de información clara y precisa sobre los factores que pueden afectar los procesos de lactancia, puede proporcionar herramientas de ergonomía y diseño para la generación de principios y propuestas más coherentes con las necesidades y expectativas de las usuarias en esta actividad tan importante.

Con base en lo anterior, el presente trabajo tiene como propósito examinar las investigaciones existentes sobre las salas de lactancia, e identificar las experiencias, necesidades y carencias de las usuarias con relación al servicio de estas salas en entornos educativos y laborales. Para esto, se llevó a cabo una revisión no sistemática de literatura. Las palabras clave utilizadas para la búsqueda fueron salas de lactancia, lactarios, calidad, ergonomía y diseño.

A partir de la literatura revisada, 20 artículos fueron considerados relevantes para el objetivo del presente trabajo. Se identificaron 4 subtemas principales: Las salas de lactancia como estrategia para el incremento de la lactancia materna, experiencias y preferencias de las usuarias, diseño y operatividad.

Se encontró que diversos estudios han demostrado la efectividad de las salas de lactancia para aumentar las tasas de inicio y mantenimiento de lactancia en madres trabajadoras. Además, se ha subrayado la importancia del equipamiento de estos espacios, destacando elementos clave como el refrigerador, lavamanos y extractor de leche. También se han señalado aspectos funcionales como la ubicación, la distancia respecto al lugar de trabajo y la disponibilidad de periodos de descanso adecuados para hacer uso de estas instalaciones. Por otro lado, se encontró que las necesidades psicoafectivas de las usuarias están vinculadas a factores como la privacidad, el confort, la sensación de calidez y la percepción de apoyo social.

Finalmente, se evidenció que las intervenciones multifacéticas de diseño, en los cuales se toma en cuenta la calidad de las salas de lactancia han demostrado tener incrementos en la satisfacción y uso de estas, así como en la percepción de apoyo social.

De acuerdo con la evidencia encontrada en los resultados, se identifica la necesidad de adoptar una perspectiva sistémica en el diseño e implementación de las salas de lactancia en el lugar de trabajo. Considerar la diversidad de factores involucrados puede influir significativamente en la eficacia del diseño, lo que, a su vez, está estrechamente relacionado con la decisión de utilizar estos espacios.

Palabras clave: Sala de lactancia, Ergonomía de Diseño, Lactancia materna, Calidad

Relevancia para la Ergonomía: Existen pocas investigaciones en el campo de la ergonomía, al igual que estudios hechos en México relacionados al diseño de los lactarios a partir de las necesidades y características de las usuarias. Estos son espacios con asociaciones emocionales fuertes, lo que hace más complejo su diseño; además de la importancia en cuestiones de funcionalidad y operatividad, aspectos que no deben ser excluidos en su implementación. Todo esto tiene relevancia en la decisión de uso de las salas de lactancia por parte de las usuarias.

Explorar la construcción de estos espacios desde un punto de vista sistémico y centrado en el usuario, contribuye a una mayor satisfacción en las usuarias y, por ende, a una percepción de apoyo por parte de las instituciones de trabajo para continuar con la práctica de la lactancia materna.

Abstract: Lactation rooms are defined as dedicated and appropriate spaces for expressing milk or breastfeeding. They are one of the most common strategies used by workplaces worldwide to promote breastfeeding. Because of the crucial importance of breastfeeding for the healthy development of children, it is essential to identify the optimal conditions under which this activity can be carried out. The availability of clear and precise information on the factors that can have an impact on the lactation process can provide ergonomic and design tools for the development of principles and proposals that are more in line with the needs and expectations of the users of this vital activity.

Building on the above, this study aims to review existing research on lactation rooms and identify users' experiences, needs, and shortcomings regarding these facilities in educational and workplace settings. To achieve this, a non-systematic literature review was conducted. Keywords used in the search included lactation rooms, breastfeeding rooms, quality, ergonomics, and design.

Based on the reviewed literature, 20 articles were deemed relevant to the objective of this study. Four main subtopics were identified: lactation rooms as a strategy to increase breastfeeding rates, user experience and preferences, design, and functionality.

Research has demonstrated that lactation rooms are effective in increasing both initiation and continuation rates of breastfeeding among working mothers. The importance of properly equipping these facilities has been emphasized, highlighting essential elements such as refrigerators, sinks, and breastpumps. Functional considerations, including the location of the rooms, their distance from the workplace, and the availability of sufficient rest periods to use them, were also addressed. In addition, the psycho-emotional needs of users were found to be closely linked to factors such as privacy, comfort, warmth, and perceptions of social support.

Finally, it was observed that multifaceted design interventions, which consider the quality of lactation rooms, have resulted in increased user satisfaction and utilization of these facilities, as well as enhanced perceptions of social support.

According to the evidence found in the results, there is a need to adopt a systemic perspective in the design and implementation of lactation rooms in the workplace. Taking into account the variety of factors involved can have significant impact on the effectiveness of the design, which in turn is closely related to the decision to use these facilities.

Keywords: Lactation room, Ergonomics of design, Breastfeeding, Quality.

Relevance to Ergonomics: There is a limited amount of research on ergonomics, as well as studies carried out in Mexico on the design of lactation rooms based on the needs and characteristics of the users. These rooms are associated with strong emotional factors that complicate their design. In addition to the critical aspects of functionality and operability that must be considered in their implementation, these factors play a significant role in influencing users' decisions to use lactation rooms.

Examining the design of these spaces from a systemic and user-centered perspective enhances user satisfaction and fosters a perception of institutional support from workplaces for the continued practice of breastfeeding.

1. INTRODUCTION

Breastfeeding is a crucial public health issue worldwide, as it directly affects the survival and health of millions of mothers, newborns, and infants. Lactation rooms, or breastfeeding rooms, are defined as “designated, dignified, private, hygienic, and accessible areas where breastfeeding women can either breastfeed or express and store their milk properly” (Secretaría de Salud et al., 2021, p11).

The importance of breastfeeding for the proper development of children necessitates identifying appropriate conditions for carrying out this activity. Specifically, understanding these conditions is crucial in settings such as the workplace or educational institutions, which, due to various intervening factors, have been recognized as contributing to the interruption of breastfeeding (Van Dellen et al., 2022). Having clear information on the factors that can affect breastfeeding processes can provide ergonomic and design tools for developing principles and proposals that are more aligned with the needs and expectations of users in this critical activity.

In this context, studies that focus on users' experiences and perceptions will be explored in order to understand the requirements for lactation rooms from a more comprehensive perspective. This approach aims to make these services more user-friendly and functional for breastfeeding mothers.

2. OBJECTIVES

1. To learn about the research that has been done on lactation rooms.
2. To identify users' experiences, needs, and shortcomings regarding the service of these rooms in study and work places.

3. METHODOLOGY

A non-systematic literature review was conducted using databases such as Google Scholar, ScienceDirect, Taylor and Francis Journals, ResearchGate, and the digital library of the University of Guadalajara. Keywords used in the search included lactation rooms, breastfeeding rooms, quality, ergonomics, and design. The selection of articles began with a review of the titles, followed by an analysis of the abstracts to assess their relevance to the objectives of the study and to identify their main focus. Articles that did not fall within the predetermined age range or that deviated from the research objective were excluded. A thorough review of each selected article was then performed.

Articles from 2012 to 2023 were considered relevant to the research objectives, except for one article from 2008, which was included due to its relevance to the background of the research country (Mexico). The search was conducted in both Spanish and English.

4. RESULTS

Based on the reviewed literature, 20 articles were deemed relevant to the objectives of this study. The review, focusing on the main emphasis of each article, identified four subtopics (see Table 1)

Table 1. Classification of articles according to subtopics.

Subtopic	Number of articles
Lactation rooms as a strategy to increase breastfeeding rates	4
user experience and preferences	7
Design	5
Functionality	4

4.1 Lactation rooms as a strategy to increase breastfeeding rates.

Lactation rooms have been part of public policies and/or strategies implemented by various governments around the world in recent years. These policies have been influenced by global organizations such as the World Health Organization (WHO) and the United Nations International Children's Emergency Fund (UNICEF), which aim to create conditions conducive to increasing breastfeeding rates. In Mexico alone, the Federal Labor Law, Article 170, Section IV, mentions the implementation of "a suitable and hygienic space exclusively for breastfeeding or expressing breast milk" (SS et al., 2021, p 18).

Various studies have been conducted to determine whether there is a relationship between the presence of a lactation room in the workplace and an increase in the percentage of breastfeeding mothers, as well as the duration of breastfeeding. Dinour & Szaro (2017) found that private spaces for milk expression are among the most studied breastfeeding supports. Their research indicates a significant difference in both the initiation and duration of breastfeeding between working mothers who had access to such spaces and those who did not. They also found that other external factors, such as break times and the distances traveled, influence the use of these spaces, as noted by Hoffmann & Hoffman (2023).

Similarly, Vilar-Compte et al. (2021) identified lactation rooms as one of the most common interventions to support breastfeeding in the workplace. These authors highlighted evidence linking the presence of lactation rooms to an increase in breastfeeding duration. This finding is consistent with Kim et al. (2019), who found that, overall, workplace interventions supporting breastfeeding increased initiation rates and exclusive breastfeeding.

Bai & Wunderlich (2013) identified four dimensions of breastfeeding in the workplace: break time (for expressing milk), work policies, work environment, and technical support (lactation room space and equipment). The study found that the latter two dimensions had a more significant association with the duration of exclusive breastfeeding.

In México, Ibarra-Ortega et al. (2020) reported an association between the presence and use of lactation rooms at work and a longer duration of breastfeeding. This finding is supported by the study of Van Dellen et al. (2022), which emphasizes that not only the availability of a lactation space but also its quality is an important facilitator of breastfeeding in the workplace.

Mourad et al. (2023) found that improving lactation room conditions improves workers' perceptions, which in turn has a positive impact on productivity and working conditions. This aspect is also highlighted in studies by Van Dellen et al. (2022) and Van Dellen et al. (2021).

4.2 User experience and preferences

Several studies have focused on understanding users' opinions, experiences, and perceptions of lactation rooms. These studies range from the functional needs of these spaces (such as furniture, equipment, space characteristics, and operability) to the psychological and emotional needs. Obtaining this information is critical, as Henry-Moss et al. (2018, p1) state: "Users' needs and preferences can guide the design of lactation rooms to ensure a minimum standard of design, equipment, and distance."

Henry-Moss et al. (2018) found that the most important item in a lactation room is the electric breast pump. This finding is consistent with the report by Sturtevant et al. (2021), which highlights other essential elements such as desks, sinks, and the availability of a refrigerator to store expressed milk. Similarly, these elements were found to be relevant in the studies by Barasinski et al. (2022), Campos Placencia & Mogollón Torres (2019), and Muhammad Roslan et al. (2022).

Henry-Moss et al. (2018) found that users preferred shared or multiple spaces over private ones, due to the high demand for the service. This aspect is also noted by Rose (2012).

In Mexico, one of the few studies conducted on this topic is the one by Garcia-Ramos et al. (2008), which highlights the importance of users' perceptions regarding the quality of the physical space, furniture, equipment, and materials, as well as the lack of awareness of the norms and regulations that govern the space. This finding is similar to the study by Campos Placencia & Mogollón Torres (2019), which shows the unfamiliarity of users with the infrastructure and regulations of lactation spaces. The latter study also highlights the critical importance of hygiene, comfort, and privacy, which were key factors in users' decisions to use the facilities.

Ningsih et al. (2022) found that knowledge of the benefits of breast milk was the most important factor in the use of lactation rooms, followed by other factors such as attitudes, practices, and perceived support from coworkers. This latter aspect is also noted in several studies, including those by Bai & Wunderlich (2013), Vilar-Compte et al. (2021), Hoffmann & Hoffman (2023), and Van Dellen et al. (2021). It is also explored in the work of Ahmad et al. (2022), which highlights the strong need for support in all the mother's social circles.

On the other hand, Hoffmann & Hoffman (2023) found that there are different psychological needs among users. Some women need to reconnect with their motherhood and distance themselves from the work environment, while others need amenities that allow them to continue their work activities within the room. This highlights the importance of addressing both needs when designing lactation rooms.

4.3 Design

Recently, special emphasis has been placed on the development of guidelines for the design and implementation of lactation rooms, the most important of which are:
The guide developed by the American Institute of Architects (AIA), focuses on building professionals and designers, and the guide developed by WHO and UNICEF, which includes country-specific adaptations and is aimed at employers. In this context, the Guide for the Implementation and Operation of Lactation Rooms, used in Mexico, was developed in collaboration with the Secretariat of Labor and Health.

The review found some studies that focused on analyzing the design characteristics of lactation rooms, and some studies were interested in exploring the design considerations or testing certain guidelines proposed in the guide.

Among the studies with an ergonomic perspective, Badriyah & Suyasa (2021) focused on anthropometry and furniture measurements combined with user experiences of breastfeeding mothers. On the other hand, Muhammad Roslan et al. (2022) conducted a study to identify design gaps based on user-centered design theory, exploring the experiences of mothers and their interaction with the space and equipment. This study confirmed the importance of factors such as the size of the space, the placement of elements such as desks and chairs, and the relevance of equipment such as refrigerators and sinks, which were previously mentioned.

Other studies, such as Van Dellen et al. (2021), have highlighted the importance of lactation room quality concerning user satisfaction. In this regard, Ibarra-Ortega et al. (2020, p 924) state, "Having a lactation room but not using it produces results similar to not having a lactation room at all". Van Dellen et al. refer to the quality of the room in terms of environmental and aesthetic aspects, as well as the presence of more comprehensive equipment in the room. In another study, Van Dellen et al. (2022) explored the development of a high-quality lactation room based on Ulrich's (1991) supportive design theory, which resulted in reduced stress perceptions and more positive perceptions of breastfeeding at work.

On the other hand, Sturtevant et al. (2021) found that the most relevant affective factor in the design of lactation rooms is the need for privacy. In terms of the most important affective element, López-Tarruella et al. (2019) identified the sense of coziness, followed by factors such as safety, elegance, simplicity, brightness, and spaciousness. López-Tarruella et al. (2019) also found that the most preferred colors by users are orange and yellow due to their association with a cozy feeling, while cyan and red were the least preferred.

4.4 Functionality

As previously mentioned, the implementation of designated spaces for milk extraction at work is stipulated in Mexico's Federal Labor Law. However, as Hoffmann & Hoffman (2023, p. 209) note, “The law does not address the accessibility of the rooms or their content. Lactation spaces, which might technically meet the regulatory requirements, often prove to be less effective or even completely unusable.”

The study by Hoffmann & Hoffman (2023) reports the need for sufficient time during the workday for milk pumping and for spaces that are adequately designed to meet multiple needs and preferences. They also emphasize the importance of the space being sufficiently accessible. This aspect is also explored in Henry-Moss et al. (2018), where it was found that the maximum tolerable travel time from the workplace to the lactation room should be 5.6 minutes.

Sturtevant et al. (2021) developed an evaluation of lactation rooms based on the AAAQ concept (Availability, Accessibility, Acceptability, and Quality), finding several deficiencies such as a lack of information about the spaces, difficult access, and descriptions like “functional but not comfortable or pleasant” (2021, p. 179). This study is like that of Dinour et al. (2022), who assessed the types of use of lactation room spaces as dedicated, designated, and accommodated based on their usage type, and investigated the accessibility of information about these spaces on university campuses.

In México, García-Ramos et al. (2008) explored the opinions and perceptions of users in hospital lactation rooms, highlighting descriptors such as "poor" in aspects like infrastructure, cleanliness, and comfort.

Finally, studies such as that by Mourad et al. (2023) show that multifaceted interventions that address not only the physical but also the functional aspects, improve user satisfaction in lactation rooms.

5. CONCLUSIONS

Based on the evidence found in the results, there is a need for a systemic perspective in the design and implementation of lactation spaces in the workplace. This is due to the involvement of several external factors (social, political, etc.) and internal factors (interpersonal, psychological, emotional, etc.) that go beyond simply equipping a physical space with the minimum required elements.

Therefore, it is critical to start with the needs, limitations, and characteristics of the users to guide the design of lactation rooms. This approach recognizes both the physical and functional characteristics necessary to optimize the use of these facilities.

Considering the variety of these factors can influence the effectiveness of the design, which in turn is related to the decision to use these rooms. It is clear that the characteristics of lactation rooms can act as facilitators or barriers to the breastfeeding process in the workplace, which in turn has implications for the health and economic well-being of the population.

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AIR QUALITY ASSESSMENT IN UNIVERSITY CLASSROOMS

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Resumen: Este capítulo examina cómo la calidad del aire en espacios educativos afecta el confort ergonómico de los ocupantes. Se evaluaron parámetros como dióxido de carbono (CO2), humedad relativa y temperatura en aulas universitarias, y se discuten las implicaciones ergonómicas de los resultados obtenidos. Los hallazgos indican que la ventilación insuficiente y las condiciones ambientales inadecuadas pueden comprometer el bienestar y el rendimiento cognitivo de los estudiantes.

Palabras Clave: Calidad del aire, dióxido de carbono, confort ambiental, Ventilación, Ergonomía Ocupacional.

Relevancia para la Ergonomía: Este capítulo es relevante para la ergonomía porque aborda cómo los factores ambientales interiores influyen en el bienestar físico y cognitivo de los estudiantes, proponiendo soluciones para mejorar las condiciones de aprendizaje.

Abstract: This chapter examines how air quality in educational spaces affects the ergonomic comfort of occupants. Parameters such as carbon dioxide (CO2), relative humidity and temperature in university classrooms were assessed, and the ergonomic implications of the results obtained are discussed. The findings indicate that insufficient ventilation and inadequate environmental conditions may compromise students' well-being and cognitive performance.

Keywords: Air quality, carbon dioxide, environmental comfort, ventilation, occupational ergonomics.

Relevance to Ergonomics: This chapter is relevant to ergonomics because it addresses how indoor environmental factors influence students' physical and cognitive well-being, proposing solutions to improve learning conditions.

1. INTRODUCTION

Today, the relationship between the use of indoor spaces, such as classrooms, offices or the home, and the appearance of symptoms that affect well-being and performance, such as drowsiness, lack of concentration, and learning problems, is an indisputable reality in the field of ergonomics. Ergonomics studies how environmental factors can optimize the interaction between people and their work environment, with the aim of improving health, comfort and productivity.

Studies show that urban humans spend between 80% and 90% of their time in closed environments. These environments, when poorly ventilated, can accumulate pollutants in significantly higher concentrations than those found outdoors, which can lead to an ergonomically unfavorable environment. The need for energy savings has led to the construction of more airtight buildings with increased air recirculation through thermal conditioning systems, but often with insufficient air renewal. This affects not only air quality but also the thermal comfort and environmental quality of the space, which are key components of ergonomic comfort.

In learning spaces, such as schools and universities, poor ventilation can raise carbon dioxide (CO2) levels, which has a negative impact on the health and comfort of users. From an ergonomic perspective, the accumulation of CO2 not only causes drowsiness and lack of concentration, but also significantly reduces students' ability to process information and retain knowledge, directly affecting their academic performance.

Ergonomics emphasizes the importance of a healthy work environment, where air quality is adequately controlled. The implementation of adequate ventilation systems is not only crucial for the health of the occupants, but also optimizes working and study conditions, promoting an ergonomic environment that favors physical and cognitive well-being. Rigorous controls on air renewal in classrooms are essential to avoid negative health effects, improve comfort and maximize the effectiveness of learning processes.

2. OBJECTIVES

The objective of this study is to evaluate the indoor air quality in educational classrooms and analyze how it affects the ergonomic comfort of students. To achieve this, the aim is to quantify the concentration of carbon dioxide (CO2), relative humidity and temperature in different occupancy conditions, since these factors are critical for the perception of comfort and well-being in enclosed spaces. In addition, it is intended to determine the hourly air renewal rate in classrooms, a fundamental aspect to ensure a healthy indoor environment that promotes cognitive performance and student well-being. From the data collected, ergonomic recommendations will be developed aimed at improving indoor air quality and, consequently, optimizing environmental comfort in educational environments. These recommendations will focus on ventilation and environmental control strategies that contribute to creating an ergonomically appropriate environment that supports both the physical health and academic performance of students.

3. METHODOLOGY

This study focuses on evaluating how indoor air quality influences ergonomic comfort in educational classrooms, with a focus on its impact on students' health and cognitive performance. The methodology was designed to measure key parameters that affect the ergonomic environment, such as carbon dioxide (CO2) concentration, relative humidity, temperature and air velocity, under different occupancy and ventilation conditions.

3.1 Site Description

The study was conducted in two representative classrooms located in an educational building, selected for their characteristics that are typical of a closed learning environment. These classrooms, referred to as Classroom 1 and Classroom 2 for the purposes of this study, have a capacity of approximately 35 students, with floor areas of 62 m² and volumes of 183 m³ each.

The building where these classrooms are located is used for various academic activities and offers a space representative of common closed educational environments. The classrooms have a natural ventilation system, complemented by a mechanical air extraction system, which was inoperative during the study period. This scenario allowed us to analyze how natural ventilation, prevalent in many educational environments, affects ergonomic conditions, considering the limited airflow and its impact on thermal comfort and indoor air quality.

3.2 Classroom Characteristics

Both classrooms have a similar structure, which allows a comparative analysis under controlled conditions. They are equipped with windows that can be opened for natural ventilation and an air extraction system designed to create a vacuum and allow fresh air to enter from the corridors through ventilation louvers in the doors.

The lack of operation of the air extraction system during the study meant that ventilation relied primarily on natural convection, a process in which air moves due to differences in temperature and density. This context is ideal for assessing how insufficient ventilation conditions affect the perceived comfort and ergonomic well-being of the occupants.

3.3 Measurement Procedure

Air quality measurements were performed in two scenarios: empty classrooms and classrooms during teaching activities, to simulate real conditions of occupancy and use. Several parameters were measured to assess their impact on students' ergonomic comfort.

Carbon dioxide (CO2) concentration was recorded to evaluate how the accumulation of this gas can influence students' fatigue, drowsiness and reduced cognitive capacity, critical aspects in educational ergonomics. Relative humidity and temperature were also measured to understand how these factors affect the thermal comfort and respiratory health of occupants. Maintaining these parameters within ergonomically acceptable ranges is essential to prevent discomfort and improve the quality of the learning environment.

Air velocity was measured using an anemometer to calculate the air turnover rate per hour (ARHR), which is crucial to ensure an adequate supply of fresh air and maintain a healthy indoor environment. Ergonomics focuses on how adequate ventilation and airflow contribute to the comfort and well-being of students, improving their ability to concentrate and learn.

3.4 Data Analysis

The data collected were analyzed to identify patterns in air quality and their relationship to ergonomic comfort. Measurements of CO2, humidity, temperature and air velocity were compared under different occupancy conditions, using ergonomic standards and international regulations as a reference to assess optimal air quality conditions in educational environments.

The analysis focused on how variations in these parameters affect the perception of comfort and productivity, providing a basis for developing ergonomic recommendations to improve indoor air quality in educational classrooms.

3.5 Implementation of Recommendations

Based on the results obtained, ergonomic recommendations were developed to optimize indoor air quality and, consequently, environmental comfort in educational settings. These recommendations focus on strategies to improve natural ventilation, adjust temperature and humidity settings, and maintain adequate levels of air renewal, fundamental elements to ensure a healthy ergonomic environment that favors learning and student well-being.

4. RESULTS

Indoor air quality is a fundamental factor for ergonomic comfort in educational environments, as it directly affects the health, well-being and cognitive performance of students. The results obtained in this study, analyzed with an ergonomic approach to understand how environmental conditions in classrooms impact user ergonomics, are presented below.

4.1 Hallway Wind Speed Analysis

Velocities were sampled in the corridors as shown in Figure 4.1. The strategy is based on the fact that the corridors would be the only external source for the entry of fresh air into the rooms, due to a concentration gradient produced basically by the partial pressure of oxygen O2 between the room interior and the corridor.

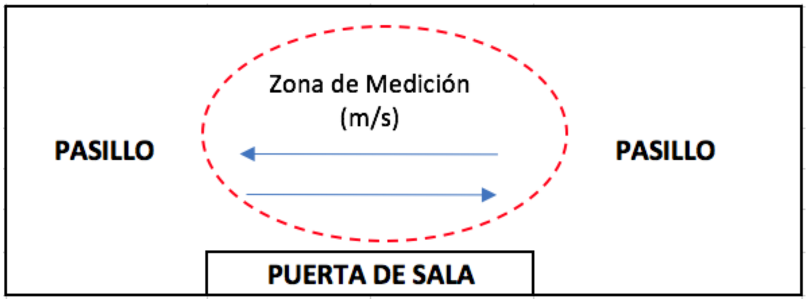

Figure 1. Plan view of the air measurement area in corridors

The results of the wind speed measurements in the corridors, presented in Tables 4.1 and 4.2, indicate significant variations in air speed at different locations within the building.

The lowest velocities were recorded in the corridors corresponding to classrooms 405 to 408 and 505 to 509, with average values of 0.189 m/s and 0.079 m/s respectively.

Table 1. Results of corridor measurements indicating standard deviation

Detail	Velocity (m/s)	S.D (m/s)
Aisle speed Rooms 110 to 115	0,811	0,268
Aisle speed Rooms 101 to 104	0,553	0,221
Aisle speed Rooms 201 to 204	0,346	0,132
Aisle speed Rooms 301 to 305	0,258	0,124
Aisle speed Rooms 401 to 404	0,195	0,068
Aisle speed Rooms 403 to 404	0,198	0,101
Aisle speed Rooms 405 to 408	0,189	0,094
Aisle speed Rooms 505 to 509	0,079	0,024

Table 2. Results of measurements outside the rooms indicated.

Rooms	velocity (m/s)	S.D (m/s)
405	0,182	0,071
406	0,176	0,072
407	0,164	0,091
408	0,161	0,085
505	0,101	0,038
506	0,198	0,099
507	0,079	0,031
508	0,067	0,022
509	0,063	0,021

From an ergonomic point of view, air velocity in corridors is relevant because it influences air renewal and the quality of the indoor environment in adjacent classrooms. In corridors with low air velocity, such as those mentioned above, natural ventilation is less effective, which can result in an accumulation of pollutants such as CO2. This negatively affects students' perception of comfort, as poor ventilation can lead to symptoms of fatigue, lack of concentration and general discomfort, all critical aspects of educational ergonomics.

4.2 Analysis of measurements in empty classrooms

4.2.1 Room 509

The results of the measurements in Room 509, taken under empty classroom conditions between 07:45 and 08:00 hours in September, show variations in both temperature and relative humidity. Figure 4.1 shows that the average relative humidity is approximately 44%, while the temperature ranges around 17°C.

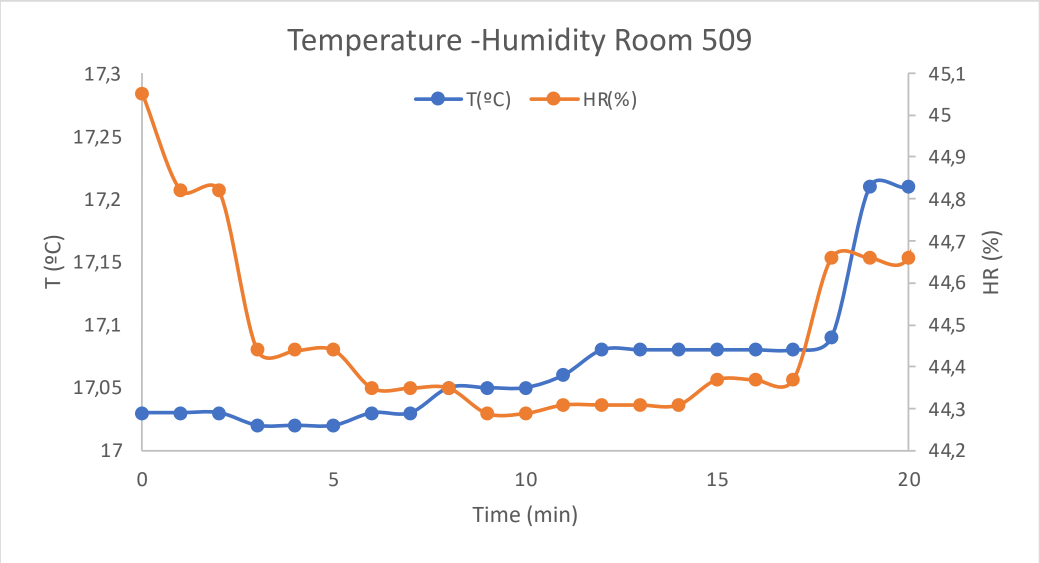

Figure 2: variation of temperature and humidity, room 509, empty

From an ergonomic perspective, humidity is within the upper recommended range for educational environments, which according to ASHRAE is between 40% and 60%. Although these values seem adequate, excessive humidity can generate long-term thermal discomfort, affecting students' sense of well-being, especially under conditions of prolonged occupancy. Thermal comfort is crucial in learning spaces, since a feeling of discomfort can reduce the capacity for concentration and attention, generating stress and decreasing academic performance.

Temperatures around 17°C can be perceived as cool, especially during colder times of the year. According to studies on thermal comfort, maintaining an optimal temperature in the classroom, generally between 19°C and 22°C, ensures that students do not experience feelings of cold that may divert their attention from learning. A lower temperature, such as the one recorded in this case, can generate distractions and a feeling of discomfort in the body, negatively affecting cognitive ability.

Figure 4.2 shows the variation of CO2 concentration in the empty Room F-509. At the beginning of the day, the CO2 concentration was around 460 ppm, which is in equilibrium with the outside conditions, where a similar concentration of 465 ppm was recorded. These values are normal for an unoccupied space, as there is no internal generation of CO2 by the occupants.

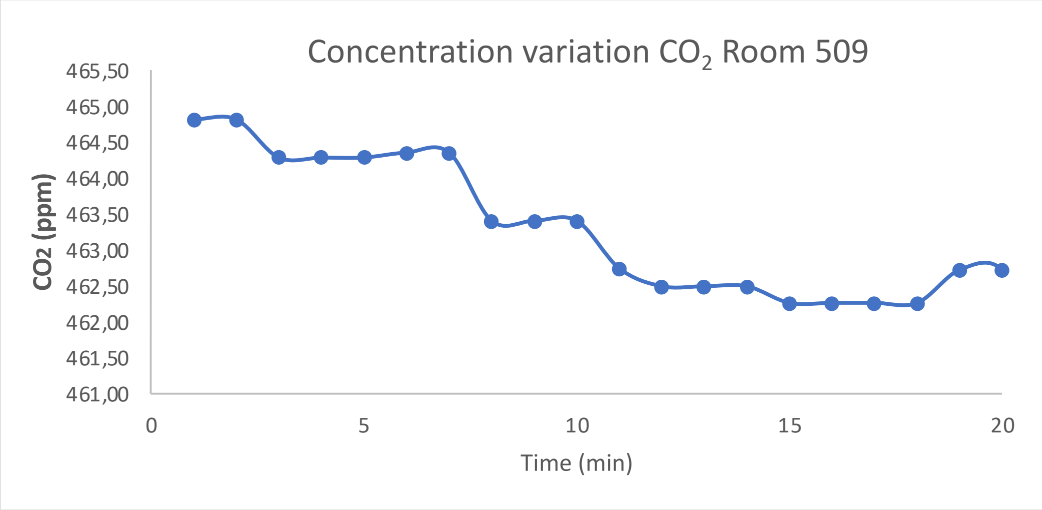

Figure 3: CO2 variation in empty room 509

However, from an ergonomic approach, it is crucial to anticipate the impact of room occupancy. As spaces fill up, CO2 accumulation increases rapidly, affecting the comfort and health of students. In poorly ventilated environments, elevated CO2 levels can exceed 1000 ppm in a short time, leading to drowsiness, fatigue and decreased cognitive performance. In the long term, this can have negative implications on the physical and mental well-being of students.

4.2.2 Room 408

The analysis of Room 408 shows similar behavior. In Figure 4.3, the relative humidity is around 42%, while the average temperature is 16°C. These values reflect conditions relatively similar to those observed in Room F-509. As in the previous case, the humidity remains in an acceptable range, although close to the recommended lower limit, which may influence the feeling of dryness of the environment, affecting the students' perception of comfort. In low humidity conditions, skin and mucous membranes may dry out, which in turn increases the feeling of discomfort.

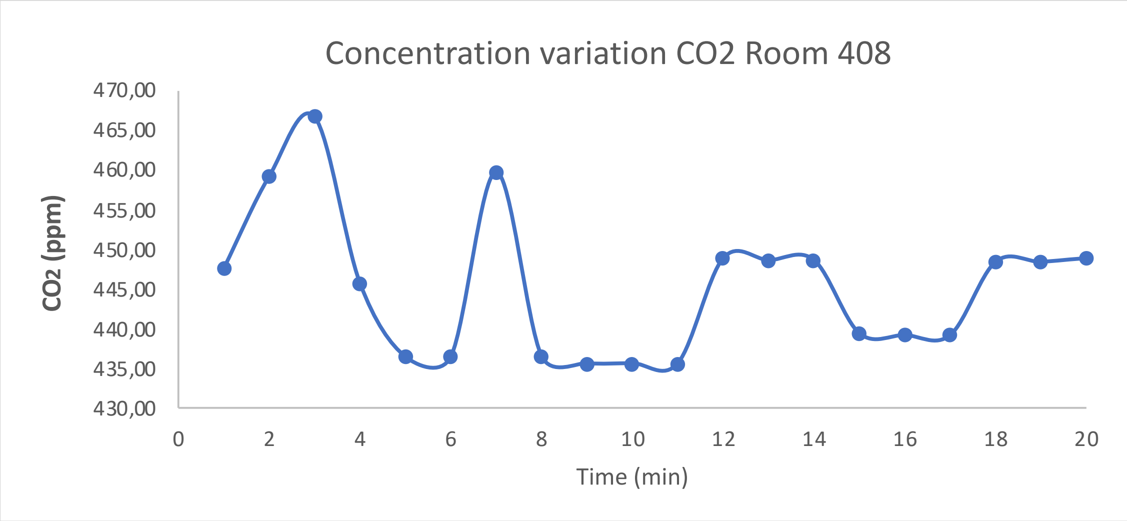

Figure 4: variation of temperature and humidity in empty room 408

The temperature of 16°C can also be perceived as cold, and according to thermal comfort recommendations, an optimal learning environment should maintain a temperature above 18°C. This low temperature can affect physical comfort, especially if students remain still for long periods. Lack of thermal comfort can increase distraction and decrease academic performance.

Figure 4.4 shows the variation of CO2 concentration in Room 408 before the start of the normal school day. The CO2 values range from 430 to 460 ppm, indicating equilibrium conditions when the classroom is empty. These levels are normal and do not represent a health or comfort risk at that time.

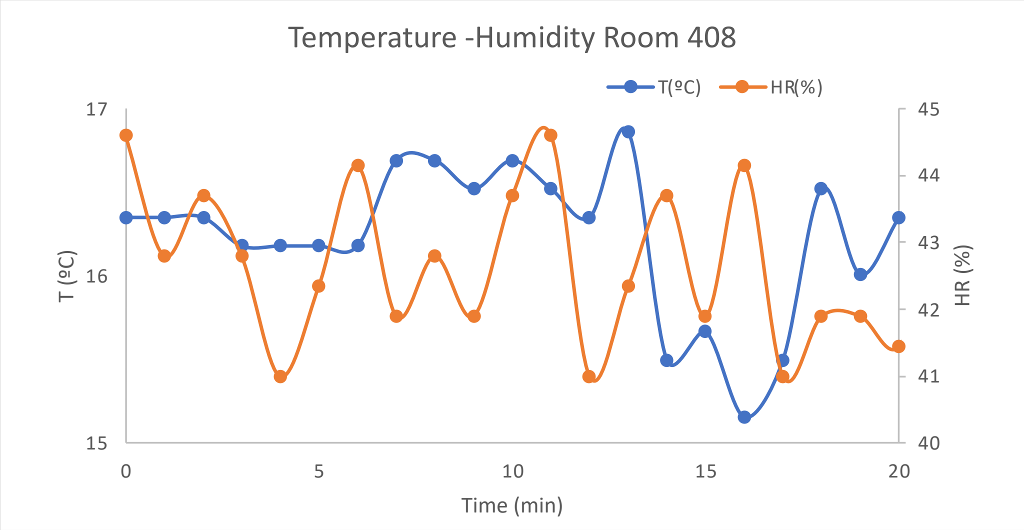

Figure 5: CO2 variation in empty room 408

However, when conditions during regular classroom use are considered, CO2 accumulation becomes critical. Under full occupancy conditions, lack of adequate ventilation can result in a rapid increase in CO2 levels, affecting air quality and perception of comfort. Elevated CO2 levels are associated with negative effects on attention span, leading to fatigue, headaches and decreased academic performance.

4.3 Analysis of Indoor Air Quality Measurements in Classrooms with Teaching Activities

4.3.1 Analysis of Air Quality in Classroom 408

During the months of September and October, air quality measurements were taken in Classroom 408 during teaching activities, obtaining results that reflect conditions that affect student comfort. Figures 4.5 and 4.6 show the evolution of CO2 concentration in the room with 20 and 35 students, respectively, during classes between 08:30 and 11:00 hours. For 20 students, the CO2 concentration reached a maximum value of 1654 ppm 70 minutes into the day. For 35 people, the maximum concentration was 2150 ppm at 65 minutes. These CO2 levels exceed 1000 ppm, which is related to decreased environmental comfort and cognitive performance of students, since concentrations above 1000 ppm are associated with symptoms such as drowsiness, fatigue and lack of concentration. These effects can severely affect productivity in teaching activities.

In addition, the time required to reach 1000 ppm is also relevant. With 20 students, 1000 ppm was reached in approximately 50 minutes, while with 35 students, this value was reached in only 22 minutes. This implies that, in classrooms with high occupancy, air quality deteriorates more rapidly, affecting the well-being and attention span of students.

In both situations, after 60 minutes of classes, students began to leave the classroom, which is reflected in the decrease in CO2 levels. This phenomenon indicates that the indoor air quality was affecting the comfort of the students, forcing them to leave the room to seek fresh air. This behavior can negatively influence the development of learning activities.

Regarding temperature and humidity conditions, graphs 4.7 and 4.8 show the evolution of these parameters in the room with 20 and 35 students. With 20 students, humidity reached a maximum of 59% at 75 minutes, while with 35 students humidity reached 69% at 45 minutes. These values exceed the recommended optimum humidity levels, which are generally between 40% and 60%. High humidity can generate feelings of thermal discomfort, making it difficult for students to learn and concentrate.

On the other hand, the temperature remained relatively constant at around 17°C (63°F). Although this temperature is within acceptable limits, a more precise and adequate temperature control could contribute to improve the thermal comfort of the students.

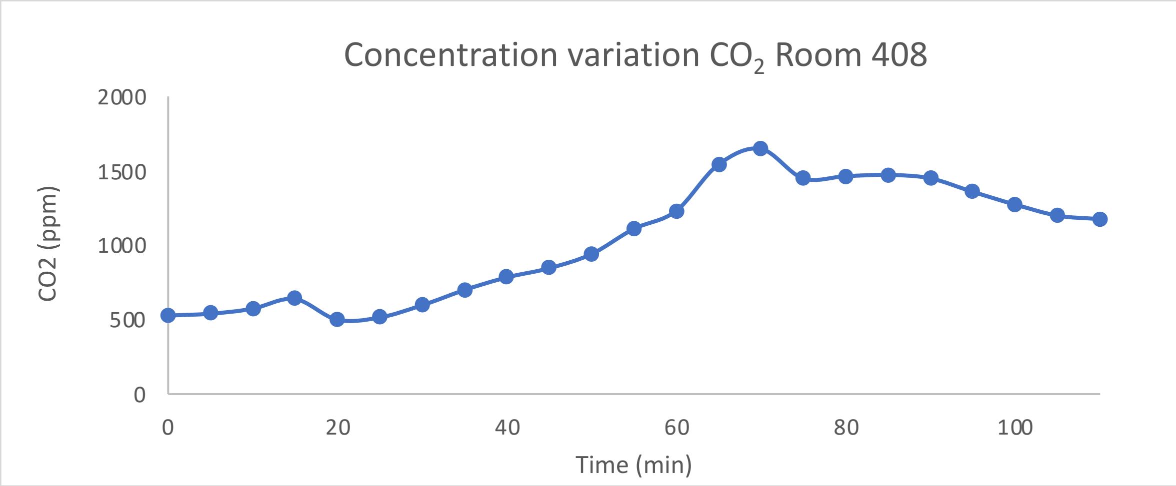

Figure 6: CO2 behavior in the room with 20 students

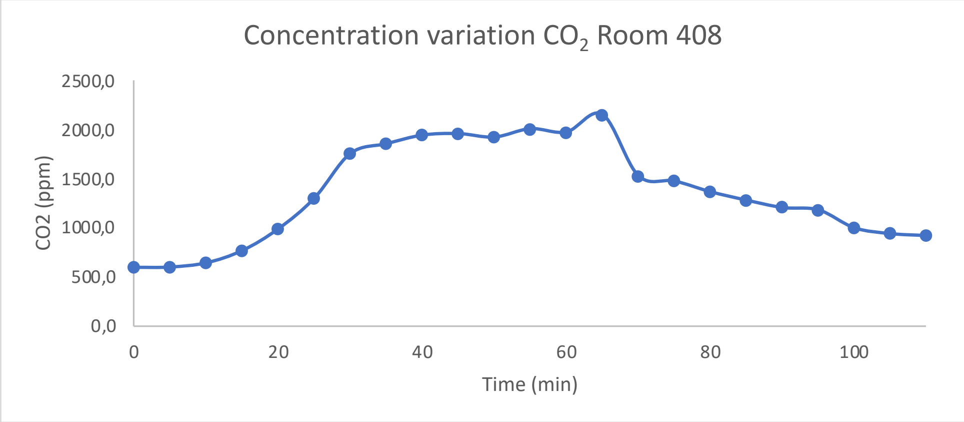

Figure 7: CO2 performance in the room with 35 students

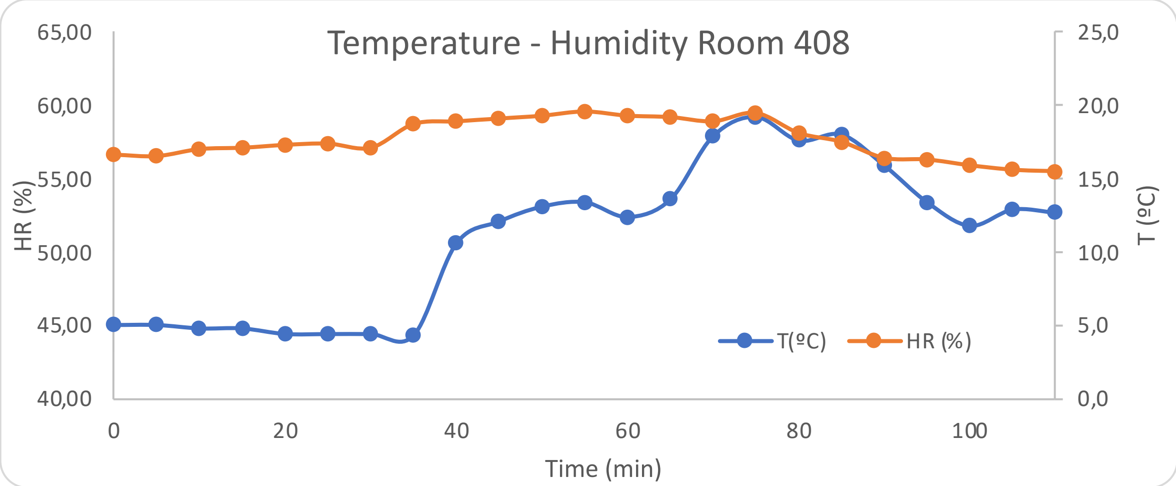

Figure 8: Humidity and temperature behavior in the room with 20 students

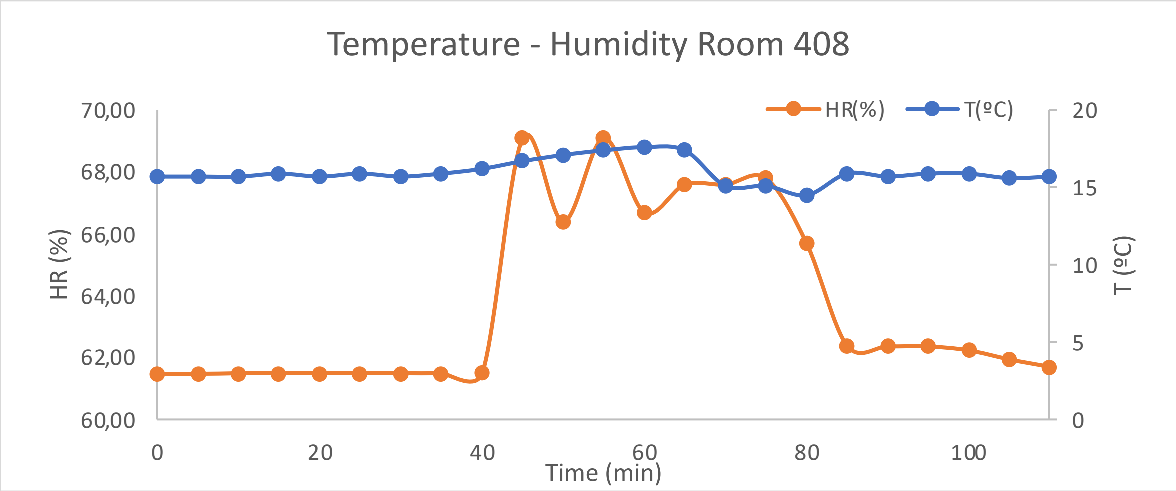

Figure 9: Humidity and temperature behavior in the room with 35 students

4.3.2 Analysis of Air Quality in Classroom 509

Measurements taken between September and October in Classroom 509 also reveal problems related to air quality during teaching activities. Figures 4.9 and 4.10 show the evolution of the CO2 concentration in the room with 45 and 30 students, respectively.

In the case of 45 students, the CO2 concentration reached a maximum peak of approximately 3500 ppm at 75 minutes, coinciding with the performance of a contest. This concentration is significantly higher than the recommended levels for maintaining a healthy and productive environment. Inadequate ventilation and lack of air renewal contribute to CO2 levels quickly exceeding the acceptable threshold of 1000 ppm, which was reached in this case in only 30 minutes. This situation causes significant discomfort, with possible adverse health effects, such as fatigue and lack of concentration.

For the case of 30 students, the CO2 concentration reached 1000 ppm in about 30 minutes and reached a stationary maximum at 50 minutes, maintained for a period of about 30 minutes. This trend shows once again how indoor air quality deteriorates rapidly with room occupancy, affecting occupant comfort.

The decrease in CO2 concentration observed in both graphs can be attributed to the fact that students began to leave the room, reflecting that the poor indoor air quality was negatively impacting their well-being. This indicates that it is critical to improve ventilation and air renewal systems to prevent CO2 concentrations from affecting student comfort and productivity.

Regarding humidity and temperature, Figures 4.11 and 4.12 show their evolution in the classroom with 30 and 45 students. In the case of 30 students, the measurement was taken on a rainy day, which caused the humidity in the room to reach a peak close to 70%, with temperatures in the range of 14°C to 17°C. These conditions, combined with the high outdoor humidity, negatively affected the thermal comfort of the students.

In the case of 45 students, humidity peaked at 65% in clear weather conditions, and the temperature peaked at 20°C, remaining constant for approximately 50 minutes. Although these conditions are within acceptable limits, high humidity is still a factor that can generate discomfort and affect student performance.

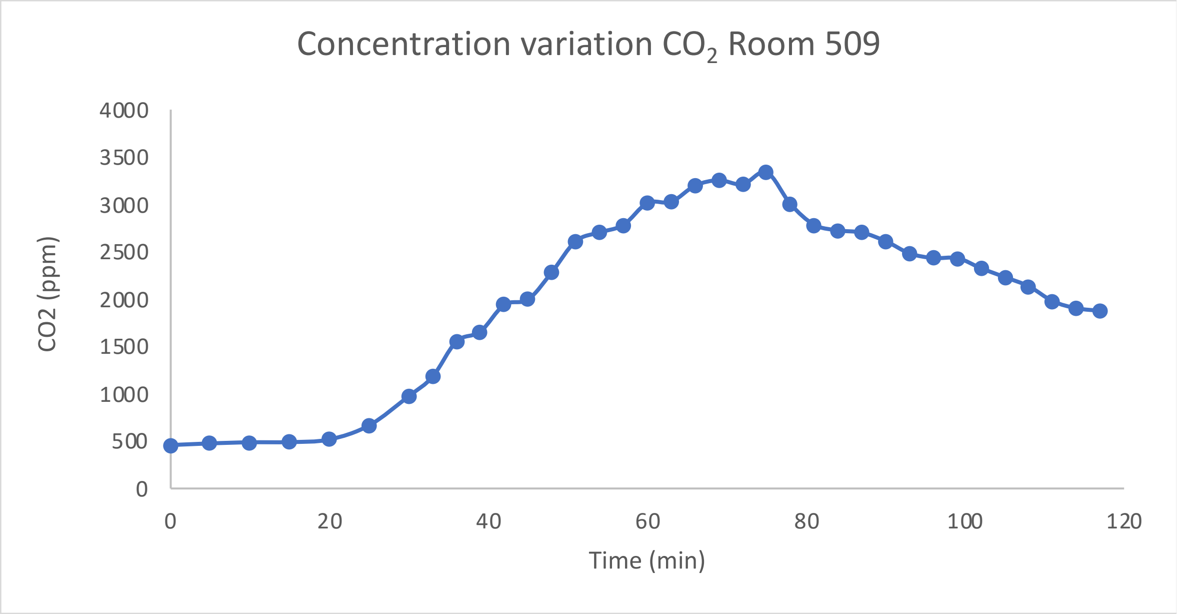

Figure 10: CO2 performance in the room with 45 students

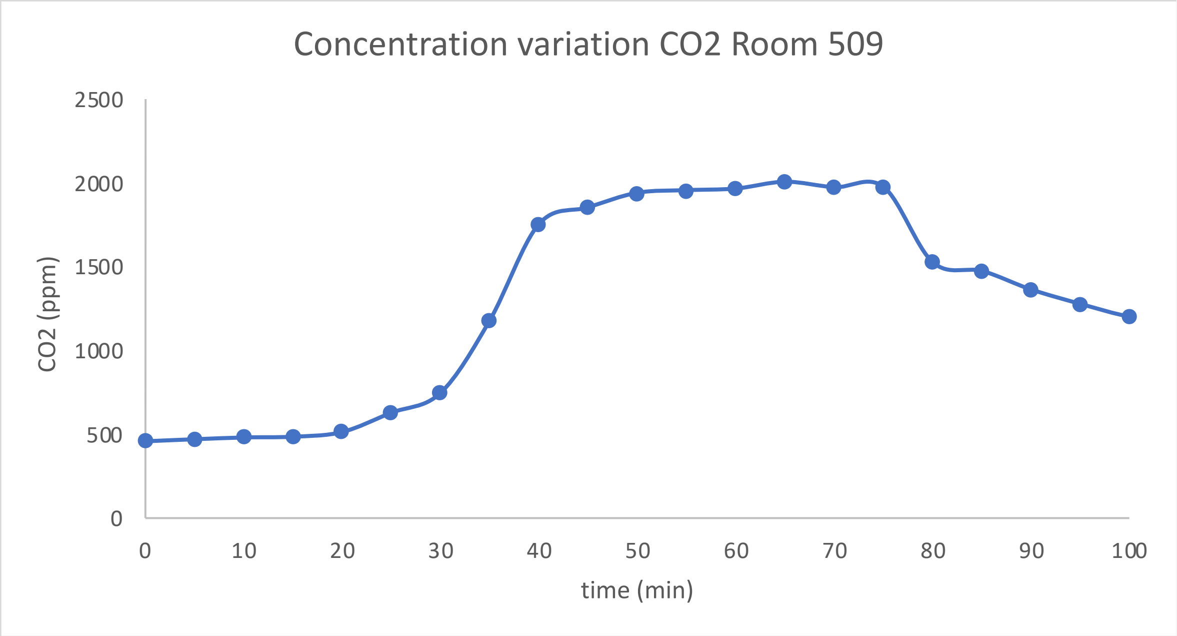

Figure 11: CO2 performance in the room with 30 students

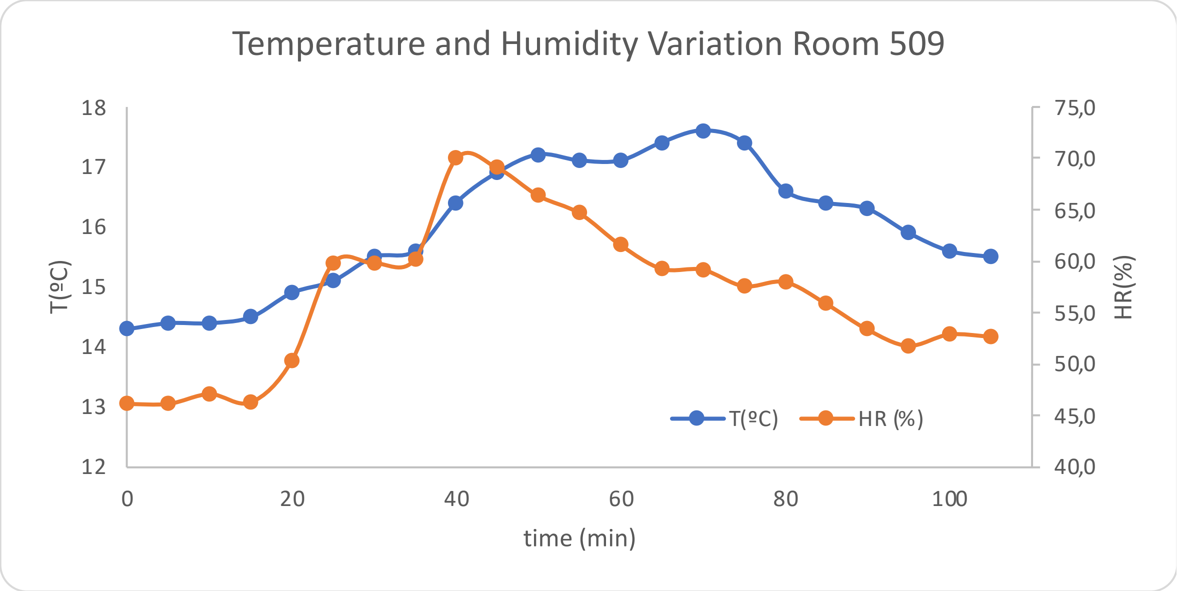

Figure 4.11: Humidity and Temperature behavior in the room with 30 students

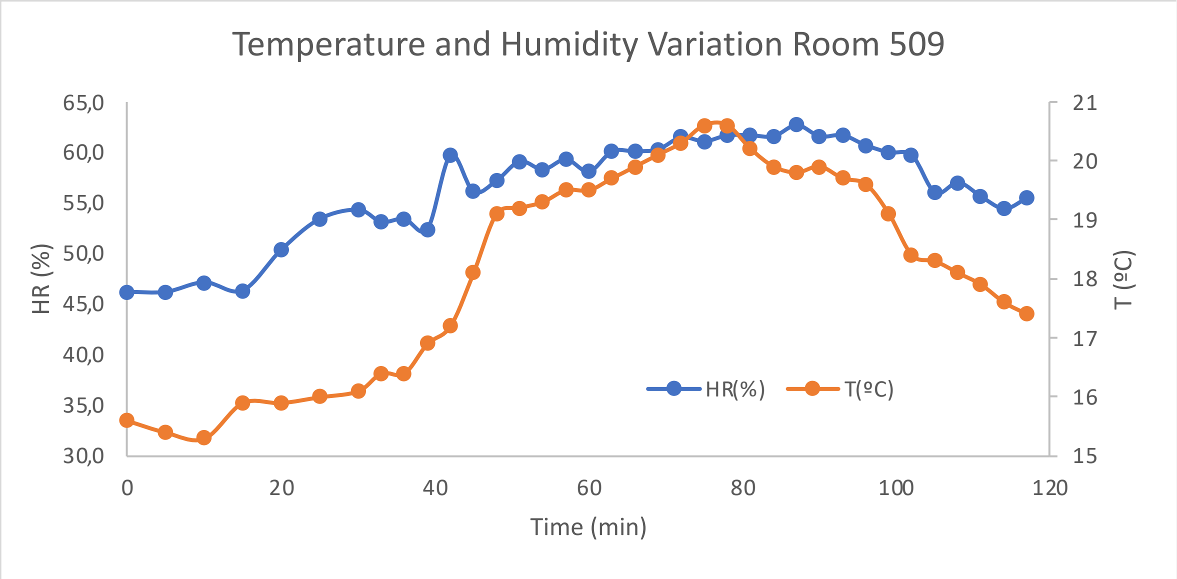

Figure 12: Humidity and Temperature behavior in the room with 45 students

4.3.2 Air velocity analysis inside the classrooms

Air velocity measurements were carried out inside the classrooms from 09:00 to 12:00 hours. The average values obtained were as follows:

- Velocity Inside Classroom 509: 0.06 m/s (±0.01).
- Indoor Velocity Classroom 408: 0.08 m/s (±0.01)

The value of 0.01 m/s corresponds to the margin of error of the measuring equipment used, according to the data provided by the manufacturer. It should be noted that although both classrooms are equipped with two exhaust fans each, these were not operational at the time of the measurements, as evidenced by the data obtained with the hot wire thermo anemometer.

In this scenario, the only sources of air movement are the currents circulating through the door ventilation louvers, as well as a small fraction entering through the door joints and slots.

The velocities measured at the ventilation louvers in the classroom doors were as follows:

- Classroom 509: 0.10 ±0.01 m/s.
- Classroom 408: 0.12 ±0.01 m/s

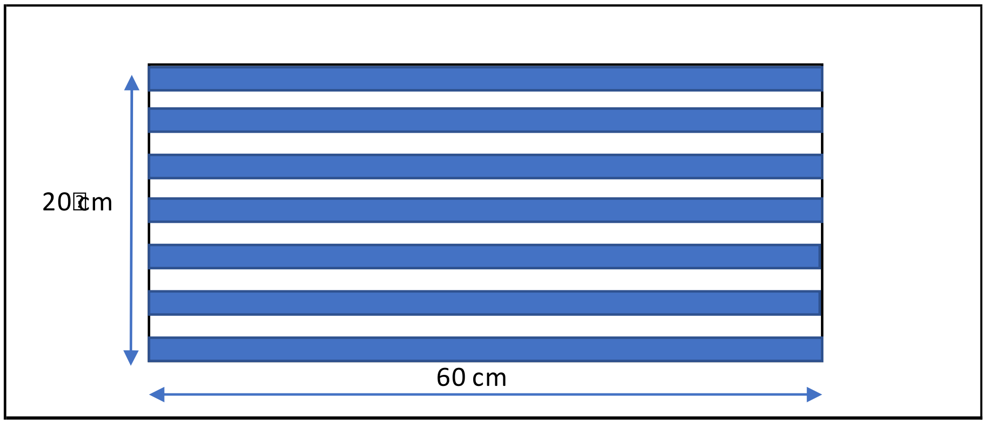

Figure 13: sketch of the dimensions of the ventilation louvers of both access doors

Using the data on the dimensions of the ventilation louvers (Figure 4.2), the effective air circulation area was calculated. In both classrooms, this area corresponds to approximately 70% of the total area of the ventilation louvers. The calculation of the air circulation area is as follows:

$$Circulation\ Area = Grid\ Length\ \times Width\ of\ Air\ Inlet\ Space\ \times No.of\ Spaces$$
$$Circulation\ Area = 0.6\,m\ \times 0.02\,m\ \times\ 6 = 0.072\,m^2$$

Together we calculate the air flow rate from equation:

$$Q\left(\frac{m^3}{h}\right) = 0{,}11\frac{m}{s}\times\ 0{,}072\,m^2 = 28{,}51\frac{m^3}{h} \quad (1)$$

Finally, the following formula was used to calculate the air turnover per hour (AHR):

$$AHR = \frac{28{,}51\,m^3/h}{183\,m^3} = 0{,}16\ \frac{Renovations}{h} \quad (2)$$

This value indicates that the air in both classrooms is renewed only 0.16 times per hour, which is significantly lower than the recommended standard of 4 to 8 renewals per hour for teaching spaces.

4.4 Results based on the Theoretical Framework

4.4.1 Carbon Dioxide

The results obtained in classrooms F-408 and F-509 reveal that in all scenarios evaluated, the concentration of carbon dioxide (CO2) exceeded 1000 ppm, even under conditions of lower occupancy. This increase in CO2 is not immediate; it starts at approximately 400 ppm and reaches 1000 ppm in a period ranging from 20 to 40 minutes. Concentrations above 1000 ppm are associated with an inadequate environment for attention and cognition, fundamental aspects in learning processes (del Campo and Mendivil, 2006; Marta et al., 2010; Montero et al., 2011).

Prolonged exposure to high levels of CO2 can generate fatigue, decreased concentration and drowsiness, directly affecting the ability of students to perform their academic activities effectively. From the data obtained, it is observed that in both classrooms, CO2 concentration decreases when students begin to leave the classroom, suggesting that poor air quality is affecting their well-being and, possibly, their ability to concentrate and perform.

The observed behavior is also related to the intermittent opening of the access door, which facilitates air transfer and decreases CO2. However, this method has drawbacks, such as the entry of external noise and a loss of heat, which generates a “cold sensation” in the students, affecting their thermal comfort. This cycle of opening to ventilate, followed by thermal discomfort, interrupts concentration and affects learning efficiency.

4.4.2 Relative Humidity and Temperature

Indoor relative humidity performance remains around 60% in all scenarios evaluated, even with fewer students. According to ASHRAE (standard 62-1989), the ideal humidity should be between 40% and 60%. However, Pérez Soriano (2012) states that, in educational centers, humidity levels should be between 35% and 45% to ensure a comfortable and healthy environment. Higher humidity levels generate discomfort, hindering the learning process and affecting health by promoting the development of biological contaminants such as fungi and bacteria (NTP 409: Biological contaminants: assessment criteria).

Air thinning due to high humidity can aggravate thermal discomfort, making students uncomfortable, which negatively influences their performance. In addition, the interior temperature observed in both classrooms ranges between 13°C and 17°C, which can result in a cold sensation, especially when the door is opened to ventilate. According to Pérez Soriano (2012), a temperature variation greater or less than one degree above or below body temperature (37°C) can generate thermal discomfort and affect physical and mental performance.

The lack of temperature control in classrooms can exacerbate thermal discomfort, so it is recommended to implement a heating system in cold periods or an air conditioning system in warm periods. This would allow maintaining a stable temperature and improve the thermal comfort of the students, avoiding thermal stress that can influence their ability to learn.

4.4.3 Air Velocity and Air Renewal

The air velocity measured inside the classrooms is extremely low, on the order of hundredths of meters per second, which is attributed to natural convection processes. This parameter is almost imperceptible to the occupants of the classrooms, which contributes to the feeling of air stagnation. The highest velocity point recorded corresponds to the ventilation louver at the doors, where a velocity of approximately 0.10 m/s was measured, resulting in a ventilation flow rate of approximately 28.51 m^3/h.

To maintain a healthy indoor environment, ASHRAE recommends a minimum of 36 m^3/h per person. Considering this standard, the air supply per person in classrooms with 20 students is only 1.42 m^3/h, which represents a deficit of 96% with respect to the recommended standard. In the case of classrooms with 45 students, the fresh air supply drops to 0.63 m^3/h per person, which represents a deficit of 98.2%.

From an ergonomic perspective, this insufficient level of air renewal has a negative impact on the well-being and health of students. Lack of adequate ventilation not only affects air quality, but also cognitive ability and overall comfort. Low oxygenation levels and the accumulation of pollutants can result in fatigue, irritation and decreased academic performance.

4.4.4 Improvement Proposals

To improve these conditions, it would be necessary to ensure an air renewal per hour in the range of 4 to 8 times. Considering that the volume of each classroom is approximately 183 m^3, the air flow necessary to meet this standard would be between 732 m^3/h and 1464 m^3/h. This flow rate should be distributed between the two air extraction points in the classrooms, as shown in Figure 14.

In addition, in the fall and winter seasons, consideration should be given to installing a system that preheats the fresh air to avoid sudden temperature changes. This would help maintain a more stable environment and avoid respiratory illnesses that can affect the well-being of students. In the long term, it is recommended that a mechanical ventilation system be implemented to ensure adequate indoor air quality and, therefore, an environment conducive to learning and the development of academic activities.

5. CONCLUSIONS

The study conducted on indoor air quality in educational classrooms has highlighted the importance of this factor in ensuring an adequate ergonomic environment that favors the well-being and cognitive performance of students. The main findings with an ergonomic approach are presented below:

- Current air quality conditions in the classrooms evaluated do not meet the minimum standards required for a healthy learning environment. The accumulation of carbon dioxide (CO2) at significantly high levels, due to insufficient ventilation, negatively affects the comfort and cognitive ability of students. These elevated CO2 levels exceed the limits recommended by ergonomic regulations, which can cause drowsiness, fatigue and decreased concentration, all factors that compromise the teaching-learning process.
- The fresh air flow available to students under current teaching conditions is significantly lower than recommended by international ergonomic standards. With air renewal values that are between 94% and 96.2% below what is recommended, the indoor environment quickly becomes inadequate to maintain student concentration and comfort.
- The air renewal rate per hour in both classrooms is approximately 0.16, well below the recommended range of 4 to 8 renewals per hour for educational spaces. This low renewal rate implies that indoor air is insufficiently cooled, which contributes to the accumulation of pollutants and deterioration of air quality, affecting both the physical health and academic performance of students.

5.1 Recommendations

To improve the ergonomic environment in classrooms and ensure a healthy and productive learning environment, the following recommendations are proposed:

5.1.1 Administrative Recommendations

Reduction of Class Time: It is recommended to reduce the duration of classes in classrooms that reach their maximum occupancy capacity, limiting class blocks to 40 effective minutes. This measure can help reduce the accumulation of CO2 and other pollutants, providing students with a healthier and more comfortable learning environment.

Scheduled Breaks: In situations where teaching activities extend over two or more class blocks in classrooms with maximum occupancy, it is suggested that breaks of 15 minutes every 40 minutes be implemented. During these breaks, air renewal should be allowed by fully opening the door in cold weather and both the door and windows in warm weather. This practice will help improve natural ventilation and reduce CO2 and humidity levels, thus improving thermal comfort and indoor air quality.

5.1.2 Engineering Recommendations

Improvement of the Ventilation System: It is proposed to develop a project that contemplates the installation of a mechanical ventilation system that allows fresh air to enter and extract fresh air in the classrooms. This system should be located at the points currently used for the screen projectors. In addition, the system should include filters to purify the replacement air and mechanisms to regulate the temperature of the incoming air, ensuring that the indoor environment is comfortable and healthy at all times. The implementation of a controlled ventilation system will contribute significantly to maintaining adequate levels of CO2, temperature and humidity, which are critical for ergonomic comfort and student health.

These recommendations are designed to address the problems identified in the study and improve the ergonomic conditions of classrooms, providing a learning environment conducive to student health, well-being and academic performance. Implementing these measures will not only improve air quality, but also promote a more productive and comfortable educational environment.

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EVALUATION OF NOISE LEVELS IN THE SHRIMP SPAWNING AREA OF AN AQUACULTURE COMPANY

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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.

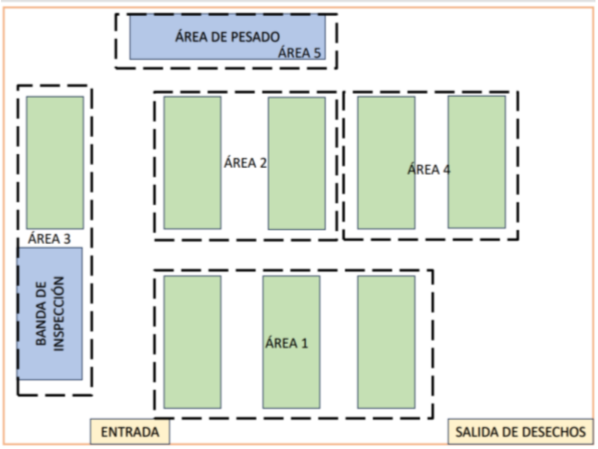


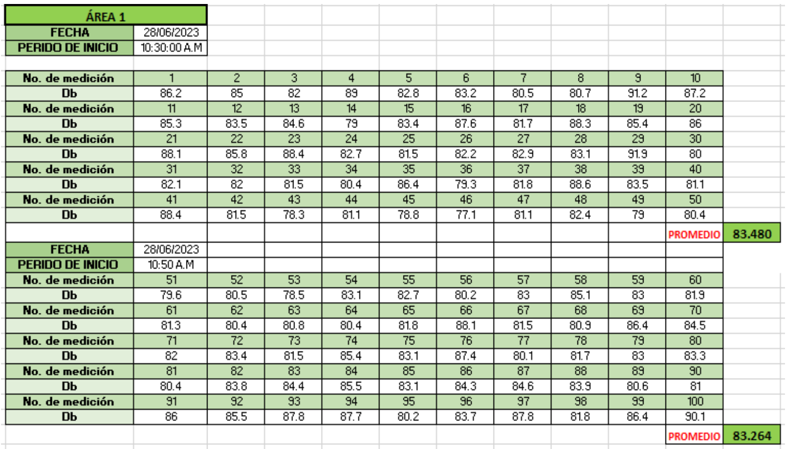
Figure 1. Sectioned area of decapitation

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

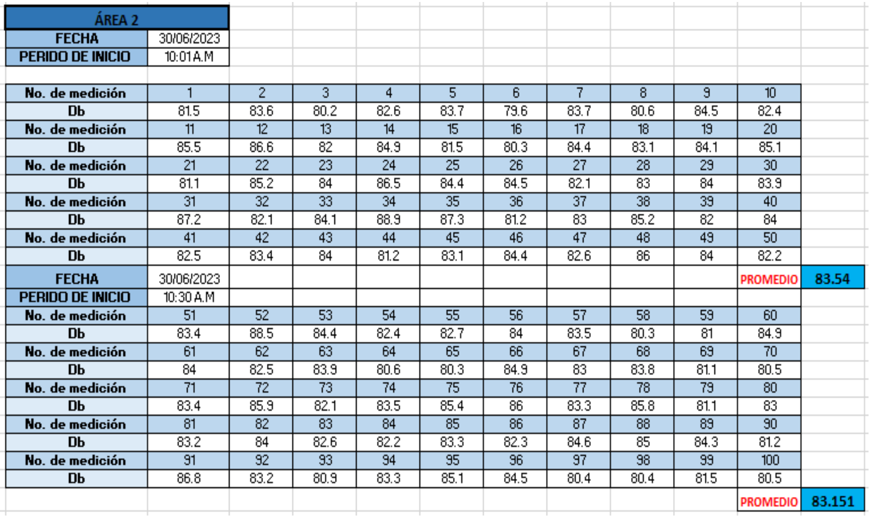
The sampling of each of the areas began. Below is the information collected from areas 1, 2 and 3 with the NSA records captured with the sound level meter (see table 1, 2 and 3), the complement of the samples can be seen in the annexes.

Table 1. NSA samples record area 1



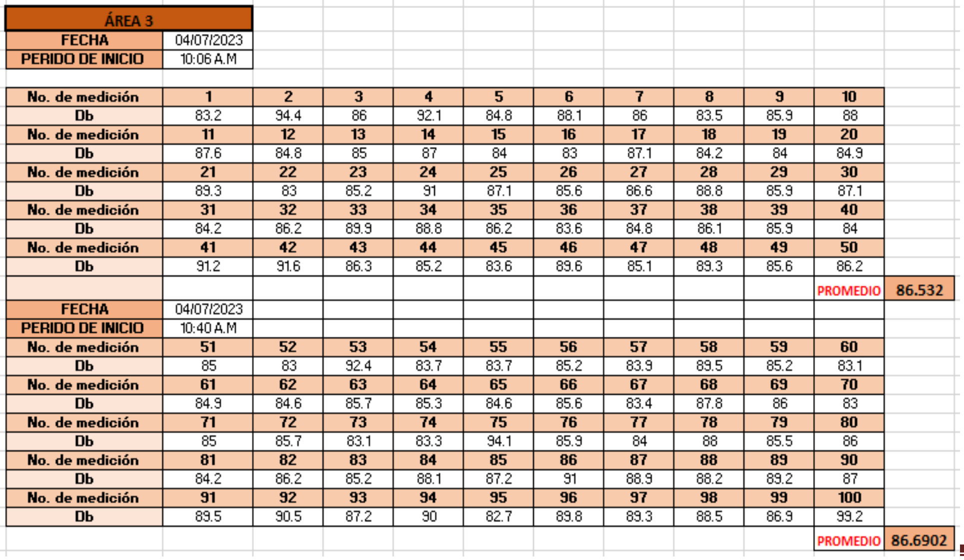
ÁREA 1											
FECHA	28/06/2023										
PERIDO DE INICIO	10:30:00 A.M										
No. de medición	1	2	3	4	5	6	7	8	9	10	
Db	86.2	85	82	89	82.8	83.2	80.5	80.7	91.2	87.2	
No. de medición	11	12	13	14	15	16	17	18	19	20	
Db	85.3	83.5	84.6	79	83.4	87.6	81.7	88.3	85.4	86	
No. de medición	21	22	23	24	25	26	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.

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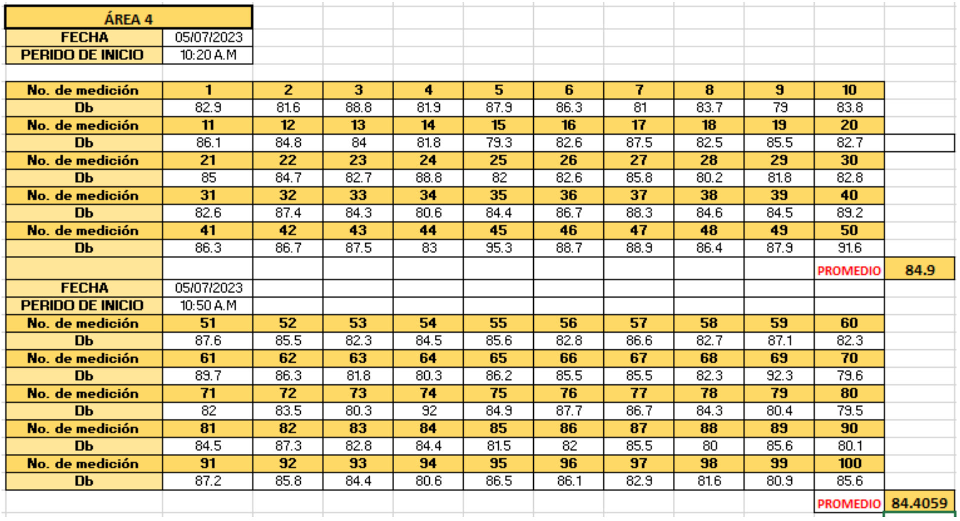
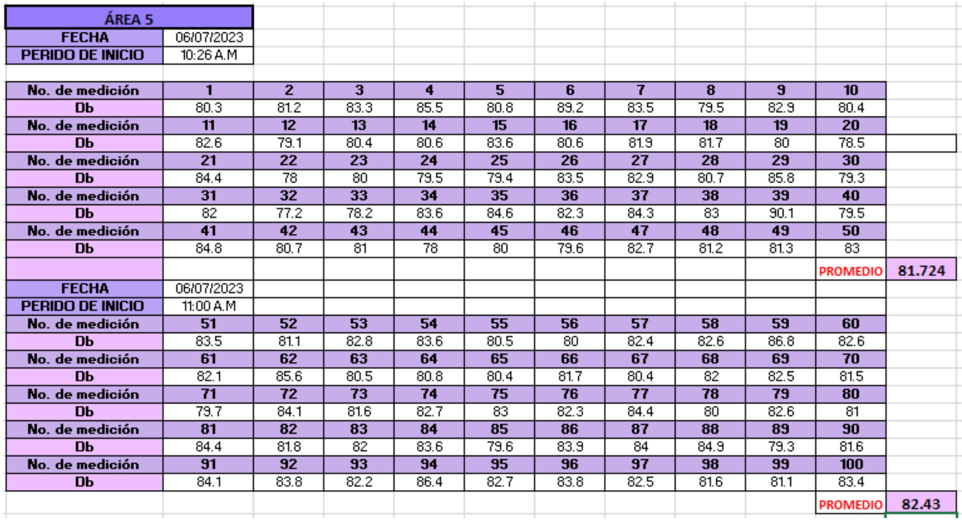
ANNEXES

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 Assessment with a Systems Approach of a Sample of Manicurists in the Metropolitan Area of Guadalajara

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Resumen: La ocupación de manicurista es crucial para la economía mexicana, contribuyendo significativamente al Producto Interno Bruto (PIB) del sector servicios. En el cuarto trimestre de 2023, había 210,000 manicuristas en México, con un 87.5% en la informalidad y un 91.3% de ellas siendo mujeres con una edad promedio de 30 años. La falta de formalidad limita el acceso a prestaciones básicas y al sistema de salud. Aunque la manicura parece sencilla, conlleva riesgos biológicos, físicos, mecánicos, químicos y psicosociales. La ausencia de regulación específica contribuye a condiciones laborales precarias, y la literatura sobre salud en esta industria es limitada. Este estudio busca evaluar cómo el sistema de trabajo afecta los factores psicosociales, la carga postural y la fatiga mental en las manicuristas de la Zona Metropolitana de Guadalajara, en el sector informal, entre septiembre de 2023 y mayo de 2024. Se utilizó una metodología cualitativa exploratoria con 24 participantes, usando entrevistas semiestructuradas, el Método RULA para evaluar posturas, el Diagrama de Corlett y Bishop para síntomas musculoesqueléticos, la Guía 2 de la NOM-035-STPS para factores psicosociales, y la Prueba de Síntomas Subjetivos de Fatiga. Los resultados mostraron que el 25% de las manicuristas presentaba fatiga mental severa y el 50% fatiga física severa. El análisis del Método RULA reveló que el 80% de las participantes estaban en una categoría de riesgo alto para posturas inadecuadas. Los síntomas físicos comunes incluyeron dolores de cabeza, reacciones alérgicas y problemas musculoesqueléticos. La mayoría no usaba equipo de protección adecuado, a pesar de reportar un alto control sobre su trabajo. Las horas de trabajo y la falta de separación entre el espacio laboral y doméstico afectaban negativamente a las trabajadoras. El estudio destaca la necesidad de una evaluación sistémica del sector para abordar las deficiencias en ergonomía física y factores psicosociales. Recomienda la implementación de regulaciones y mejoras en el entorno laboral para proteger mejor a las manicuristas y elevar su calidad de vida. Sin embargo, la muestra no es representativa a nivel nacional, y se sugiere realizar investigaciones adicionales para validar y ampliar estos hallazgos.

Palabras clave: Ergonomía y genero, manicusitas, trabajo infromal

Relevancia para la ergonomía: Esta investigación sobre las condiciones laborales de las manicuristas y su enfoque en la ergonomía proporciona varias contribuciones significativas al campo. Primero, identifica y categoriza los riesgos físicos, químicos, ergonómicos, biológicos, y organizacionales a los que están expuestas las manicuristas. Esto es crucial para diseñar intervenciones efectivas que mejoren las condiciones de trabajo y reduzcan el riesgo de lesiones ocupacionales de este sector tan poco explorado.

No solo se busca beneficiar a las trabajadoras, la investigación aboga por condiciones laborales más justas y seguras, promoviendo el cumplimiento de los derechos laborales y contribuyendo a una mejor calidad de vida en el trabajo.

Finalmente, al educar tanto a las manicuristas como a empleadores y legisladores sobre la importancia de la ergonomía en la prevención de riesgos ocupacionales, esta investigación puede influir en la formulación de políticas públicas y empresariales que fomenten entornos laborales más saludables y sostenibles para todos los trabajadores del sector de la belleza.

Abstract: The occupation of manicurist is crucial for the Mexican economy, significantly contributing to the Gross Domestic Product (GDP) of the service sector. In the fourth quarter of 2023, there were 210,000 manicurists in Mexico, with 87.5% working informally and 91.3% of them being women with an average age of 30. The lack of formalization limits access to basic benefits and the healthcare system. Although manicuring may seem simple, it involves biological, physical, mechanical, chemical, and psychosocial risks. The absence of specific regulation contributes to precarious working conditions, and literature on health in this industry is limited. This study aims to assess how the work system affects psychosocial factors, postural load, and mental fatigue among manicurists in the Guadalajara Metropolitan Area in the informal sector from September 2023 to May 2024. A qualitative exploratory methodology was used with 24 participants, employing semi-structured interviews, the RULA Method to evaluate postures, the Corlett and Bishop Diagram for musculoskeletal symptoms, Guide 2 of NOM-035-STPS for psychosocial factors, and the Subjective Symptoms of Fatigue Test. Results showed that 25% of manicurists had severe mental fatigue and 50% had severe physical fatigue. The RULA Method analysis revealed that 80% of participants were in a high-risk category for inadequate postures. Common physical symptoms included headaches, allergic reactions, and musculoskeletal problems. Most did not use adequate protective equipment, despite reporting a high level of control over their work. Working hours and the lack of separation between work and domestic spaces negatively affected the workers. The study highlights the need for a systemic evaluation of the sector to address deficiencies in physical ergonomics and psychosocial factors. It recommends implementing regulations and improving the work environment to better protect manicurists and enhance their quality of life. However, the sample is not nationally representative, and further research is suggested to validate and expand these findings.

Keywords: Ergonomics and Gender, Manicurists, Informal Work

Relevance to Ergonomics: This research on the working conditions of manicurists and its focus on ergonomics offers several significant contributions to the field. First, it identifies and categorizes the physical, chemical, ergonomic, biological, and organizational risks to which manicurists are exposed. This is crucial for designing effective interventions to improve working conditions and reduce occupational injury risks in this underexplored sector. The research not only aims to benefit workers but also advocates for fairer and safer working conditions, promoting labor rights compliance and contributing to a better quality of work life. Finally, by educating both manicurists and employers as well as legislators about the importance of ergonomics in preventing occupational risks, this research may influence the development of public and business policies that foster healthier and more sustainable work environments for all workers in the beauty sector.

1. INTRODUCTION

The occupation of manicurist, part of the service sector, is crucial to the Mexican economy. According to the National Institute of Statistics, Geography, and Informatics (INEGI), 65% of this sector depends on it in terms of the national Gross Domestic Product (PIB). In the fourth quarter of 2023, the National Occupation and Employment Survey (ENOE) reported that there are 210,000 employed manicurists in Mexico, with Jalisco being the second state with the highest population in this occupation, reaching 19,300 individuals. Alarmingly, 87.5% of these workers are employed informally, and 91.3% are women with an average age of 30 years. These figures highlight the prevalence of informality and the high participation of women and youth in this occupation, underscoring the need to improve working conditions in the sector.

The high level of informality in these jobs means that manicurists do not receive the basic benefits required by law, leaving them in a vulnerable situation with inadequate access to public health services.

The appeal of manicure as a job for many women lies in its apparent simplicity and the low requirements for tools and supplies (Willet, 2005). However, this work involves exposure to various biological, physical, mechanical, chemical, and psychosocial risks. Most manicurists work independently, often from their homes, complicating the separation between work and family life.

In Mexico, there is no specific regulation for the manicure industry, with the only reference being the NORMA NMX-R-085-SCFI-2016 for beauty salons in general. This lack of regulation contributes to precarious working conditions and exposure to toxic substances, with many workplaces lacking proper furniture, adequate ventilation, sufficient lighting, and ergonomic tools, which affects the physical, sensory, and mental health of manicurists.

In terms of research and regulation, the existing literature on the health effects of manicurists is limited (Quirós, 2019), highlighting the need for an ergonomic approach to improve working conditions and promote good practices in the beauty industry. This would not only benefit the health and well-being of workers but also the quality of service provided to the community.

The perspective of this study is a systems approach as it constitutes a holistic and interdisciplinary approach to understanding and solving complex problems. This approach considers that the job consists of interconnected and interdependent elements, whether people, tools, or other components, emphasizing their relationships and interactions.

The main objective of a systemic approach is to design and implement systems that offer the best possible service. This approach has the potential to improve efficiency and understanding of threats and opportunities in service delivery. It is based on principles of systems thinking, systems engineering, design thinking, and social sciences to integrate four key and complementary perspectives:

- People: Analyze how interactions between individuals, groups, organizations, and societies affect the overall performance of the system.
- Systems: Address complex problems involving interconnected technical and social elements, observing behaviors and emerging properties.
- Design: Improve by clearly identifying the problem, exploring multiple solutions, and refining the most effective option to achieve optimal results.
- Risk: Manage risks by identifying threats and opportunities in advance, assessing associated risks, and managing necessary changes.

As noted, one of the four key perspectives is people, making it essential in this study to consider the psychosocial factors that influence the well-being and mental health of workers. Understanding the interaction between physical, organizational, and psychosocial ergonomics can lead to promoting a healthier and more satisfying work environment for all employees.

To define psychosocial factors, we will refer to the report of the Joint ILO-WHO Committee on Occupational Health (Geneva, 1984), which defines them as: “Psychosocial factors at work consist of interactions between work, its environment, job satisfaction, and the conditions of its organization on the one hand, and on the other, the worker's capabilities, needs, culture, and personal situation outside of work, all of which, through perceptions and experiences, can influence health and performance and job satisfaction” (ILO-WHO, 1984, p.12).

These factors can be grouped into the following categories:

- Job content: Refers to the nature of the task that needs to be performed.
- Workload: Includes the demands placed on the worker, including attention effort, quantity and difficulty of tasks, emotional demands, and time pressure.
- Working time: Refers to the number of hours devoted to work activities.
- Autonomy: Relates to the worker's ability to manage certain aspects of their work, including control over time and decisions.
- Interpersonal relationships: Includes the relationships established in the work environment, including social support, leadership, communication, and perception of connection with others.

The occupation of manicure is an artisanal process that, while having a very structured sequence of activities to be followed methodically to achieve its goal, involves countless variations affecting workers' experiences. Without a specific schedule, working hours can exceed those set by law, extreme working hours and lack of breaks add to the physical and mental demands that can severely affect workers.

Working conditions and subjective perception of work are closely linked to workers' mental health, highlighting the need for specific interventions to improve these conditions. It is crucial to note how gender affects the performance of this type of work differently.

A study by Garduño (2005) reviewed literature to analyze the relationship between stress and work on women's mental health and emphasized the importance of considering gender in research on this topic. The study included working women in various labor sectors in both Mexico and Canada. The results highlight that stress has a significant impact on the mental health of working women, manifesting through physical and psychological symptoms. This phenomenon is exacerbated by the additional burden of a double workday, contributing to specific wear and tear experienced by women. Considering gender differences in stress and mental health research is crucial for fully understanding its effects and adequately addressing its causes and consequences. Recognizing and addressing stressful working conditions and domestic work demands emerge as an imperative need to safeguard women's mental health in both work and domestic environments.

In the workplace, not only is stress present, but also psychosocial risk factors (PRFs). In this regard, it has been observed that women predominantly experience sleep disorders, immune system disturbances, eating disorders, and sexual dysfunctions such as anorgasmia, vaginismus, and loss of sexual appetite. Additionally, they often experience emotional effects such as low self-esteem, feelings of guilt, anxiety, distress, sadness, and depression (International Labour Organization, 2016).

If a worker exceeds their capacity, they may experience consequences such as fatigue symptoms, low performance, increasing dissatisfaction, higher risk of accidents, reduced attention, slower thinking, and loss of motivation.

The effects on workers based on psychosocial risks are as follows:

- Physical load**:** Refers to when the task requires muscular activity.
- Mental load**:** When the primary demand is intellectual.

Mental fatigue refers to the sensation people may experience after or during extended periods of cognitive activity. These feelings are common in modern daily life and typically involve tiredness or exhaustion, aversion to continuing the current activity, and decreased commitment to the task (Holding, 1983; Hockey, 1997; Meijman, 2000).

A trauma in the musculoskeletal system results from various factors, many of which are related to workspace design. The process of developing a trauma is so complex that preventing isolated factors proves to be not very useful (Chaffin, 1987). To improve workplace design and reduce the risks of a Cumulative Trauma Disorder, several sub-disciplines have been developed that are useful for the specific job discussed in this study.

Identifying risk factors faced by manicurists, inadequate static postures held for extended periods, unbalanced repetitive hand movements, poor lighting, poor ventilation, and inhalation of chemicals are notable. Some are also exposed to noise, and most experience vibrations from their work tools. The furniture used by manicurists varies widely, and in most cases, the furniture they use is not optimal for performing their tasks, which worsens their already poor posture.

In the last decades of the last century, several studies demonstrated that prolonged sitting work can cause lower back pain (Pope et al., 1984). It is crucial to select a chair and desk that fit the individual's anthropometric characteristics and the type of work performed. In such activities, good lumbar and lower limb support is required to prevent fatigue and circulatory problems (Chaffin, 1987). These requirements, combined with good postural support, reach and visual capacity, increase the complexity of the seated work environment.

Marras (2000) indicates that work postures cause static load on the person's musculoskeletal system. During static work, blood circulation and muscle metabolism decrease, resulting in low work efficiency. Continuous or repeated static loading of uncomfortable postures at work causes local muscle constriction and subsequent fatigue, which, in cases of long duration, can lead to work-related disorders or pathologies.

It is essential to analyze the physical factors that provoke or aggravate a wide variety of inflammatory disorders, often referred to as Cumulative Trauma Disorders from trauma to the upper body or wrist area.

2. OBJECTIVE

To evaluate how the work system influences the presence of psychosocial factors, postural load, and mental fatigue in manicurists.

3. DELIMITATION

Manicurists in the Metropolitan Zone of Guadalajara, belonging to the informal sector. The study was conducted from September 2023 to May 2024.

4. METHODOLOGY

Se realizó un estudio mixto, la primera parte cualitativa exploratorio para obtener un panorama general de las condiciones de trabajo y la segunda parte cuantitativa para complementar la información obtenida.

4.1 Participants

A mixed study was conducted, with the first part being qualitative exploratory to obtain a general overview of working conditions and the second part quantitative to complement the information obtained.

4.2 Variables

- Postural Load: Often during the execution of occupational activities, workers make excessive efforts, maintain inappropriate postures for extended periods, and/or perform repetitive movements. These factors, combined with other occupational sources, can lead to musculoskeletal disorders (Bravo et al., 1988).

- Musculoskeletal Symptoms: A set of symptoms and conditions affecting the musculoskeletal system of the human body. These disorders can include pain, discomfort, stiffness, muscle weakness, swelling, muscle spasms, limited movement, and other symptoms related to muscles, bones, joints, tendons, and nerves (Dunn, 2000).
- Mental Fatigue: Mental fatigue refers to the sensation people may experience after or during prolonged periods of cognitive activity. These feelings are common in modern daily life and generally involve tiredness or even exhaustion, aversion to continuing the current activity, and decreased commitment to the task being performed (Holding, 1983; Hockey, 1997; Meijman, 2000).
- Psychosocial Factors: Psychosocial factors at work consist of interactions between work, its environment, job satisfaction, and organizational conditions, on the one hand, and the worker's capabilities, needs, culture, and personal situation outside of work on the other. These interactions, through perceptions and experiences, can influence health, performance, and job satisfaction (International Labour Organisation; Joint ILO/WHO Committee on Occupational Health, 1984, Geneva, Switzerland).

4.3 Materials and Methods

a. Semi-Structured Interview: Comprising 16 questions covering personal data, health habits, working hours, perception of their work, set goals, limitations, barriers, problems, and benefits related to their profession.
b. RULA (Rapid Upper Limb Assessment): Evaluates static postures of the upper body through frames taken during the task's work cycle. Annotations are made on a worksheet based on the angle relationships between body segments. Scores range from 1 to 7 and are grouped into 4 categories indicating a recommended course of action based on the results.
c. Corlett and Bishop Diagram: A subjective symptom survey tool that assesses the respondent's direct experience of discomfort in various body parts. This tool includes a body map and scales to evaluate the severity, frequency, and duration of pain/discomfort experienced.
d. Guide 2 of NOM-035-STPS**:** A 72-item questionnaire aimed at analyzing and preventing psychosocial risk factors. Employees answer the questionnaire using a Likert scale. The following 5 categories are evaluated:

- Work Environment
- Activity-Specific Factors
- Work Time Organization
- Leadership and Workplace Relationships
- Organizational Environment

e. Subjective Fatigue Symptoms Test: A dichotomous questionnaire designed to identify the type of fatigue experienced by employees (Physical Fatigue, Psychological Fatigue, and Mixed Fatigue/Occupational Fatigue). It consists of 30 items grouped into the following 3 blocks:

- Monotony and Dullness
- Difficulty Concentrating
- Physical Deterioration

5. RESULTS

The sample of the study consisted of 24 female manicurists, with an average age of 34 years and a mode of 24 years. Regarding education, 60% had completed a bachelor's degree, 18% had an incomplete degree, 14% had completed high school, and 8% had incomplete high school. In terms of family, 60% of participants had children, while 50% were single, 21% were married, another 21% were in a common-law relationship, and 8% were divorced.

Regarding physical activity, 21% of the manicurists exercised, while 79% reported a lack of time to do so. In labor terms, 71% indicated that manicure is their main source of income, while 29% considered it a hobby with additional income. Of the participants, 17 worked in their own premises, and 7 worked from home, with an average of 59 hours worked per week.

Knowledge acquisition in manicure varied: 21% learned through product brand courses (e.g., Organic and Fantasy Nails), 29% through courses by self-proclaimed expert manicurists, 37.5% were self-taught using online tutorial videos, and 12.5% received training through the National System for Integral Family Development (DIF).

Analysis of semi-structured interviews, the Corlett and Bishop diagram, the psychosocial risk factors questionnaire according to NOM-035-STPS, and the Subjective Fatigue Symptoms Test revealed important perceptions and working conditions. Repeated concerns related to health were observed, including throat conditions due to inhalation of acrylic dust, headaches from monomer odor, allergic reactions to chemicals, eye injuries from acrylic fragments, chemical burns, and fungal infections on hands and nails.

According to the New York State Department of Health, manicurists should use N-95 or N-100 masks, nitrile gloves or similar impermeable material, eye protection, and a protective uniform. However, in the sample, only 6 manicurists used surgical masks, none used eye protection, 3 used gloves occasionally, and 9 wore aprons, though only 3 used them consistently.

The results indicated that, despite all participants perceiving a high degree of control over their work, they face significant challenges related to working conditions. All manicurists reported having high control over their work, but most were exposed to a workload that falls into a high-risk level. Many worked more hours than the average formal worker, and the lack of separation between work and rest spaces when working from home negatively impacted their ability to disconnect. Additionally, they faced social rejection of their profession, with criticism affecting their perception of the job.

The working canvas involves nails, which are a small surface requiring significant visual attention to work on details. A particular characteristic observed in manicurists, particularly those over 30, was tired eyesight after their shift.

Although each manicurist limits their clientele to certain styles or techniques (e.g., stone application, effects, realistic drawings), they express that each client is a new opportunity for decoration. Depending on their work system, this can be a surprise, putting pressure on them to figure out how to meet the client's final product expectations. The difficulty level of each set created by manicurists is quite broad. Depending on their level of experience, they try to minimize uncertainties by implementing steps in their work system to prepare before appointments. They mention feeling significant pressure during peak seasons or when unprepared, compounded by the expectation of social interaction with clients, which also demands considerable attention from the manicurist.

Regarding fatigue, the Subjective Fatigue Symptoms Test showed that 25% of participants experienced severe mental fatigue, 34% moderate mental fatigue, and 41% mild mental fatigue. Physical fatigue was also significant, with 50% reporting severe physical fatigue and the other 50% moderate physical fatigue. 90% of participants experienced discomfort in areas such as the dominant wrist, neck, and lower back, as well as other physical issues in the upper back, buttocks, and shoulders. These adverse physical conditions are worsened by the informal nature and lack of recognition of their occupation, contributing to stigmatization and social rejection.

The RULA method results showed that 80% had a final score of 7, indicating the need for immediate investigation and change, while the remaining 20% had a final score of 5 or 6, indicating the need for further investigation and prompt change. The body segments with the most significant issues were the wrists and the neck, trunk, and legs, which aligns with the pain reported in the Corlett and Bishop diagram.

In summary, the findings of this initial research provide a detailed and concerning perspective on the working conditions of manicurists. These results highlight the urgent need for substantial changes that not only protect their labor rights but also significantly improve their quality of life. It is imperative to address both the physical and psychosocial aspects of their work environment to ensure fairer and healthier conditions for these workers.

6. DISCUSSION

Based on the results, there is a need for a comprehensive systemic evaluation of the manicure sector. The integration of existing literature and the study's findings reveals that issues in this labor sector are complex and multifaceted. The lack of specific regulations, poor working conditions, and high informality underscore a network of interactions that negatively impact workers' health and well-being. A systemic evaluation allows understanding how different elements, such as physical ergonomics, psychosocial factors, and sector regulation, are interconnected and how each contributes to the observed problems. This holistic approach not only facilitates identifying the underlying causes of the problems but also provides a framework for designing and implementing comprehensive and effective solutions.

Although the study provides a detailed view of manicurists' working conditions, it has limitations that should be considered. The sample is not nationally representative, and the results are based on an exploratory qualitative study. Future research could include longitudinal and broader studies to validate these findings and assess the effectiveness of proposed interventions.

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PSYCHOMETRIC STUDY OF THE NASA-TLX MENTAL WORKLOAD INDEX IN UNDERGRADUATE STUDENT MOTHERS

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Resumen: Este estudio explora la carga mental en madres estudiantes de licenciatura del Tecnológico Nacional de México, campus Agua Prieta, utilizando el Índice NASA-TLX adaptado como herramienta de evaluación. La investigación se centra en identificar y analizar los factores que contribuyen a la carga mental, particularmente en actividades académicas como la presentación de exámenes y la elaboración de trabajos finales en equipo. A través de un enfoque cuantitativo y un diseño no experimental transversal, se recopilaron datos de 47 madres estudiantes, permitiendo evaluar cómo las demandas cognitivas, emocionales y temporales se ven exacerbadas por la necesidad de equilibrar las responsabilidades académicas y familiares.

El estudio validó la adaptación del Índice NASA-TLX en este contexto específico, mostrando una consistencia interna moderada (α=0.644) que mejoró significativamente al eliminar la dimensión de frustración (α=0.816). Este hallazgo sugiere que la frustración podría no ser un factor consistentemente relevante en la evaluación de la carga mental en madres estudiantes, posiblemente debido a la influencia de variables contextuales como el apoyo familiar y las expectativas sociales.

Los resultados destacan la alta carga mental asociada a las actividades académicas, con la actividad de exámenes cumpliendo con los supuestos de normalidad en los datos, lo que indica que las variaciones en la carga mental pueden ser predecibles. En contraste, la actividad de trabajo final mostró una mayor variabilidad, reflejando la influencia de factores externos como la dinámica de grupo y las demandas adicionales de tiempo.

El análisis adicional reveló que el número de hijos no está correlacionado de manera significativa con el rendimiento académico, lo que sugiere que las madres estudiantes desarrollan mecanismos de adaptación efectivos. Sin embargo, las horas dedicadas a responsabilidades familiares mostraron una relación más clara con la carga mental, indicando que estas responsabilidades imponen una carga significativa que podría limitar el rendimiento académico.

Este estudio subraya la necesidad de desarrollar estrategias e intervenciones que aborden la alta carga mental en madres estudiantes, incluyendo la implementación de horarios académicos más flexibles, acceso a servicios de cuidado infantil y una distribución más equitativa de las responsabilidades familiares. Además, se recomienda que las instituciones educativas adopten un enfoque inclusivo y sensible a las necesidades de esta población para mejorar su bienestar y éxito académico. La creación de un entorno educativo que apoye a las madres estudiantes no solo es una cuestión de equidad, sino también de eficiencia, dado que estudiantes con menor carga mental tienen mayores probabilidades de completar sus estudios con éxito.

La investigación contribuye al conocimiento sobre ergonomía cognitiva en contextos académicos, proponiendo adaptaciones específicas del Índice NASA-TLX y destacando la importancia de intervenciones dirigidas a mejorar la experiencia académica de las madres estudiantes.

Palabras clave: Carga mental, madres estudiantes, NASA-TLX

Relevancia para la ergonomía: Este estudio contribuye de manera significativa al campo de la ergonomía, especialmente en la ergonomía cognitiva, al proporcionar una validación contextual del índice NASA-TLX y al caracterizar la carga mental en madres estudiantes de licenciatura. La investigación demuestra la flexibilidad del índice NASA-TLX al adaptarlo cultural y lingüísticamente para su aplicación en madres estudiantes, ampliando su aplicabilidad a nuevas poblaciones y contextos académicos específicos. Esta adaptación asegura que el índice refleje con mayor precisión las experiencias cognitivas y emocionales de esta población particular.

Además, el estudio ofrece una caracterización detallada de la carga mental en actividades académicas críticas, como la presentación de exámenes y la elaboración de trabajos finales en equipo. Este enfoque permite comprender la complejidad de la carga mental que enfrentan las madres estudiantes, al tener que equilibrar demandas cognitivas, emocionales y temporales con sus responsabilidades familiares. La investigación proporciona una base sólida para diseñar intervenciones ergonómicas que aborden estas demandas, mejorando la capacidad de las madres estudiantes para gestionar el estrés y mantener un rendimiento académico satisfactorio.

Asimismo, al identificar las fuentes específicas de carga mental, el estudio ofrece una base empírica para el desarrollo de políticas institucionales y estrategias ergonómicas que faciliten la gestión del estrés en entornos educativos. Estas estrategias podrían incluir la flexibilización de horarios, el apoyo psicológico especializado y la reorganización de la planificación académica para acomodar mejor las necesidades de las madres estudiantes.

Por último, el estudio subraya la importancia de considerar el género en la ergonomía cognitiva, al destacar las experiencias únicas de las madres estudiantes. Esto abre la puerta a futuras investigaciones que exploren cómo diferentes grupos enfrentan la carga mental y cómo las herramientas y políticas ergonómicas pueden adaptarse para satisfacer las necesidades específicas de diversos subgrupos. En conjunto, este trabajo no solo enriquece el conocimiento en ergonomía cognitiva, sino que también promueve un enfoque más inclusivo y sensible a las diferencias individuales dentro del entorno académico.

Abstract: This study explores the mental workload of undergraduate student mothers at the National Technological Institute of Mexico, Agua Prieta campus, using the adapted NASA-TLX Index as an assessment tool. The research focuses on identifying and analyzing the factors contributing to mental workload, particularly in academic activities such as exam presentations and final team projects. Through a quantitative approach and a non-experimental cross-sectional design, data were collected from 47 student mothers, enabling an evaluation of how cognitive, emotional, and temporal demands are exacerbated by the need to balance academic and family responsibilities.

The study validated the adaptation of the NASA-TLX Index in this specific context, showing moderate internal consistency (α=0.644), which significantly improved after removing the frustration dimension (α=0.816). This finding suggests that frustration may not be a consistently relevant factor in assessing mental workload in student mothers, possibly due to the influence of contextual variables such as family support and social expectations.

The results highlight the high mental workload associated with academic activities, with the exam activity meeting the normality assumptions in the data, indicating that variations in mental workload may be predictable. In contrast, the final team project activity showed greater variability, reflecting the influence of external factors such as group dynamics and additional time demands.

Further analysis revealed that the number of children is not significantly correlated with academic performance, suggesting that student mothers develop effective coping mechanisms. However, the hours dedicated to family responsibilities showed a clearer relationship with mental workload, indicating that these responsibilities impose a significant burden that could limit academic performance.

This study underscores the need to develop strategies and interventions that address the high mental workload in student mothers, including implementing more flexible academic schedules, access to childcare services, and a more equitable distribution of family responsibilities. Additionally, educational institutions are encouraged to adopt an inclusive and sensitive approach to the needs of this population to improve their well-being and academic success. Creating an educational environment that supports student mothers is not only a matter of equity but also of efficiency, as students with lower mental workloads are more likely to successfully complete their studies.

This work contributes to the understanding of cognitive ergonomics in academic contexts, proposing specific

Keywords: Mental workload, student mothers, NASA-TLX.

Relevance to Ergonomics: This study makes a significant contribution to the field of ergonomics, particularly cognitive ergonomics, by providing a contextual validation of the NASA-TLX index and characterizing the mental workload in undergraduate student mothers. The research demonstrates the flexibility of the NASA-TLX index by adapting it culturally and linguistically for use with student mothers, expanding its applicability to new populations and specific academic contexts. This adaptation ensures that the index more accurately reflects the cognitive and emotional experiences of this particular population.

Additionally, the study offers a detailed characterization of the mental workload in critical academic activities, such as exam presentations and final team projects. This approach allows for a deeper understanding of the complexity of the mental workload faced by student mothers, as they must balance cognitive, emotional, and temporal demands with their family responsibilities. The research provides a solid foundation for designing ergonomic interventions that address these demands, improving the ability of student mothers to manage stress and maintain satisfactory academic performance.

Furthermore, by identifying specific sources of mental workload, the study provides an empirical basis for the development of institutional policies and ergonomic strategies that facilitate stress management in educational settings. These strategies could include flexible scheduling, specialized psychological support, and the reorganization of academic planning to better accommodate the needs of student mothers.

Finally, the study emphasizes the importance of considering gender in cognitive ergonomics by highlighting the unique experiences of student mothers. This opens the door to future research exploring how different groups face mental workload and how ergonomic tools and policies can be adapted to meet the specific needs of various subgroups. Overall, this work not only enriches the knowledge in cognitive ergonomics but also promotes a more inclusive and sensitive approach to individual differences within the academic environment.

1. INTRODUCTION

The phenomenon of stress and mental workload has been the subject of study for decades, evolving in its understanding and approach within the fields of psychology and ergonomics. Historically, mental workload has been understood as a complex interaction between the cognitive demands imposed by tasks and the individual's ability to manage these demands. In a dialectical framework, mental workload is recognized as arising from the continuous and changing interaction between the demands of the academic environment and the personal capacities to adapt to these demands. For student mothers, these demands are particularly acute due to the confluence of academic, work and family responsibilities, which generates a continuous stress field that can significantly impact their well-being and academic performance.

The study of stress and mental workload has acquired relevance in cognitive ergonomics, where the interactions between cognitive demands and the individual's resources to manage them are explored (Karasek, 1979; Moray, 1996). In the academic context, mental workload may be particularly high in populations facing multiple roles, such as student mothers. Previous studies have shown that excessive mental workload can lead to decreased performance and increased mental health problems, including anxiety and depression (Guzman & Campos, 2014; Hart & Staveland, 1988).

In recent decades, women's access to higher education has advanced significantly in many countries, including Mexico. This progress has resulted in an increase in the presence of student mothers in universities, who, despite advances in gender equality, continue to face unique challenges. These challenges include the need to balance their studies with family care responsibilities and, in many cases, work obligations (Boyd & DeJean, 2010; Mason, Goulden, & Frasch, 2011). However, institutional infrastructure and support policies in Mexican universities, as in many other parts of the world, are not always adapted to meet the specific needs of this group, which generates a considerable mental burden that impacts their well-being and academic performance (Rodriguez, 2020).

Chronic stress and high mental workload are associated with various negative consequences for mental and physical health. In student mothers, it has been observed that high levels of mental workload are correlated with a higher incidence of anxiety, depression, and burnout, which in turn affects their ability to concentrate and perform academically (López, Ramírez, & Herrera, 2018). In addition, the lack of resources to manage this mental workload can lead to a higher dropout rate, poor academic performance, and an unsatisfactory educational experience, underscoring the urgent need for targeted interventions (Smith & Klein, 2020).

Mental workload, as assessed through tools such as the NASA-TLX index, provides an accurate metric for measuring the perceived cognitive demand of student mothers. This index, originally developed to assess mental workload in aviation settings, has been widely adapted for academic contexts and has proven to be a valid and reliable tool (Hart & Staveland, 1988; Rubio et al., 2016). However, there is a paucity of research focusing on its specific application in undergraduate mothers, making it crucial to adapt and validate these tools to ensure their accuracy in specific contexts (Peters, O'Connor, & Loughlin, 2013).

The issue of high mental workload in student mothers is directly related to the objective of this research, which is to conduct a psychometric study of the NASA-TLX index in this specific population. The purpose of this research is to evaluate the validity and reliability of the NASA-TLX for measuring mental workload in undergraduate student mothers, providing an adapted tool that can be used to identify critical stress points. This, in turn, will facilitate the development of strategies and policies that support these students, improving their academic experience and quality of life. The adaptation and validation of the NASA-TLX index will allow for a more accurate understanding of mental workload in this context, contributing to the body of knowledge in ergonomics and mental health in academic settings.

2. OBJECTIVES

General objective:

To develop a systematic and validated procedure for the evaluation of stress level in undergraduate mothers at the Tecnológico Nacional de México Campus Agua Prieta.

Especific objetives:

1. To analyze the main theories and previous studies on stress in academic contexts, with a focus on measurement tools and their applicability in undergraduate student mothers.
2. To design and validate a methodological procedure to accurately and reliably evaluate the level of stress in undergraduate mothers at the Tecnológico Nacional de México Campus Agua Prieta, using the NASA-TLX index adapted to the local context.
3. To perform a descriptive and correlational analysis of stress levels in student mothers, identifying associated factors and their impact on academic performance and social relationships.

3. METHODOLOGY

The present study was developed under a descriptive non-experimental cross-sectional design with a quantitative approach, selected to describe the mental workload in undergraduate mothers at a specific time without manipulating variables. The research was framed within a positivist paradigm, seeking to observe and measure reality objectively through empirical methods.

The target population of the study was composed of all student mothers enrolled in undergraduate programs at the Tecnológico Nacional de México campus Agua Prieta, totaling 47 women. Given the accessibility and size of the population, it was decided to include all of these student mothers in the sample. The inclusion criteria were: being a woman, being enrolled in an undergraduate program and having children.

For the measurement of mental workload, we used the NASA-TLX index, a tool widely validated in various contexts to assess mental workload. This index is composed of six dimensions: mental demand, physical demand, time demand, effort, performance and frustration. Additionally, a complementary questionnaire was designed to collect relevant demographic and academic data, including age, career, year of study, family situation and hours dedicated to studies and family responsibilities.

For the characterization of mental workload in the academic context, two critical activities were selected: the presentation of a knowledge exam and the delivery of a final paper in a team. These activities were chosen for their relevance and high cognitive load observed in student mothers.

Data collection was carried out by means of structured interviews with a questionnaire in hand. Prior to implementation, a detailed explanation of the study was provided to the participants and their written informed consent was obtained, ensuring the confidentiality and anonymity of the data collected.

The data collected were subjected to a review and cleaning process to ensure quality and consistency. Descriptive analyses were performed to calculate means, standard deviations, frequencies and percentages of sample characteristics and

NASA-TLX index scores. In addition, inferential analyses are planned to explore relationships between stress levels and demographic and academic factors.

To assess the construct validity of the NASA-TLX index in the sample of student mothers, the internal reliability of the NASA-TLX dimensions was examined by calculating Cronbach's alpha coefficient, providing a measure of internal consistency of the scales.

Given that the NASA-TLX index was originally developed in different contexts, a cultural adaptation was carried out to ensure its relevance to the population studied. A process of translation and back-translation was used to adapt the language of the index to the Mexican context, ensuring that the terms were understandable and relevant to the participants. Subsequently, a pilot test was conducted with a small group of student mothers to evaluate the clarity and functioning of the adapted index. In addition, a review by experts in ergonomics and mental health was carried out to evaluate the relevance and clarity of the adapted items, confirming the content validity of the instrument.

The study was conducted following the ethical principles of research, including obtaining informed consent, respecting the privacy and confidentiality of the participants, and using the data exclusively for research purposes.

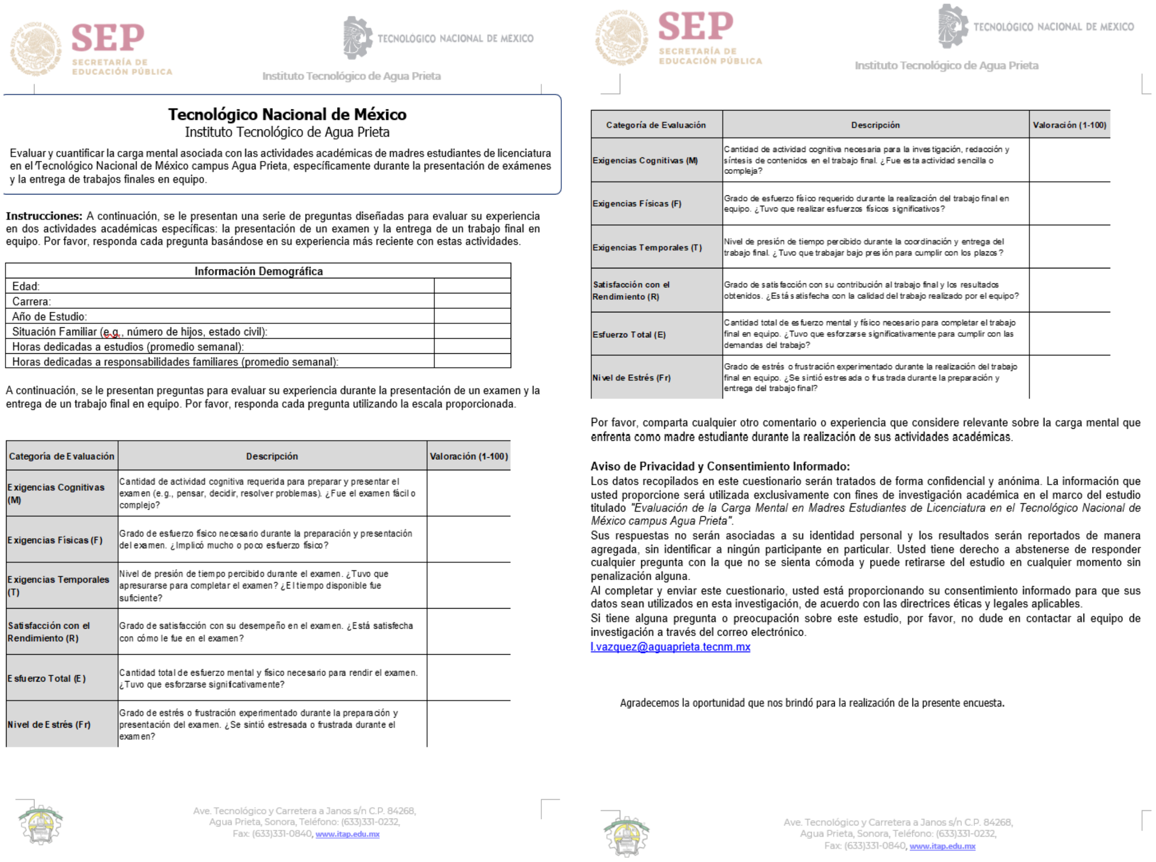
4. RESULTS

In order to develop a structure of analysis that reflects the mental load with which undergraduate mothers face the academic challenges in their training process, two of the activities that involve a high mental load were characterized: the presentation of an exam and the delivery of a final paper in a team.

Characterization of the exam: Presenting an exam involves high cognitive load by processing and applying knowledge under time pressure. Emotional demands include managing anxiety and maintaining concentration, while temporal demands require planning the use of time during the exam. For student mothers, these tasks are complicated by balancing exam preparation with family responsibilities, which intensifies stress. Added to this, it is necessary that the student mother manages to concentrate on the exam and establishes a virtual separation of thoughts about her child, situations that emphasize her thinking such as: the child ate, slept well, nothing has happened to him, he will not be dirty, these thoughts distract her attention on the exam and affect her academic performance.

Characterization of Final Teamwork: Final teamwork requires high cognitive load for research, writing, and synthesis of content. Emotional demands include managing collaboration, conflict resolution, and managing stress related to coordination and delivery of work. Temporal demands are significant due to the need to balance team meetings and work preparation with family obligations, increasing the complexity of the task for student mothers since time planning involves a greater number of variables than the student population that does not fall into this category.

Once characterized, the assessment instrument was established based on the NASA-TLX index, since it was necessary to adapt both the translation and the context of the question, in order to better reflect the mental workload of the student mothers. Figure 1 shows the instrument designed. The aforementioned generates the need to carry out a validation process of the instrument, so the reliability of the NASA-TLX instrument is analyzed, understood as internal consistency, Cronbach's alpha coefficient was calculated for the total scale. Now, if we eliminate variables with the idea of assessing the internal consistency of the variables with the greatest impact on the mental workload, we get the following results: If we eliminate the time dimension we get a result of .459, if we eliminate effort we get a result of .644, if we eliminate the performance dimension we get a result of .399, if we eliminate the frustration dimension we get a result of . 399, eliminating the frustration dimension gives us a result of .816, eliminating the mental effort gives us a result of .386 and finally if we remove the physical effort gives us a result of .651. These considerations imply that by eliminating the frustration dimension the internal consistency of the instrument increases considerably.



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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?	

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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.
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Agradecemos la oportunidad que nos brindó para la realización de la presente encuesta.

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Figure 1: assessment instrument as a function of the NASA-TLX index.

The instrument was validated and applied to the study population. Table 1 shows the results of the mental workload assessment for the examination activity. A high level of mental workload was observed, with a total weighted score of 1258. This high level of mental workload suggests that taking an exam is a significant source of stress and cognitive demand for the student mothers

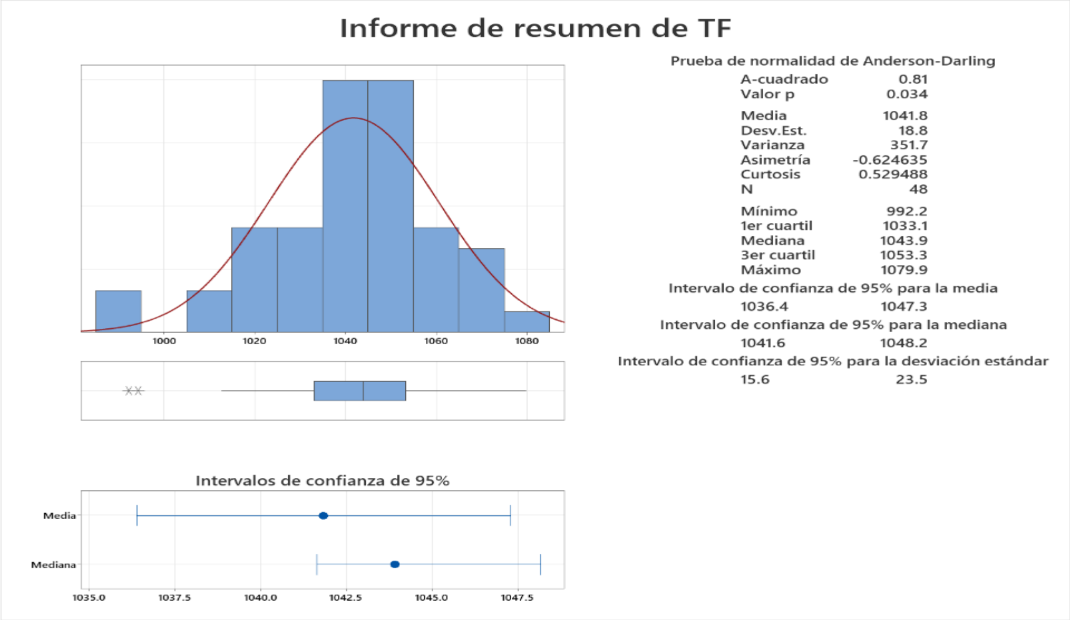
Table 1: result of the mental workload assessment for the examination activity.

Variable	Weight	Punctuation	weighted score
Mental requirements	5	90	450
Physical requirements	0	40	0
Temporary requirement	4	87	348
Performance	1	90	90
Effort	2	50	100
Frustration	3	88	264
TOTAL	15		1258
Mental workload level: High.			

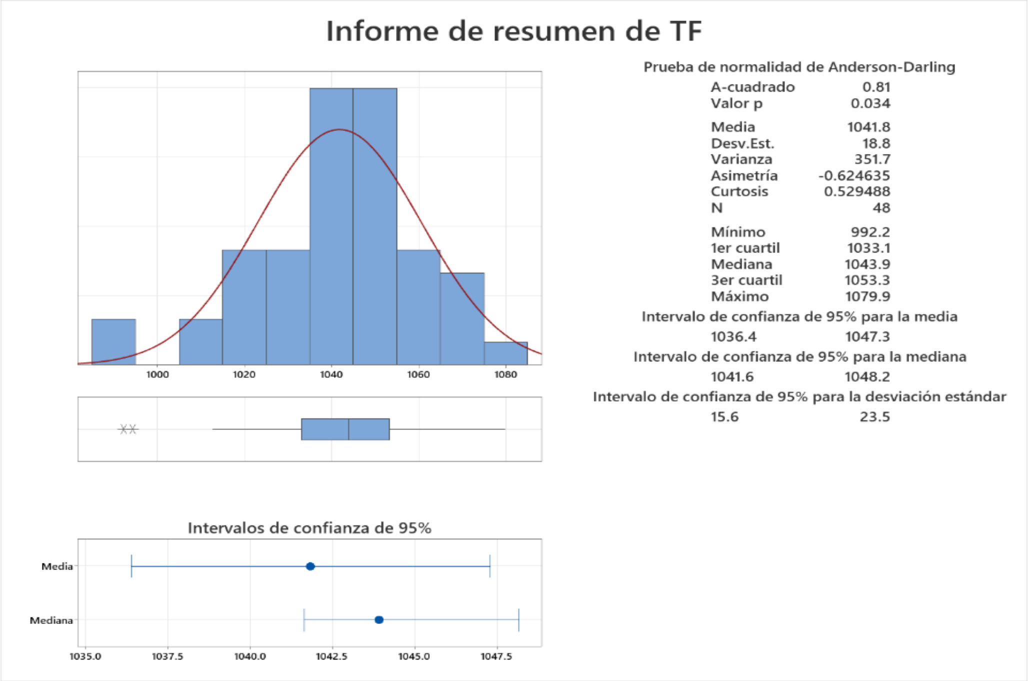
A total of 48 assessments were carried out with the validated instrument. Graphs 1 and 2 show the results in terms of frequency and level of mental workload for the two selected activities.

In the case of the exam activity and based on the histogram, the Anderson-Darling normality test, and the descriptive statistics (skewness and kurtosis), the data can be considered normal, observing that all the evaluations are at a high level of mental workload.

However, for the analysis of the final work activity and based on the Anderson-Darling test, which has a p-value of less than 0.05, the “Final Work” data do not meet the assumptions of normality. Although the histogram and descriptive statistics suggest that the data are approximately normally distributed, the formal test indicates that there are significant differences from a normal distribution. The statistical data obtained are presented in the graph. However, all the evaluations are in a high range in their mental workload.



Graph 1: Results of the levels of mental workload obtained in the study for the examination activity



Graph 2: Results of the mental workload levels obtained in the study, for the final teamwork activity.

In addition to evaluating specific activities that involve a high mental workload, such as taking exams and submitting final papers in teams, a detailed analysis was conducted to explore how certain external factors, such as the number of children, hours of study, and hours devoted to family responsibilities, influence the stress levels and academic performance of student mothers.

Initially, the relationship between the number of children and test scores was explored as a proxy indicator of academic performance. The results indicated that there is no clear correlation between these variables. It is specified that mothers with different numbers of children present a wide dispersion in their test scores, suggesting that the number of children alone is not a determining factor in academic performance. This could be explained by the adaptation that mothers develop in the face of the demands of motherhood, effectively balancing their family responsibilities with academic demands, or the existence of other factors that modulate the influence of the number of children on mental workload, such as family or institutional support.

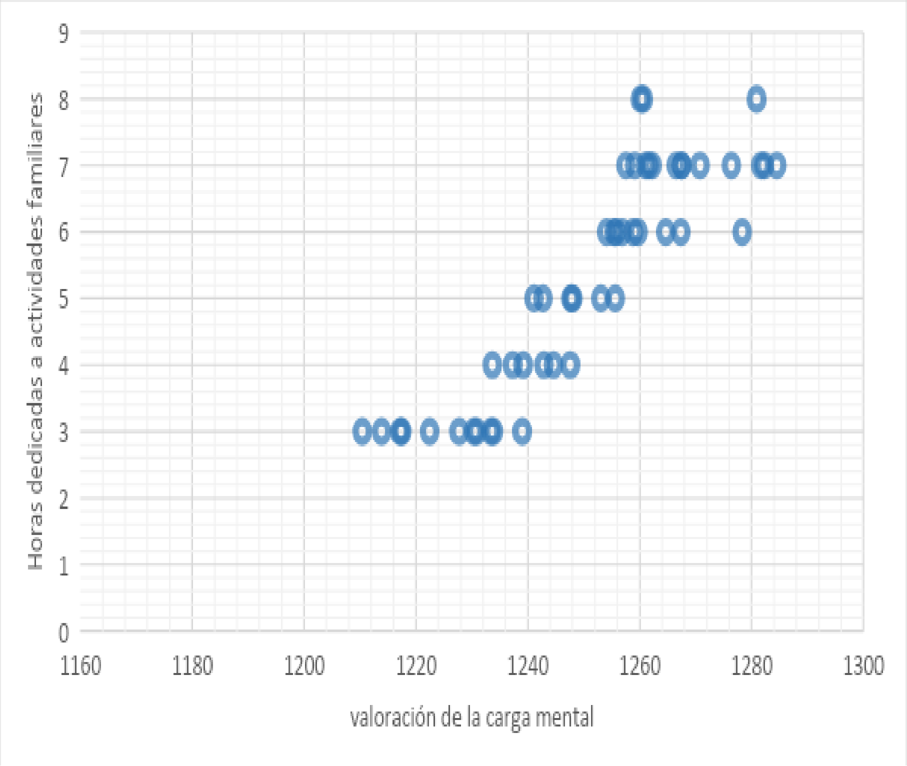
The next factor analyzed was the number of hours dedicated to study. Contrary to what might be expected, the study shows that there is no direct correlation between study hours and test scores. The data reveal considerable dispersion, suggesting that simply devoting more time to study does not necessarily translate into better scores. This finding highlights the importance of efficiency in study strategies and time management, beyond the number of hours spent. It is likely that other factors, such as the quality of study time, access to educational resources, and mental and emotional state during study, play a more relevant role in the academic success of these students.

One of the most significant findings of this analysis is related to the hours dedicated to family responsibilities. Unlike the other factors, a clearer trend was observed here. Mothers who dedicate more hours to family responsibilities tend to have test scores in a narrower range, although not necessarily higher. Figure 3 shows the scatter plot reflecting the condition explained above. This observation suggests that family responsibilities impose a significant burden that could stabilize academic performance in a lower or specific range, limiting the potential for variation.

This finding is particularly important, as it highlights a cause of mental burden that is deeply rooted in societally imposed gender roles and expectations. Student mothers face a dual challenge: not only must they meet academic demands, but they are also expected to maintain a high level of commitment to family responsibilities. This dual role not only intensifies the mental burden but may also limit their opportunities for optimal academic performance, as much of their energy and time is channeled into responsibilities that are not part of their studies.

It is essential to emphasize that the additional burden generated by family responsibilities does not arise in a vacuum; it is deeply influenced by sociocultural structures that disproportionately assign care and household maintenance tasks to women. This expectation is not only perpetuated in the family environment but is also reinforced through educational and labor policies that do not always provide the necessary support for student mothers to balance their multiple roles.

Analysis of these graphs reveals a complex and significant relationship between family responsibilities and mental workload. Society, by imposing these expectations on mothers, indirectly contributes to a greater mental burden that affects their academic performance. This underscores the need to develop policies and interventions that not only consider academic support, but also address the equitable distribution of responsibilities within the home, as well as the creation of more inclusive and flexible educational spaces that recognize and respond to the specific needs of student mothers.



Graph 3: Scatterplot between mental workload assessment and hours dedicated to family duties

5. CONCLUSIONS

The present study provides a comprehensive look at the mental workload faced by undergraduate student mothers in balancing academic and family demands, using the NASA-TLX Index as a tool to measure such workload. Through the adaptation and validation of the index in this particular context, it demonstrates not only its utility, but also the need for a more nuanced approach in assessing mental workload in populations with multiple and varied responsibilities.

One of the most significant findings of this research lies in the validation of the NASA-TLX Index for student mothers. Although the overall internal consistency of the instrument was moderate (α=0.644), detailed analysis showed that the removal of the frustration dimension significantly improved the reliability of the index (α=0.816). This suggests that frustration, although relevant, may not be as consistent a factor in the assessment of mental workload in this specific population group. It is possible that frustration is more influenced by contextual variables that vary widely among student mothers, such as family support, social expectations, and individual circumstances, which explains the variability observed in this dimension.

The study underscores the high mental workload imposed by academic activities, particularly taking exams and writing final papers in teams. Detailed characterization of these activities reveals that the cognitive, emotional, and temporal demands are significantly exacerbated by the need for student mothers to balance their academic responsibilities with their family obligations. This balancing, as noted, is not trivial and contributes significantly to mental workload, increasing the risk of chronic stress and potentially affecting academic performance.

Exam activity, for example, showed compliance with normality assumptions in the data, indicating that variations in mental workload during this activity may be predictable and systematic. This suggests that student mothers may develop relatively consistent strategies for managing mental workload during exams, although these strategies may not be sufficient to completely mitigate stress. On the other hand, the final teamwork activity did not meet normality assumptions, reflecting greater variability in the experience of mental workload. This finding indicates that the mental workload experience in final papers is less predictable and more dependent on external factors, such as group dynamics, coordination with other students, and additional demands on time and effort.

In addition to specific academic activities, the study explored how external factors such as number of children, hours of study, and hours devoted to family responsibilities influence mental workload and academic performance. The number of children was found to have no clear correlation with academic performance, suggesting that student mothers develop effective coping mechanisms to balance their roles. However, the relationship between hours spent on family responsibilities and mental workload was found to be more significant. Mothers who devote more time to these responsibilities tend to have test scores in a narrower range, indicating a possible stabilization of academic performance in the presence of greater family demands.

This finding is critical, as it reflects how societally imposed gender roles and expectations contribute to a greater mental burden on student mothers. The need to meet family responsibilities, coupled with academic demands, creates a significant source of stress that affects not only the well-being of female students, but also their ability to perform at the highest academic level. Society, by imposing these expectations, perpetuates a cycle of high mental workload that is difficult to mitigate without specific interventions.

The results of this study underscore the urgency of developing strategies and interventions that address the high mental workload faced by student mothers. These strategies should be multifaceted, ranging from adapting assessment tools such as the NASA-TLX Index to designing supportive policies that consider the unique needs of this population. For example, implementing more flexible academic schedules, access to child care services, and raising awareness about the equitable distribution of household chores are measures that could contribute significantly to reducing mental workload.

In addition, it is crucial that educational institutions such as the Tecnológico Nacional de México, Agua Prieta campus, adopt a more inclusive and sensitive approach to the needs of student mothers. This would not only improve the academic experience of these students, but also contribute to their academic success and overall well-being. Creating an educational environment that supports student mothers in their multiple roles is not only a matter of equity, but also of efficiency, as less mentally burdened students are more likely to perform better and complete their studies successfully. Addressing the underlying causes of mental workload and developing policies tailored to the needs of these students can significantly improve their academic experience and promote a more equitable and inclusive educational environment.

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EFFECTS OF LIGHTING LEVELS ON BLINKING IN ARCHITECTURE AND INTERIOR DESIGN STUDENTS: A COMPARATIVE STUDY RELATED TO COMPUTER VISION SYNDROME.

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Palabras clave: Síndrome de Visión por Computadora, parpadeo, nivel de iluminación, estudiantes universitarios

Aportación a la ergonomía: La evaluación de los factores ambientales presentes en los entornos de trabajo/estudio desde una perspectiva ergonómica ayuda a mejorar la comodidad de los usuarios, adaptando estas condiciones a sus distintas capacidades, así como a las exigencias visuales de las tareas en un mismo puesto de trabajo. Esto sugiere la necesidad de generar recomendaciones específicas para puestos de trabajo/estudio con uso de computadora y modificaciones en la NOM-025-STPS-2008, agregando monitores de contexto como lo incluyen otras normativas**.**

Keywords: Computer Vision Syndrome, blinking, lighting levels, university students

Contribution to Ergonomics: Evaluating environmental factors in work/study environments from an ergonomic perspective helps enhance user comfort by adapting these conditions to their capabilities and visual task demands within a single workstation. This suggests the need to generate specific recommendations for computer-based work/study stations and to amend standards such as NOM-025-STPS-2008 by including contextual monitors as seen in other regulations.

Ergonomics topic: Fatigue

1. Introduction

Computer Vision Syndrome (CVS) is defined as a set of visual and ocular problems resulting from prolonged computer use (AOA, n.d.), and due to its high prevalence, it has been considered an overlooked occupational disease (Moldovan et al., 2020). This condition affects nearly 60 million people worldwide (Zalat et al., 2022). Additionally, one million new cases are reported each year (Al Tawil et al., 2020).

The American Optometric Association relates CVS to multiple factors, one of which is poor lighting (AOA, n.d.). Furthermore, it has been reported that lighting has received little attention in experimental studies (Doughty, 2001, 2013, 2014).

2. Objective

To analyze the effect of applying three different lighting levels (500 lx, 1000 lx, and 1500 lx) on the blinking of architecture and interior design students with positive and negative CVS.

3. Scope

The study was conducted at the facilities of the Centro Universitario de Arte, Arquitectura y Diseño (CUAAD) during the period from August 2021 to May 2023.

4. Methodology

The study is quantitative with an experimental design, organized into two phases.

Phase 1: 171 Architecture and Interior Design students participated, selected for their high exposure to computer screens, using intentional non-probabilistic sampling. After signing the informed consent, the Computer Vision Syndrome Questionnaire (CVS-Q©) was administered to obtain Group A (CVS positive) with visual fatigue and Group B (CVS negative) without visual fatigue, each group consisting of ten participants.

Phase 2: The division of the groups allowed for a comparison of how different lighting conditions affected students with varying predispositions to visual fatigue. Each participant's blink rate was recorded using the Gazepoint eye tracker, measured in three sessions, one for each level (500 lx, 1000 lx, 1500 lx) established according to both Mexican and European standards. The study reported the Spontaneous Eye Blink Rate (SEBR) in the last minute of the task and the Total Number of Blinks (NTB) during the 15 minutes of the task, as blinking is reported as an indicator of visual fatigue (Benedetto et al., 2013; Doughty, 2014; Kim et al., 2011; and Stern et al., 1994). This is due to the reduction in blinks directly associated with CVS symptoms, such as redness, burning, sandy sensation, itching, light sensitivity, tearing, blurred vision, and visual fatigue (del Mar Seguí, 2015; Kaur et al., 2022; Sheedy et al., 2003). Inclusion criteria for Group A considered results with severe positive CVS (high scores).

The eye tracking test was conducted in the Ergonomics Laboratory, which was adapted following the PVD Workspace Characterization Protocol (Rodríguez and Pattini, 2006). Calibrated measurement instruments were used, such as the Extech® model 407026 luxmeter to specify each lighting level, Hagner brand EC 1 – L screen luminance meter to record screen brightness, and Konica Minolta brand

CL-200A digital colorimeter to measure the color temperature emitted by the luminaire. Dimmable light panels model Azmid II with their respective Creator IV controller, both by Tecnolite, were used to create each condition, as shown in Figure 1.

Figure 1. Test application in Condition 1 (500 lx), Condition 2 (1000 lx), and Condition 3 (1500 lx)

Each session lasted approximately 30 minutes, which included furniture adjustment, tracker calibration, and task performance. The task consisted of tracing and modeling Tadao Ando's Azuma House in SketchUp software for 15 minutes. The statistical analysis of the data was performed using SPSS® software version 22, employing non-parametric tests: Friedman's Test and the Mann-Whitney U Test.

5. Results

5.1. Phase 1 Results

After applying exclusion and elimination criteria, the study included 116 students, 65 females (56%) and 51 males (44%); 62.9% were from Architecture and 37.1% from Interior Design. 92.2% reported working in front of a computer for more than 20 hours per week, 59.5% wore glasses, and 37.9% of the sample had myopia and astigmatism.

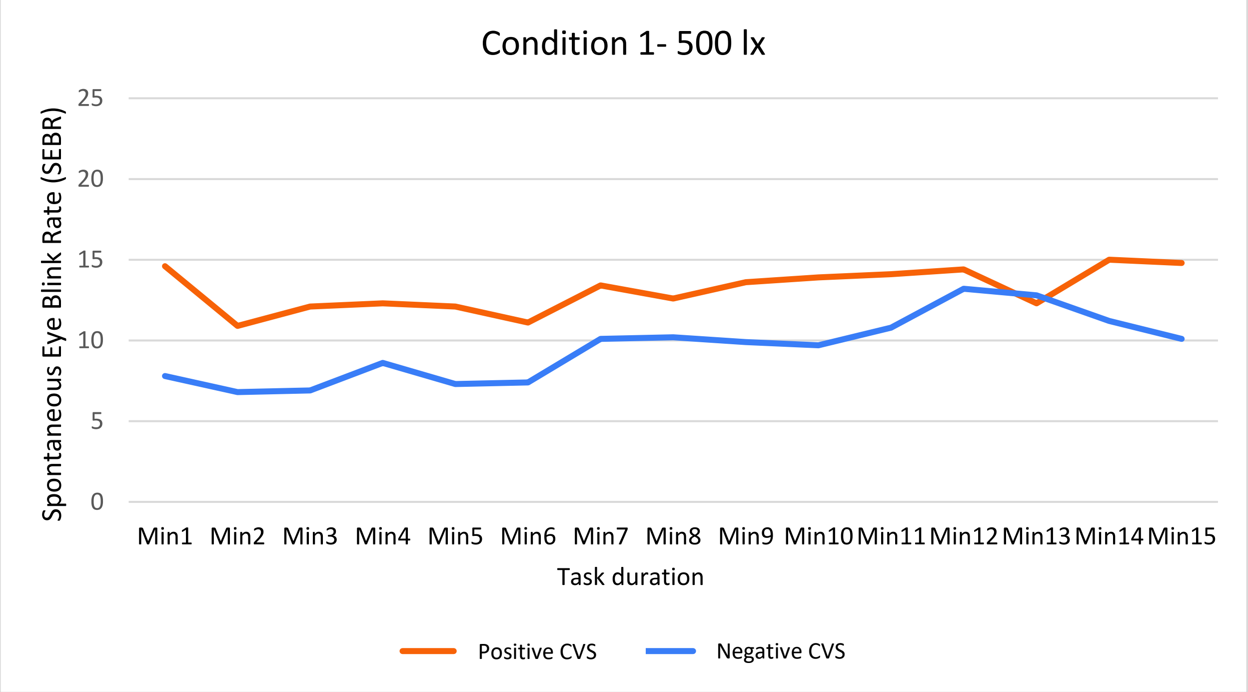
A CVS prevalence of 89.7% was reported, with the most frequent symptoms including blurred vision (87%), increased light sensitivity (86.2%), headache (77.6%), eye burning (71.6%), and feeling worse vision (69.9%).

5.2. Phase 2 Results

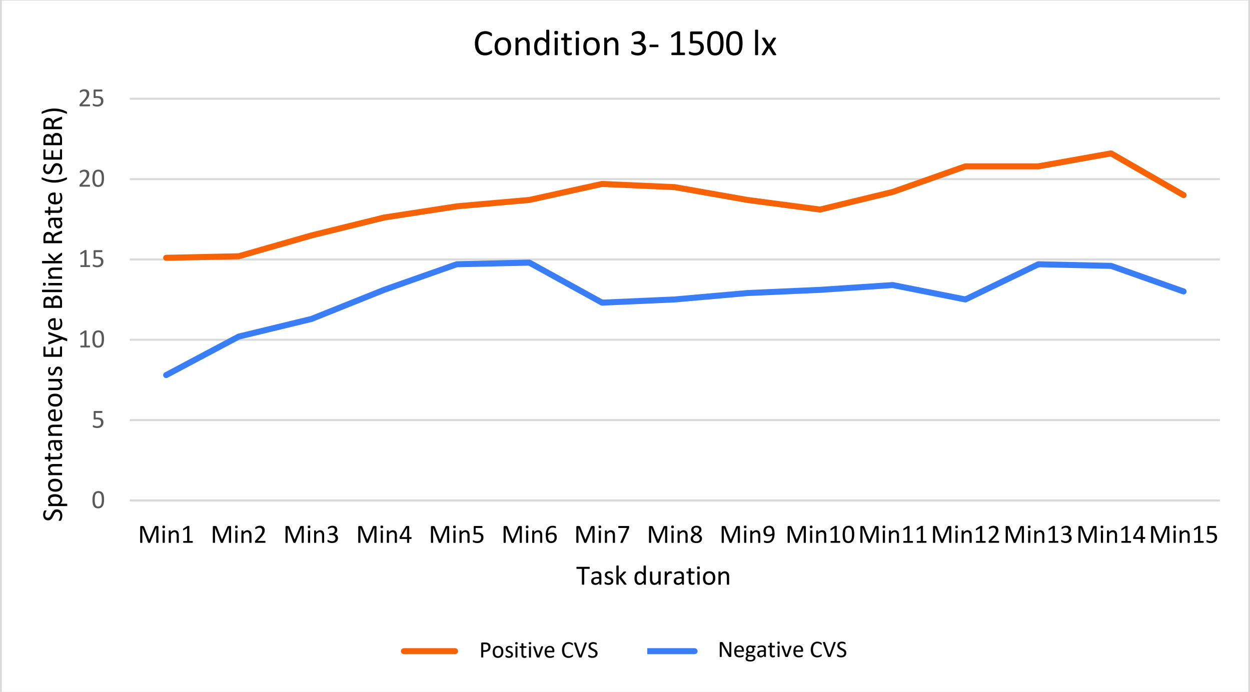
Twenty students participated, 11 females (55%) and 9 males (45%), aged between 19 and 28 years (Mean = 21.8 ± 2.28).

The results of eye tracking in Group A and Group B with Friedman's Test showed no statistically significant difference in SEBR measured in the 15th minute for the three conditions: Group A X^2 (2, n=10) = 2.6, p = .273 and Group B X^2 (2, n=10) = 2.32, p = .31. However, in Condition 1, both groups recorded between 1.4 and 14.4 blinks/min for VDT-SEBR (Doughty, 2001), Graph 1. Group A, when exposed to Condition 3, approaches the optimal zone with 20 to 25 blinks/min, which is considered beneficial for maintaining tear film quality while working with VDT (Robinson and Hernández, 2010), Graph 2.

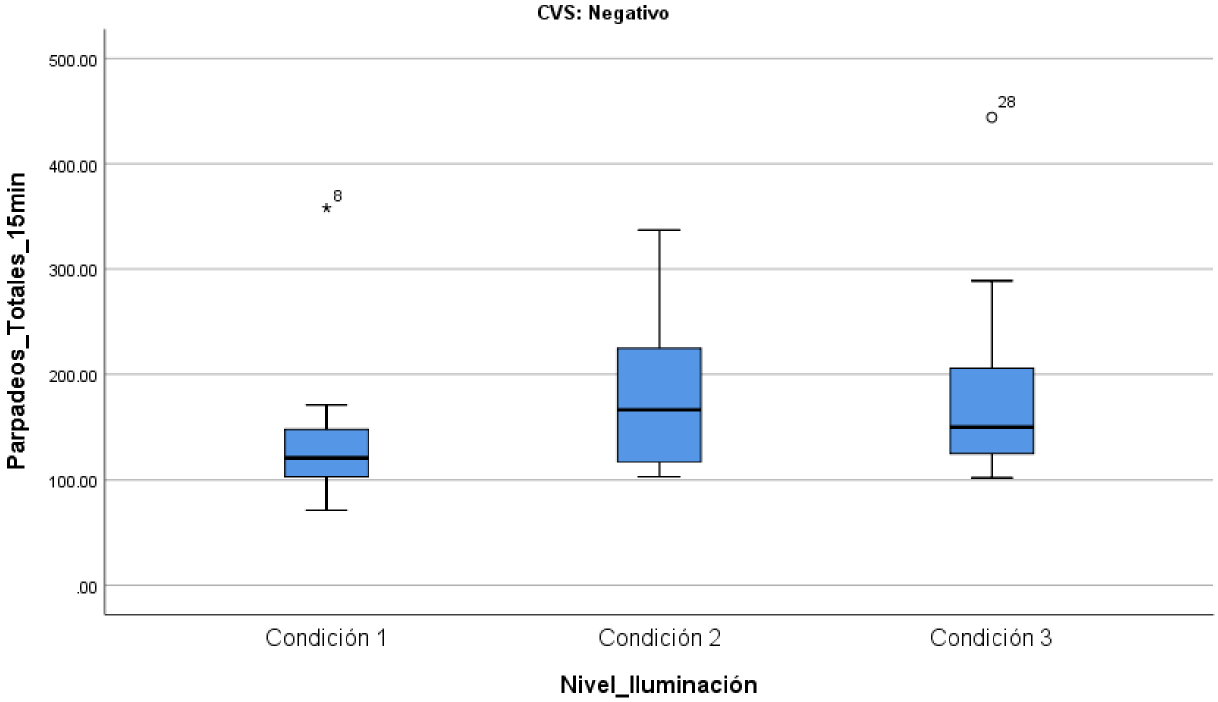
On the other hand, results of NTB during the task with the Friedman Test in Group A did not show a significant difference X^2 (2, n=10) = 3.2, p = .202. In Group B, an increase in NTB was reported with statistically significant differences among the three lighting conditions X^2 (2, n=10) = 6.52, p = .038. To determine between which levels, the Wilcoxon signed-rank test was conducted, showing a significant increase in NTB between Level 1 and Level 2 (z = -2.09, p < .05, r = .66) and between Level 1 and Level 3 (z = -2.521, p < .05, r = .79), Graph 3.



Graph 1. SEBR in each minute during the task development for each group in Phase 2, exposed to Condition 1.



Graph 2. SEBR in each minute during the task development for each group in Phase 2, exposed to Condition



Graph 3. Results in the total number of blinks in 15 minutes with different lighting levels for Group B.

5.2.1. Eye tracking: Comparison between Group A and Group B for each condition

The results of the Mann-Whitney U Test indicate that there is no statistically significant difference in SEBR between the groups in each condition, Z (2, n=10) = -1.86, p = .063, Z (2, n=10) = -1.06, p = .289, and Z (2, n=10) = -1.25, p = .211. Similarly, when analyzing NTB between Group A and Group B, for each condition Z (2, n=10) = -1.85, p = .064, Z (2, n=10) = -1.36, p = .174, and Z (2, n=10) = -1.47, p = .14.

6. Conclusions

This study aligns with others that consider Computer Vision Syndrome (CVS) as an alarming condition due to its high prevalence, which diminishes people's quality of life and reduces their performance (Zalat et al., 2022). The results obtained in the total number of blinks for Group B with significant differences could help prevent ocular symptoms in this group by increasing blinking rates with higher levels of illumination.

Some limitations of the study include the absence of a group not exposed to the task to establish baseline SEBR and NTB. Additionally, due to resource constraints such as time, variables like light color temperature, screen illuminance, and localized lighting over the working plane (without affecting participant vision angles) were not controlled. These results could lead to new recommendations based on task requirements and user-reported comfort.

The intention is to continue this research line to evaluate the effects of lighting and visual ergonomics on visual health among workers.

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PHYSICAL CONDITIONS AND FATIGUE EVALUATION IN A COSMETIC DEPARTMENT STORE

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Resumen: La salud ocupacional radica en la importancia de proteger y promover la salud y bienestar de los trabajadores en el entorno laboral. Se centra en prevenir enfermedades y lesiones relacionadas con el trabajo, así como en mejorar las condiciones laborales para garantizar un ambiente seguro y saludable.

La implementación de prácticas seguras y la formación en salud ocupacional ayudan a prevenir accidentes en el lugar de trabajo. Esto no solo protege la salud de los trabajadores, sino que también reduce los costos asociados con la compensación laboral y los tiempos de inactividad.

Para este proyecto, se analizaron las condiciones físicas del entorno de trabajo en que la labora la dependienta en relación con las Normas Oficiales Mexicanas (NOM) para determinar si se cumplen con los estándares de seguridad y salud en el trabajo.

Se utilizo el cuestionario de Yoshitake y Corlett and Bishop para medir los niveles de fatiga y conocer los factores que la provocan. Además, se realizaron observaciones directas y se recopilación datos sobre las condiciones físicas de la dependienta, como la postura, el movimiento y el esfuerzo físico requerido para realizar sus tareas.

La importancia de conocer la fatiga de los trabajadores radica en su impacto en la productividad, la calidad del trabajo y la salud en general. La fatiga puede afectar la capacidad de los trabajadores para realizar sus tareas de manera segura y eficiente, lo que puede llevar a errores, accidentes y lesiones. Además, la fatiga crónica puede tener efectos negativos en la salud física y mental de los trabajadores, como el estrés, la ansiedad y la depresión.

Palabras claves: Fatiga, posturas, rendimiento

Relevancia para la ergonomía: Con base en los resultados del estudio, se pueden diseñar o ajustar las estaciones de trabajo para mejorar la ergonomía, como ajustar la altura de los mostradores, o instalar tapetes antifatiga en áreas de trabajo de pie prolongado.

Abstract: Occupational health lies in the importance of protecting and promoting the health and well-being of workers in the work environment. It focuses on preventing work-related illnesses and injuries, as well as improving working conditions to ensure a safe and healthy environment.

Implementing safe practices and occupational health training help prevent workplace accidents. Not only does this protect workers' health, but it also reduces costs associated with workers' compensation and downtime.

For this project, the physical conditions of the work environment in which the clerk works were analyzed in relation to the Official Mexican Standards (NOM) to determine if they comply with occupational health and safety standards.

The Yoshitake and Korlet and Bishop questionnaire was used to measure fatigue levels and to know the factors that cause it. In addition, direct observations were made and data was collected on the physical conditions of the shop assistant, such as posture, movement and the physical effort required to perform her tasks.

The importance of knowing worker fatigue lies in its impact on productivity, quality of work, and overall health. Fatigue can affect workers' ability to perform their tasks safely and efficiently, which can lead to errors, accidents, and injuries. In addition, chronic fatigue can have negative effects on workers' physical and mental health, such as stress, anxiety, and depression.

Keywords: Fatigue, postures, performance

Relevance to ergonomics: Based on the results of the study, workstations can be designed or adjusted to improve ergonomics, such as adjusting the height of counters, or installing anti-fatigue mats in areas of prolonged standing work.

1. INTRODUCTION

Work involves the worker consuming his physical and mental energy. Fatigue is the logical consequence of the effort made, and it must be within limits that allow the worker to recover after a day of rest. In the workplace, assessing employees' physical conditions and fatigue is essential to ensure a healthy and productive work environment. As for the work environment of a department store, it requires employees to stand for long periods, perform repetitive tasks, and maintain a friendly and helpful attitude with customers. These demands can lead to a number of physical and health problems, including muscle aches from poor posture and long periods of standing, stress and generalized fatigue, which can affect your performance and the quality of customer service.

2. OBJECTIVES

General objective:
Evaluate the physical conditions and level of fatigue of a worker in a department store, in order to identify risk factors and propose improvement strategies to optimize her well-being and work performance.

Specific objective:

- Identify the main risk factors that contribute to fatigue and physical discomfort. Assess and measure psychosocial risks and the level of physical and mental fatigue to which the worker is exposed.
- Assess regulatory compliance with terms and conditions, physical aspects of the work environment such as; lighting, ventilation, vibration, sound and temperature.
- Propose strategies and recommendations to reduce fatigue and improve working conditions, such as the implementation of adequate breaks and ergonomics in the workplace.

3. METHODOLOGY

3.1 Physical Condition Assessment:

The conditions of the worker's work environment were analyzed, covering factors such as lighting, temperature, noise and ventilation. In addition, the physical conditions of the clerk were evaluated in relation to the Official Mexican Standards (NOM) to determine if they comply with occupational health and safety standards.

3.1.1 Lighting

The work area to be evaluated has a high ceiling with several lamps in it, both in warm and cold tones to generate a balance in the tonality of the light in general. The lights are mostly located in the center of the premises (ceiling), others more on the edge of the window that faces the square, and one in each corner of the premises. There are also two lamps that are specifically located above the entrance (door).

According to the values set out in the table where we compare the lighting levels obtained with those specified in NOM-025-STPS-2008, the evaluated work area complies with the regulations and has an adequate lighting level, which provides a safe and healthy environment in the performance of the tasks carried out by the workers.

Table 1. Lighting level.

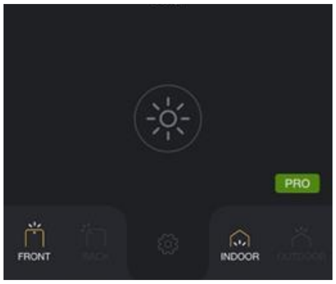
LIGHTING LEVEL (LUX) BY WORKSTATION				
Measuring Point	**Location**	**Lighting level found**	**Minimum Illumination Level NOM-025-STPS-2008**	**Meets with The Norm**
1	Puerta	330	200	Si
2	Racks with merchandise	308	200	Si
3	Cash register	314	300	Si

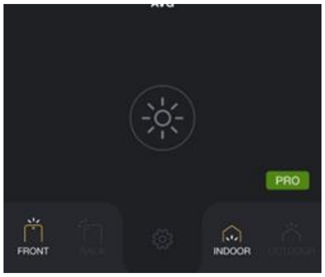
Evidence

Figure 1. Door .

Figure 2. Racks.

Figure 3. Cash register.





3.1.2 Temperature

The work area to be evaluated is located inside the Sendero plaza, in general the plaza has regulated cooling systems to maintain a moderate temperature where it does not feel extremely cold or hot, so the place is always maintained with a constant temperature of approximately 24 degrees C to 25 degrees C.

In this case, NOM-015-STPS-2001 is used to evaluate and analyze whether this establishment is within the limits established in the standard.

Table 2. Temperature level per workstation.

TEMPERATURE LEVEL PER WORKSTATION				
Measuring Point	**Location**	**Temperature**	**Maximum temperature limit NOM-015-STPS-2001**	**Compliant**
1	Entrance	24º C	30º C	Si
2	Racks with merchandise	24º C	30º C	Si
3	Cash register	24º C	30º C	Si

In this case we can observe that the place complies with the temperature established by the standard in a light work category with an eight-hour day.

3.1.3 Noise

The work area to be evaluated is constantly in noise, since they have 2 speakers on the ceiling inside the premises and there is always music, as well as the noise that is generated by customers and the square in general.

According to the values set out in the table where we compare the noise levels obtained with those specified in NOM-011-STPS-2001, the evaluated work area complies with the maximum limits established because it is below the decibels allowed for an 8-hour workday.

Table 3. Noise level per workstation.

NOISE LEVEL dB(A) LEVEL PER WORKSTATION				
Measuring Point	**Location**	**Temperature**	**Maximum temperature limit NOM-011-STPS-2001**	**Compliant**
1	Entrance	70 dB(A)	90 dB(A)	Si
2	Racks with merchandise	54 dB(A)	90 dB(A)	Si
3	Cash register	56 dB(A)	90 dB(A)	Si

3.1.4 Ventilation

Regarding ventilation, despite being an enclosed place without natural air flow, the site has an appropriate ventilation system according to its dimensions, which consists of an air conditioning system and air extraction system, in addition to that it has doors designed to allow adequate air flow and organizes its furniture so that it does not obstruct the ventilation ducts and free airflow is allowed.

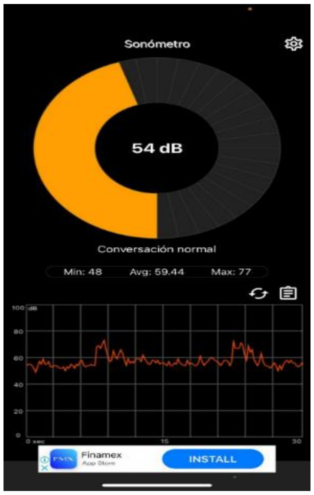
Evidence

70 dB

Un poco ruidoso

Min: 48 Avg: 60.19 Max: 76

Figure4. Entrance.

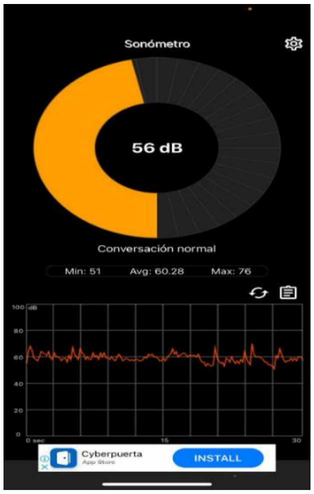


54 dB

Conversación normal

Min: 48 Avg: 59.44 Max: 77

Figure 5. Racks.



56 dB

Conversación normal

Min: 51 Avg: 60.28 Max: 76

Figure 6. Cash register.

Figure 7. Ventilation.

3.1.5 Vibration

Within this workplace it was 0.01-0.04 m/s2 since there was no vibration that affected the work environment and the worker, thus giving a good place to work without risks.

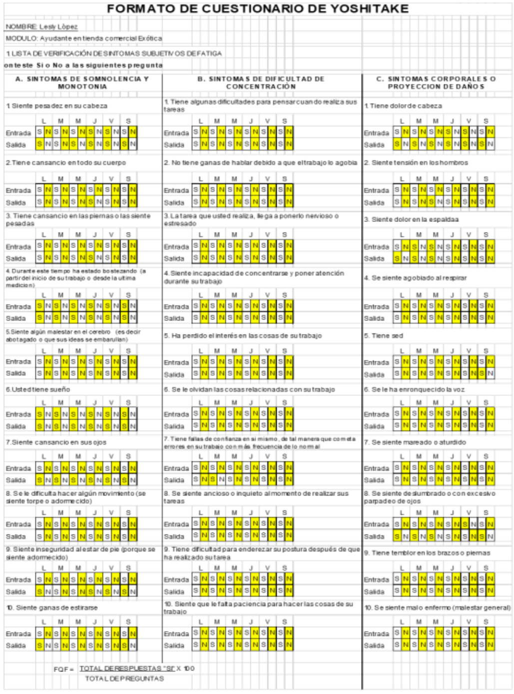
Table 4. Vibration level per workstation.

VIBRATION LEVEL (m/s2) PER WORKSTATION				
Measuring Point	**Location**	**Vibration level found**	**Maximum vibration limit Nom-024-stps-2001**	**Compliant**
1	Door	0.01 **m/s^2**	4 **m/s^2**	Si
2	Racks	0.01 **m/s^2**	4 **m/s^2**	Si
3	Cash register	0.04 **m/s^2**	4 **m/s^2**	si

3.2 Yoshitake's Questionnaire

Yoshitake's method was used to assess the worker's level of fatigue. This method included the application of specific questionnaires that made it possible to identify and quantify the fatigue perceived during and at the end of the working day.

As for fatigue due to drowsiness and monotony, it can be seen that there is no accumulated fatigue over the course of the days and that it is present especially at the end of the working day



FORMATO DE CUESTIONARIO DE YOSHITAKE

NOMBRE: Lesly Lòpez

MODULO: Ayudante en tienda comercial Exótica

1 LISTA DE VERIFICACIÓN DE SINTOMAS SUBJETIVOS DE FATIGA

onteste Si o No a las siguientes pregunta

A. SINTOMAS DE SOMNOLENCIA Y MONOTONIA

1 Siente pesadez en su cabeza
2 Tiene cansancio en todo su cuerpo
3. Tiene cansancio en las piernas o las siente pesadas
4. Durante este tiempo ha estado bostezando (a partir del inicio de su trabajo o desde la ultima medicion)
5. Siente algún malestar en el cerebro (es decir abotagado o que sus ideas se embarullan)
6. Usted tiene sueño
7. Siente cansancio en sus ojos
8. Se le dificulta hacer algún movimiento (se siente torpe o adormecido)
9. Siente inseguridad al estar de pie (porque se siente adormecido)
10. Siente ganas de estirarse

B. SINTOMAS DE DIFICULTAD DE CONCENTRACIÓN

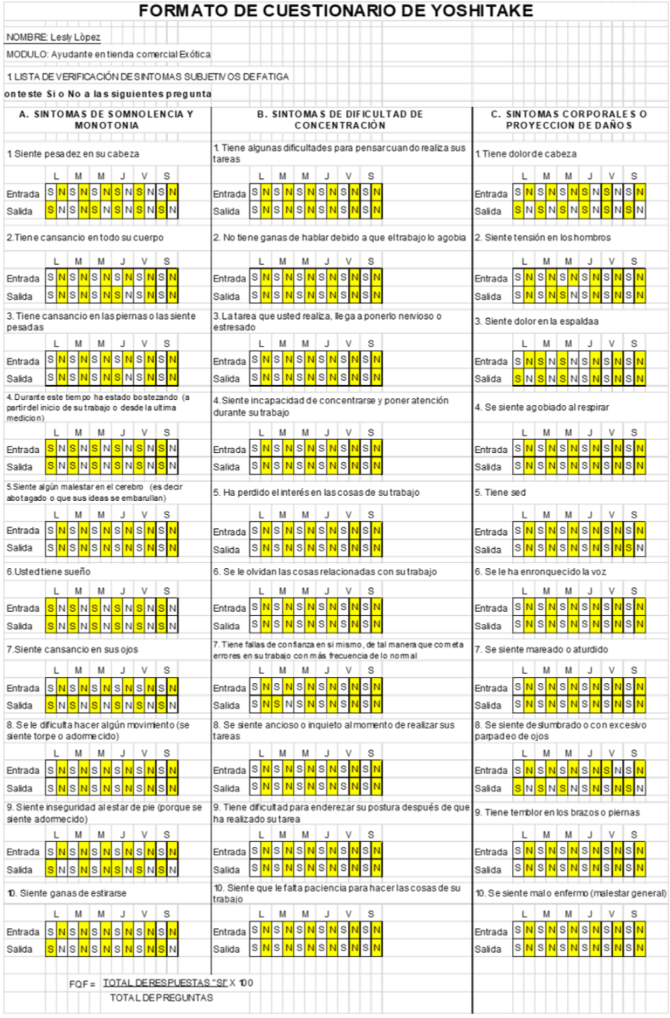
1. Tiene algunas dificultades para pensar cuando realiza sus tareas
2. No tiene ganas de hablar debido a que el trabajo lo agobia
3. La tarea que usted realiza, llega a ponerlo nervioso o estresado
4. Siente incapacidad de concentrarse y poner atención durante su trabajo
5. Ha perdido el interés en las cosas de su trabajo
6. Se le olvidan las cosas relacionadas con su trabajo
7. Tiene fallas de confianza en si mismo, de tal manera que cometa errores en su trabajo con más frecuencia de lo normal
8. Se siente ancioso o inquieto al momento de realizar sus tareas
9. Tiene dificultad para enderezar su postura después de que ha realizado su tarea
10. Siente que le falta paciencia para hacer las cosas de su trabajo

C. SINTOMAS CORPORALES O PROYECCION DE DAÑOS

1. Tiene dolor de cabeza
2. Siente tensión en los hombros
3. Siente dolor en la espaldaa
4. Se siente agobiado al respirar
5. Tiene sed
6. Se le ha enronquecido la voz
7. Se siente mareado o aturdido
8. Se siente deslumbrado o con excesivo parpadeo de ojos
9. Tiene temblor en los brazos o piernas
10. Se siente malo enfermo (malestar general)

FQF = TOTAL DE RESPUESTAS "SI" X 100 / TOTAL DE PREGUNTAS

Figure 8. First-week evaluation.



FORMATO DE CUESTIONARIO DE YOSHITAKE

NOMBRE: Lesly Lòpez

MODULO: Ayudante en tienda comercial Exótica

1 LISTA DE VERIFICACIÓN DE SINTOMAS SUBJETIVOS DE FATIGA

onteste Si o No a las siguientes pregunta

A. SINTOMAS DE SOMNOLENCIA Y MONOTONIA

1 Siente pesadez en su cabeza

2.Tiene cansancio en todo su cuerpo

3. Tiene cansancio en las piernas o las siente pesadas

4. Durante este tiempo ha estado bostezando (a partir del inicio de su trabajo o desde la ultima medicion)

5.Siente algùn malestar en el cerebro (es decir abotagado o que sus ideas se embarullan)

6.Usted tiene sueño

7.Siente cansancio en sus ojos

8. Se le dificulta hacer algún movimiento (se siente torpe o adormecido)

9. Siente inseguridad al estar de pie (porque se siente adormecido)

10. Siente ganas de estirarse

B. SINTOMAS DE DIFICULTAD DE CONCENTRACIÒN

1. Tiene algunas dificultades para pensar cuando realiza sus tareas

2. No tiene ganas de hablar debido a que el trabajo lo agobia

3. La tarea que usted realiza, llega a ponerlo nervioso o estresado

4. Siente incapacidad de concentrarse y poner atención durante su trabajo

5. Ha perdido el interés en las cosas de su trabajo

6. Se le olvidan las cosas relacionadas con su trabajo

7. Tiene fallas de confianza en si mismo, de tal manera que cometa errores en su trabajo con más frecuencia de lo normal

8. Se siente ancioso o inquieto al momento de realizar sus tareas

9. Tiene dificultad para enderezar su postura después de que ha realizado su tarea

10. Siente que le falta paciencia para hacer las cosas de su trabajo

C. SINTOMAS CORPORALES O PROYECCION DE DAÑOS

1 Tiene dolor de cabeza

2. Siente tensión en los hombros

3. Siente dolor en la espaldaa

4. Se siente agobiado al respirar

5. Tiene sed

6. Se le ha enronquecido la voz

7. Se siente mareado o aturdido

8. Se siente deslumbrado o con excesivo parpadeo de ojos

9. Tiene temblor en los brazos o piernas

10. Se siente mal o enfermo (malestar general)

FQF = TOTAL DE RESPUESTAS "SI" X 100 / TOTAL DE PREGUNTAS

Figure 9. Second week evaluation.

	BLOQUE A	
	ENTRADA	SALIDA
DIA	FQFA-E	FQA-S
M	30	70
M	30	60
J	40	50
V	30	50
S	20	40
D	20	40
M	20	20
M	20	30
J	30	60
V	30	20
S	20	50
D	20	50

Fatiga	0-30
Fatiga moderada	40-70
Fatiga excesiva	70-100

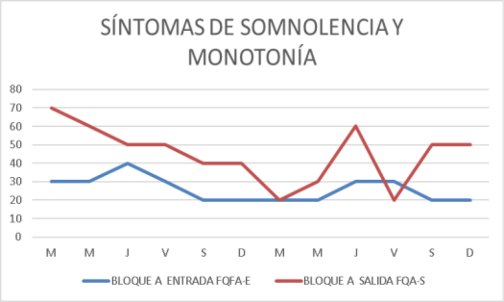
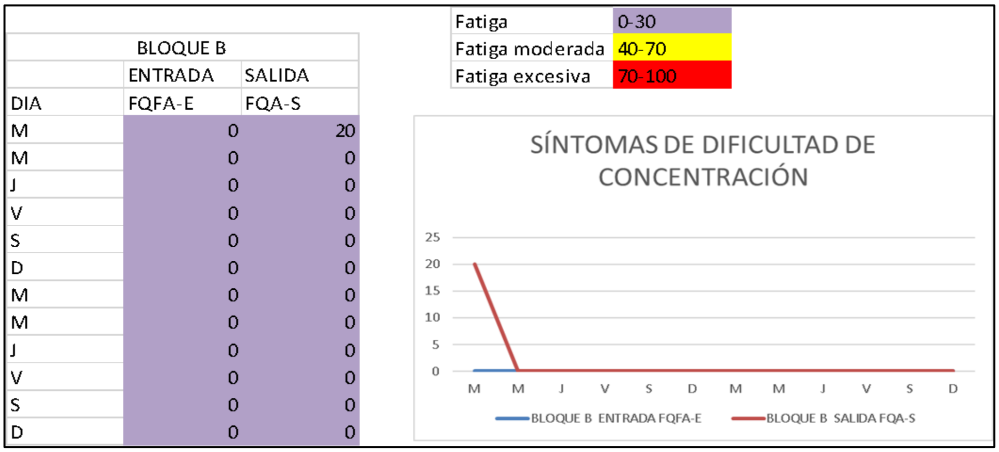


Figure 10. Symptoms of drowsiness and monotony.

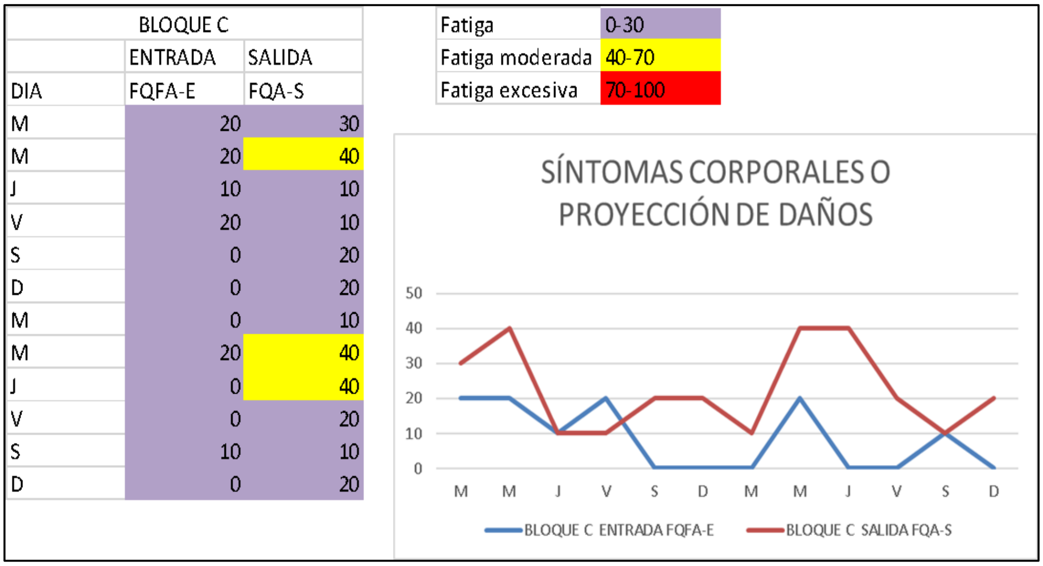


	BLOQUE B	
	ENTRADA	SALIDA
DIA	FQFA-E	FQA-S
M	0	20
M	0	0
J	0	0
V	0	0
S	0	0
D	0	0
M	0	0
M	0	0
J	0	0
V	0	0
S	0	0
D	0	0

Fatiga	0-30
Fatiga moderada	40-70
Fatiga excesiva	70-100

Figure 11. Symptoms of difficulty concentrating.

As far as concentration difficulties are concerned, this does not cause fatigue, since there are no factors that harm or affect their ability to concentrate within their work activities.

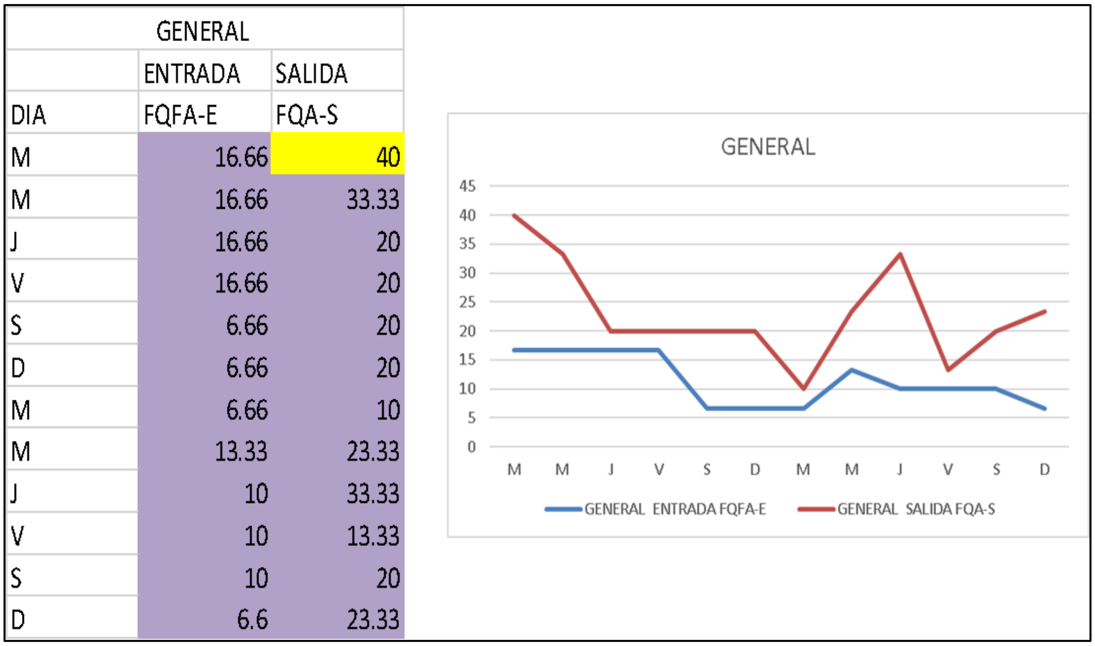


	BLOQUE C	
	ENTRADA	SALIDA
DIA	FQFA-E	FQA-S
M	20	30
M	20	40
J	10	10
V	20	10
S	0	20
D	0	20
M	0	10
M	20	40
J	0	40
V	0	20
S	10	10
D	0	20

Fatiga	0-30
Fatiga moderada	40-70
Fatiga excesiva	70-100

Figure 12. Bodily symptoms and damage.

Therefore, the clerk has few symptoms of bodily injury that causes fatigue and is also not cumulative, has no tendency to increase with the passing of the days and shows moderate fatigue for the most part



	GENERAL	
	ENTRADA	SALIDA
DIA	FQFA-E	FQA-S
M	16.66	40
M	16.66	33.33
J	16.66	20
V	16.66	20
S	6.66	20
D	6.66	20
M	6.66	10
M	13.33	23.33
J	10	33.33
V	10	13.33
S	10	20
D	6.6	23.33

Figure 13. General Graphics.

3.2 Corlett and Bishop

The Corlett and Bishop method was used to assess physical load and body discomfort. Data was collected through surveys and interviews that identify the areas of the body that experience the most fatigue and discomfort.

Corlett and Bishop's body mapping involves dividing the human body into specific anatomical regions and assigning a load or discomfort value to each region. This is done to assess the cumulative load on the body while a person performs a task or maintains a specific posture.

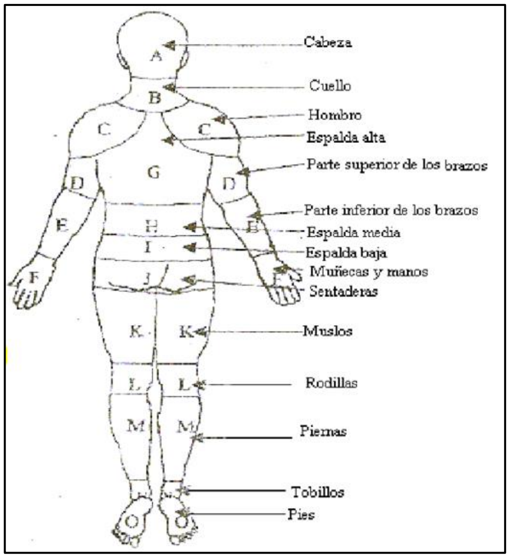


Figure 14. Body mapping

Figure 15. First week evaluation

	LUNES		MARTES		MIERCOLES		JUEVES		VIERNES		SABADO		DOMINGO	
	E	S	E	S	E	S	E	S	E	S	E	S	E	S
A	0	0	1	2	1	2	1	2	0	2	0	2	0	2
B	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	0	0	0	2	0	0	0	0	0	0	0	0	0	0
D	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0	0	0	0	0	0
J	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L	0	0	0	0	0	2	0	2	0	0	0	0	0	2
M	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O	0	0	2	2	0	2	0	2	0	2	0	2	0	0

In this case, the process of the method consisted of carrying out a type of survey to the young woman where she was asked every day that she had to work if at the entrance or exit of her work she felt discomfort or pain in any part of her body, categorizing these with the help of numbers, 0 for no discomfort, 1 for discomfort and 2 for pain. This survey was conducted over six days for two weeks

	LUNES		MARTES		MIERCOLES		JUEVES		VIERNES		SABADO		DOMINGO	
	E	S	E	S	E	S	E	S	E	S	E	S	E	S
A	0	0	0	2	1	2	1	2	0	2	0	2	0	2
B	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	0	0	0	2	0	0	0	0	0	0	0	0	0	0
D	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0	0	0	0	0	0
J	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L	0	0	0	0	0	0	0	2	0	0	0	2	0	0
M	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O	0	0	0	2	0	2	0	2	0	2	0	2	0	2

Figure 16. Second week evaluation.

Looking at the tables, it can be said that the most mentioned parts of the body and therefore those that cause some type of discomfort or pain are: head, shoulders, knees and feet.

As the figure 17 showing the results of the body part: head (A), we can say that there is a slight discomfort at the beginning of the day, mostly in the first days of the beginning of the week, however there is an alarming situation at the end of the day since every day of both weeks there is a headache, marked with the number 2.

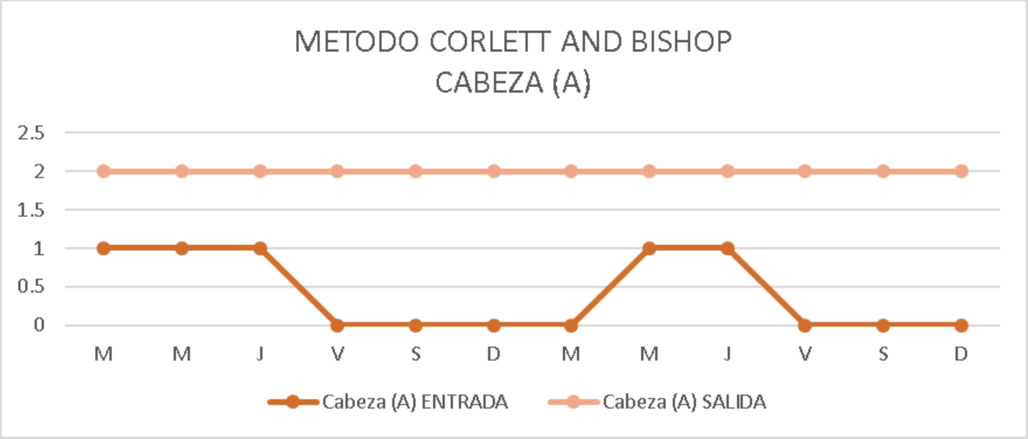


Figure 17. Head.

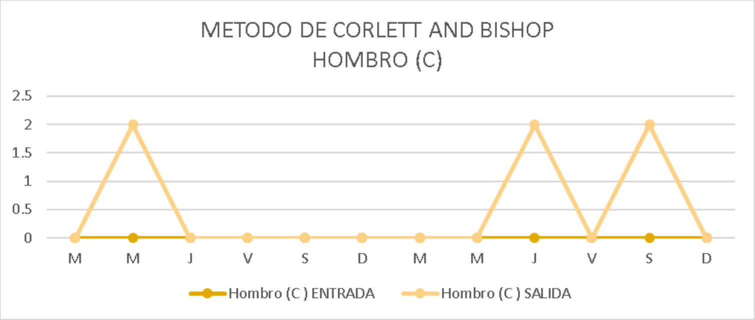


Figure 18. Shoulder.

In this case, shoulder pain is not constant, it shows itself on some days at the end of the working day, in the second week.

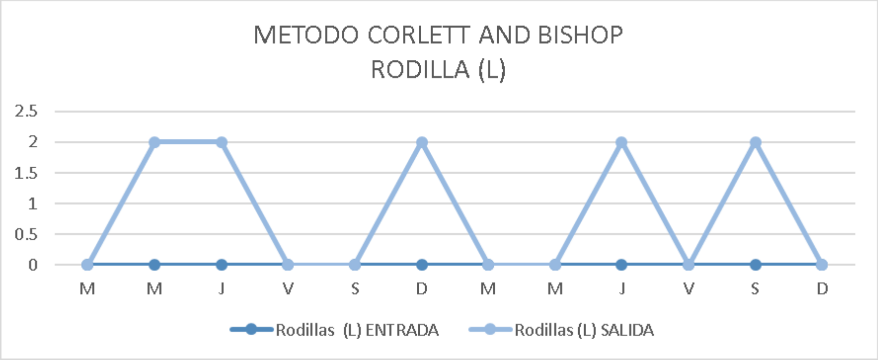


Figure 19. Knees.

In figure 19, at the beginning there is no discomfort in the knees, however, not constantly, but a classification of knee pain (2) is shown at the end of the 8-hour day.

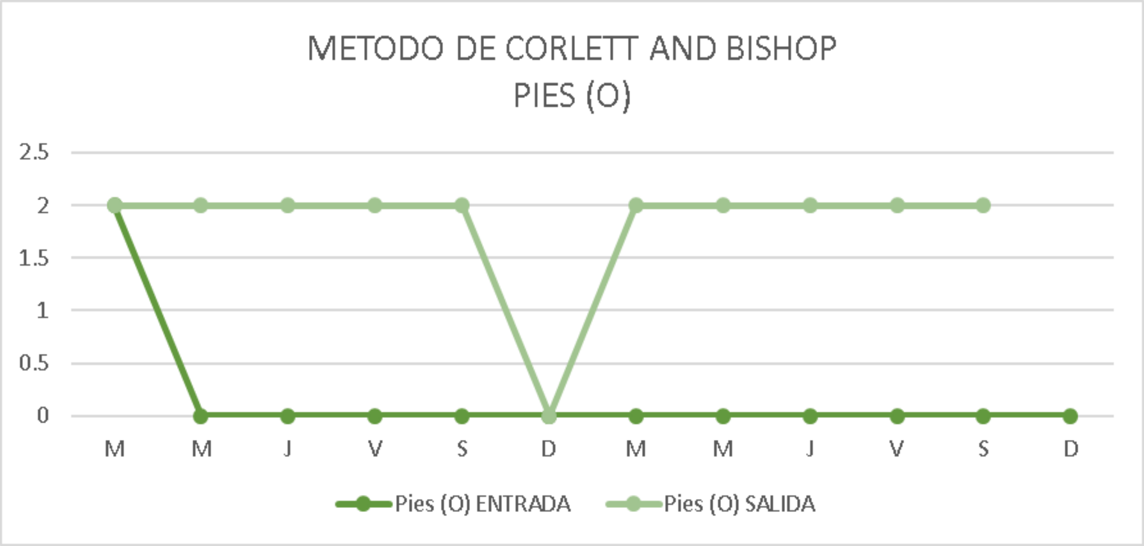


Figure 20. Feet.

The graph shows us that in the part of the body "O" corresponding to the feet there is a predominant pain (2) most of the days after leaving and finishing work. As for the input, it shows a value of zero almost always which means that there is no disturbance.

4. RESULTS

- **Lighting**: the evaluated work area complies with the regulations and has an adequate level of lighting, which provides a safe and healthy environment in the performance of the tasks carried out by the workers
- **Temperature**: the site meets the temperature set by the standard in a light duty category with an eight-hour day
- **Noise**: the evaluated work area complies with the maximum established limits because it is below the permitted decibels.
- **Ventilation**: despite being an enclosed place without natural air flow, the site has an appropriate ventilation system according to its dimensions.

Regarding Yoshitake's questionnaire applied, it indicates that the clerk shows signs of fatigue mainly due to symptoms of drowsiness and monotony, which is not accumulated with the passing of the days and is only reflected in the time of departure mainly, in the same way, she shows fatigue due to damage projection which emphasizes that when she leaves her work she suffers from pain or discomfort at the end of her day of work.

According to the results obtained and the analysis carried out using the Corlett and Bishop, we have that the parts of the body where there is some kind of discomfort or pain are: head, shoulders, knees and feet.

5.CONCLUSIONS

Although most of these factors are within acceptable limits, it is necessary to improve the postures and positions that lead the dependent to perform her work activities. In addition, the Yoshitake method showed that the shop assistant experiences moderate to high fatigue at the end of her day due to symptoms of drowsiness and monotony, highlighting the importance of providing adequate breaks.

According to the Corlett and Bishop method, the main areas of body discomfort are the head, shoulders, knees, and feet., indicating that repetitive postures and tasks contribute significantly to physical fatigue. Therefore, it is recommended to implement regular breaks and stretching exercises, and ergonomic review of the workspace is suggested to ensure that the postures and movements performed are as appropriate as possible, thus minimizing the risk of injury and fatigue.

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PHYSICAL AND MENTAL FATIGUE AND ITS RELATIONSHIP WITH THE RATE OF UNSAFE ACTS AMONG INDUSTRIAL WORKERS

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Resumen: Los actos inseguros representan una causa importante y directa de accidentes. Los actos inseguros son un precursor clave de incidentes graves en las instalaciones industriales y su prevención puede reducir significativamente la incidencia de accidentes. A pesar de los importantes avances logrados por investigaciones anteriores en el análisis de las causas de los actos inseguros y en el desarrollo de estrategias de control del comportamiento, se ha hablado relativamente poco de las interacciones entre los actos inseguros y la fatiga de los trabajadores. Este estudio pretendía explorar la relación entre la fatiga mental y física y la ocurrencia de actos inseguros entre los trabajadores industriales. El estudio se centró exclusivamente en trabajadores industriales de un sector específico (manufactura). Los participantes se limitaron a empleados de tiempo completo que han estado en la organización por lo menos seis años para asegurar suficiente exposición al ambiente de trabajo. La investigación se llevó a cabo dentro de la ciudad de Hermosillo, Sonora, para mantener la consistencia en factores externos como regulaciones e influencias culturales. Se construyó un modelo de regresión múltiple, con la fatiga mental y la fatiga física como variables independientes y la tasa de actos inseguros como variable dependiente. Los coeficientes de correlación fueron los siguientes: fatiga física y actos inseguros (0,45), fatiga mental y actos inseguros (0,50), y fatiga física y fatiga mental (0,30). El análisis de correlación indicó que existían correlaciones positivas moderadas entre la fatiga física y la fatiga mental con la tasa de actos inseguros, lo que sugiere posibles relaciones dignas de una investigación más profunda mediante el análisis de regresión. Los resultados del modelo de regresión múltiple indicaron que no parece haber relación entre los dos enfoques de la fatiga y los actos inseguros de los trabajadores. Este resultado puede estar relacionado con el hecho de que, en un momento dado, la formación de los trabajadores puede ser un factor que contribuya a reducir los efectos de la fatiga. Dada la importante relación entre la fatiga y los actos inseguros, es imperativo que las organizaciones industriales apliquen estrategias eficaces de gestión de la fatiga. Esto podría incluir el rediseño de los horarios de trabajo para garantizar periodos de descanso adecuados, la promoción de pausas regulares durante los turnos y la aplicación de medidas ergonómicas para reducir el esfuerzo físico. La supervisión periódica de los niveles de fatiga de los trabajadores mediante encuestas de autoinforme y evaluaciones fisiológicas puede ayudar a identificar precozmente los riesgos relacionados con la fatiga. Ofrecer apoyo a la salud mental y programas de gestión del estrés también puede reducir el impacto de la fatiga mental en la seguridad.

Palabras clave: actos inseguros, fatiga, física, mental.

Relevancia para la ergonomía: Es ampliamente reconocido que la Ergonomía juega un papel importante en la reducción de actos inseguros entre los trabajadores. A través del diseño de ambientes que consideran sus necesidades físicas y cognitivas, la ergonomía ayuda a crear lugares de trabajo más seguros. La intervención ergonómica permite la creación de lugares de trabajo más seguros a través de la reducción de lesiones, mejorando las condiciones ambientales y promoviendo posturas y movimientos adecuados durante la ejecución de una tarea. En los ambientes industriales los trabajadores trabajan en tareas con demandas físicas y mentales que tienen un impacto en su desempeño, en su salud, así como en su seguridad, las cuales conducen a la fatiga. La fatiga puede tener un impacto significativo en su desempeño, en su seguridad y en su salud. En esta investigación puede conducir a la creación de políticas e intervenciones que ayuden a mitigar la fatiga, mejorando la seguridad. Adicionalmente, a través de minimizar la cantidad de actos inseguros, así como los accidentes relacionados, se promueve la reducción de tiempos en investigación y reparación, asegurándose de esta manera operaciones más eficientes. En términos de la salud y el bienestar de los trabajadores, el conocimiento obtenido a partir de este estudio puede emplearse para realizar intervenciones ergonómicas y diseño de estaciones de trabajo para reducir el estrés físico. Por otra parte, el conocimiento de la fatiga en su connotación metal, ofrece oportunidades para establecer sistemas de soporte de salud y de manejo del estrés. Los hallazgos de esta investigación pueden dar pautas para el diseño de equipos, estaciones de trabajo que permitan la reducción tanto de la fatiga física como mental. Además, estos resultados permiten el diseño de programas de trabajo y descanso, así como de turnos de trabajo que sean acordes a los ciclos circadianos y reduzcan la fatiga. Finalmente, este estudio puede contribuir al desarrollo de estándares industriales, así como regulaciones para reducir los riesgos relacionados con la fatiga. El establecimiento de niveles aceptables de fatiga física y mental puede ayudar a monitorear y administrar la fatiga de manera más eficiente. Esta investigación provee de una comprensión acerca de cómo la fatiga física y mental puede tener un efecto sobre los actos inseguros entre trabajadores industriales. A través del tratamiento de estos factores, este estudio apoya la creación de lugares de trabajo más seguros, más productivos y ambientes más saludables, contribuyendo con bienestar de los trabajadores y la eficiencia de las operaciones industriales.

Abstract: It is widely acknowledged that unsafe acts represent a significant and direct cause of accidents. Unsafe acts as a key precursor to major incidents in industrial sites and the prevention of unsafe acts can significantly reduce the incidence of accidents. Despite the significant advances made by previous research in the analysis of the causes of unsafe acts and in the development of behavioral control strategies, there has been relatively little discussion of the interactions between unsafe acts and worker’s fatigue. This study aimed to explore the relationship between mental and physical fatigue and the occurrence of unsafe acts among industrial workers. The study was focus exclusively on industrial workers within a specific sector (manufacturing). Participants were limited to full-time employees who have been with the organization for at least six years to ensure sufficient exposure to the work environment. The research was conducted within the city of Hermosillo, Sonora to maintain consistency in external factors like regulations and cultural influences. Data collection occurred over a five-week specific period providing a snapshot of the relationship between fatigue and unsafe acts during this time. a multiple regression model was constructed, with mental fatigue and physical fatigue as the independent variables and the rate of unsafe acts as the dependent variable. The correlation coefficients were as follows: physical fatigue and unsafe acts (0.45), mental fatigue and unsafe acts (0.50), and physical fatigue and mental fatigue (0.30). Correlation analysis indicated that there were moderate positive correlations between both physical fatigue and mental fatigue with the rate of unsafe acts, suggesting potential relationships worthy of further investigation through regression analysis. The results of the multiple regression model indicated that there does not appear to be a relationship between the two fatigue approaches and workers’ unsafe acts. This result may be linked to the fact that at a given time, worker training may be a factor that helps to reduce the effects of fatigue. Given the significant relationship between fatigue and unsafe acts, it is imperative that industrial organizations implement effective fatigue management strategies. This could include redesigning work schedules to ensure adequate rest periods, promoting regular breaks during shifts, and implementing ergonomic measures to reduce physical strain. Regular monitoring of workers' fatigue levels through self-report surveys and physiological assessments can help identify fatigue-related risks early. Providing mental health support and stress management programs can also reduce the impact of mental fatigue on safety.

Keywords: Unsafe acts, fatigue, physical, mental.

Relevance to Ergonomics: It is widely recognized that ergonomics plays an important role in reducing unsafe acts among workers. By designing work environments that accommodate their physical and cognitive needs, ergonomics can help to create safer workplaces. It is thought that ergonomic interventions can help to create safer workplaces by minimizing strain, preventing injuries, improving environmental conditions, and promoting proper posture and movement. In industrial environments, workers often face physically demanding tasks and mentally taxing conditions that lead to fatigue. This fatigue can have a significant impact on their performance, health and safety, making it a critical area of study in ergonomics. Understanding how fatigue contributes to unsafe actions can help develop strategies to reduce workplace accidents and injuries. This research can lead to the creation of policies and interventions aimed at mitigating fatigue, thereby improving overall safety. In addition, managing fatigue can help maintain high levels of worker performance and productivity by reducing errors and improving focus and efficiency. In addition, by minimizing the rate of unsafe acts and related accidents, there will be less downtime for investigation and repair, ensuring smoother operations. In terms of worker health and well-being, the knowledge gained from the study can be used to make ergonomic adjustments and design workstations that reduce physical stress. Understanding the mental aspects of fatigue allows for the implementation of mental health support systems and stress management programs. The research findings can guide the design of ergonomic tools, equipment and workstation layouts tailored to minimize both physical and mental fatigue. It can also inform the design of better work/rest schedules and shift patterns to match human circadian rhythms and reduce fatigue. Finally, the study can contribute to the development of industry standards and regulations aimed at minimizing fatigue-related risks. Establishing benchmarks for acceptable levels of physical and mental fatigue can help monitor and manage worker fatigue more effectively. This research is critical to advancing ergonomics by providing a deeper understanding of how physical and mental fatigue affect the rate of unsafe acts among industrial workers. By addressing these factors, the study supports the creation of safer, more productive and healthier work environments, ultimately contributing to the well-being of workers and the efficiency of industrial operations.

1. INTRODUCTION

It is widely acknowledged that unsafe acts represent a significant and direct cause of accidents (Es'Haghi et al., 2022). Baldissone et al., 2019; Mirzaei Aliabadi et al. (2018) have identified unsafe acts as a key precursor to major incidents in industrial sites and have concluded that the prevention of unsafe acts can significantly reduce the incidence of accidents (Choudhry and Fang, 2008). Zarei et al., 2022 have suggested that the prevention of unsafe acts could potentially reduce the incidence of accidents. Zhang et al., (2019) found that 88% of accidents were mainly due to unsafe acts of workers. A considerable amount of research effort has been invested in this area. On the one hand, existing studies have mainly discussed the correlation between unsafe acts and various accident factors. These include inadequate management systems (J. Liu et al., 2019), and poor safety culture (Zhang et al., 2020). Despite the significant advances made by previous research in the analysis of the causes of unsafe acts and in the development of behavioral control strategies, there has been relatively little discussion of the interactions between unsafe acts and worker's fatigue. It is widely acknowledged that fatigue can play a role in unsafe behavior (Shang and Lou, 2014; Xing, et al., 2020). It seems that people are more prone to safety accidents when working in a state of fatigue. This is supported by research from Aryal et al. (2017) and Zhang and Murphy et al. (2015). It may be the case that fatigue has an impact on human cognitive ability (Cian et al. 2001). Hockey (1997) and Zhang et al. (2015) highlighted the impact of fatigue on movement ability. In the field of occupational safety and health, fatigue is defined as a decline in the mental or physical ability of staff members engaged in long-duration and high-workload work (Vries et al. 2003) and fatigue can be divided into two categories:

physical and mental. Physical fatigue is caused by the production of lactic acid in a muscle that exceeds the metabolic load of the human body during long-term activities or short periods of intense exercise. This may manifest as muscle fatigue and a decreased muscle contraction rate (Lin et al., 2003). Mental fatigue is a fatigue reaction that can occur when one is required to concentrate on repetitive and monotonous work activities for an extended period. It is often accompanied by difficulty concentrating, decreased responsiveness, low mood, and irritability. The objective of this study is to examine the interrelationships between industrial workers unsafe acts and how physical and mental fatigue combine to cause them. The results of the analysis will provide a basis for decision-making industrial worker's accident prevention efforts. This study aimed to explore the relationship between mental and physical fatigue and the occurrence of unsafe acts among industrial workers. The study was focus exclusively on industrial workers within a specific sector (manufacturing). Participants were limited to full-time employees who have been with the organization for at least six years to ensure sufficient exposure to the work environment. The research was conducted within the city of Hermosillo, Sonora to maintain consistency in external factors like regulations and cultural influences. Data collection occurred over a five-week specific period providing a snapshot of the relationship between fatigue and unsafe acts during this time. The study distinguished between mental fatigue (cognitive weariness, reduced concentration) and physical fatigue (muscular exhaustion, physical tiredness) based on standardized assessment tools. Self-reported questionnaires and objective measures (e.g., wearable devices) will be used to assess both types of fatigue. Unsafe acts will be defined and categorized based on existing safety frameworks and incident reports within the industry. The focus will be on observable and recorded unsafe behaviors rather than near-misses or subjective perceptions of safety. Primary data was collected through surveys, and direct observation of workers. Workers with pre-existing conditions that significantly affect fatigue levels, such as chronic illnesses or sleep disorders, will be excluded to prevent confounding variables. Temporary workers and those in administrative roles will be excluded to maintain focus on operational staff directly involved in industrial tasks.

2. OBJETIVES

The objective of this study is to determine the relationship between unsafe acts of industrial workers when performing a work task with physical and mental fatigue using multiple regression analysis.

3. METHODOLOGY

3.1 Participants and study design

A longitudinal study over five weeks was designed to measure both mental and physical fatigue, as well as counting the number of unsafe acts when doing a welding operation in a harnesses industrial manufacturing process. The experimental design considered a group of 25 industrial workers who performed a welding operation (Figure 1) over six harnesses 100 times after experiencing induced physical and mental fatigue through a walk and solving a crossword puzzle by 30 minutes. Each worker was responsible for completing twenty welding tasks each week, which added up to a total of 100 welding tasks. During each task the worker welded six harnesses. Following the completion of the welding task, two surveys related to physical (Johansson et al. 2010), and mental fatigue (Michielsen et al., 2003) were distributed to workers for their self-answering then it was counted the number of unsafe acts that occurred during the completion of six harnesses welding during each welding task. A database was created with the intention of collating both mental and physical fatigue indexes and unsafe act counts.

Figure 1 Welding operation

3.2 Physical fatigue survey

The physical fatigue assessment (FAS) developed by Michielsen et al. (2003). The FAS is a 10-item scale that assesses symptoms of chronic fatigue. The FAS treats fatigue as a unidimensional construct and does not dimensional construct and does not break its into different factors. However, to ensure that the scale assesses all aspects of aspects of fatigue, the developers selected items to represent both physical and psychological symptoms. The FAS is a self-report, paper and pencil measure that takes approximately 2 minutes to administer. Developers analyzed the psychometric properties of the metric properties of the scale and found an internal consistency of .90. Scores on the scale also correlated highly with the fatigue-related subscales of other measures such as the Individual Strength Checklist. In subsequent analyses, four of the of the scale's ten items showed a gender bias - women tended to bias-women tended to score significantly higher than men. However, when adjusted scores, the researchers found that this that this bias had only a negligible effect on everyone’s overall score, suggesting that the scale's original simplified scoring method is still appropriate. Each item on the FAS is answered using on a five-point Likert-type scale ranging from 1 ("never") to ("never") to 5 ("always"). Items 4 and 10 are reverse-scored. The total score can be as high as 10, indicating the lowest level of fatigue, to 50 indicating the highest. The survey was translated in Spanish. A pilot study was developed to test the validity and reliability of the Spanish version survey. Cronbach’s alpha measures internal consistency and its value was 0.746, which indicates good consistency. Confirmatory factor analysis was used to test validity of survey. Chi-squared was $\chi^2 = 135.85$, $p < 0.001$, RMSEA was 0.05 which indicates a good fit. Goodness-of-Fit Index (GFI) was 0.94.

3.3 Mental fatigue survey

This self-reported multidimensional questionnaire comprehends 15 questions and was published by and adapted it from Rodholm et al. (2001). The responses ranges from 0 to 3, where 0 referred to the absence of fatigue manifestation. Questions are related to affective, cognitive and sensory symptoms, duration of sleep and daytime variation (See appendix 1). Each question is described with examples of common activities. The rating is based on intensity, frequency and duration. The survey has been translated into Spanish. A pilot study was developed to test the validity and reliability of the Spanish version survey. Cronbach's alpha measures internal consistency and its value was 0.866, which indicates good consistency. Confirmatory factor analysis was used to test validity of survey. Chi-squared was $\chi^2 = 156.23$, $p < 0.001$, RMSEA was 0.04 which indicates a good fit. Goodness-of-Fit Index (GFI) was 0.95.

3.4 Survey administration

Mental and physical fatigue surveys were administered for five consecutive weeks after each experiment. The survey was answered by the workers themselves. Workers were trained in a previous session before the start of the experiment.

3.5 Statistical analysis

Statistical data treatment considered the identification of independent variables as measures of physical fatigue and mental fatigue and dependent variable: Rate of unsafe acts. The sample size was sufficiently large and representative of industrial workers to provide reliable results. A data cleaning process was applied to check and handle missing values, outliers and inconsistencies. An exploratory data analysis was performed, including calculating means, medians, standard deviations, and ranges for physical fatigue, mental fatigue, and unsafe acts. Correlation analysis was performed to calculate correlation coefficients to assess the strength and direction of relationships between physical fatigue, mental fatigue, and unsafe acts. Multiple linear regression was used. The assumptions of the model were checked: Linearity, to verify the linear relationship between the independent and dependent variables; Independence to ensure that the observations are independent of each other. Homoscedasticity to check that the variance of the residuals is constant. Normality, to verify the normality of residuals; and multicollinearity. Model fit was assessed using SPSS v.24. Model evaluation included goodness-of-fit: Assessment of model fit using R-squared. A 5% statistical significance was used to check p-values for regression coefficients to determine the significance of predictors and residual analysis was performed to ensure that the model assumptions are met. A hypothesis test was developed to determine the significance of each predictor variable in the multiple regression model with the same value of statistical significance.

4 RESULTS

4.1 Sample demographics

Participants were female (100%), aged 21 to 32 years, BMIs ranging from 23.35 to 35.67, and 48.00% were overweight and 80.00% married, as seen in Table 1.

Table 1 Demographic details of workers

Variables		Values
Age(years)	Mean	26.24
	Range	21-32
	SD	5.22
Gender	Female	100%
BMI(Kg/m2)	Mean	26.36
	Range	23.35-35.67
Health risk (%)	Normal weight	8(32.00%)
	Overweight	12(48.00%)
	Obesity	5(20.00%)
Marital status (%)	Married	20(80.00%)
	Single	5(20.00%)

3.1 Exploratory analysis

In manufacturing environments, the safety of workers is a critical concern, with unsafe acts being a major contributor to accidents and injuries. Among the numerous factors influencing safety, mental and physical fatigue have been identified as key contributors to unsafe behavior. This exploratory analysis seeks to quantify the relationship between these two forms of fatigue and the rate of unsafe acts in a manufacturing process. To achieve this, a multiple regression model was constructed, with mental fatigue and physical fatigue as the independent variables and the rate of unsafe acts as the dependent variable.

Table 2 shows the descriptive statistics of the two predictor variables: physical fatigue and mental fatigue, and the dependent variable: rate of unsafe acts.

Table 2 Descriptive statistics of variables

Variable	Mean	Median	Standard deviation	Range
Physical fatigue	3.5	3.6	0.8	2.0-5.0
Mental fatigue	4.1	4.0	0.7	2.5-5.5
Rate of unsafe acts	2.7	2.8	1.2	1.0-5.0

The correlation coefficients were as follows: physical fatigue and unsafe acts (0.45), mental fatigue and unsafe acts (0.50), and physical fatigue and mental fatigue (0.30). Correlation analysis indicated that there were moderate positive correlations between both physical fatigue and mental fatigue with the rate of unsafe acts, suggesting potential relationships worthy of further investigation through regression analysis. The multiple linear regression analysis showed that the intercept coefficient was 1.2 (p=0.03), the physical fatigue coefficient was 0.45 (p=0.01), and the mental fatigue coefficient was 0.52 (p<0.001). The model results indicate that both mental and physical fatigue are significant predictors of unsafe acts, with mental fatigue showing a stronger relationship. Specifically, mental fatigue ($\beta = X$, $p < 0.01$) was found to have a more substantial impact on the unsafe acts rate than physical fatigue ($\beta = Y$, $p < 0.05$), suggesting that cognitive strain may play a more critical role in safety-related behaviors. The hypothesis test related to the regression line was accepted with a significance level of 5%, which suggests that the regression line may have a slope of zero, indicating that there may be no correlation between physical and mental fatigue and the number of unsafe acts among industrial workers performing welding tasks.

The results of the model fit are as follows: R-squared: 0.38, adjusted R-squared: 0.35, and F-statistic: 12.45 ($p < 0.001$). The regression model explained 38% of the variance in the rate of unsafe acts underscoring the importance of addressing fatigue in safety interventions. Both physical and mental fatigue were significant predictors of unsafe acts, as indicated by the fact that their p-values were less than the significance level (α=0.05). Regarding the verification of assumptions, linearity was confirmed because the scatter plots and residual plots confirmed a linear relationship between the independent variables (physical and mental fatigue) and the dependent variable (rate of unsafe acts). Independence was confirmed by the Durbin-Watson statistic, which was 1.98, indicating that the residuals were independent. Homoscedasticity indicated that the variance of the residuals was constant (Breusch-Pagan test ($p = 0.22$). The Shapiro-Wilk test and Q-Q plot analysis confirmed that the residuals were normally distributed ($p = 0.15$) and normality was confirmed. Finally, the variance inflation factor (VIF) values were below the threshold of 10, indicating no significant multicollinearity among the predictor variables. The multiple linear regression analysis showed that both physical and mental fatigue were significant predictors of the rate of unsafe acts among industrial workers. The model assumptions were verified, ensuring the reliability and validity of the results.

This study highlights the importance of addressing both physical and mental fatigue in efforts to reduce unsafe acts and improve workplace safety. Future research could explore additional variables and intervention strategies to further mitigate these risks. The results of the regression model examining the relationship between physical and mental fatigue and the rate of unsafe acts among industrial workers provide insightful implications for workplace safety and ergonomics. Correlation analysis revealed moderate positive correlations between both physical and mental fatigue and the rate of unsafe acts ($r = 0.45$ and $r = 0.50$, respectively). This suggests that as the level of fatigue increases, so does the likelihood of unsafe acts, highlighting the need to address fatigue as a significant factor in workplace safety. The multiple linear regression model explained 38% of the variance in the rate of unsafe acts (R-squared = 0.38). Both physical fatigue ($\beta = 0.45$, $p = 0.01$) and mental fatigue ($\beta = 0.52$, $p < 0.01$) were significant predictors, indicating that each unit increase in fatigue is associated with a corresponding increase in the rate of unsafe acts.

This finding underscores the critical impact of fatigue on safety performance in industrial settings. Besides these findings suggest that strategies aimed at reducing mental and physical fatigue could be effective in lowering the incidence of unsafe acts and enhancing overall workplace safety. This analysis provides a data-driven foundation for targeted interventions, emphasizing the need for measures such as adequate rest breaks, workload management, and mental health support to mitigate fatigue-related risks in manufacturing processes. The assumptions of linearity, independence, homoscedasticity and normality were satisfactorily met. The Durbin-Watson statistic (1.98) indicated no autocorrelation in the residuals, and the Breusch-Pagan test confirmed constant variance of the residuals. In addition, the Shapiro-Wilk test and Q-Q plot analysis verified the normality of the residuals, ensuring the robustness and validity of the regression model. Given the significant relationship between fatigue and unsafe acts, it is imperative that industrial organizations implement effective fatigue management strategies.

This could include redesigning work schedules to ensure adequate rest periods, promoting regular breaks during shifts, and implementing ergonomic measures to reduce physical strain. Regular monitoring of workers' fatigue levels through self-report surveys and physiological assessments can help identify fatigue-related risks early. Providing mental health support and stress management programs can also reduce the impact of mental fatigue on safety. Educating workers about the risks associated with fatigue and promoting awareness of safe practices can improve the overall safety culture. Training programs that focus on recognizing signs of fatigue and taking appropriate action can be beneficial. While the study provides valuable insights, the findings are based on the sample of workers studied and may not be generalizable to all industrial settings. Future research should include a larger and more diverse sample to validate these findings. This study focused on physical and mental fatigue. Future research could explore other factors that may influence unsafe acts, such as organizational culture, workload, and environmental conditions. Longitudinal studies that track fatigue levels and unsafe acts over time would provide a deeper understanding of the causal relationships and long-term effects of fatigue on safety.

5. CONCLUSIONS

It is known that incidents result from a combination of various unsafe acts that occur prior to the accident in question. It would be beneficial to consider the unsafe acts in an accident as a collection of different factors. This study aimed to shed light on the causal relationships of unsafe acts and fatigue (physical and mental) in industrial workers. The results of the multiple regression model indicated that there does not appear to be a relationship between the two fatigue approaches and workers' unsafe acts. This result may be linked to the fact that at a given time, worker training may be a factor that helps to reduce the effects of fatigue. However, it would be beneficial to conduct a further study with a larger sample size to gain a more precise understanding of the relationship between fatigue and unsafe acts. This could then be used to inform decision-making in accident prevention. The study highlights the significant role of both physical and mental fatigue in contributing to unsafe behaviors among industrial workers. By addressing fatigue through targeted interventions, monitoring and training, organizations can improve workplace safety and reduce the incidence of accidents and injuries. These findings support a holistic approach to ergonomics that addresses both physical and mental well-being to promote a safer and more productive work environment.

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.

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Appendix 1

CUESTIONARIO DE FATIGA MENTAL
(Versión en Español)

1. Fatiga: ¿Se ha sentido fatigado? No importa si la fatiga es física (muscular) o mental.

(0) No me siento fatigado en absoluto.
(1) Me siento fatigado varias veces al día, pero me siento más alerta después de un descanso.
(2) Me siento fatigado durante la mayor parte del día y tomando el descanso tiene poco o ningún efecto.
(3) Me siento fatigado todo el tiempo y descansando no hace ninguna diferencia.

2. Falta de iniciativa: ¿Le resulta difícil empezar las actividades del día? ¿Falta de iniciativa cuando tiene que empezar algo, no importa si es un nueva tarea o parte de sus actividades diarias?

(0) No tengo dificultad para empezar las cosas.
(1) Me resulta más difícil empezar las actividades. Prefiero hacerlo en otro momento.
(2) Se necesita un gran esfuerzo para empezar las actividades. Esto se aplica a las actividades cotidianas.
(3) No puedo hacer las tareas cotidianas más sencillas (comer, vestirse). Necesito ayuda con todo.

3. Fatiga mental: ¿Su cerebro se fatiga rápidamente cuando usted tiene que pensar mucho? ¿Te vuelves mentalmente cansado de cosas como leer, ver la televisión o participar en una conversación con varias personas? ¿Tienes que tomar descansos o cambiar a otra actividad?

(0) No.
(1) Me fatigo rápidamente, pero todavía puedo hacer el mismo esfuerzo mental que antes.
(2) Me fatigo rápidamente.
(3) Me fatigo tan rápidamente que no puedo hacer nada o tengo que abandonar todo después un período breve de (5 minutos).

4. Recuperación mental: Si tienes que tomarte un descanso, ¿cuánto tiempo necesitas recuperarse después de haber trabajado?

(0) Necesito descansar menos de una hora antes y continuar con lo que estoy haciendo.
(1) Necesito descansar más de una hora
(2) Necesito dormir una noche antes de poder continuar lo que sea que esté haciendo.
(3) Necesito varios días de descanso para recuperarme.

5. Dificultades de concentración: ¿Le resulta difícil concentrarse?

(0) Puedo concentrarme siempre.
(1) A veces pierdo concentración, por ejemplo, al leer o ver la televisión.
(2) Encuentro tan difícil concentrarme que tengo problemas, por ejemplo, leer un periódico o participar en una conversación con un grupo de personas.

(3) Siempre me cuesta tanto concentrarme que es casi imposible hacer nada.

6. Problemas de memoria: Olvidas las cosas más a menudo que antes, ¿Tienes necesidad de tomar notas?

(0) No tengo problemas de memoria.
(1) Olvido las cosas un poco más de lo que debería, pero me las arreglo tomando notas.
(2) Mi mala memoria causa problemas frecuentes, por ejemplo, olvidar reuniones importantes.
(3) Apenas puedo recordar nada.

7. Lentitud del pensamiento: ¿Te sientes lento o lento cuando piensas en algo? ¿Sientes que tomas un largo tiempo para concluir resolver una tarea que requiere esfuerzo mental?

(0) Mis pensamientos no son lentos ni lentos cuando se trata de trabajo que involucra esfuerzo mental.
(1) Mis pensamientos son un poco lentos una o varias veces cada día cuando tengo que hacer algo que requiere un serio esfuerzo mental.
(2) Mis pensamientos a menudo se sienten lentos, incluso en la realización de actividades cotidianas, ejemplo una conversación con una persona o al leer el periódico.
(3) Mis pensamientos siempre se sienten muy lentos y lento.

8. Sensibilidad al estrés: ¿Le resulta difícil lidiar con el estrés, es decir haciendo varias cosas al mismo tiempo mientras presión del tiempo?

(0) Soy capaz de hacer frente al estrés de la misma manera que habitual.
(1) Me vuelvo más fácilmente estresado, pero solo en situaciones exigentes que antes podía para gestionar.
(2) Me estreso más fácilmente que antes.
(3) Me estreso muy fácilmente. Me siento estresado en situaciones desconocidas o difíciles.

9. Mayor tendencia a volverse emocional: ¿Encuentras que lloras más fácilmente que antes? ¿Sueles llorar cuando, por ejemplo, ver una película triste o hablar con los miembros de su familia? Si recientemente ha experimentado algo inusual (por ejemplo, un accidente o una enfermedad corta) debe tratar de ignorarlo en su evaluación.

(0) No.

(1) Soy más emocional que otras personas, pero es algo que es natural para mí. Empiezo llorar o mis ojos se llenan de lágrimas fácilmente, pero solo en relación con cosas que me afectan profundamente.

(29 A veces incluso empiezo a llorar por cosas que no significa nada para mí. Trato de evitar ciertas situaciones debido a esto.

(4) Mis emociones me causan grandes problemas.

(10). Irritabilidad: ¿Es usted inusualmente de mal genio o irritable por
cosas que antes no te molestaban?

(0) No.
(1) Me irrito más fácilmente, pero no dura mucho tiempo.
(2) Me irrito muy rápidamente.

(3) Reacciono con extrema ira o rabia, que encuentro muy difícil de controlar.

11. Sensibilidad a la luz: ¿Eres sensible a la luz?

(0) No tengo sensibilidad a la luz.

(1) A veces experimento problemas pero soy capaz hacer frente a ella, por ejemplo, mediante el uso gafas de sol.

(2) Soy tan sensible a la luz que prefiero llevar a cabo mis actividades diarias en la luz tenue. Encuentro difícil salir de la casa sin gafas de sol.

(3) Mi sensibilidad a la luz es tan fuerte que no puede salir de la casa sin gafas de sol.

12. Sensibilidad al ruido: ¿Eres sensible al ruido?

(0) No

(1) A veces me cuesta hablar alto (por ejemplo, música, ruido de la TV o radio o sonidos repentinos e inesperados), pero puedo manejarlo fácilmente. Mi sensibilidad al ruido no perturba mi vida cotidiana.

(2) Tengo sensibilidad al ruido. Para evitar ruidos fuertes o reducirlo uso tapones para los oídos.

(3) Mi sensibilidad al ruido es tan grande que lo encuentro difícil de manejar.

13. Disminución del sueño por la noche: ¿Duermes mal por la noche? Si estás durmiendo más que antes por la noche, seleccione su opción.

(0) No.

(1) Tengo pequeños problemas para conciliar el sueño o el sueño es más corto, más ligero o inquieto que antes.

(2) Duermo al menos 2 horas menos que antes y despierto con frecuencia durante la noche sin nada que me moleste.

(3) Duermo menos de 2-3 horas por noche.

14. Aumento del sueño: ¿Duerme más tiempo y/o más profundamente que antes? Si usted está durmiendo menos que antes, por favor seleccione la opción. Tenga en cuenta tiempo que pasa durmiendo durante el día.

(0) No duermo más de lo normal.

(1) Duermo más o menos, pero menos de 2 horas más de lo habitual, incluidas las siestas día.

(2) Duermo más o más. Al menos 2 horas más que de costumbre, incluidas las siestas.

(3) Duermo más o más. Al menos 4 horas más que de costumbre y además necesito tomar una siesta durante el día.

15. Variaciones de 24 horas ¿Encuentras en ciertos momentos del día o de la noche tienes cansancio o falta de concentración?

(0) No tengo problemas.

(1) Hay una clara diferencia entre ciertos tiempos del día. Puedo predecir que me voy a sentir mejor en ciertos momentos y peor en otros momentos.

(2) Me siento mal en todo momento del día

(3) Me siento mal todo el día y la noche.

Appendix 2

Cuestionario de medición de la fatiga física
(Versión en Español)

	Nunca	*A veces*	*Regularmente*	*A menudo*	*Siempre*
1. Me molesta el cansancio.	1	2	3	4	5
2. Me canso muy rápido.	1	2	3	4	5
3. No realizo mucho durante el día.	1	2	3	4	5
4. Tener suficiente energía para la vida diaria.	5	4	3	2	1
5. Físicamente me siento agotado.	1	2	3	4	5
6. Tener problemas para empezar las actividades.	1	2	3	4	5
7. Tener problemas para pensar con claridad.	1	2	3	4	5
8. No siento ganas de hacer nada.	1	2	3	4	5
9. Mentalmente me siento agotado.	1	2	3	4	5
10. Cuando realizo una actividad, puedo concentrarme.	5	4	3	2	1

ASSOCIATION BETWEEN STRESS AND MENTAL FATIGUE AMONG INDUSTRIAL QUALITY INSPECTORS

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Resumen: La fatiga mental es un estado psicológico de cansancio que puede provocar una reducción de la eficacia en el rendimiento cognitivo, concretamente entre los inspectores de calidad industriales. La fatiga mental puede complicarse aún más por el estrés. Con frecuencia, los inspectores de calidad deben tratar con mucha información. Esto puede provocar estrés, que a su vez puede causar fatiga mental. Existen otros factores relacionados con la fatiga mental y el estrés, como los factores demográficos y laborales.

La interrelación entre los factores demográficos y laborales, el estrés percibido y la fatiga mental se ha abordado de manera escaza. Se diseñó un estudio transversal para examinar la posible relación entre el estrés, los factores laborales y demográficos con la fatiga mental entre los inspectores de calidad industrial. Se utilizó un modelo de regresión logística multivariante para explorar esta relación. La muestra se seleccionó mediante un muestreo de conveniencia en el que participaron 75 inspectores. Se elaboró un cuestionario para recoger datos sobre el estrés, la fatiga mental y factores demográficos laborales como la edad, los años de experiencia laboral, el riesgo para la salud, el sexo, los periodos de descanso, el trabajo por turnos y el estado civil. Los resultados de este estudio indican varias asociaciones estadísticamente significativas entre el estrés, diversos factores laborales y demográficos y la fatiga mental. Uno de los hallazgos más significativos es la fuerte asociación entre presión laboral y fatiga mental, con una odds ratio (OR) de 3,58 (IC 95% [3,22-7,69]).

Esto subraya la necesidad de estrategias para gestionar el estrés en el lugar de trabajo y reducir los riesgos relacionados con la presión. La edad también mostró asociaciones significativas, en particular para los trabajadores de 29-34 años (ORs: 1,26 (IC 95% [1,15-3,63]), lo que sugiere que los trabajadores de este grupo de edad podrían ser especialmente vulnerables a los efectos adversos de los factores estresantes relacionados con el trabajo y la fatiga mental. Los datos revelan que los factores de estrés laboral, como la presión en el trabajo y la falta de apoyo organizativo, se encuentran entre los determinantes más importantes de los resultados adversos, lo que subraya la necesidad urgente de que las organizaciones den prioridad a la salud mental y a los entornos de trabajo favorables. En conclusión, este estudio establece la naturaleza polifacética de los riesgos para la salud en el trabajo, donde la cultura organizativa, las características demográficas y los comportamientos de salud se entrecruzan para influir en el bienestar de los empleados. Las asociaciones significativas identificadas sugieren que las intervenciones holísticas basadas en pruebas son cruciales. Las organizaciones deben ir más allá de las medidas reactivas y adoptar un enfoque proactivo que fomente un entorno laboral más saludable, equitativo y solidario.

Palabras clave: estrés, fatiga, inspectores de calidad, factores demográficos, mental.

Relevancia para la ergonomía: Este estudio proporciona información sobre cómo el estrés y los factores demográficos y laborales contribuyen a la fatiga mental entre los inspectores de calidad del sector industrial, destacando las áreas en las que las intervenciones ergonómicas pueden mitigar estos efectos. Por otra parte, la identificación de factores de estrés específicos y su impacto en la fatiga mental, permite que los ergónomos puedan diseñar soluciones específicas para mejorar el entorno de trabajo, reduciendo el estrés y aumentando el bienestar mental. Además, la fatiga mental puede provocar una disminución de la atención y un aumento de los errores, por lo que abordar los factores ergonómicos que contribuyen al estrés y la fatiga puede ayudar a mejorar la precisión y la seguridad en las tareas de inspección de calidad. Además, las intervenciones ergonómicas que reducen el estrés y la fatiga mental pueden mejorar la productividad general al permitir a los inspectores realizar sus tareas con mayor eficacia y concentración.

El estrés crónico y la fatiga mental pueden provocar problemas de salud a largo plazo, como agotamiento y trastornos mentales. La reducción del estrés mediante mejoras ergonómicas puede conducir a una mayor satisfacción en el trabajo, menores tasas de rotación y una cultura más positiva en el lugar de trabajo. Los resultados de este estudio proporcionan pruebas empíricas que pueden servir de base para el desarrollo de normas y directrices ergonómicas destinadas a reducir el estrés y la fatiga mental en el lugar de trabajo. Las organizaciones pueden utilizar las conclusiones del estudio para elaborar políticas que den prioridad al bienestar de los trabajadores, como la realización de pausas regulares, la formación ergonómica y los programas de apoyo a la salud mental.

El estudio identifica áreas en las que es necesario seguir investigando, como los efectos a largo plazo del estrés y la fatiga mental y la eficacia de intervenciones ergonómicas específicas. Al vincular la ergonomía con estudios psicológicos y organizativos, la investigación fomenta un enfoque multidisciplinar para comprender y abordar los retos del lugar de trabajo. El estudio sobre la asociación entre el estrés, factores laborales y demográfico con la fatiga mental entre los inspectores de calidad industrial subraya el papel fundamental de la ergonomía en la promoción de la salud, la seguridad y la productividad de los trabajadores.

Abstract: Mental fatigue is a psychobiological state of tiredness that potentially led to a reduction in efficiency in cognitive performance, specifically among industrial inspectors. Mental fatigue can be further complicated by stress. Quality inspectors frequently must deal with a lot of information. This can lead to stress, which in turn can cause mental fatigue. There are some other factors related to mental fatigue and stress, such job and demographic factors. The interrelationship between demographic and job factors and, perceived stress and mental fatigue has been scarcely explored. A cross-sectional study was designed to examine the potential relationship between stress, job and demographic factors with mental fatigue among industrial quality inspectors. Multivariate logistic regression models were used to explore this relationship.

The sample was selected using convenience sampling, which involved 75 inspectors. A questionnaire was created to collect data on stress, mental fatigue, and job demographic factors such, age, years of labor experience, health risk, gender, resting periods, shift work, and marital status. The results of this study indicate several statistically significant associations between stress, various occupational and demographic factors and mental fatigue. One of the most significant findings is the strong association between job pressure and mental fatigue, with an odds ratio (OR) of 3.58 (95% CI [3.22-7.69]). This highlights the need for strategies to manage workplace stress and reduce pressure-related risks. Age also showed significant associations, particularly for workers aged 29-34 years (ORs: 1.26 (95% CI [1.15-3.63]), suggesting that workers in this age group might be particularly vulnerable to the adverse effects of work-related stressors and mental fatigue. The data reveal that occupational stressors such as job pressure and lack of organizational support are among the most critical determinants of adverse outcomes, underscoring the urgent need for organizations to prioritize mental health and supportive work environments.

In conclusion, this study stablishes the multifaceted nature of occupational health risks, where organizational culture, demographic characteristics, and health behaviors intersect to influence employee well-being. The significant associations identified suggest that holistic, evidence-based interventions are crucial. Organizations must move beyond reactive measures and toward a proactive approach that fosters a healthier, more equitable, and supportive work environment.

Keywords: stress, fatigue, quality inspectors, demographics, mental.

Relevance to Ergonomics:

This study provides insights into how stress and demographic factors contributes to mental fatigue among industrial quality inspectors, highlighting areas where ergonomic interventions can mitigate these effects, by identifying specific stressors and their impact on mental fatigue, ergonomists can design targeted solutions to improve the work environment, reduce stress, and enhance mental well-being. Besides, mental fatigue can lead to decreased attention and increased errors, addressing the ergonomic factors contributing to stress and fatigue can help improve accuracy and safety in quality inspection tasks. Additionally, ergonomic interventions that reduce stress and mental fatigue can enhance overall productivity by enabling inspectors to perform their tasks more efficiently and with greater focus. Chronic stress and mental fatigue can lead to long-term health problems, including burnout and mental health disorders.

Ergonomics plays a crucial role in creating a healthier work environment that prevents these adverse outcomes. Reducing stress through ergonomic improvements can lead to higher job satisfaction, lower turnover rates, and a more positive workplace culture. The findings of this study provide empirical evidence that can inform the development of ergonomic standards and guidelines aimed at reducing stress and mental fatigue in the workplace. Organizations can use the study's insights to shape policies that prioritize worker well-being, such as implementing regular breaks, ergonomic training, and mental health support programs. The study identifies areas where further research is needed, such as the long-term effects of stress and mental fatigue and the efficacy of specific ergonomic interventions.

By linking ergonomics with psychological and organizational studies, the research encourages a multidisciplinary approach to understanding and addressing workplace challenges. The study on the association between stress and mental fatigue among industrial quality inspectors underscores the critical role of ergonomics in promoting worker health, safety, and productivity. By addressing the ergonomic factors contributing to stress and mental fatigue, organizations can create healthier, more efficient, and more satisfying work environments.

4. INTRODUCTION

Mental fatigue can be described as a psychobiological state of tiredness that may result from prolonged periods of performing demanding activities that require a significant cognitive load. This can potentially lead to a reduction in efficiency in cognitive performance (Roelands et al., 2023). Mental fatigue can be further complicated by stress. It is possible that stress may have a fatigue-enhancing effect when an individual is performing a highly cognitive and attention-demanding task. Furthermore, it is worth noting that stress can potentially impact learning. This is because stress can affect brain areas that control working memory, which could increase the risk of cognitive overload (Johansson et al., 2012). One possible way to understand the concept of mental load is to consider it alongside perceptual load and processing capacity. Firstly, it seems that there is a link between perceptual load and the amount of information involved in processing a relevant task (Elmada˘g, & Ellinger,2016).

It is thought that high perceptual load may result in inattentional blindness, which could potentially lead to impairments of memory (Caparos & Linnell, 2010). It is known that perceptual load is one of the causes of high mental load. However, it is also important to consider that higher mental load can occur from tasks involving executive functioning skills, irrespective of whether they involve higher perceptual load (Bhagat et al., 2010). Secondly, it might be helpful to define processing capacity as the amount of information an individual can process at any given time

(Kunasegaran et al. 2023). Once the capacity is reached, it becomes increasingly challenging to process new information, which can result in mental overload. It is worth noting that prolonged periods of mental overload can lead to feelings of mental fatigue (Mizuno et al., 2011).

The European Commission defines job stress as a pattern of emotional, cognitive, behavioral, and physiological reactions to adverse and noxious aspects of work content, work organization, and work environment. Job stress is caused by poor matches between people and their associated work and by conflicts between their roles at work and the work environment. It might be said that stress and mental fatigue can be differentiated based on their inducers (Gaillard, 2001). It seems that the mechanisms underlying stress and mental fatigue are different, and that they produce bio-behavioral states that are distinguishable. It is thought that stress is induced when a stressor (a perceived threat) causes the body to release stress hormones, which result in behavioral and physical changes (Darwish et al. 2023; Lupien et al., 2009; Reznikov et al., 2007). It is worth noting that stress does not typically result in a feeling of tiredness, unlike mental fatigue.

Rather than causing a feeling of tiredness, stress causes the body to produce a fight-or-flight response (Johnson et al., 1992). Previous studies have indicated that job stress problems (i.e., general, physical, psychosocial, and environmental) may play a role in the process of mental fatigue (Lee et al., 1991). There are limited studies that have explored the interrelationship between socio-demographic and job factors and, perceived stress and mental fatigue. Quality inspectors frequently must deal with a lot of information. This can lead to stress, which in turn can cause mental fatigue. This study employs a cross-sectional design, which captures data at a single point in time. This limits the ability to infer causality between stress and mental fatigue, as the temporal sequence of these factors cannot be established. Data on stress and mental fatigue are collected through self-reported questionnaires. Self-reported measures are subject to biases such as social desirability, recall bias, and subjective interpretation, which can affect the accuracy of the data. The sample size has been limited to 75 industrial quality inspectors from Hermosillo, Sonora, México.

The findings may not be generalizable to all industrial quality inspectors, especially those in different industries, geographic locations, or organizational cultures. There may be unmeasured confounding variables that influence both stress and mental fatigue, such as personal life stressors, overall health status, and organizational factors. The presence of confounders can affect the validity of the logistic regression model, and the associations found between stress and mental fatigue. Inconsistent measurement tools can lead to errors in data interpretation and weaken the study's findings. The reliability and validity of the instruments used to measure stress and mental fatigue had been assessed in previous pilot study. The logistic regression model assumes a linear relationship between the log odds of the dependent variable and the independent variables.

If the relationship is not linear, the model may not accurately capture the association between stress and mental fatigue. Additionally, logistic regression does not account for potential interactions between variables without explicitly including interaction terms. The study does not account for temporal variations in stress and mental fatigue levels, such as fluctuations due to work cycles, seasons, or organizational changes. variations over time can influence the relationship between stress and mental fatigue, and the study may miss capturing these dynamics. The response rate from participants may be low or selective, with those experiencing higher levels of stress or mental fatigue being likely to participate. Non-response bias can skew the results and limit the representativeness of the sample. The study may not account for cultural and contextual differences in how stress and mental fatigue are perceived and reported. Cultural variations can affect the generalizability of the findings across different populations and work environments. The study is specific to industrial quality inspectors and may not consider other occupational groups. The unique stressors and working conditions of quality inspectors may not be applicable to other job roles, limiting the broader applicability of the findings.

5. OBJECTIVES

The objective of this study is to analyze the association between reported job stress factors, demographics and the occurrence of mental fatigue among industrial quality inspectors.

6. METHODOLOGY

3.1 Participants and study design

A cross-sectional study was designed to examine the potential relationship between stress, demographic factor and mental fatigue among industrial quality inspectors. Logistic regression models were used to explore this relationship. The target population consisted of industrial quality inspectors from a local manufacturing industry. The sample was selected using convenience sampling, which involved 75 inspectors. Stratified random sampling will be used to ensure that the sample is representative of various shifts within the manufacturing plants. A questionnaire was created with the intention of collecting data on stress, mental fatigue, and demographic factors such, age, years of labour experience, body index mass, gender, resting periods, shift work, and marital status. A mental fatigue survey and a Stress Survey were administered during the five weeks the study lasted. Prior to the study, participants were informed about the study objectives and asked to consent to their participation. The questionnaire was administered in person during work breaks to ensure minimal disruption. The following variables were considered: levels of stress (independent variable), mental fatigue, and control variables were demographic factors (age, gender), work-related factors (years of experience, work shift). All variables were then subjected to a series of calculations, including means, standard deviations, frequencies, and percentages. A correlation analysis was conducted to examine the potential relationships between stress, mental fatigue, and other variables.

6.2 Job stress survey

The Job Stress Survey (JSS) (Spielberger et al., 1999) consists of three scales and six subscales. The stress scales are Job Stress Severity (JSS), Job Stress Frequency (JSF), and Job Stress Index (JSX). The JSS scale shows the average rating of the severity of the 30 JSS stressor events. The JSF scale indicates the average frequency of the 30 JSS stressor events over the past 6 months. The JSX scale is the overall job stress scale, which is a combination of the JSS and JS-F scales. The index scores are the product of the severity and frequency of each item in the JSS.

The index scores provide an indication of the perceived level of occupational stress experienced by the respondent. The range of the index score is from 0 to 81, with 0 representing the lowest level of is the lowest level of job stress and 81 is the highest level of job stress. From the selection of the JSS items, the subscales can be formed, namely Job Pressure (JPFrecuency, JPSeverity, and JP Index) and Lack of Organizational Support (LSFrequency, JPSeverity, and LSIndex). The survey has been translated into Spanish. A pilot study was developed to test the validity and reliability of the Spanish version survey. Cronbach's alpha measures internal consistency and its value was 0.985, which indicates a perfect consistency. Confirmatory factor analysis was used to test validity of survey. Chi-squared was $\chi^2 = 138.24$, $p < 0.001$, RMSEA was 0.03 which indicates a good fit. Goodness-of-Fit Index (GFI) was 0.94.

6.3 Mental fatigue survey

This self-reported multidimensional questionnaire comprehends 15 questions and was published by and adapted it from Rodholm et al. (2001). The responses ranges from 0 to 3, where 0 referred to the absence of fatigue manifestation. Questions are related to affective, cognitive and sensory symptoms, duration of sleep and daytime variation (See appendix 1). Each question is described with examples of common activities. The rating is based on intensity, frequency and duration. The survey has been translated into Spanish. A pilot study was developed to test the validity and reliability of the Spanish version survey. Cronbach's alpha measures internal consistency and its value was 0.866, which indicates good consistency. Confirmatory factor analysis was used to test validity of survey. Chi-squared was $\chi^2 = 156.23$, $p < 0.001$, RMSEA was 0.04 which indicates a good fit. Goodness-of-Fit Index (GFI) was 0.95.

6.4 Statistical treatment

To examine the association between stress and mental fatigue, while controlling for demographic and work-related factors, logistic regression models were used. The first model was an unadjusted model, which was used to examine the direct association between stress and mental fatigue. The second model was an adjusted model that included control variables with the aim of accounting for potential confounders. A significance level of 5% was used.

3.2 Survey administration

The survey administration process was designed to ensure accurate data collection while minimizing respondent burden and maximizing participation rates. Participants were recruited from a manufacturing company employing industrial quality inspectors. A list of potential companies was compiled, and company management was contacted to obtain permission to conduct the survey within their organization. Information sessions were held to explain the study's objectives, procedures, and the importance of participation to potential respondents.

During these sessions, participants were provided with an overview of the study, emphasizing the confidentiality of their responses and the voluntary nature of participation. Prior to participation, all respondents were provided with an informed consent form detailing the purpose of the study, the types of data being collected, the risks and benefits of participation, and assurances of confidentiality. Participants were informed that they could withdraw from the study at any point without penalty. Participants were required to sign the consent form before proceeding with the survey. The survey, which included the Job Stress Scale (JSS), the Mental Fatigue Scale (MFS) including the demographic details, was administered through paper formats to accommodate different preferences and accessibilities of the participants. The surveys were completed during work rest hours and collected by a designated study coordinator. Participants completed the survey every working day during the five weeks.

A reminder was sent one week after the initial distribution to encourage participation and to ensure a higher response rate. Paper surveys were collected by the study coordinator and securely transported to the research team, where they were manually entered into the same database. This process was double-checked for accuracy to prevent data entry errors. All data were anonymized by removing identifying information and assigning unique participant codes to each response. To ensure the reliability and validity of the data, surveys with incomplete responses or inconsistent answers were flagged for review. Participants who submitted incomplete surveys were contacted and asked if they would like to complete the missing sections. This thorough and flexible approach to survey administration ensured that data were collected efficiently and accurately, providing a robust dataset for subsequent analysis of the relationship between job stress, demographic factors, and mental fatigue among industrial quality inspectors.

5 RESULTS

3.2 Sample demographics

Participants were female (80%) and male (20%), aged 28-37 years, BMI ranged from 25.87 to 38.24. Most participants were overweight (47%) and 64.00% were married, years of experience ranged from 8-17, and most participants worked the night shift (80%), as shown in Table 1.

Table 1 Demographic details of workers

Variables		Values
Age(years)	Mean	31.26
	Range	23-42
	SD	2.89
	Female	80%
Gender	Male	20%
Health risk (%)	Normal weight	12(16.00%)
	Overweight	35(47.00%)
	Obesity	23(31.00%)
Marital status (%)	Married	48(64.00%)
	Single	27(36.00%)
Years of job experience	Mean	15.6
	Range	8-17
	SD	1.25
Shift work Day		60(80%)
Night		15(20%)

3.3 Multivariate logistic regression

Multivariate Logistic Regression (MLR) models result show the association between stress, demographic factors and mental fatigue. The MLR model results are shown in table 2.

Table 2
Associations between stress, demographic factors and mental fatigue

Factors	Category	OR (95% CI)
Stress	Job pressure	**3.58(3.22-7.69)**
	Lack of organizational support	**2.23(1.96-3.37)**
Age	23-28 yrs.	0.89(0.78-2.39)
	29-34 yrs.	**1.26(1.15-3.63)**

	35-42 yrs.	**2.39(2.25-6.95)**
Gender	Male	1
	Female	**1.72(1.02-2.91)**
Health risk	Normal weight	1.06(1.01-2.55)
	Overweight	**2.26(2.21-3.36)**
	Obesity	**2.96(2.55-4.66)**
Marital status	Married	**1.80(1.06-3.07)**
	Single	1
Job experience	1-5 yrs.	**3.69(3.45-8.99)**
	5-10 yrs.	1.38(1.26-5.69)
	10-20 yrs.	2.36(2.17-6.78)
Shift work	Day	1.02(0.98-2.38)
	Night	**2.26(2.15-3.66)**
Duration of work without breaks	< 2 hrs.	1.25(0.97-1.86)
	2-3 hrs.	1.89(0.89-2.65)
	< 3 hrs.	**2.69(1.65-4.58)**

p-value < 0.05 in bold
Significance level α=0.05

The results shown in Table 2 found statistically significant associations (p< 0.05) on job pressure (OR= 3.58; 95% CI [3.22-7.69]), Lack of organizational support (OR= 2.23; 95% CI [1.96-3.37]); age (29-34 years) (OR= 1.26; 95% CI [1.15-3.63]), age 29-34 years (OR= 2.39; 95% CI [2.25-6.95]), gender (female) (OR= 1.72; 95% CI [1.02-2.91]), health risk (overweight) (OR= 2.26; 95% CI [2.21-3.36]), health risk (obesity) (OR= 2.96; 95% CI [2.55-4.66]), marital status (married) (OR= 1.80; 95% CI [1.06-3.07]), job experience (1-5 years)(OR= 3.69; 95% CI [3.45-8.99]), shift work (night) (OR= 2.26; 95% CI [2.15-3.66]), and duration of works without breaks (<3 hours) (OR= 2.69; 95% CI [1.65-4.58]) while the other factors did not reach statistical significance.

The results of this study indicate several statistically significant associations between stress, various occupational and demographic factors and mental fatigue. The data reveal critical insights into the risk factors that may influence worker well-being and organizational dynamics. One of the most significant findings is the strong association between job pressure and mental fatigue, with an odds ratio (OR) of 3.58 (95% CI [3.22-7.69]). This suggests that workers experiencing high job pressure are over three times more likely to mental fatigue, highlighting the need for strategies to manage workplace stress and reduce pressure-related risks. Similarly, lack of organizational support emerged as a significant factor, with an OR of 2.23 (95% CI [1.96-3.37]). This finding underscores the critical role of supportive work environments in mitigating the risks associated with occupational stress and mental fatigue. Organizations may need to focus on enhancing support systems, such as employee assistance programs, to foster a more resilient workforce.

Age also showed significant associations, particularly for workers aged 29-34 years, with two distinct ORs: 1.26 (95% CI [1.15-3.63]) and 2.39 (95% CI [2.25-6.95]). This suggests that workers in this age group might be particularly vulnerable to the adverse effects of work-related stressors and mental fatigue. These findings could reflect life stage challenges, such as balancing career and family responsibilities, that require targeted interventions. Gender was another significant factor, with females having an OR of 1.72 (95% CI [1.02-2.91]), indicating a higher likelihood of adverse outcomes compared to males. This result aligns with existing literature that suggests women may face unique workplace challenges, including gender discrimination, work-life balance issues, and role overload. Health risks, particularly overweight (OR= 2.26; 95% CI [2.21-3.36]) and obesity (OR= 2.96; 95% CI [2.55-4.66]), were also strongly associated with metal fatigue. These findings highlight the intersection between occupational health and general health, suggesting that initiatives promoting healthy lifestyles within the workplace could be crucial in reducing these risks. Marital status, specifically being married, was associated with an OR of 1.80 (95% CI [1.06-3.07]). This may reflect the added pressures that married individuals might experience, such as financial obligations or family responsibilities, which can exacerbate work-related stress. Job experience, particularly for those with 1-5 years of experience, was significantly associated with mental fatigue (OR= 3.69; 95% CI [3.45-8.99]). This could indicate that less experienced workers are more susceptible to occupational stress and mental fatigue due to a lack of coping strategies or job security. Organizations may benefit from providing additional support and training for newer employees.

Shift work, especially night shifts, was another critical factor with an OR of 2.26 (95% CI [2.15-3.66]), reinforcing the well-documented challenges associated with irregular work hours. The impact of night shifts on circadian rhythms and overall health is well-established, suggesting that interventions to mitigate these effects, such as shift rotation policies or better rest facilities, could be beneficial.

Finally, the duration of work without breaks (<3 hours) was significantly associated with mental fatigue (OR= 2.69; 95% CI [1.65-4.58]). This finding highlights the importance of regular breaks to maintain productivity and well-being, supporting the implementation of policies that enforce or encourage taking breaks during work hours. In summary, the study identifies stress and key occupational and demographic factors associated with adverse outcomes, emphasizing the need for comprehensive interventions that address job pressure, organizational support, health risks, and work conditions. Addressing these factors could significantly improve worker well-being and productivity, leading to a healthier and more supportive workplace environment.

6. CONCLUSIONS

This study aimed to gain insight into the potential association between stress, demographic factors, and mental fatigue among industrial quality inspectors. To this end, multivariate logistic regression models were employed. The findings indicated a correlation between stress levels and an increased likelihood of experiencing high mental fatigue, even after accounting for various demographic and work-related factors. The data reveal that occupational stressors such as job pressure and lack of organizational support are among the most critical determinants of adverse outcomes, underscoring the urgent need for organizations to prioritize mental health and supportive work environments. These factors are not isolated; rather, they interact with demographic variables such as age, gender, and health status, creating a complex web of risks that can undermine both individual and organizational success.

It is notable that inspectors working night were more likely to report high mental fatigue. The findings of this study provide a compelling and nuanced understanding of the factors that significantly impact employee well-being and organizational outcomes. The significant associations between job and demographic factors and, mental fatigue suggests that high-stress work environments are a pervasive issue with profound consequences. This highlights the necessity for organizations to rethink their work culture, moving away from high-pressure environments toward more sustainable and supportive models. Similarly, the lack of organizational support as a major risk factor points to the critical role that management and leadership play in shaping employee experiences. Effective support systems, clear communication, and resources for stress management can mitigate these risks, leading to better job satisfaction and overall health. The demographic factors—particularly age, gender, and health risks—illuminate the differentiated impact of work-related stress.

For instance, workers aged 29-34 years appear particularly vulnerable, likely due to the confluence of career demands and personal life challenges. Similarly, the heightened risk for women suggests persistent gender-specific barriers in the workplace that require targeted interventions, such as flexible work arrangements and gender-sensitive policies. The significant role of health risks like overweight and obesity further emphasizes the interplay between physical and occupational health, suggesting that promoting healthier lifestyles within the workplace could have far-reaching benefits.

Moreover, the significant associations with job experience and shift work illustrate the importance of tailoring organizational policies to meet the diverse needs of the workforce. Less experienced workers may require additional mentorship and support, while the well-documented risks of night shifts call for interventions that address the unique challenges of irregular work hours. The finding that insufficient breaks are linked to negative outcomes further underscores the importance of policies that prioritize worker health over relentless productivity.

In conclusion, this study stablishes the multifaceted nature of occupational health risks, where organizational culture, demographic characteristics, and health behaviors intersect to influence employee well-being. The significant associations identified suggest that holistic, evidence-based interventions are crucial. Organizations must move beyond reactive measures and toward a proactive approach that fosters a healthier, more equitable, and supportive work environment.

By addressing these identified risk factors, companies can not only improve the well-being of their employees but also enhance productivity, reduce turnover, and create a more sustainable and successful organizational culture. These results suggest that it may be beneficial to consider addressing ergonomic factors to mitigate stress and reduce mental fatigue. It would be beneficial to consider interventions that could help to manage workloads, enhance social support, and optimize shift schedules. This could potentially contribute to improvements in the well-being, safety, and productivity of quality inspectors. Furthermore, it may be beneficial to consider tailoring interventions to the specific needs of experienced workers and those in demanding shift patterns, which could potentially enhance their effectiveness.

The study's cross-sectional design does not allow for the drawing of causal conclusions. Additionally, the reliance on self-reported measures may introduce potential biases. Future research could benefit from incorporating longitudinal designs and objective measures to gain a deeper understanding of the dynamics of stress and mental fatigue. It would be beneficial to replicate the study in different settings and with diverse occupational groups to enhance the generalizability of the findings. In conclusion, this research suggests the ergonomics may play a role in managing stress and mental fatigue among industrial quality inspectors. It is our hope that by implementing targeted ergonomic interventions, organizations will be able to foster a healthier, safer, and more productive work environment.

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.

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Appendix 1

CUESTIONARIO DE FATIGA MENTAL
(Versión en Español)

1. Fatiga: ¿Se ha sentido fatigado? No importa si la fatiga es física (muscular) o mental.
(4) No me siento fatigado en absoluto.
(5) Me siento fatigado varias veces al día, pero me siento más alerta después de un descanso.
(6) Me siento fatigado durante la mayor parte del día y tomando el descanso tiene poco o ningún efecto.
(7) Me siento fatigado todo el tiempo y descansando no hace ninguna diferencia.

2. Falta de iniciativa: ¿Le resulta difícil empezar las actividades del día? ¿Falta de iniciativa cuando tiene que empezar algo, no importa si es un nueva tarea o parte de sus actividades diarias?
(4) No tengo dificultad para empezar las cosas.
(5) Me resulta más difícil empezar las actividades. Prefiero hacerlo en otro momento.
(6) Se necesita un gran esfuerzo para empezar las actividades. Esto se aplica a las actividades cotidianas.
(7) No puedo hacer las tareas cotidianas más sencillas (comer, vestirse). Necesito ayuda con todo.

3. Fatiga mental: ¿Su cerebro se fatiga rápidamente cuando usted tiene que pensar mucho? ¿Te vuelves mentalmente cansado de cosas como leer, ver la televisión o participar en una conversación con varias personas? ¿Tienes que tomar descansos o cambiar a otra actividad?
(4) No.
(5) Me fatigo rápidamente, pero todavía puedo hacer el mismo esfuerzo mental que antes.
(6) Me fatigo rápidamente.
(7) Me fatigo tan rápidamente que no puedo hacer nada o tengo que abandonar todo después un período breve de (5 minutos).

4. Recuperación mental: Si tienes que tomarte un descanso, ¿cuánto tiempo necesitas recuperarse después de haber trabajado?
(0) Necesito descansar menos de una hora antes y continuar con lo que estoy haciendo.
(1) Necesito descansar más de una hora
(2) Necesito dormir una noche antes de poder continuar lo que sea que esté haciendo.
(3) Necesito varios días de descanso para recuperarme.

5. Dificultades de concentración: ¿Le resulta difícil concentrarse?
(4) Puedo concentrarme siempre.
(5) A veces pierdo concentración, por ejemplo, al leer o ver la televisión.
(6) Encuentro tan difícil concentrarme que tengo problemas, por ejemplo, leer un periódico o participar en una conversación con un grupo de personas.

(7) Siempre me cuesta tanto concentrarme que es casi imposible hacer nada.

6. Problemas de memoria: Olvidas las cosas más a menudo que antes, ¿Tienes necesidad de tomar notas?

(4) No tengo problemas de memoria.
(5) Olvido las cosas un poco más de lo que debería, pero me las arreglo tomando notas.
(6) Mi mala memoria causa problemas frecuentes, por ejemplo, olvidar reuniones importantes.
(7) Apenas puedo recordar nada.

7. Lentitud del pensamiento: ¿Te sientes lento o lento cuando piensas en algo? ¿Sientes que tomas un largo tiempo para concluir resolver una tarea que requiere esfuerzo mental?

(4) Mis pensamientos no son lentos ni lentos cuando se trata de trabajo que involucra esfuerzo mental.
(5) Mis pensamientos son un poco lentos una o varias veces cada día cuando tengo que hacer algo que requiere un serio esfuerzo mental.
(6) Mis pensamientos a menudo se sienten lentos, incluso en la realización de actividades cotidianas, ejemplo una conversación con una persona o al leer el periódico.
(7) Mis pensamientos siempre se sienten muy lentos y lento.

8. Sensibilidad al estrés: ¿Le resulta difícil lidiar con el estrés, es decir haciendo varias cosas al mismo tiempo mientras presión del tiempo?

(5) Soy capaz de hacer frente al estrés de la misma manera que habitual.
(6) Me vuelvo más fácilmente estresado, pero solo en situaciones exigentes que antes podía para gestionar.
(7) Me estreso más fácilmente que antes.
(8) Me estreso muy fácilmente. Me siento estresado en situaciones desconocidas o difíciles.

9. Mayor tendencia a volverse emocional: ¿Encuentras que lloras más fácilmente que antes? ¿Sueles llorar cuando, por ejemplo, ver una película triste o hablar con los miembros de su familia? Si recientemente ha experimentado algo inusual (por ejemplo, un accidente o una enfermedad corta) debe tratar de ignorarlo en su evaluación.

(0) No.

(1) Soy más emocional que otras personas, pero es algo que es natural para mí. Empiezo llorar o mis ojos se llenan de lágrimas fácilmente, pero solo en relación con cosas que me afectan profundamente.

(29 A veces incluso empiezo a llorar por cosas que no significa nada para mí. Trato de evitar ciertas situaciones debido a esto.

(9) Mis emociones me causan grandes problemas.

(10). Irritabilidad: ¿Es usted inusualmente de mal genio o irritable por cosas que antes no te molestaban?

(4) No.
(5) Me irrito más fácilmente, pero no dura mucho tiempo.
(6) Me irrito muy rápidamente.

(7) Reacciono con extrema ira o rabia, que encuentro muy difícil de controlar.

11. Sensibilidad a la luz: ¿Eres sensible a la luz?

(4) No tengo sensibilidad a la luz.

(5) A veces experimento problemas pero soy capaz hacer frente a ella, por ejemplo, mediante el uso gafas de sol.

(6) Soy tan sensible a la luz que prefiero llevar a cabo mis actividades diarias en la luz tenue. Encuentro difícil salir de la casa sin gafas de sol.

(7) Mi sensibilidad a la luz es tan fuerte que no puede salir de la casa sin gafas de sol.

12. Sensibilidad al ruido: ¿Eres sensible al ruido?

(4) No

(5) A veces me cuesta hablar alto (por ejemplo, música, ruido de la TV o radio o sonidos repentinos e inesperados), pero puedo manejarlo fácilmente. Mi sensibilidad al ruido no perturba mi vida cotidiana.

(6) Tengo sensibilidad al ruido. Para evitar ruidos fuertes o reducirlo uso tapones para los oídos.

(7) Mi sensibilidad al ruido es tan grande que lo encuentro difícil de manejar.

13. Disminución del sueño por la noche: ¿Duermes mal por la noche? Si estás durmiendo más que antes por la noche, seleccione su opción.

(4) No.

(5) Tengo pequeños problemas para conciliar el sueño o el sueño es más corto, más ligero o inquieto que antes.

(6) Duermo al menos 2 horas menos que antes y despierto con frecuencia durante la noche sin nada que me moleste.

(7) Duermo menos de 2-3 horas por noche.

14. Aumento del sueño: ¿Duerme más tiempo y/o más profundamente que antes? Si usted está durmiendo menos que antes, por favor seleccione la opción. Tenga en cuenta tiempo que pasa durmiendo durante el día.

(4) No duermo más de lo normal.

(5) Duermo más o menos, pero menos de 2 horas más de lo habitual, incluidas las siestas día.

(6) Duermo más o más. Al menos 2 horas más que de costumbre, incluidas las siestas.

(7) Duermo más o más. Al menos 4 horas más que de costumbre y además necesito tomar una siesta durante el día.

15. Variaciones de 24 horas ¿Encuentras en ciertos momentos del día o de la noche tienes cansancio o falta de concentración?

(4) No tengo problemas.

(5) Hay una clara diferencia entre ciertos tiempos del día. Puedo predecir que me voy a sentir mejor en ciertos momentos y peor en otros momentos.

(6) Me siento mal en todo momento del día

(7) Me siento mal todo el día y la noche.

ERGONOMIC ANALYSIS AND INERTIAL SUIT FOR MAN-MACHINE SYSTEM RELATED TO A TELESCOPIC FORKLIFT (CRANE)

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Resumen: La ergonomía es clave en el diseño de espacios laborales, sobre todo en lugares donde los trabajadores pasan horas manejando maquinaria pesada, como en la industria. La cabina de un montacargas telescópico es un ejemplo perfecto de esto, ya que su diseño puede afectar directamente la seguridad, eficiencia y comodidad del operador mientras realiza sus labores.

Es esencial que los analistas puedan identificar los posibles problemas ergonómicos en la cabina del montacargas telescópico para poder tomar medidas preventivas. Por eso, se realizó un análisis en una instalación que utiliza estos montacargas utilizando el MoCap denominado Traje Inercial. Los montacargas son cruciales en diversas industrias. El objetivo es evaluar las condiciones de trabajo utilizando el método ergonómico Art Tool. Basándose en los resultados y en los estándares ergonómicos, se propusieron recomendaciones para mejorar el ambiente laboral y reducir las lesiones en los operadores.

Palabras clave: Grúa Telescópica, Análisis Ergonómico, Art Tool.

Relevancia para la ergonomía: Las tecnologías de la industria 4.0 se encuentran en todas las disciplinas, y la ergonomía, no es la excepción, con la irrupción de los sensores inerciales en los sistemas MoCap, el análisis de la actividad humana se ve ampliamente favorecido.

Abstract: Ergonomics is key in the design of workspaces, especially in places where workers spend hours operating heavy machinery, such as in industry. The telescopic forklift cabin is a perfect example of this, as its design can directly affect the operator's safety, efficiency, and comfort while performing their work.

Analysts must identify potential ergonomic problems in the telescopic forklift cabin to take preventive measures. Therefore, an analysis was carried out in a facility that uses these forklifts using the MoCap called Inertial Suit. Forklifts are crucial in various industries. The objective is to evaluate the working conditions using the Art

Tool ergonomic method. Based on the results and ergonomic standards, recommendations were proposed to improve the work environment and reduce operator injuries.

Keywords. Telescopic Forklift, Ergonomic Analysis, Art Tool.

Relevance to Ergonomics: Industry 4.0 technologies are found in all disciplines, and ergonomics is no exception. With the emergence of inertial sensors in MoCap systems, the analysis of human activity is greatly favored.

1. INTRODUCTION

The need to lift and manipulate heavy materials at various heights on construction sites, warehouses, or other industrial facilities has been widely documented in technical and industrial literature. The efficient and safe handling of these materials is essential to maintaining productivity and safety in these environments, and specialized equipment use, such as cranes, forklifts, and hoisting systems, is crucial to meeting this need.

Ergonomics is the study of ways in which people can be helped to work more efficiently and without injury in their environment. In a human-machine system, ergonomics helps to adapt the work to the worker (INSST, 2024; TDI, 2021).

The idea of ergonomics is to make the workplace fit the capabilities and limits of the people working there. Therefore, the goal is for the operator to be safe, comfortable, and able to perform their job efficiently and productively. In the case of a telescopic forklift cabin, this includes thinking about the characteristics of the dashboard and how the controls are located, how comfortable the seat is, whether the operator can see well from the cabin, and whether he can reach everything easily, all of which will lead to being able to have control of the system. The research cited below has contributed to achieving these goals.

Gajsek et. al. (2016) presented an overview of scientific research articles on forklift ergonomics, identifying low back pain injuries as frequent injuries due to the non-ergonomic postures of forklift drivers. Additionally, they proposed some solutions from manufacturers to address this problem. To identify opportunities for future research, they developed a schematic model of the causes of most current forklift driver injuries.

Ming-Lun et. al. (2018) assessed forklift operators' risk of neck and back pain due to poor body posture and whole-body vibration when operating a forklift. Driving a forklift in reverse increases the risk of neck problems due to excessive neck rotation and extreme positions. In addition, forklift operators' exposure to whole-body vibration sometimes exceeded recommended limits, which could lead to an increased risk of health effects. They recommended minimizing forklift operations that require driving in reverse, piloted rotating seat designs that can reduce extreme head and torso rotation, and using task rotation to reduce the time forklift operators spend in extreme head and torso postures.

Anandakumar et. al. (2020) assessed postural discomfort of electric overhead crane (EOT) operators in the tubular goods workshop of a boiler manufacturing company located in South India. They used the modified Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) to interact with 67 crane operators, who were working with 24 EOT cranes of three different models on alternate shifts. The study revealed that 48 (71.6%) employees were suffering from some form of MSD. Most of them suffered from low back pain followed by neck pain. The level of discomfort increased with age. They measured sixteen anthropometric dimensions of all the operators. Statistical analysis was carried out using ANOVA. Frequent working postures were analyzed using RULA, Egrofellow-3 software was used. The RULA score obtained was 6. A suitable ergonomic chair was provided for comfortable sitting and the height of the front cabin guard was reduced by 100 mm to increase visibility. After 3 months of testing, they conducted a survey again which indicated that the level of discomfort was drastically reduced and the RULA score was also reduced to 3.

Elkina et. al., (2015) conducted an analytical study with an overview of forklifts in the performance of loading tasks for different temporary loads during the maintenance of logistics machines. The objective was to collect, process, and analyze the results of the conducted questionnaire. The summarized information and analysis of the results allow them to refine the operating conditions of forklift drivers to provide a basis for new ergonomic requirements and to re-monitor the working environment after the change's introduction.

Yousuf & Karthikeyan (2022) evaluated the potential between existing forklift seat dimensions and the anthropometric characteristics of all forklift operators. The aim was to propose a new seat dimension based on the anthropometric data.

Jach (2020) applied two diverse methods: REBA and revised QEC for three jobs assessment involving forklift driving. The application of the MSD risk assessment tools was followed by an analysis of ergonomic checklists. The results were used for the ergonomic intervention program. Although both methods proved useful in MSD risk assessment, the QEC results were more specific, provided more detailed information on possible forms of ergonomic intervention, and better showed the decrease in MSD risk as an effect of the applied changes.

Ergonomic changes, even small, in the design of equipment, the workstation, or tasks can greatly improve the comfort, health, safety, and productivity of workers (ILO, 2024), these changes can occur because of an ergonomic analysis. Various tools facilitate the ergonomic analysis of workstations, such as REBA (Rapid Entire Body Assessment) (Hignett & McAtamney, 2000) and ART Tool (HSE, 2010). This tool was designed by the HSE (Health and Safety Executive), a British government agency responsible for regulating safety and well-being in the workplace and performs the research function on occupational risks in England. In 2010, this agency published the tool to be used in carrying out ergonomic analyses of workstations to improve the working conditions of the man-machine systems involved. This ART tool was used for this project.

A well-functioning ergonomic design can help prevent the operator from becoming physically or mentally tired and developing musculoskeletal injuries. It can also make work faster and better and make the operator happier with what he does.

In addition, a well-designed workplace based on ergonomic guidelines can help prevent accidents and make it safer for everyone. The above constitute the objectives of this project, and after the analysis, a series of recommendations are established.

1.1 Delimitation

This project was carried out by “Transportes Enríquez”, a company dedicated to offering heavy cargo transportation services through subcontracting by third-party organizations.

2. OBJECTIVE

The objective of this project is to consider the company called “Transportes Enríquez” to carry out a detailed ergonomic analysis of a telescopic forklift cabin using the ART Tool (Repetitive Task Assessment), seeking to determine the current working conditions and propose improvements to improve the working conditions of the workers of this company. Figure 1 shows the man-machine system involved in the project.

Figure 1. Man-Machine System Involved (Auhors).

3. METHODOLOGY

To carry out this ergonomic improvement project at "Transportes Enríquez", the work area on which the analysis is focused is first delimited, in this case the operation and loading area.

Then, it is important to make observations, take photographs, videos and even motion capture (MoCap) of the tasks performed by the operator, mainly the postures adopted, the movements and the loads handled when performing their functions. Ergonomic measurements and analysis are carried out through the ART Tool methodology, in addition to having the support of environmental measurements involved in the system that are carried out using appropriate equipment (Temperature, Humidity, Noise Level, etc.), to determine if they comply with the relevant ergonomic guidelines.

Step 1: Preparation and Collection of Information

Documentation Collection: Manufacturer manuals, technical data sheets, safety regulations, and any information related to the telescopic forklift were collected. An example of the electrical hazards to which the telescopic forklift operator is exposed is shown in Figure 2.

Figure 2. Electrical Hazard Information.

Team Formation: A work team was formed that included analysts, who are Industrial Engineering students from the Instituto Tecnológico Cd. Cuauhtémoc, and a telescopic forklift operator.

Step 2: Visual Inspection and Observation

Preliminary Inspection: As a team, a general visual inspection of the telescopic forklift was performed to identify key controls and components (Figure 3).

Operator Observation: Operators were observed while working with the machine to understand how they interacted with the controls and identify any obvious problems, and photographs, videos and MoCap were taken to complement the ergonomic analysis of the workstation.

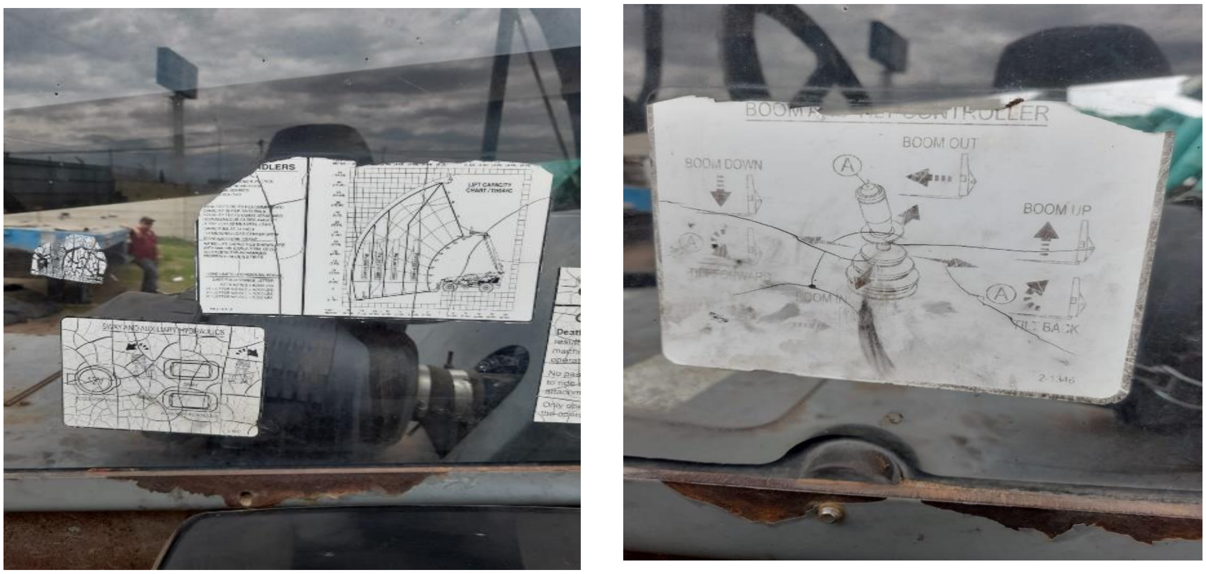


Figure 3. Key components identification.

Step 3: Ergonomic assessment

Physical measurements: Measuring equipment, such as tape measures, measuring tapes and calipers, were used to assess the location, height, dimensions and reach of the controls.

Strength assessment: The strength required to operate the controls was assessed, which was important to avoid overexertion.

Posture and movement assessment: The operator's postures and the movements he performs when performing his work activities were observed and recorded using photographs, videos, and a skeleton diagram obtained by the yostlabs® MoCap (Yostlabs, 2024) to consider whether his posture follows ergonomic guidelines based on the use of ART Tool.

Accessibility: The ease of access to the controls is assessed and whether the operator can reach them without problems.

Figure 4 shows the dashboards and controls of the cabin of the man-machine system involved.

Figure 4. Controls and dashboards involved in the system.

Step 4: Data analysis and conclusions

Comparison with standards: We compare the results of the assessment with the relevant ergonomic standards and safety regulations.

Problem identification: We identify any ergonomic problems that have arisen during the assessment.

Step 5: Recommendations and action plan

Development of recommendations: Based on the findings, we propose specific recommendations to improve working conditions based on ergonomic guidelines.

4. RESULTS

Figure 5 shows the operator's posture while performing work activities. It is important to mention that, as seen in Figure 5, the subject was using a set of MoCap inertial sensors (Inertial Suit), whose main objective is to create a 3D biomechanical model of the operator's movements. This computational model can be rotated, enlarged, and viewed from different perspectives, and serves as support, along with other records: photos, and videos, to perform the ergonomic analysis of the workplace, in this case using the ART tool.

Figure 5. Photographs for ergonomic workstation analysis.

After performing the job analysis, a greater use of the operator's right side was observed, because the operator's right arm is used to control the hydraulic system of the machine's telescopic arm. Although the operator's left side is also used to control the machine's steering wheel, it does not have the same wear as the right side. Regarding the back and neck, it was observed that as the operator worked for longer periods, the upper back and neck began to slouch, and due to poor posture, the operator was exposed to musculoskeletal injuries such as low back pain or cervical pain.

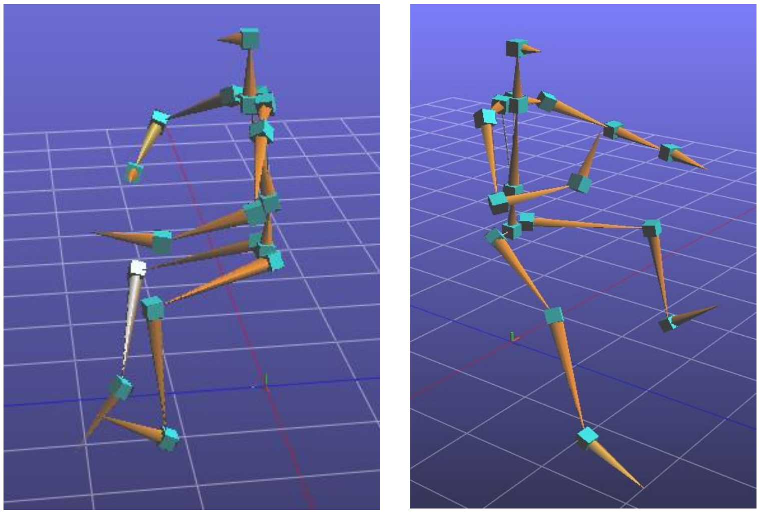


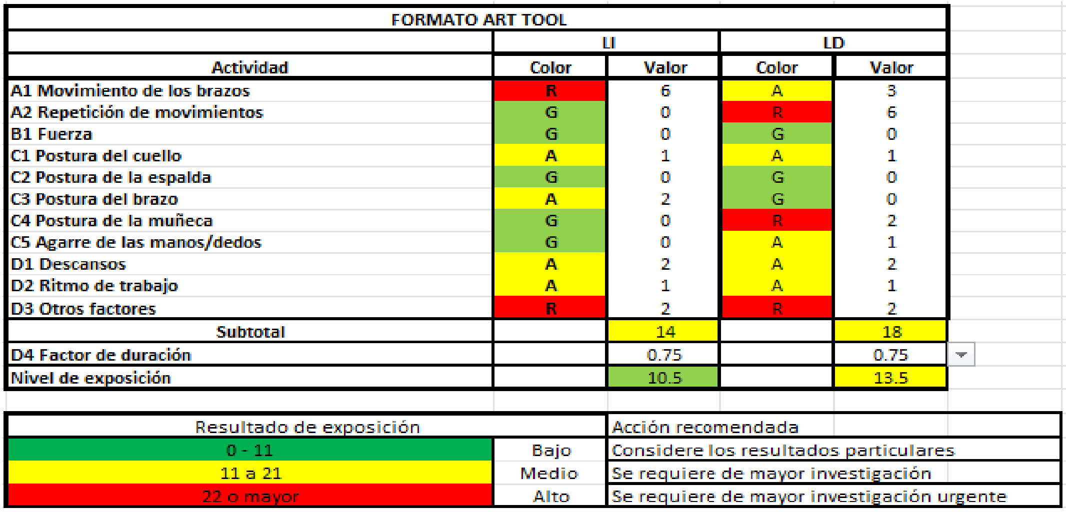
Figure 6. Skeleton diagram obtained by the biomechanical model of yostlabs.

Based on the score of 13.5 on the right side with the ART Tool (Figure 7) which implies a medium risk, we have a starting point for the implementation of certain improvements that help us improve the ergonomic conditions for the operator, focusing on the areas where greater risk was identified, such as the posture of the back, neck and the load that it represents for the right side. It is recommended to use a posture vest to avoid back hunching, also, train the worker in musculoskeletal injuries and the importance of good posture to avoid them. On the other hand, the organization can also be recommended to take measures that help the operator prevent any situation that puts their safety, health, and work activities at risk by using protective equipment such as gloves, helmet, and headphones to counteract the noise of the crane engine since there is an average noise level of 98 dB when the regulations (STPS, 2001) indicate a maximum of 85 dB in 8 hours, so it is also advisable to allow breaks according to the hours worked.

5. CONCLUSIONS

After conducting a thorough ergonomic analysis of a telescopic forklift cabin, a clear insight into the factors that influence operator comfort, safety and efficiency has been gained. This analysis included assessing posture, visibility, accessibility, working environment, safety, and technology integration.

The analysis revealed that operator posture is crucial to preventing long-term health problems. Many forklift cabins today lack seats with sufficient adjustments and adequate lumbar support, forcing operators into uncomfortable postures. The ergonomic seat implementation was recommended with multiple adjustments and adequate cushioning to absorb vibrations. Therefore, not only comfort is improved, but also reduces the risk of musculoskeletal disorders, increasing operator efficiency and well-being.



FORMATO ART TOOL				
	LI		LD	
Actividad	Color	Valor	Color	Valor
A1 Movimiento de los brazos	R	6	A	3
A2 Repetición de movimientos	G	0	R	6
B1 Fuerza	G	0	G	0
C1 Postura del cuello	A	1	A	1
C2 Postura de la espalda	G	0	G	0
C3 Postura del brazo	A	2	G	0
C4 Postura de la muñeca	G	0	R	2
C5 Agarre de las manos/dedos	G	0	A	1
D1 Descansos	A	2	A	2
D2 Ritmo de trabajo	A	1	A	1
D3 Otros factores	R	2	R	2
Subtotal		14		18
D4 Factor de duración		0.75		0.75
Nivel de exposición		10.5		13.5

Resultado de exposición		Acción recomendada
0 - 11	Bajo	Considere los resultados particulares
11 a 21	Medio	Se requiere de mayor investigación
22 o mayor	Alto	Se requiere de mayor investigación urgente

Figure 7. ART Tool® Results.

Visibility from the cabin is essential for safety and precision in operations. During the analysis, blind spots were identified caused by poor layout of internal structures and controls. To mitigate these issues, it is essential to redesign the cabin with larger, clearer windows, as well as integrate cameras and sensors to assist in complex maneuvers. These devices must be intuitive and must not interfere with the daily operations of the forklift.

Operator comfort also depends on an adequate working environment. We observed that many cabins lack efficient HVAC systems, which can be problematic in extreme conditions. It is crucial to implement air conditioning and heating systems to maintain a comfortable temperature. In addition, good ventilation and adequate lighting are essential to prevent fatigue and ensure the operator's concentration.

Safety in access and exit from the cabin is a critical aspect. Stairs and handrails must be accessible and safe, minimizing the risk of falls. During the analysis, access to the forklift cabin was detected. The use of non-slip stairs and firm handrails is recommended, as well as wide, easy-to-open doors to facilitate safe entry and exit of the operator.

Technology can help decrease the physical and mental burden on the operator. Electronic controls and touch screens should be easy to use and well-integrated into the cab. Automating some forklift functions can also improve operational efficiency and reduce operator fatigue.

Ergonomic analysis of the telescopic forklift cab demonstrates that operator-centric design is important to improve operator comfort, safety and productivity. Implementing ergonomic improvements not only reduces the risk of injury and health problems, but also optimizes operational efficiency, contributing to a safer and more productive work environment. Therefore, forklift manufacturers should adopt these ergonomic principles in the design and development of their products.

Applying these recommendations derived from ergonomic analysis will enable companies to not only protect the health and well-being of their operators, but also maximize the efficiency and longevity of their equipment. Ultimately, a focus on ergonomics will benefit everyone involved, from operators to forklift owners, driving a safer, healthier and more efficient work environment.

6. ACKNOWLEDGMENTS

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VALIDATION OF THE LATIN QUESTIONNAIRE IN MEXICAN POPULATION

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Resumen: Introducción: Recientemente se presentó la validación del Cuestionario Latino para la vigilancia de trastornos musculoesqueléticos (Colombini et al. 2022) aplicado en diferentes países de América Latina. El Cuestionario Latino cubre la presencia de síntomas durante los 12 meses anteriores, e identifica casos positivos, y aquellos con síntomas menos severos. Instrumentos como el cuestionario Latino pueden ser útiles si tienen la confiabilidad y validez adecuadas en la población trabajadora mexicana. **Método:** En este proyecto se realizó el análisis de la validez de la confiabilidad del Cuestionario Latino en trabajadores de diferentes actividades y sectores económicos. Para el análisis de confiabilidad se usó la prueba estadística del Coeficiente Kappa de Cohen. En un primer momento se aplicó el Cuestionario Latino al mismo individuo en dos ocasiones por el mismo médico y en un segundo momento, se compararon la primera y la tercera entrevista para obtener la concordancia entre observadores. Participaron cincuenta y seis trabajadores que dieron su aceptaron participar y dieron su consentimiento y finalizaron las tres entrevistas. El análisis estadístico se hizo con el software MedCalc. **Resultados:** Los resultados mostraron, en el análisis de los casos que cumplieron con el umbral positivo, que en el miembro superior existe una alta concordancia intraobservador en hombro (0,90) y parestesia nocturna (0,91) y una moderada concordancia intraobservador en mano-muñeca (0,79) y parestesia diurna (0,73). La concordancia interobservador en hombro (0,78), parestesia nocturna (0,73) y mano-muñeca (0,79) fue moderada a alta.

En cuanto a la columna, la concordancia intraobservador en las regiones lumbosacra (0,86) y dorsal (0,77) fue alta, y en las regiones cervical (0,61) y cadera (0,65) fue moderada. La concordancia interobservador en las regiones lumbosacra (0,77) y dorsal (0,60) fue moderada a alta, y en las regiones cervical (0,43) y cadera (0,46) fue moderada a baja. **Conclusiones:** El Cuestionario Latino demostró ser un instrumento sensible para monitorear la salud musculoesquelética de los trabajadores.

Estudios futuros con diferentes grupos de trabajadores y períodos de seguimiento más prolongados proporcionarán más información sobre el comportamiento del Cuestionario Latino en la población trabajadora mexicana.

Palabras clave: Cuestionario Latino, vigilancia, musculoesquelética

Contribución a la ergonomía: Estos resultados muestran que, para la mayoría de las enfermedades musculoesqueléticas relacionadas con el trabajo, el cuestionario latino es útil para fines de vigilancia de la salud ocupacional. Este instrumento permite seleccionar casos anamnésicos positivos en comparación con casos con trastornos menores.

Abstract: Introduction: The validation of the Latino Questionnaire for the surveillance of musculoskeletal disorders (Colombini et al. 2022) was recently presented after being applied in different Latin American countries. This questionnaire covers the presence of symptoms during the previous 12 months and identifies positive cases as well as those with less severe symptoms. Instruments like the Latino Questionnaire can be very helpful if they are found to be reliable and valid in the Mexican working population. To assess the reliability of the Latino Questionnaire, a validity analysis was conducted in this project with workers from different activities and economic sectors. The Cohen Kappa coefficient statistical test was used for the reliability analysis. The Latino Questionnaire was administered three times to the same individual: first, it was given twice by the same doctor, and then the first and third interviews conducted by a second doctor were compared to determine inter-observer agreement. Fifty-six workers agreed to participate, gave their consent, and completed the three interviews. Statistical analysis was performed using MedCalc software. **Results:** The results showed, in the analysis of cases meeting a positive threshold, in the upper limb, there is high intraobserver agreement in the shoulder (0.90) and Nigthtime- paresthesia (0.91) and moderate intraobserver agreement in Hand-Wrist (0.79) and Daytime paresthesia (0.73). The interobserver agreement. In the shoulder (0.78), Nigthtime- paresthesia (0.73) and Hand-Wrist (0.79) were moderate to high.

As for the spine, the intraobserver agreement at the lumbosacral (0.86) and dorsal (0.77) regions were high, and at the cervical (0.61) and hip (0.65) regions were moderate. The interobserver agreement at the lumbosacral (0.77) and dorsal (0.60) regions were moderate to high, and at the cervical (0.43) and hip (0.46) regions were moderate to low.

Conclusions: The Latino questionnaire proved to be a sensitive instrument for monitoring the musculoskeletal health of workers.

Future studies with different worker groups and longer follow-up periods will provide more insights into the behavior of the Latino Questionnaire in the Mexican working population.

Keywords: Latin, questionnaire, musculoskeletal, surveillance

Relevance to Ergonomics: These results demonstrate the usefulness of the Latino questionnaire for most work-related musculoskeletal diseases in occupational health surveillance. The Latino questionnaire helps identify positive anamnestic cases rather than cases with minor disorders.

1. INTRODUCTION

The use of standardized instruments is essential for monitoring and early detection of musculoskeletal health issues in workers. The Mexican standard for assessing risks due to manual handling of loads NOM 036-1 STPS 2018 (STPS, 2018) recommends the Nordic Questionnaire (Kuorinka et al. 1987) as a useful instrument for monitoring the health of the working population exposed to ergonomic risks. However, for effective identification and monitoring of workers with musculoskeletal disorders, instruments with greater sensitivity are needed to identify "probable cases" and not just those with some discomfort.

The Nordic Questionnaire is widely used to describe musculoskeletal disorders that have occurred in the previous 12 months, but it does not explicitly include a severity threshold. Given the extremely widespread nature of WMSDs, even in the unexposed populations and with differences by gender and age, the Nordic Questionnaire appears to not be a sensitive and specific instrument.

In different studies the Nordic Questionnaire reports an extremely high prevalence of musculoskeletal symptoms in different occupationally exposed groups, a prevalence between 60 and 90. The few comparative studies between exposed and non-exposed subjects using the Nordic Questionnaire rarely indicate significant differences in musculoskeletal disorders between exposed and unexposed subjects, creating difficulties in interpreting the ergonomic risk-damage relation (López et al. 2017).

The Latin Questionnaire for the surveillance of musculoskeletal disorders (Colombini et al. 2022) has been validated for application in different Latin American countries. This questionnaire explores during the las 12 months conditions of the spine and the upper and lower extremities, covering the presence of symptoms, pain, paresthesia, location, duration, number of episodes, irradiation, and treatment. It identifies positive cases according to a threshold and classifies them as "Positive Threshold" cases for frequent pain events and as cases with minor disorders for less severe symptoms. The Spanish version of the questionnaire can be obtained at the following link: bit.ly/4coaOAm

Given the increasing cases of musculoskeletal diseases at work in Mexico (IMSS, 2023), there is a need to improve the health surveillance of personnel exposed to ergonomic risk factors. Instruments like the Latino questionnaire can be useful if it shows an adequate reliability and validity. Therefore, it is important to study the behavior of the instrument in the Mexican working population.

2. OBJECTIVE

The objective of this study is to validate the reliability of the Latino Questionnaire in a group of Mexican workers.

3. DELIMITATION

This is an analytical, cross-sectional study to validate an instrument for the prevention of musculoskeletal disorders.

4. METHODS

In this cross-sectional study, the validity and reliability of the Latin Questionnaire were analyzed in workers from different activities and economic sectors.

Fifty-six workers from both sexes agreed to participate, gave their consent, and completed the three interviews.

It is important to determine whether the instruments used in the surveillance of musculoskeletal disorders effectively identify the conditions they are designed to detect.

After constructing an instrument and validating its content using the most recent knowledge and the expertise of field specialists, it is essential to analyze the reliability or consistency of the information obtained. This involves ensuring that the same subject produces consistent results at different times and that different subjects following the same procedure yield similar outcomes.

For instance, if an applicator identifies a shoulder injury, this diagnosis should be consistently obtained when the examination is repeated by the same applicator at another time. Similarly, if a different applicator reaches the same diagnosis when applying the instrument to the same person, it demonstrates reliability. When different doctors and different times yield consistent results for the same subject, it is considered reliable. A reliable instrument is valuable for monitoring and tracking the health of the working population as it is not influenced by the applicator or the timing of the assessment.

For this purpose, the statistical test of Cohen's Kappa coefficient can be used to measure the degree of agreement between evaluations carried out by multiple evaluators. The higher the agreement, the greater the reliability and validity of an instrument. When recorded under standardized conditions, the results do not depend on who uses it or when they use it. The Kappa coefficient is used to analyze the degree of agreement between the nominal or ordinal evaluations performed by multiple evaluators when assessing the same group of individuals (Wikipedia, 2024).

If the Kapa coefficient is zero, it means that the observed agreement coincides with what would occur by pure chance, indicating no relationship between the observations. Positive values of the coefficient indicate greater agreement than expected by chance, with a result of 1 representing perfect agreement. Establishment of higher agreement can help validate the reliability and validity of the instrument under standardized conditions (SAMIUC, 2024). The greater the agreement, the better the reliability and validity of an instrument. Data collected under standardized conditions should not be influenced by the user or timing of its application.

For the reliability analysis of the Latin questionnaire, the questionnaire was administered to the same individual by the same physician on two separate occasions to assess the intraobserver agreement within the same observer. This was done to detect patients with positive thresholds, minor complaints, or no disorders in different body segments.

In a second analysis, the first and a third interview by a second physician were compared to assess the interobserver agreement between different observers for patients with positive thresholds, minor complaints, or no disorders in different body segments.

Two separate Kappa index analyses were performed. The first analysis focused on intra- and inter-observer agreement in classifying cases with positive thresholds. The second analysis focused on agreement in classifying cases with positive thresholds and minor symptoms.

The statistical analysis was conducted using MedCalc software.

5. RESULTS

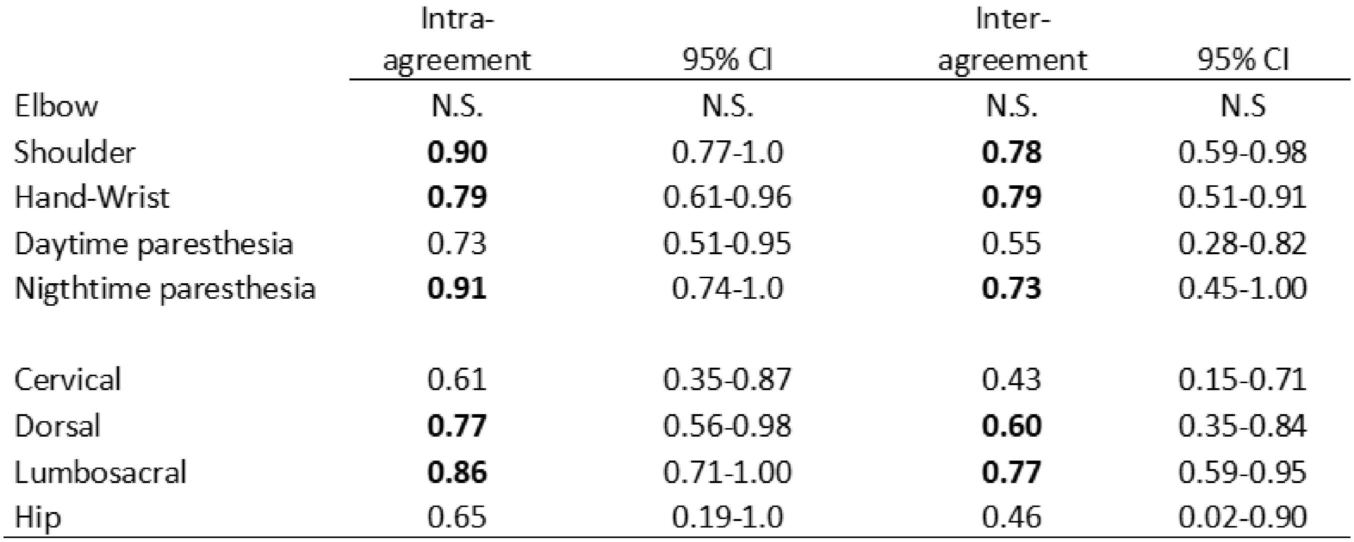
In the initial analysis of cases meeting a positive threshold (See Table 1), in the upper limb, there is high intraobserver agreement in the shoulder (0.90) and Nigthtime-paresthesia (0.91) and moderate intraobserver agreement in Hand-Wrist (0.79) and Daytime paresthesia (0.73).

In the analysis of cases meeting a positive threshold, the interobserver agreement. In the shoulder (0.78), Nigthtime- paresthesia (0.73) and Hand-Wrist (0.79) were moderate to high.

As for the spine, the intraobserver agreement at the lumbosacral (0.86) and dorsal (0.77) egions were high, and at the cervical (0.61) and hip (0.65) regions were moderate.

At the spine, the interobserver agreement at the lumbosacral (0.77) and dorsal (0.60) regions were moderate to high, and at the cervical (0.43) and hip (0.46) regions were moderate to low.

Table 1. Positive threshold cases



	Intra-agreement	95% CI	Inter-agreement	95% CI
Elbow	N.S.	N.S.	N.S.	N.S
Shoulder	**0.90**	0.77-1.0	**0.78**	0.59-0.98
Hand-Wrist	**0.79**	0.61-0.96	**0.79**	0.51-0.91
Daytime paresthesia	0.73	0.51-0.95	0.55	0.28-0.82
Nigthtime paresthesia	**0.91**	0.74-1.0	**0.73**	0.45-1.00
Cervical	0.61	0.35-0.87	0.43	0.15-0.71
Dorsal	**0.77**	0.56-0.98	**0.60**	0.35-0.84
Lumbosacral	**0.86**	0.71-1.00	**0.77**	0.59-0.95
Hip	0.65	0.19-1.0	0.46	0.02-0.90

The second analysis included the total number of positive cases in addition to those with minor symptoms (see Table 2).

In the upper limb, there is a moderate intraobserver agreement in the shoulder (0.68), Hand-Wrist (0.77) and Daytime paresthesia (0.71), and Nigthtime-paresthesia (0.62).

The interobserver agreement in the Hand-Wrist (0.69) was moderate and in the shoulder (0.45), Daytime paresthesia (0.48) and Nigthtime paresthesia (0.39) were low to moderate.

As for the spine, the intraobserver agreement at the lumbosacral (0.74) was high, and at the dorsal (0.55), cervical (0.61) and hip (0.50) regions were moderate.

At the spine, the interobserver agreement at the lumbosacral (0.60) was moderte, and and dorsal (0.37) cervical (0.37) and hip (0.24) regions were low.

Table 2. Positive threshold cases and minor symptoms

	Intra-agreement	95% CI	Inter-agreement	95% CI
Elbow	0.19	-0.01-0.39	0.03	-0.18-0.25
Shoulder	**0.68**	0.52-0.84	0.45	0.24-0.66
Hand-Wrist	**0.77**	0.65-0.88	**0.69**	0.55-0.82
Daytime paresthesia	**0.71**	0.57-0.84	0.48	0.29-0.67
Nigthtime paresthesia	0.62	0.42-0.84	0.39	0.13-0.65
Cervical	0.61	0.44-0.77	0.37	0.19-0.55
Dorsal	0.55	0.34-0.75	0.37	0.16-0.59
Lumbosacral	**0.74**	0.61-0.87	**0.60**	0.44-0.76
Hip	0.50	0.22-0.77	0.24	-0.56

6. CONCLUSIONS

In both analyses, there were differences in intra- and inter-agreement by body segment.

The variation in agreement between the same observer and different observers may be initially due to the timing of the interviews. The time between the first two interviews conducted by the same physician was 15 to 20 days, while the time lapse between the first interview and the third interview conducted by another physician was 20 to 30 days. This time gap may influence the information gathered during the interviews.

Additionally, over this period, changes in musculoskeletal symptoms may result in variations in the information recorded by the same physician and different physicians.

This discrepancy in reporting is more pronounced for individuals with minor symptoms and less noticeable for individuals with "positive threshold".

Nonetheless, the correlation between the reports indicates good consistency and reliability of the information.

Cases with a positive threshold showed substantial intraobserver agreement and moderate interobserver agreement in the upper extremity and daytime paresthesia. For cases with positive thresholds in the spine, there was substantial intraobserver agreement and moderate interobserver agreement. However, there was no agreement found in the elbow analysis.

The intraobserver agreement varied by segment, being higher in the lumbar region and hand (0.71), while the interobserver agreement by segment was moderate (0.57).

The second analysis indicated moderate agreement in the classification of positive cases as well as cases with minor symptoms, in both the upper limb and spine regions.

As anticipated, the intraobserver results were higher than the interobserver results, but the latter still demonstrated moderate and significant agreement.

It was observed during application that it is important to adequately train doctors in how to use the instrument for correct symptom recording and definition of cases with a positive threshold.

The Latino questionnaire proved to be a sensitive instrument for monitoring the musculoskeletal health of workers.

Future studies with different worker groups and longer follow-up periods will provide more insights into the behavior of the Latino Questionnaire in the Mexican working population.

7. CONTRIBUTION TO ERGONOMICS

The presented results are important for the initial phase of the health surveillance process and serve multiple purposes in occupational health surveillance programs to identify workers with disorders and diseases related to biomechanical overload (Colombini, 2023).

The occupational health musculoskeletal preventive programs consist of the following levels of action:

- Primary level: aimed at all workers exposed to ergonomic risks to detect probable cases with a positive threshold. This involves recording the medical histories of individual workers through interviews conducted by trained health personnel. Cases that meet the positive threshold are referred to the next level.
- Secondary level: clinical musculoskeletal-specific examination at the workplace for individuals with a positive threshold to detect clinical cases and to provide follow-up. If necessary, the positive case is referred to the next level.
- Tertiary level: clinical attention by a specialist and instrumental examinations (ultrasound, electromyography, etc.) to determine a diagnosis and provide follow-up.

The results demonstrate the usefulness of the Latino questionnaire for most work-related musculoskeletal diseases in occupational health surveillance. This instrument helps identify positive anamnestic cases rather than cases with minor disorders. The Latino questionnaire assists healthcare professionals in obtaining anamnestic data more accurately and efficiently through structured questions and guided interpretation of the answers (anamnestic thresholds), which is useful in identifying workers who will undergo the second and third-level examinations.

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EFFECTIVENESS OF THE AWARENESS AND MANAGEMENT PROGRAM OF NOM-036-1-STPS-2018 IN INDUCTION PROCESSES.

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Resumen: La integración de principios ergonómicos en los procesos de inducción laboral es crucial para la prevención de lesiones y la mejora de la seguridad en el trabajo. Este estudio se centra en la implementación de la Norma Oficial Mexicana NOM-036-1-STPS-2018, la cual establece los lineamientos para la identificación, análisis, prevención y control de riesgos ergonómicos asociados con el manejo manual de cargas. La norma es aplicable a diversos sectores industriales en México, con un enfoque particular en la protección de la salud de los trabajadores mediante la mejora de las condiciones ergonómicas en el lugar de trabajo.

El objetivo principal de este estudio fue analizar el impacto de un programa de concientización y manejo de la NOM-036-1-STPS-2018, integrado en los procesos de inducción de nuevos empleados, y su influencia en la salud y seguridad laboral. Para ello, se desarrolló una metodología basada en técnicas ergonómicas para evaluar los riesgos laborales antes y después de la implementación de la norma. Se utilizaron herramientas de análisis ergonómico, tales como la evaluación de posturas, la medición de la repetitividad de movimientos y el esfuerzo físico requerido en las tareas, con el fin de cuantificar la efectividad del programa.

La metodología se dividió en dos fases. En la primera fase, se diseñaron y validaron instrumentos de recolección de datos, incluyendo cuestionarios y protocolos de observación ergonómica, adaptados a los estándares de la NOM-036-1-STPS-2018. Estos instrumentos permitieron la recopilación de datos cualitativos y cuantitativos sobre las condiciones de trabajo en estaciones de ensamble manual, antes de la implementación de la norma. En la segunda fase, se realizó un análisis comparativo utilizando técnicas estadísticas avanzadas, como análisis de regresión y pruebas de hipótesis, para evaluar los cambios en los indicadores ergonómicos y de seguridad laboral tras la implementación del programa.

Los resultados obtenidos fueron contundentes. Se observó una reducción del 78.26% en el número de accidentes relacionados con el manejo manual de cargas en estaciones de trabajo donde se aplicó el programa de concientización durante la inducción. Asimismo, la incidencia de quejas relacionadas con molestias físicas disminuyó en un 84.61%, y la valoración del riesgo en las estaciones de trabajo mostró una mejora significativa, pasando de un nivel de riesgo alto a un riesgo medio. Además, se evidenció un aumento del 22% en la productividad de las estaciones de trabajo, lo que subraya la relación positiva entre la ergonomía y la eficiencia operativa.

En conclusión, la implementación de la NOM-036-1-STPS-2018 en los procesos de inducción ha demostrado ser una estrategia efectiva para mejorar tanto la salud y seguridad laboral como la productividad. Este estudio proporciona una evidencia sólida de que un enfoque ergonómico durante la inducción de nuevos empleados es esencial para reducir riesgos laborales y promover una cultura de seguridad en el trabajo. La integración de prácticas ergonómicas no solo contribuye a la prevención de lesiones, sino que también optimiza el rendimiento y el bienestar de los trabajadores, reafirmando la importancia de la ergonomía en el entorno laboral industrial.

Palabras clave: Inducción, NOM-036-1-STPS-2018, concientización sobre la norma.

Relevancia para la ergonomía: Este trabajo aporta una evidencia científica crucial sobre los beneficios de implementar la NOM-036-1-STPS-2018 en los procesos de inducción de nuevos empleados, mostrando cómo esta norma reduce eficazmente los riesgos ergonómicos en estaciones de trabajo con ensamble manual, mientras mejora la productividad y el bienestar de los trabajadores.

El estudio demuestra que la capacitación y concientización sobre la NOM-036 son componentes esenciales que pueden transformar el entorno laboral. Al disminuir significativamente los accidentes y mejorar la percepción de seguridad entre los empleados.

Más allá de reforzar la importancia de la normativa ergonómica, este trabajo subraya la necesidad de integrar prácticas ergonómicas en los programas de inducción. Esta integración no solo contribuye a crear un entorno laboral más seguro, sino que también fomenta una cultura de seguridad continua, esencial para la sostenibilidad organizacional.

Este enfoque preventivo y proactivo en ergonomía, orientado a la formación desde el primer día de empleo, puede generar cambios duraderos en la gestión de la salud ocupacional. Al posicionar a la NOM-036-1-STPS-2018 como un pilar fundamental en la estrategia ergonómica de las empresas, este estudio enriquece el conocimiento en ergonomía y proporciona una herramienta valiosa para optimizar la seguridad y el rendimiento en la industria.

Abstract: The integration of ergonomic principles in work induction processes is crucial for the prevention of injuries and the improvement of safety at work. This study focuses on the implementation of the Official Mexican Standard NOM-036-1-STPS-2018, which establishes the guidelines for the identification, analysis, prevention and control of ergonomic risks associated with the manual handling of loads. The standard is applicable to various industrial sectors in Mexico, with a particular focus on protecting the health of workers by improving ergonomic conditions in the workplace.

The main objective of this study was to analyze the impact of an awareness and management program of NOM-036-1-STPS-2018, integrated into the induction processes of new employees, and its influence on occupational health and safety. To this end, a methodology based on ergonomic techniques was developed to evaluate occupational risks before and after the implementation of the standard. Ergonomic analysis tools were used, such as posture evaluation, measurement of the repetitiveness of movements and the physical effort required in the tasks, in order to quantify the effectiveness of the program.

The methodology was divided into two phases. In the first phase, data collection instruments were designed and validated, including questionnaires and ergonomic observation protocols, adapted to the standards of NOM-036-1-STPS-2018. These instruments allowed the collection of qualitative and quantitative data on working conditions in manual assembly stations, before the implementation of the standard. In the second phase, a comparative analysis was performed using advanced statistical techniques, such as regression analysis and hypothesis testing, to evaluate changes in ergonomic and occupational safety indicators after the implementation of the program.

The results obtained were overwhelming. A 78.26% reduction was observed in the number of accidents related to the manual handling of loads in workstations where the awareness program was applied during induction. Likewise, the incidence of complaints related to physical discomfort decreased by 84.61%, and the risk assessment at workstations showed a significant improvement, going from a high risk level to a medium risk. Additionally, a 22% increase in workstation productivity was evident, underscoring the positive relationship between ergonomics and operational efficiency.

In conclusion, the implementation of NOM-036-1-STPS-2018 in induction processes has proven to be an effective strategy to improve both occupational health and safety and productivity. This study provides strong evidence that an ergonomic approach during the induction of new employees is essential to reduce occupational risks and promote a culture of safety at work. The integration of ergonomic practices not only contributes to injury prevention, but also optimizes worker performance and well-being, reaffirming the importance of ergonomics in the industrial work environment.

Keywords. Induction, NOM-036-1-STPS-2018, awareness of the standard.

Relevance to Ergonomics: This work provides crucial scientific evidence on the benefits of implementing NOM-036-1-STPS-2018 in new employee induction processes, showing how this standard effectively reduces ergonomic risks in workstations with manual assembly, while improving workers productivity and well-being.

The study shows that training and awareness about NOM-036 are essential components that can transform the work environment, significantly reducing accidents and improving the perception of safety among employees.

Beyond reinforcing the importance of ergonomic regulations, this work highlights the need to integrate ergonomic practices into induction programs. This integration not only contributes to creating a safer work environment, but also fosters a continuous safety culture, essential for organizational sustainability.

This preventive and proactive approach to ergonomics, geared towards training from the first day of employment, can generate lasting changes in occupational health management. By positioning NOM-036-1-STPS-2018 as a fundamental pillar in the ergonomic strategy of companies, this study enriches knowledge in ergonomics and provides a valuable tool to optimize safety and performance in the industry.

1. INTRODUCTION

Ergonomic risks related to manual load handling are one of the main causes of work-related musculoskeletal disorders (MSDs), which represent a major problem for the health and safety of workers. MSDs not only affect the physical well-being of employees, but also directly impact the productivity and operational efficiency of companies. In fact, problems such as lower back pain, upper limb disorders and physical fatigue are common in jobs that require manual load handling, and can cause absenteeism, low employee morale and higher costs for organizations due to staff turnover and compensation. In this sense, maintaining an ergonomic approach in line with job requirements is essential to ensure a good quality of life for workers who perform manual load handling activities.

The Mexican Ministry of Labor and Social Welfare (STPS) issued the Mexican Official Standard NOM-036-1-STPS-2018 (NOM-036) in response to the seriousness of this problem. This standard is a legal tool that establishes the minimum requirements necessary to identify, analyze, prevent and control ergonomic risks in work activities that involve the manual handling of loads. By providing clear guidelines for the management of ergonomic risks, its main objective is to protect the health and well-being of workers. These guidelines are mandatory for both employers and workers throughout the country.

NOM-036 specifies specific methods for assessing and controlling ergonomic risks. Identifying risk factors such as posture, required force, repetitiveness of movements, and environmental conditions are part of these procedures. The standard also emphasizes the importance of staff training as an essential component to foster a safety culture in the workplace. Proper staff training, especially during the induction process, is essential to ensure that new workers are fully aware of the ergonomic risks associated with their tasks and know how to effectively reduce them.

Effective implementation of NOM-036 in induction processes is not only necessary to comply with legal obligations, but also provides a strategic opportunity to increase safety and productivity in the work environment. Employees can reduce the likelihood of accidents and long-term injuries by receiving specific training and early awareness about ergonomics.

In this context, an important research question arises: Has the implementation of a NOM-036 awareness and management program in induction procedures for new employees improved occupational safety? This study investigates how incorporating NOM-036 into induction processes reduces ergonomic risks and fosters a safety culture in the workplace. In particular, it will be investigated whether employees who received training on NOM-036 during their induction experience fewer musculoskeletal injuries, have a higher perception of safety, and perform their work tasks better compared to those who do not receive such training.

Implementing NOM-036 in induction processes could change the way companies handle the concept of ergonomics. By providing new employees with the knowledge and tools necessary to identify and reduce ergonomic risks, they are enabled to make informed decisions and work safely from the start of their employment. Fostering a safety culture that complies with the principles of NOM-036 can significantly reduce the number of workplace accidents, improve operational efficiency and productivity, reduce interruptions caused by injuries, and promote a generally healthy work environment.

The impact of implementing NOM-036 in induction procedures on worker health and safety will be examined in this article. A comparative method will be used to statistically assess the number of risk situations, injuries, and workplace accidents at workstations involving manual material handling. The results will be compared before and after the implementation of the NOM-036 awareness and management program in the induction process. This study will provide a solid foundation for understanding the effectiveness of early ergonomic interventions and their role in creating a safe and productive work environment.

2. OBJECTIVES

General objective: To improve occupational health and safety by reducing ergonomic risks and strengthening a culture of safety at work, based on the implementation of the Mexican Official Standard NOM-036-1-STPS-2018 in the induction processes of new employees in the manufacturing and export maquiladora industry in northeastern Sonora, Mexico.

Specific objectives:

1. To develop a theoretical framework that supports the importance of ergonomics in the prevention of occupational risks and its impact on the health and safety of workers in the manufacturing and export maquiladora industry in northeastern Sonora.
2. Implement an induction program based on NOM-036-1-STPS-2018, which includes specific training and awareness on ergonomics, and monitor its impact on risk reduction and worker health.
3. Evaluate the effectiveness of the implemented program.

3. METHODOLOGY

The methodology of this study was developed in two main phases: phase 1 focused on the preparation of instruments for information collection and phase 2 dedicated to the statistical analysis of data.

Preparation of Instruments and Collection of Information.

Development of the Theoretical Reference Framework: In this initial stage, a comprehensive review of the literature related to ergonomic risks associated with manual handling of loads, job training and the implementation of standards referenced to health and safety at work was carried out, with a special focus on NOM-036-1-STPS-2018. These regulations were compared with other recognized international guidelines, such as those issued by the International Labor Organization (ILO) and the European Agency for Safety and Health at Work (EU-OSHA). The resulting theoretical framework will serve as a basis for the construction of data collection instruments, ensuring that they are aligned with best practices and international standards in ergonomics.

Design of Data Collection Instruments: Based on the theoretical framework, specific instruments were designed for the collection of qualitative and quantitative data. These instruments included: Structured questionnaires to assess workers' perception of ergonomics and the effectiveness of the training received during induction. Semi-structured interview guides to delve deeper into the experience of supervisors and managers in the implementation of NOM-036 and its impact on occupational health. Observation protocols designed to assess ergonomic conditions at workstations, before and after implementation of the standard. These instruments were subjected to a validation process through a pilot test in a small group of companies in northeastern Sonora, adjusting the questionnaires and guides as necessary to ensure their clarity, relevance, and reliability.

Statistical Analysis of Data.

Workstations were selected where manual load handling is performed and where the company has implemented NOM-036-1-STPS-2018 in its induction processes and other similar stations where they have not done so. This selection allowed a comparison between both groups to evaluate the impact of the standard. Data collection was carried out using the instruments developed in Phase 1. Both quantitative data (e.g., accident rates, incidences of musculoskeletal injuries, productivity) and qualitative data (perceptions and experiences of workers and supervisors) were collected. Data was collected at two different times: before the implementation of the induction program based on NOM-036, and after its implementation. The findings were interpreted in the context of the theoretical framework developed in Phase 1, and were presented in terms of their practical relevance for the manufacturing and maquiladora industry in northeastern Sonora.

4. RESULTS

56 direct observations were made at manual assembly workstations, focusing on evaluating five key variables: number of accidents, number of incidents, complaints of illness, risk assessment, and production volume. The risk assessment was developed using the method provided by the NOM-036 standard, which includes the identification and analysis of risk factors associated with manual handling of loads, such as forced postures, physical effort, and repetitive movements. These variables were quantified both before and after the implementation of the NOM-036 awareness and management procedure in the induction of new workers. Table 1 shows the results of the evaluation.

Table 1 shows the results of implementing the awareness program during induction:

A 58% decrease in the number of accidents was observed after the implementation of the procedure, suggesting an improvement in workplace safety conditions.

There was a 41% reduction in the number of incidents recorded, indicating greater awareness among workers.

Table 1: Comparison of results before and after the implementation of awareness and management procedures of standard 036.

Variable	Before the Implementation	After the Implementation	Changes (%)
Number of Accidents	12	5	-58%
Number of Incidents	34	20	-41%
Complaints of Illnesses	35	18	-49%
Risk Assessment	High Risk	Medium Risk	
Production Volume	139	256	84%
	Daily Units		

Complaints about illnesses experienced a 49% decrease, reflecting a positive change in the health of workers after receiving training.

Using the method provided by NOM-036, the risk assessment at work stations showed an improvement, going from high risk to medium risk, which shows the effectiveness of the awareness procedure in reducing ergonomic risk factors.

The final assessment showed an 84% increase in production volume, which could be related to greater efficiency in activities after the implementation of the standard.

In addition to the above, a survey is conducted to analyze how workers perceive the importance of ergonomics in their daily work and to determine whether the training received during induction, based on NOM-036, has been effective in improving their understanding and ergonomic practices. Table 2 shows the survey format.

Table 2: Survey format to assess the importance of awareness of standard 036 in the induction process.

Ítem	Answer
Age	
Gender	☐ Male ☐ Female
Work Position	
Years of experience in this job	
Level of Education	☐ Elementary ☐ Junior High ☐ High School ☐ Technical School ☐ Degree ☐ Other
How to evaluate your previous knowledge on ergonomics before the training?	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (1 = Muy Bajo, 5 = Muy Alto)
After the training, how would you evaluate your actual comprehension of the ergonomics applied to your position?	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (1 = MVery Low, 5 = Very High)
Do you consider that ergonomics is important for a safe and efficient way to complete your tasks?	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (1 = Not Importante, 5 = Very Important)
Did the trainig provide you with the necessary tolos to apply ergonomic practices in your daily work?	☐ Sí ☐ No
Did the training correctly cover the specific risks for your work position?	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (1 = Not Suitable at all, 5 = Very Suitable)
Since the training, have you modified any practices in your work to improve ergonomics?	☐ Yes ☐ No
Description of the modifications:	
Since the training, have you noticed a decrease in physical aches or pains related to your work?	☐ Yes ☐ No
Do you think that training has contributed to improving your safety at work?	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (1 = Nothing , 5 = A lot)
How would you evaluate the training in terms of content and methodology?	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (1 = Very dissatisfied, 5 = Very Satisfied)
Would you recommend that this training be provided to other employees in your company?	☐ Yes ☐ No

Table 3 shows the final results of the survey application and the responses of workers who perform manual load handling activities:

Tabla 3: Survey results.

Ítem	Answer
Age	Average age 34.2 years
Gender	64% Male, 36% Female
Level of Education	12% Elementary 36 Junior High 15 High School 37 Technical school
How to evaluate your previous knowledge on ergonomics before the training?	Average 2.4 low.
After the training, how would you evaluate your actual comprehension of the ergonomics applied to your position?	Average 4.3 High
Do you consider that ergonomics is important for a safe and efficient way to complete your tasks?	Average 4.8 High
Did the trainig provide you with the necessary tolos to apply ergonomic practices in your daily work?	87% Yes 13% No
Did the training correctly cover the specific risks for your work position?	Average 4.9 Very Suitable
Since the training, have you modified any practices in your work to improve ergonomics?	77% Yes 23% No
Since the training, have you noticed a decrease in physical aches or pains related to your work?	56% Yes 44% No
Do you think that training has contributed to improving your safety at work?	Average 4.3 A lot
How would you evaluate the training in terms of content and methodology?	Average 3.2 Satisfied
Would you recommend that this training be provided to other employees in your company?	90% Yes 10% No

The survey analysis reveals that the average age of the surveyed workers was 34.2 years, indicating a relatively young workforce. In terms of gender, 64% of the respondents were male and 36% were female, suggesting a significant representation of both genders at the workstations evaluated. In terms of educational level, it was found that 12% of the respondents had primary education, 36% had completed secondary school, 15% had high school education, and 37% had technical training. These data suggest a workforce with a diverse educational base, where the majority has at least secondary or technical education, which is relevant for the understanding and application of ergonomic concepts.

The survey results reflect that prior to training, ergonomics knowledge among workers was low, with an average of 2.4 on a scale of 5. However, after training, this average increased to 4.3, indicating a high level of understanding and application of ergonomic practices.

Workers also considered ergonomics to be a crucial factor in safely and efficiently performing their daily tasks, with an average of 4.8 in the survey. The training was perceived as effective, with 87% of workers stating that it provided them with the necessary tools to apply ergonomic practices, and 77% reporting that they had modified their work practices to improve ergonomics.

Regarding health, 56% of workers noticed a decrease in physical aches or pains related to their work after training. In addition, the majority of workers, with an average of 4.3, considered that the training significantly contributed to improving their safety at work. Although overall satisfaction with the training was moderate, with an average of 3.2, 90% of workers would recommend that this training be provided to other employees in the company.

The results obtained in this study indicate that the implementation of the NOM-036-1-STPS-2018 awareness and management procedure in the induction of new workers has had a very significant positive impact on the reduction of ergonomic risks and the improvement of working conditions in manual assembly stations. These findings are in line with existing literature, which supports the effectiveness of ergonomic interventions in reducing occupational musculoskeletal disorders and improving productivity.

The 58% decrease in the number of accidents and 41% decrease in the number of incidents after the implementation of the program is consistent with previous studies that have demonstrated the effectiveness of ergonomic interventions in reducing workplace injuries. Research such as that conducted by Van der Molen et al. (2016) and Punnett et al. (2017) highlights that the implementation of specific ergonomic programs in the workplace can significantly reduce the incidence of accidents and improve safety conditions, especially in tasks that involve manual handling of loads. These studies underline the importance of ergonomic training and awareness, particularly in industries with high rates of workplace injuries such as manufacturing and maquila.

The 49% reduction in complaints of ailments is another positive indicator of the impact of ergonomics training. Studies such as that by Marras et al. (2000) have shown that ergonomic interventions that directly address the causes of musculoskeletal complaints, such as repetitive movements and awkward postures, can result in a substantial decrease in reports of pain and fatigue among workers. These findings reinforce the idea that adequate training, based on ergonomic standards such as NOM-036, not only improves safety, but also contributes to the general well-being of employees.

The shift from a high to a medium risk assessment using the NOM-036 method supports the effectiveness of the standard in mitigating ergonomic risks. The literature suggests that ergonomic risk assessment, when performed systematically and based on normative guidelines, can be a key component in identifying and correcting risk factors before they result in injuries. According to Waters et al. (2011), the use of risk assessment methods, similar to those proposed by NOM-036, is crucial to establishing effective ergonomic interventions and reducing exposure to hazards in the workplace.

The 84% increase in production volume post-implementation is a notable result that aligns with studies linking ergonomic improvements with increases in productivity. Dul et al. (2012) suggest that ergonomics, by improving working conditions and reducing injuries, not only protects workers, but can also lead to improvements in operational efficiency. This increase in productivity may be related to the reduction in work interruptions due to incidents and ailments, as well as the increased ability of workers to perform their tasks more efficiently and pain-free.

The survey results indicate that after training, workers had a greater knowledge and appreciation of ergonomics, which is consistent with studies such as Robertson et al. (2013), which show that ergonomics training improves employees' ergonomic awareness and practices. The high rating of the importance of ergonomics and the perceived effectiveness of the training reflect a positive change in the safety culture within the company. However, the moderate satisfaction with the training methodology suggests that there is room for improvement in the way ergonomic training is delivered, an observation that has also been highlighted in the literature, where the need for more interactive and personalized methodologies is suggested to maximize the impact of ergonomic learning (Fernandez et al., 2014).

Overall, the results of this study confirm the effectiveness of NOM-036-1-STPS-2018 as a tool to improve occupational health and safety in industrial environments, especially in tasks involving manual handling of loads. The reduction in accidents, incidents, and complaints of illness, along with the improvement in risk assessment and the increase in productivity, are testimony to the tangible benefits that can be obtained by implementing ergonomic practices based on robust standards. However, the experience and perception of workers suggest that the training methodology could benefit from improvements to further increase satisfaction and effectiveness in the long term.

5. CONCLUSIONS

This study reaffirms the critical importance of ergonomics in improving occupational health and safety within the manufacturing industry by providing compelling evidence that the implementation of NOM-036-1-STPS-2018 in induction processes not only significantly reduces ergonomic risks, but also optimizes productivity. By documenting notable reductions in accidents, incidents, and complaints of illness, as well as a substantial increase in operational efficiency, this work underscores the ability of ergonomic interventions to transform the work environment, creating safer and healthier conditions for employees.

The importance of this study for ergonomics lies in its contribution to the validation of a specific regulation such as NOM-036 in real work contexts, which is a significant contribution to ergonomic practice in Mexico. The ability of the standard to change a risk assessment from high to medium confirms its effectiveness and highlights the need for its implementation to become standard practice in all industries involving manual handling of loads.

The study has successfully fulfilled the mission of developing and implementing a robust ergonomic framework, based on NOM-036, and has demonstrated that this integration is vital to protect workers' health and improve occupational safety. In addition, it responds to the scientific problem addressed, clearly showing that proper ergonomic training can reduce occupational risks and improve workers' perception and practices in relation to ergonomics.

It is of utmost importance that NOM-036-1-STPS-2018 be adopted in a mandatory and standardized manner in all sectors of the manufacturing industry in Mexico. Given the positive impact demonstrated in reducing ergonomic risks and increasing productivity, companies must invest in ongoing ergonomic training and monitoring programs to ensure that the benefits observed in this study are maintained and expanded in the long term. Furthermore, it is suggested that future research explore the application of the standard in other industrial sectors and develop more interactive training methodologies to maximize the effectiveness of ergonomic learning.

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ERGONOMIC ASSESSMENT OF MANUAL MATERIAL HANDLING IN A UNIFORM MANUFACTURING FACILITY IN HERMOSILLO, SONORA

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Resumen: El presente estudio se llevó a cabo en una empresa de uniformes con el propósito de examinar las condiciones bajo las cuales los operarios realizan sus actividades. Se utilizó la observación directa de las tareas realizadas por los operarios, prestando especial atención a las posturas y cargas involucradas en su labor. Posteriormente, se evaluaron estas condiciones utilizando conforme lo dispuesto en la NOM-036-1-STPS-2018. El objetivo principal del estudio es la identificación de las condiciones en las que se efectúan las actividades de la empresa, principalmente las que involucran la manipulación de cargas de forma manual. Además, se propusieron acciones de mejora necesarias para reducir y eliminar los riesgos identificados. Como resultado de este estudio, se identificaron dos estaciones con nivel de riesgo alto y muy alto en la manipulación de objetos y se plantearon diversas acciones preventivas y correctivas. Estas propuestas están orientadas a optimizar las condiciones laborales y a minimizar los riesgos para los operarios en el manejo manual de materiales.

Palabras clave: Lesiones musculoesqueléticas, riesgos ergonómicos, manipulación manual de objetos, NOM-036-1-STPS-2018.

Relevancia para la ergonomía: La realización de evaluaciones de manejo de cargas contribuye a la prevención y gestión de riesgos ergonómicos al optimizar la administración del personal, adaptándolo a sus habilidades y entorno laboral. Esto conduce a un sistema operativo más efectivo, priorizando la seguridad y bienestar de los empleados.

Abstract: This study was conducted at a uniform manufacturing company, specifically in the area of manual material handling, with the aim of examining the conditions under which operators perform their activities. The goal was to understand the potential repercussions these conditions might have on workers, considering the manual handling of loads. The study was conducted using direct observation of the tasks performed by the operators, with particular attention to the

postures and loads involved in their work. This entire analysis was conducted in accordance with the guidelines established in NOM-036-1-STPS-2018, which regulates the manual handling of loads in Mexico. Additionally, necessary improvement actions were proposed to reduce and eliminate the associated risks.
As a result of this study, various proposals and ideas were presented to implement improvements that adequately address the observed situations. These proposals are aimed at optimizing working conditions and minimizing risks for operators in the manual handling of materials.

Keywords: Musculoskeletal injuries, ergonomic risks, manual handling of objects, NOM-036-1-STPS-2018.

Relevance to Ergonomics: Conducting load handling assessments contributes to the prevention and management of ergonomic risks by optimizing personnel management, adapting it to their skills and work environment. This leads to a more effective operating system, prioritizing the safety and well-being of employees.

1. INTRODUCTION

Manual material handling (MMH) is a prevalent activity in the manufacturing sector, involving the lifting and transporting of objects. MMH is a significant risk factor for lower back musculoskeletal injuries, especially when handling loads exceeding 3 kilograms (STPS, 2018). Numerous studies have linked poor MMH practices to musculoskeletal disorders, decreased productivity, and increased absenteeism (Vásquez Gómez, 2019; ILO, 2024; IMSS, 2024).

Mexican labor law mandates employers to provide safe working conditions, including training and protective equipment for MMH tasks (Federal Labor Law, 2023). The NOM-036-1-STPS-2018 standard provides specific guidelines for managing MMH risks. Given the legal requirements and the prevalence of MMH-related injuries, this study aims to investigate the specific conditions in a uniform manufacturing company.

2. OBJECTIVES

The primary objective of this study is to identify and assess ergonomic risks associated with manual material handling tasks within the uniform production process. This evaluation will be conducted in accordance with NOM-036-1-STPS-2018, with the aim of developing effective control measures to reduce risk levels.

3. DELIMITATION

The analysis focused on the production area, excluding administrative functions. In compliance with NOM-036-1-STPS-2018, the study included only tasks involving the manual handling of loads exceeding 3 kilograms.

4. METHODOLOGY

Based on the requirements of NOM-036-1-STPS-2018, the methodology included the following phases:

4.1 Initial recognition analysis:

- **Work area 1: Unloading.** Fabric rolls, weighing a maximum of 25 kg, are manually transported 35 meters from the warehouse to the cutting area.
- **Work area 2: Cutting.** Fabric rolls are placed on the cutting table, 15 meters from the warehouse. Fabric is cut according to patterns.
- **Work area 3: Design.** Primarily desk-based activities involving pattern creation.
- **Work area 4: Preparation.** Includes assembly, sewing, trimming, adjustments, quality control, and packaging.
- **Work area 5: Embroidery.** Involves design preparation, thread selection, machine configuration, embroidery, quality control, and finishing.
- **Work area 6: Arrangement, folding, and packaging.** Includes final inspection, folding, packaging, labeling, and storage.

4.2 Identification of MMH activities: Activities involving lifting, lowering, pushing, pulling, and carrying loads exceeding 3 kg were identified within the production process.

4.3 Ergonomic risk assessment: The level of ergonomic risk for identified MMH activities was assessed using Appendices I and II of NOM-036-1-STPS-2018. Data for these assessments were collected through observations and workers interviews.

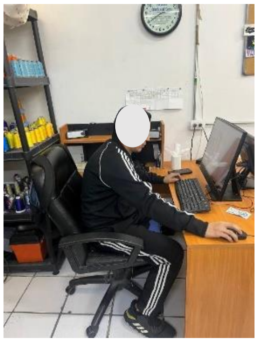
4.4 Control measures: Engineering and administrative controls, including equipment modifications, work process changes, and training, were developed to mitigate or eliminate ergonomic hazards.

a) Workstation 1. Unloading

b) Workstation 2. Cuttting

c) Workstation 3. Design

d) Workstation 4. Preparation



e) Workstation 5. Embroidery

f) Workstation 6. Arrangement

Figure 1. Production process. Source: Own elaboration

5. RESULTS

5.1 Identification of MMH activities

Table 1 presents the work areas involving MMH activities with loads exceeding 3 kg. Based on the analysis, work areas 1 (unloading) and 2 (cutting) were identified as requiring further ergonomic risk assessment. Work areas 3 (design), 4 (preparation), 5 (embroidery), and 6 (arrangement, folding, and packaging) did not involve MMH activities meeting the specified criteria.

Table 1 MMH Workstations

Process activity	**Lift/Lower**	**Push/Pull**	**Carrying**	**Team carrying**	**NOM-036-1-STPS-2018 Appendix**
1. Unloading	**X**		**X**		**I**
2. Cutting	**X**		**X**		**I**
3. Design					
4. Confection					
5. Embroidery					
6. Arrangement					

5.2 Ergonomic Risk Assessment

5.2.1 Workstation 1: Unloading

Table 2 presents the results of the evaluation using Appendix I of the standard. The results indicate a high-to-very-high risk level, necessitating immediate corrective actions. Key risk determinants include load weight of 25 kg, lifts per hour, vertical lift region, frequent torso twisting, and poor load coupling.

5.2.2 Workstation 2: Cutting

Table 3 presents the risk assessment for the cutting station. Results indicate a need for prompt intervention, primarily due to excessive vertical lifting, restricted postures, 15-meter transport distance, and unfavorable environmental conditions.

Table 2 Workstation 1 Risk Estimation - Appendix I

Risk Factors	**Lift**		**Carrying**	
	Color	**Value**	**Color**	**Value**
Weight / Carrying distance	**Orange**	4	**Red**	6
Horizontal distance between the hands from the lower back	**Green**	0	**Orange**	3
Vertical lift region	**Red**	3	**Green**	0

Torso twisting and lateral flexion; Asymmetrical torso load (carrying)	**Red**	2	**Purple**	3
Postural restraints (awkward, forced, or restrained postures)	**Green**	0	**Red**	3
Hand-load coupling (fasteners)	**Red**	2	**Orange**	1
Work surface	**Orange**	1	**Orange**	1
Other environmental factors	**Orange**	1	**Green**	0
Transportation Distance	**Green**	0	**Red**	3
Obstacles on the route (transportation only)	**Green**	0	**Orange**	1
Punctuation	**13**		**21**	
Risk level	**HIGH RISK**		**VERY HIGH RISK**	
Priority	**Corrective action is required immediately**			
Control measures	**Activities must be stopped, and control measures implemented through an ergonomic program for manual load handling**			
Actions	**Corrective actions must be taken for the transport of goods**			

Source: Prepared by the authors based on data obtained from ergonomic evaluation.

Table 3 Workstation 2 Risk Estimation - Appendix I

Risk factors	**Lift**		**Carrying**	
	Color	**Value**	**Color**	**Value**
Weight /carrying frequency	**Orange**	4	**Orange**	4
Horizontal distance between the hands from the lower back	**Green**	0	**Orange**	3
Vertical lift region	**Red**	3	**Green**	0
Torso twisting and lateral flexion; Asymmetrical torso load (carrying)	**Orange**	1	**Red**	2
Postural restraints (awkward, forced, or restrained postures)	**Green**	0	**Red**	3
Hand-load coupling (fasteners)	**Green**	0	**Orange**	1
Work surface	**Orange**	1	**Green**	0
Other environmental factors	**Red**	2	**Red**	2

Transportation Distance	**Green**	0	**Red**	3
Obstacles on the route (transportation only)	**Green**	0	**Orange**	1
Punctuation	11		19	
Risk level	**Medium Risk**		**High Risk**	
Priority	**Corrective action required soon**			
Actions	**Activities must be stopped, and control measures implemented through an ergonomic program for manual load handling**			
Actions	**Corrective actions must be taken for the transport of goods**			

Source: Prepared by the authors based on data obtained from ergonomic evaluation.

5.3 Control measures:

The proposal of preventive and corrective actions was made based on the hierarchy of controls set out in ISO 45001:2018: elimination, replacement, engineering and administrative solutions, and, finally, suggestion of the use of personal protective equipment (PPE) (ISO, 2018). Tables 4 and 5 present the control proposals according to the risk factors identified in the risk estimation.

Table 4 Proposed controls for Workstation 1: Unloading

Control Type	Action recommended
Elimination and replacement.	**Ergonomic workspace design or relocation:** Relocating and redesigning the unloading and storage area can significantly minimize travel distances and improve safe access to fabric rolls. By optimizing layout and ensuring ample space, the average lifting distance could be reduced by 20%, potentially increasing worker productivity. While relocation is a primary option, alternative solutions such as material handling equipment or process optimization should also be considered.
Engineering.	**Mechanized Conveyor System:** Implementing a roller conveyor system to transport fabric rolls from the storage area to their final destination can significantly reduce manual lifting and minimize physical exertion. This measure has the potential to reduce the risk of musculoskeletal injuries and increase production efficiency.
Administrative and PPE	**Safe Load Handling Training:** Provide regular, preferably annual, training to workers on safe heavy load handling techniques, emphasizing the proper use of handling equipment and devices. Encourage teamwork and load sharing to minimize individual risk. **Continuous monitoring and improvement:** Implement a system of regular workplace inspections and worker surveys to identify and address potential ergonomic hazards in the unloading area for

	fabric rolls exceeding 25 kg. Conduct periodic assessments to refine processes and optimize existing engineering controls.

Source: Prepared by the authors based on data obtained from ergonomic evaluation.

6. CONCLUSIONS

The analysis revealed that operators are exposed to various activities requiring different levels of physical effort, including significant manual handling tasks. By identifying ergonomic risks associated with these tasks and proposing corrective measures, this study aims to improve the work environment and prevent injuries.

Careful evaluation of operator exposure to manual handling is crucial to protect both individual well-being and overall production efficiency. The application of NOM-036-1-STPS-2018 proved invaluable in assessing current conditions and developing effective solutions.

By implementing the recommended corrective actions, the company can significantly reduce the risk of musculoskeletal injuries, improve worker satisfaction, and enhance overall productivity.

Table 5 Proposed controls for Workstation 2

Control Type	Action recommended
Elimination and replacement.	**Redesign of the workstation:** Analysis indicates that worktable and shelf heights are primary risk factors. Adjust the height of adjustable shelves to [recommended height range] to optimize ergonomic conditions. Replace non-adjustable worktables with height-adjustable options, targeting a range of elbow height to accommodate workers of various heights and reduce strain.
Engineering	**Implementation of auxiliary equipment:** Providing auxiliary equipment such as pallet jacks, hand trucks, or dollies can significantly reduce the physical strain associated with lifting and carrying activities. These tools can help to distribute the load more evenly and reduce the need for manual lifting and carrying.
Administrative and PPE	**Visual displays and training:** Implement comprehensive training programs for workers on correct lifting postures, emphasizing techniques like bending knees, maintaining a neutral spine, and using leg muscles for lifting. Supplement training with visual aids such as posters and job aids to reinforce proper lifting practices.

Source: Authors' elaboration based on data obtained from ergonomic evaluation.

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ERGONOMIC RISK FACTORS THAT GENERATE A DECREASE IN PRODUCTION VOLUME.

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Resumen: Las estaciones de trabajo con ensamble manual juegan un papel crucial en los procesos de producción que operan bajo una dinámica secuencial. En estos entornos, la eficiencia operativa se estructura en torno al tiempo estándar asignado a cada actividad productiva y al tiempo necesario para el transporte de materiales entre estaciones de trabajo. El tiempo estándar es una medida que refleja la capacidad productiva de un operario tipo medio, calculada en función de parámetros predefinidos, como la velocidad de ejecución, las tolerancias permitidas y las calificaciones de la actuación, que representan la habilidad y destreza del operador para cumplir con su tarea a lo largo de la jornada laboral.

Sin embargo, cuando las estaciones de trabajo no están diseñadas bajo criterios ergonómicos adecuados, emergen una serie de condiciones que elevan significativamente el tiempo de ciclo de las operaciones. Entre estas condiciones de riesgo ergonómico se encuentran la alta repetitividad de las tareas, la monotonía inherente a actividades sin variabilidad, la necesidad de mantener una alta concentración durante periodos prolongados, la baja locomoción que limita el movimiento del trabajador, y los tiempos de ciclo cortos que exigen un ritmo de trabajo sostenido. Estas condiciones no solo incrementan el tiempo de ciclo, sino que también imponen una carga física y mental considerable sobre el operario, lo que se traduce en un crecimiento cronológico del tiempo de ciclo a lo largo de la jornada laboral.

El presente estudio se centra en la identificación y análisis de estos factores de riesgo ergonómico y su impacto en el tiempo de ciclo, con el objetivo de cuantificar cómo este incremento afecta directamente el volumen de producción en líneas de ensamble manual. A través de una metodología de clasificación multivariante, se han evaluado diversas estaciones de trabajo, demostrando que en situaciones donde las condiciones ergonómicas son deficientes, el tiempo de ciclo puede aumentar hasta en un 70%. Este incremento en el tiempo de ciclo tiene una correlación directa con la disminución del volumen de producción, ya que la capacidad de la línea de producción para cumplir con los estándares establecidos se ve comprometida.

La fatiga acumulada por los trabajadores es un factor determinante en esta dinámica, ya que afecta negativamente la capacidad del operario para mantener un ritmo de trabajo constante y eficiente. A medida que avanza la jornada laboral, la fatiga reduce la capacidad del trabajador para realizar las actividades que exige la tarea, lo que se refleja en un aumento progresivo del tiempo de ciclo. Este fenómeno, a su vez, resulta en una disminución del volumen de producción, impactando no solo en los resultados operativos de la empresa, sino también en la calidad de vida del operario, al verse expuesto a condiciones de trabajo no óptimas que incrementan su carga física y mental.

Los hallazgos de esta investigación subrayan la importancia de la implementación de directrices ergonómicas en el diseño de estaciones de trabajo con ensamble manual. Al mitigar los riesgos ergonómicos identificados, es posible reducir el tiempo de ciclo, por ende, minimizar la disminución en el volumen de producción, mejorando tanto la eficiencia operativa como el bienestar de los trabajadores. Este estudio ofrece una contribución significativa al campo de la ergonomía física, al demostrar cómo la optimización de las condiciones de trabajo puede influir positivamente en los resultados productivos y en la salud laboral. La implementación de estas directrices es esencial para garantizar la sostenibilidad operativa y la calidad de vida de los trabajadores en entornos industriales.

Palabras clave: Ergonomía, Estaciones de trabajo con ensamble manual, volumen de producción.

Relevancia para la ergonomía: La investigación aporta un procedimiento de valoración ergonómica específico y validado para estaciones de trabajo con ensamble manual, demostrando su efectividad en reducir riesgos ergonómicos y mejorar la productividad. Proporciona evidencia empírica sobre el impacto de la fatiga en la producción y promueve un enfoque de mejora continua en la industria manufacturera.

Abstract: The workstations with manual assembly are circumscribed in production processes that maintain operative sequential dynamics, the sequencing is structured from the standard time assigned to each productive activity and the transport time from one workstation to another. The standard time is defined according to the productive capacity of an average operator, plus the conjunction of tolerances and performance qualifications, which describe the behavior of the operator, in the development of his task, maintaining this time throughout the working day. This situation masks a differential between the cycle time of the operation and the defined standard time, which frames a chronological growth throughout the working day in the cycle time, when the workstation does not carry ergonomic guidelines, mainly due to characteristics of the activity, such as high repetitiveness, monotony, high concentration, low locomotion and short cycle times. The present investigation is based on a multivariate classification of workstations with manual assembly, which shows an increase in cycle time of up to 70%. This increase is due to the effect of fatigue on the worker and leads to an implicit decrease in production volume, reducing the company's profitability and affecting the operator's quality of life.

Keywords. Ergonomics, Manual assembly workstations, Cycle time.

Relevance to Ergonomics: The research provides a specific and validated ergonomic assessment procedure for manual assembly stations, demonstrating its effectiveness in reducing ergonomic risks and improving productivity. It provides empirical evidence on the impact of fatigue on production and promotes a continuous improvement approach in the manufacturing industry.

1. INTRODUCTION

The northwestern border zone of Mexico has been distinguished by its economic development based on the manufacturing industry, with a particular emphasis on the Manufacturing, Maquiladora, and Export Services Industry (IMMEX) program. This program has been a growth engine for the region, with a national average monthly increase of 0.2% in the number of establishments registered under this scheme (INEGI, 2023). Within the area of influence of this study, which encompasses the northwestern border states of the country, a total of 1,630 productive entities were registered under the program as of November 2023 (INEGI, 2023).

The predominant operational system in the manufacturing industry of this region is characterized by the use of intermittent systems with inline flows, which, depending on the production sequencing, can follow linear, "U-shaped," or hybrid distributions (Zhang et al., 2020). These configurations are strategically selected to optimize the combination of product volume and variety, as well as to manage the repetitiveness and monotony of operations, customer demands, and product life cycles.

In the design and measurement of work within these linear flows, there is a critical interdependent relationship between the work area configuration and the workforce, particularly in the man-machine-work environment triad (Diego-Mas, 2020). This interdependence is especially relevant in manual assembly workstations, which are often characterized by high repetitiveness, monotony, high levels of concentration, low locomotion, and short cycle times. These conditions are fundamental to the company's ability to produce items that meet the quality, quantity, flexibility, and cost specifications demanded by the market.

The synergy between the anatomical and physiological capabilities of operators and the functional structure of the workstation is essential for achieving a balance between productive efficiency and worker well-being. This balance, however, can be compromised when the postures adopted by the worker, the force required for tasks, and the repetitiveness of activities are not ergonomically adequate. The lack of ergonomic adjustment increases worker fatigue (Karwowski & Marras, 2003), which in turn prolongs the cycle time of operations, ultimately reducing production volume.

The increase in cycle time, along with its relationship to the decrease in production volume and its impact on worker health, constitutes the central research problem of this study. Existing literature indicates that traditional ergonomic evaluation methods do not always effectively demonstrate the direct relationship between accumulated fatigue and the decrease in production volume in operational systems (Kolus et al., 2023). Therefore, it is imperative to establish an ergonomic diagnosis that allows for the identification and correction of discrepancies between current working conditions and optimal ergonomic requirements.

2. OBJECTIVES

General Objective: To design an ergonomic assessment procedure that allows for evaluating the impact of posture, force, and work repetitiveness on the reduction of production volume in manual assembly workstations.

Specific Objectives:

1. Identify the characteristics of manual assembly workstations that contribute to the reduction in production volume due to worker fatigue.
2. Develop a multivariate prioritization procedure to assess the impact of ergonomic characteristics on production volume in manual assembly workstations.
3. Propose ergonomic improvements based on the results of the assessment procedure to reduce risk levels and increase production in manual assembly workstations.

3. METHODOLOGY

The research is structured based on the positivist paradigm of science, utilizing the quantitative research approach (Hernández-Sampieri & Mendoza, 2018), by developing a multivariate prioritization procedure using the technique known as the prioritization tree, which allows for relating the impact of posture, force, and task repetitiveness with the reduction in production volume.

When establishing the dependent variable and the independent variables of the prioritization model, it is only possible to observe the behavior of the two variables without the ability to manipulate them. Based on this, the research design is defined as non-experimental. The research was conducted over a single period, making it cross-sectional and correlational in scope (Hernández-Sampieri & Mendoza, 2018).

The scientific foundation validating this research is supported by the following set of investigative tools:

The analysis from general to specific to define the characteristics of the object of study; from simple to complex for the development of the technique that evaluates the impact of worker posture on the operation's cycle time and the corresponding reduction in production volume; from abstract to concrete for the theoretical foundation of the scientific problem; analysis-synthesis, employed throughout the research process to examine specialized literature and synthesize results; the inductive-deductive method, used to make generalizations about the object of study and to form the theoretical framework that serves as the basis for this research.

The development of the research process was defined in three systematic and chronologically ordered phases, which ranged from the analysis of theories to the application and validation of the ergonomic assessment procedure in the industry.

3.1 Phase 1. Methodological Analysis of Theories.

The epidemiological evidence necessary for the development of the ergonomic assessment procedure is based on a methodological analysis of theories, allowing the recognition of biomechanical efforts of operators, levels of task repetitiveness, uncomfortable working postures, and the occurrence of Musculoskeletal Disorders. In addition to this, it is essential to analyze ergonomic evaluation methods and the discrepancies, sufficiencies, and inefficiencies of each method in assessing the workstations, which are the object of study in our research. Another indispensable aspect for the development of the procedure is the standards, rules, and guidelines of ergonomics, which allow for structuring improvement recommendations when applying the procedure. With this theoretical foundation, a scientific support platform is structured for the development of the ergonomic assessment procedure.

The assessments established by the procedure are based on the difficulty that posture generates for the operator, calculated by determining the difference between the neutral posture of the human body and the posture in which the worker performs their activity. The greater the difference between the two postures mentioned, the more significant the negative impact on the worker’s quality of life. Table 1 shows the movements occurring in the body planes of each part of the body that are assessed by the procedure, thereby allowing for the quantitative establishment of values reflecting the difference between the compared postures.

Table 1: Body Movements Assessed by the Procedure.

Head		
Coronal Plane	Lateral Bending Movement: This movement occurs when the head tilts to one side, reducing the angle between the head and the trunk on that side while increasing it on the opposite side.	
Sagital Plane	Flexion Movement: Head flexion occurs when the chin moves closer to the chest, decreasing the angle between the head and the trunk.	Extension Movement: In this case, the head tilts backward, increasing the angle between the head and the torso.
Transvers	Rotation Movement: In this plane, the	

e Plane	head can rotate left or right around its vertical axis, allowing the gaze to move to the sides without moving the trunk.	
Arm		
Coronal Plane	Abduction: Movement of the arm outward from the body, moving it away from the midline of the body.	Adduction: Movement of the arm towards the body, bringing it closer to the midline of the body.
Sagittal Plane	Flexion: Movement of the arm that decreases the angle between the forearm and the arm in the sagittal plane.	Extension: Movement opposite to flexion that increases the angle between the forearm and the upper arm in the sagittal plane.
Transverse Plane	Medial (or internal) Rotation: Rotation of the arm inward, so that the palm of the hand moves toward the body.	Lateral (or external) rotation: Rotation of the arm outward, so that the palm of the hand moves away from the body.
Hand		
Coronal Plane	Abduction: Movement of the fingers away from the longitudinal axis of the hand.	Adduction: Movement that brings the fingers closer together, moving them toward the longitudinal axis of the hand.
Sagittal Plane	Flexion: Bending movement of the fingers toward the palm of the hand, decreasing the angle between the hand and the fingers.	Extension: The opposite movement of flexion, which straightens the fingers, increasing the angle between the hand and the fingers.
Transverse Plane	Thumb Abduction: Movement of the thumb away from the palm of the hand, in a plane perpendicular to the longitudinal axis of the hand.	Thumb adduction: Movement of the thumb approaching the palm of the hand, in a plane perpendicular to the longitudinal axis of the hand.
Forearm		
Coronal Plane	Radial Deviation (Wrist Abduction): Movement of the forearm that brings the hand toward the thumb, away from the longitudinal axis of the forearm.	Ulnar deviation (carpal adduction): Movement of the forearm that brings the hand towards the little finger, bringing it closer to the longitudinal axis of the forearm.

Sagittal Plane	Flexion: Movement of the forearm that decreases the angle between the arm and the forearm.	Extension: Movement opposite to flexion; increases the angle between the arm and forearm.
Transverse Plane	Pronation: Movement of the forearm that rotates the palm of the hand downward or backward, with the thumb moving outward.	Supination: Movement of the forearm that rotates the palm of the hand upward or forward, with the thumb moving inward.
Shoulder		
Coronal Plane	Abduction: Movement of the arm outward from the body, moving it away from the midline of the body.	Adduction: Movement of the arm towards the body, bringing it closer to the median plane of the body.
Sagittal Plane	Flexion: Movement of the arm that decreases the angle between the arm and the torso in the sagittal plane, as when raising the arm forward.	Extension: Movement opposite to flexion; which increases the angle between the arm and torso in the sagittal plane.
Transverse Plane	Medial (or internal) Rotation: Rotation of the arm inward, so that the palm of the hand moves toward the body.	Lateral (or external) rotation: Turning the arm outward, so that the palm of the hand moves outward.
Legs		
Coronal Plane	Abduction: Movement of the leg away from the body, moving it away from the midline of the body.	Adduction: Movement of the leg approaching the body, bringing it closer to the median plane of the body.
Sagittal Plane	Flexion: Movement of the leg that decreases the angle between the leg and the trunk.	Extension: Movement opposite to flexion; increases the angle between the leg and the trunk.
Transverse Plane	Medial (or internal) Rotation: Rotation of the leg inward around its longitudinal axis, with the foot turning inward.	Lateral (or external) rotation: Turning the leg outward around its longitudinal axis, with the foot turning outward.
Trunk		
Coronal Plane	Lateral Bending: Movement of the trunk to one side, decreasing the angle between the trunk and the midline of the body on that side while increasing it on the opposite side.	

Sagittal Plane	Flexion: Movement of the trunk forward, decreasing the angle between the trunk and the legs in the sagittal plane.	Extension: Movement of the trunk backwards, increasing the angle between the trunk and the legs in the sagittal plane.
Transverse Plane	Rotation: Rotation of the trunk to the left or right around its longitudinal axis, allowing the torso to move horizontally without tilting forward or backward.	

The maximum permissible biomechanical lifting for the force component is calculated based on weight, sex, and movement in the body planes. The last component is repetitiveness, which is included in the procedure based on the guidelines outlined in ISO 11228-3:2007.

3.1.1 Characteristics of Manual Assembly Workstations.

The main characteristics of manual assembly workstations in production processes with inline flows are the monotony in postures, repetitiveness, short cycle time, speed, mechanical and contact stress, vibration, precision, and static effort. Table 2 describes the characteristics of manual assembly workstations and the activities where they are generally present in the industries under study.

Table 2: Characteristics of Manual Assembly Workstations.

Characteristics	Description	Examples of activities where they occur in the industries under study.
Monoty postures	Set of movements carried out by each main joint to carry out the sequence of technical actions that characterize a cycle.	Operation of a set of microelectronics products.
Repetitiveness	Repeated sequence of muscle contractions or postures held for a long time.	Weaving of electrical cables. Soldering on cable ends.
Short cycle time	Time of manual and machine operations that determine the minimum time necessary for the transformation of the product.	Obtaining the end of the cable. Stapled. Manual stamping.
Speed	Speed with which an activity, movement and process that generates an event is carried out.	Laminated with pipe tape.
Mechanical stress	Type of trauma that is generated by having contact between the body and the external object.	Assembly and welding machinery.
Contact	Part of the body rubs against a	Sleeve burn

stress	workstation component.	
Vibration	Oscillatory movements seen in workstations, generated by the use of mechanical systems.	Harness weavers Management of stamping machines.
Detail	High precision in the operations carried out.	Welding inspections with a fixed magnifying glass.
Static effort	An effort in which the force is constant or increases slowly with time.	Operation of machine to cut cable in harness.

3.2 Phase 2: Development of the analytical hierarchy.

A total of 2,500 systematic evaluation samples were applied with the procedure, in workstations with manual assembly, within the export maquiladora industry, located in the northwest of Mexico. Where a multivariate classification was developed, based on the construction of a multivariate ranking tree, which compared the impact of the different positions of the operator when developing their task, the force used in the action and the repetitiveness of movements, with the increase in the cycle time of the workstation throughout the work day, establishing this variable as the difference in percentage in three-time intervals in their work day. The intervals were classified according to the hours with the least negative impact on production, reducing the probability of distraction due to rest, meals, and material supply. The intervals are from 8 am to 10 am, 11 am to 1 pm, and 2 pm to 4 pm. By determining the position of each part of the operator's body, which intervenes in the achievement of the task, the force used and its repetitiveness, and comparing it with the resignation of his productive capacity, we can prioritize the influence of these three characteristics. According to the percentage increase in cycle time and its impact on production volume. In this sense, the result of the analytical hierarchy developed in the statistical software SPSS version 23 (Aguado & Provecho, 2019) is presented, which classifies us into 4 categories, the influence of the three characteristics necessary for the development of the task, with the decrease in production volume. Figure 1 shows the analytical ranking tree obtained.

Figure 1 shows the analytical hierarchy tree, where the classification of the impact of the three characteristics presented in the procedure is structured, with the percentage increase in the production volume for each classification, established in the table as nodes. For the first node, a sum of qualifications in the workstations is maintained less than 23.04 and on average it has an increase in cycle time of 8.783%, being considered a stable work condition to develop the task. In the case of the second node, we have an interval of the sum of the evaluations of (23.04-28.00] generating a 25.952% increase in cycle time, referring to an average condition for the development of the task. In node three We denote an interval of (28.00-35.04] and an increase of 59.519% in its cycle time, indicating a risk condition for the development of the task. In the fourth node, a sum greater than 35.04 and an average increase of 76.192 are specified. % which is considered a critical condition to carry out the work.

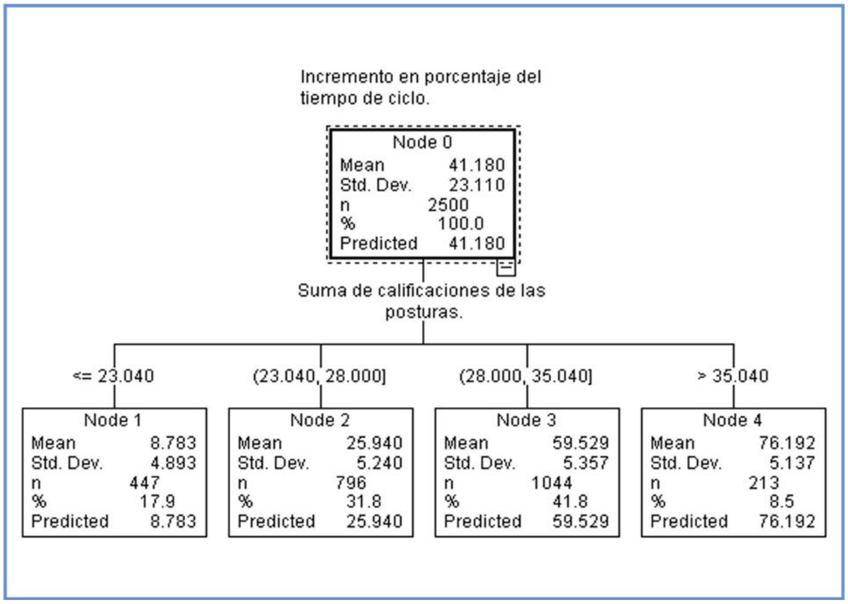

Figure 1. Multivariate analytical ranking tree.

4. RESULTS

Until now, the ergonomic assessment procedure has been applied in 560 workstations with manual assembly in the manufacturing, maquiladora, and export services industries, located in the border area of the states of Baja California, Sonora, and Chihuahua. Each application establishes the evaluation of the current situation of the workstation, a series of improvement proposals, and the cycle time of the redesigned station is presented.

Figure 2 shows the ergonomic assessment procedure applied to the assessed workstations.

Figure 2. Ergonomic assessment procedure

The application of the procedure is specified in the form of a circle, because it must entail continuous improvement, through the cyclical application of the procedure and the ergonomic improvements issued by it. This application involves direct collection work on production lines and subsequent analysis of the collected information. Table 3 shows a sample of 4 of the 560 applications carried out by the ergonomic assessment procedure.

Table 3. Applications of the procedure.

Before applying the procedure					After application of the procedure		
Workstation	Risk Level	Qualification obtained	Cycle time (min)	Improvements proposed by the procedure	Cost of improvements.	Risk Level	Cycle time (min)
CC1.	3	28.88	2.57	Move away the deposits where the material is placed, to avoid repetitive lateral movement of the wrist, concentrating the movement on the arms. Use ergonomic chairs (model JG-051). Do not lift weights greater than 5 kg. Provide the operator with a power tool.	$5,800.00 pesos.	1	1.47
CC2.	4	44.24	3.1	Adapt the work area within the reach area for the operator. Provide an adjustable footstool. Forearm support. In the case of working seated, do not lift weights greater than 5 kg.	$ 990.00 pesos.	2	1.85
CI-4.	3	28.08	1.58	Use ergonomic chairs (model JG-051). Provide an adjustable footstool. Forearm support.	$ 3,260.00 pesos.	2	1.1
CE-1.	4	39.36	0.92	The seat must be made of porous fabrics, a slight slope on the edge, height adjustment options, 5 support points and the seat must be swivel.	$2,630.00 pesos.	3	0.9

Table 3 shows the rating issued by the assessment procedure, the risk maintained by the worker who performs his work at the workstation, and the operating cycle time, that time is calculated based on what is established in the ISO standard. 11228-3:2007. You can also observe the recommendations issued by the assessment procedure and that was applied to the analyzed workstations, the cost involved in the recommendation, the level of risk that was reached with the application of the recommendations, and the cycle time maintained the workstation after application of the procedure.

Table 4. Results before and after procedure application.

Before application		**Application of the procedure**		**After application**		
Workstation	Cycle time (min)	Daily production	Risk level	Risk level achieved	Cycle time (min)	Production achieved
1	2.57	145	3	1	1.47	290
2	3.1	98	4	2	1.85	146
3	1.2	279	3	1	1.05	370
4	1.45	216	4	2	0.78	415
5	1.58	243	3	2	1.1	390
6	0.92	380	4	3	0.9	438
7	5.42	68	4	1	3.72	92
8	4.05	76	3	2	3.74	98
9	2.67	102	3	2	2.46	147
10	4.89	56	4	3	3.19	123
11	3.06	124	3	1	2.45	174
12	7.12	54	2	1	6.49	78
13	8.92	46	3	2	6.18	63
14	7.47	54	3	1	5.78	89
15	1.57	298	2	1	1.35	362
16	1.23	304	3	2	1.17	381
17	0.83	490	3	1	0.64	678
18	2.4	180	2	1	1.88	267
19	1.8	197	3	2	1.28	305
20	0.78	500	3	2	0.72	640
21	1.24	370	2	1	1.19	400
22	1.75	145	2	1	1.45	287
23	1.92	129	2	1	1.63	219
24	5.24	78	2	1	4.33	104

Table 4 shows 24 of the 560 results of the application of the ergonomic assessment procedure, where the comparison between risk levels, cycle times and the difference that occurs in the production volume before and after can be highlighted. after application.

Table 5. Compendium of final results of the application of the procedure.

Current risk level.	Risk level achieved with the application of the recommendations suggested by the procedure.	Number of applications where this level of reduction in workstation risk was obtained.	Average % increase in production volume.
4	1	156	62.76%
4	2	76	40.32%
4	3	85	10.64%
3	1	132	59.15%
3	2	87	31.59%
2	1	24	23.18%

Table 5 presents the compendium of the 560 applications, showing the number of applications where the decrease in risk levels occurs and the average percentage of increase in production volume that was achieved with the application of the procedure.

5. CONCLUSIONS

The manufacturing, maquiladora, and export services industry is one of the most dynamic sectors in northeastern Mexico, generating a considerable inflow of foreign currency, direct and indirect jobs, and technology transfer to the country. In this sector, sequential inline production processes predominate, with most workstations involving manual assembly. However, these workstations exhibit characteristics that can lead to a rapid increase in operator fatigue within a short period, raising the likelihood of developing Musculoskeletal Disorders (MSDs), decreasing quality of life, and consequently reducing production volume.

This research has conclusively demonstrated the fulfillment of the stated objectives, confirming the effectiveness of the ergonomic assessment procedure designed to evaluate the impact of posture, force, and task repetitiveness on the reduction of production volume in manual assembly workstations. By applying this procedure to 560 workstations in the border regions of Baja California, Sonora, and Chihuahua, a significant correlation has been established between the implemented ergonomic improvements and the reduction of risk levels, resulting in a considerable increase in production volume.

The study allowed for the precise identification of critical ergonomic characteristics such as uncomfortable postures, excessive force, and high task repetitiveness. These factors were assessed and prioritized using an analytical decision tree, enabling targeted interventions in the most critical workstations. Additionally, a multivariate hierarchization procedure was developed and validated to classify workstations based on the impact of ergonomic conditions on cycle time and, consequently, production volume. The proposed ergonomic improvements have proven effective in reducing risk levels, achieving an average production volume increase of 62.76% in cases where the risk level was significantly reduced.

This work is of great importance to the field of ergonomics, as it provides a systematic and quantitative approach to addressing ergonomic issues in the manufacturing, maquiladora, and export services industries. By clearly establishing the relationship between ergonomics and increased production, the study offers a solid justification for investment in ergonomic improvements, both from the perspective of worker health and safety and from the standpoint of business efficiency and competitiveness.

Moreover, the study holds significant relevance for ergonomics by proposing a model that can be adapted and applied in different industrial contexts. This sets a precedent for future research and developments in ergonomic assessment, amplifying its relevance and potential impact on improving working conditions and productivity in various sectors.

Finally, the relevance of this research for Mexico's productive and scientific development is evident. In a country where the manufacturing and maquiladora industry is an economic pillar, optimizing workstations through ergonomics not only improves worker health and well-being but also enhances the competitiveness of companies on a global scale.

In conclusion, the integration of ergonomics in the design and evaluation of workstations has proven to be an essential component for improving both productivity and the quality of life of workers. The results underscore the need for continued investment in research addressing the intersections between ergonomics, occupational health, and productive efficiency, promoting competitive and sustainable industrial development within the Mexican context.

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PRELIMINARY ERGONOMIC EVALUATION IN THE APPLE PACKING, PACKAGING, AND STORAGE PROCESS.

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Resumen El presente trabajo de investigación se llevó a cabo con la finalidad de realizar un análisis ergonómico de una actividad laboral de gran trascendencia en la región de Cd. Cuauhtémoc, Chih. y por lo tanto de incidencia significativa en las lesiones y enfermedades laborales de los trabajadores locales, el embalaje y almacenamiento de la manzana. La investigación incluyó el análisis de cargas bajo la norma NOM-036-1-STPS-018, y el análisis ergonómico de las actividades involucradas, utilizando la herramienta de Identificación Básica de Riesgos de Factores Ergonómicos (BRIEF) y el método LEST buscando determinar las condiciones generales de trabajo, y en base a los resultados, se realizaron las recomendaciones pertinentes desde el punto de vista ergonómico para optimizar las actividades laborales.

Palabras clave: Análisis Ergonómico, BRIEF, LEST, NOM-036-1-018, Producción de Manzana

Relevancia para la ergonomía: Son varias las normativas de tipo ergonómico que en los últimos años han pasado a ser de tipo obligatorio, es importante para las PYMES de la región manzanera que se realicen los estudios ergonómicos pertinentes para que de esta manera puedan cumplir con estas normas, específicamente en este proyecto hablando de la NOM-036-1-STPS-2018. De la misma manera realizar los estudios pertinentes con las herramientas de análisis ergonómico adecuadas buscando cuidar la salud física y mental de los trabajadores involucrados.

Abstract: The research objective was to make an ergonomic analysis of work activity of great importance in the Cd. Cuauhtémoc, Chih. Region, and therefore of significant impact on occupational injuries and illnesses of local workers, the packing and storage of apples cases. The research included the analysis of loads under the standard NOM-036-1-018, and the ergonomic analysis of the activities involved, using the tool Basic Identification of Ergonomic Factors (BRIEF) and the LEST method seeking to determine the general working conditions and based on the results, pertinent recommendations were made from an ergonomic point of view to optimize work activities.

Keywords. Ergonomics analysis, BRIEF, LEST, NOM-036-1-018, Apple Production Process.

Relevance to Ergonomics: Several ergonomic regulations have become mandatory in recent years. It is important for PYMES in the Apple region that the relevant ergonomic studies are carried out so that they can comply with these standards, specifically in this project, talking about the NOM-036-1-STPS-2018. In the same way, pertinent ergonomic studies should be carried out with the appropriate analysis tools, seeking to take care of the involved worker's physical and mental health.

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1. INTRODUCTION

According to data from the Ministry of Agriculture and Rural Development (SADER), the economic spillover for the state of Chihuahua due to apple production in 2021 was estimated at $7977641.88 pesos, a result of being the largest apple producer nationwide with 33267.70 hectares planted and the 664803.49 tons production (Rodríguez, 2021). Production is distributed in five municipalities as shown in Table 1.

Table 1. Distribution of Apple Production in Five State of Chihuahua Municipalities (Rodríguez, 2021)

Municipality	Production Percentage
Cuauhtémoc	33.79%
Guerrero	28.23%
Namiquipa	16.42%
Bachiniva	8.25%
Cusihuiriachi	7.02%

The municipalities mentioned have an area of 16757.36 km2, which corresponds to 6.77% of the state's total surface (INEGI, 2024). As can be seen in Figure 1, these territories are adjacent to each other.

All the information mentioned above is to put into context the importance of this work activity in the region in which the research was carried out, since, although there is a company, called "Grupo La Norteñita" that is characterized by being innovative in the apple production industry and also “brings 4 out of every 10 apples consumed in Mexico to homes” (Ortega, 2023), most of the activities related to picking, sorting, packing and packaging are done manually by a large number of workers, most of them temporary.

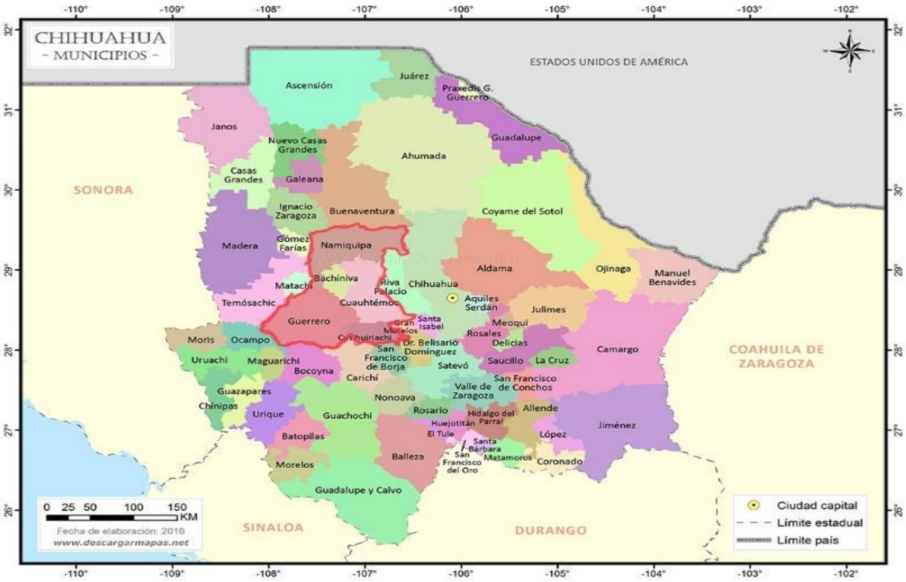


Figure 1. Chihuahua’s Apple region(DescargarMapas.net, 2024)

Concerning the research carried out in recent years about apples production and marketing, we found that most articles are related to productivity about increased apple production, innovative production systems, or how to attack and/or avoid tree diseases (Severino, 2023; Bensaci, et al., 2022; Ontiveros, 2011; Przybyłko, et al., 2021; Tougeron & Hance, 2021; Naderi, Nejad, & Taki, 2020; Ramírez, et al., 2011; Llang, Zhang, et al., 2022; UNIFRUT, 2022), Articles were also found with the processing of apples to produce cider or juice, and the use of residues from apple orchards as fuel (Duan, et al., 2021; Souza, et al., 2019; Abraham, et al., 2024).

Continuing with the previous topic, and with respect to the ergonomic part, six projects focused on the apple harvesting part were found, which definitely carries a lot of risk, since it is done manually and with the worker on a ladder (Benos, et al., 2020; Zhang, el al., 2019; Balsama & Meyer, 2020; Fulmer, et al., 2002; Kee, 2022; Houshyar & Kim, 2018) and in relation to the activities of selection, packing and packaging, only three researches were found, Soto (2020) proposes in her research work, the conceptual design of an automatic machine for washing apples, which is the first activity to be carried out when the apple is going to be packed, on the other hand Granda (2022) proposes a table for the manual process optimization of sorting a variety of apples, and with respect to the packaging activity there is the thesis of Belén (2023) which studies the symptoms and risk factors in relation to carpal tunnel syndrome in women packers in a fruit industry, it is important to mention that the aforementioned works are theses to obtain different degrees.

Based on the above, this research work was carried out to carry out an ergonomic analysis of the activities related to the packaging, packing, and storage of apples, as a way to influence a significant work activity in the region in which we are located. The research includes the analysis of loads under the standard NOM-036-1-STPS-018, and the ergonomic analysis of the activities involved with the packaging and temporary storage of the apple boxes, using the Basic Risk Identification of Ergonomic Factors tool (BRIEF) and the LEST method seeking to determine the general working conditions

2. OBJECTIVES AND DELIMITATION

2.1 General Objective

To have a preliminary impact on the ergonomic analysis of a significant work activity in the Northwest region of the State of Chihuahua, the packing, packaging, and storage of apples, seeking the worker's benefits.

2.2 Delimitation

This project included a company that meets the conditions that prevail in most organizations that are dedicated to the selection, packing, packaging and storage of apples in the Northwest region of Chihuahua.

Specifically, the position identified in the company as a "box loader" was evaluated, the analysis of the station related to the selection and placement of the apples on the fences is not included in this work.

3. METHODOLOGY

This methodology consists of the following steps to determine the worker's ergonomic risk level:

1. The work process is observed, and videos and photographs are taken during the work activity, detecting preliminarily the risks and inadequate conditions from the ergonomic point of view.
2. A preliminary analysis of the activities is carried out to determine the correct ergonomic tools. It was decided to use the methodology of Basic Risk Identification of Ergonomic Factors (BRIEF), a methodology that, allows first to characterize the workplace, and then examine nine body segments relating them to postural risk factors, as well as the force applied by the body segment, including the duration and frequency of the load, to identify physical stressors and qualify the risk from an ergonomic point of view (Martínez, 2017). The LEST method will also be applied to determine the general working conditions, specifically those involved with the physical and psychosocial environment (INSHT, 1989) and to finish the Mexican standard related to

ergonomic risk factors at work-identification, analysis, prevention, and control. Part 1: Manual Load Handling NOM-036-1-STPS-2018 (STPS, 2018).

3. A report is prepared with all the findings including recommendations based on ergonomic guidelines to reduce the risk of accidents and injuries in the workers involved in the aforementioned production process.

The activities that were included in the ergonomic analysis of this project are described below:

1. After going through a washing process, apples are placed on a belt, in which workers classify them and put them on plastic cages with measurements of 55x37 cm, being 33 cm high, the full boxes weigh around 22 kg, after this part of the process begins the activity to be evaluated in this project.
2. The Worker first closes the bag that protrudes from the cage for which he lifts the upper limbs and then places a cardboard (Figure 1).

Figure 1. Placement of cardboard on top and transfer.

3. Finally, the worker manually moves the grille with the apples to a pallet located in a specific place where it is packaged and stored for a short time before being taken to the freezers or to be marketed

Figure 2. Transfer and packaging station.

4. RESULTS

4.1 BRIEF results

Applying the survey BRIEF, Considering the variables posture, strength, duration and frequency by body segment, qualifying the level of risk, taking into account all the operations related to the "box loader" workstation, the results gave us high risk (4 o 3) in the hands and wrists, elbows, shoulder, neck and back and low risk in legs, on the other hand, the absence of physical pressure in any part of the body and the absence of the use of gloves were detected. Determining the conversion factors involved with the scores obtained yields a hazard factor score at work of 65 and taking into account that the operation is carried out between 20 and 40 hours per week, which corresponds to an exposure multiplier of 1, the hazard score at work corresponds according to very high risk, which implies that it is necessary to modify the task to avoid musculoskeletal injuries in the worker.

4.2 L.E.S.T. Method

The LEST Method results (Figure 3) show that within the physical load and environment, there is harmful damage to the worker, and within the areas of mental load, psychological aspect, and work time there are medium discomforts, there is a risk of fatigue for which it is concluded that, in physical load and environment, Changes have to be made urgently and in the others try to reduce a little that fatigue that is created to make a less tiring workplace.

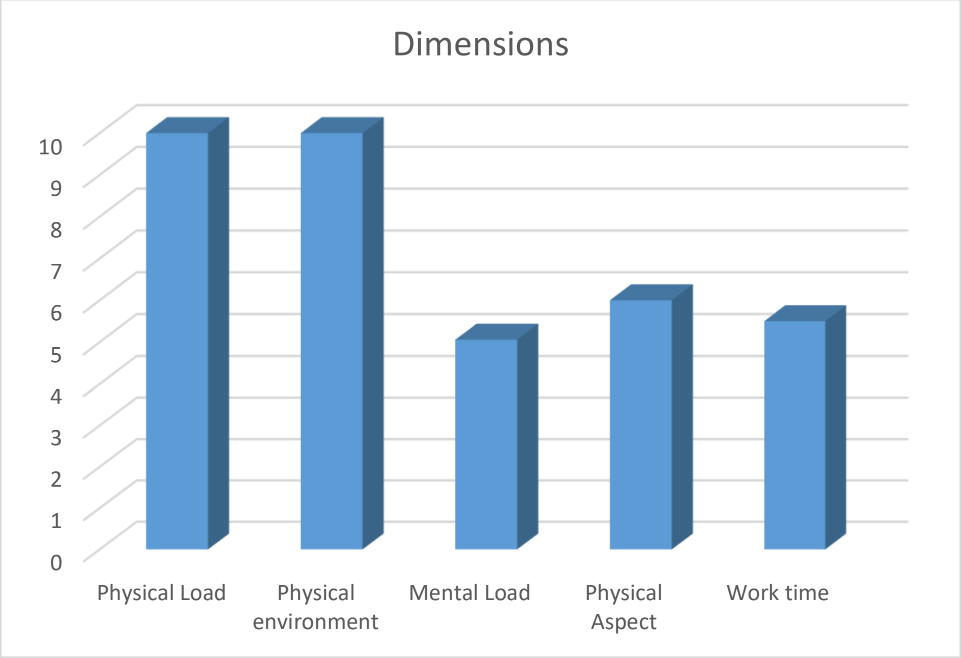


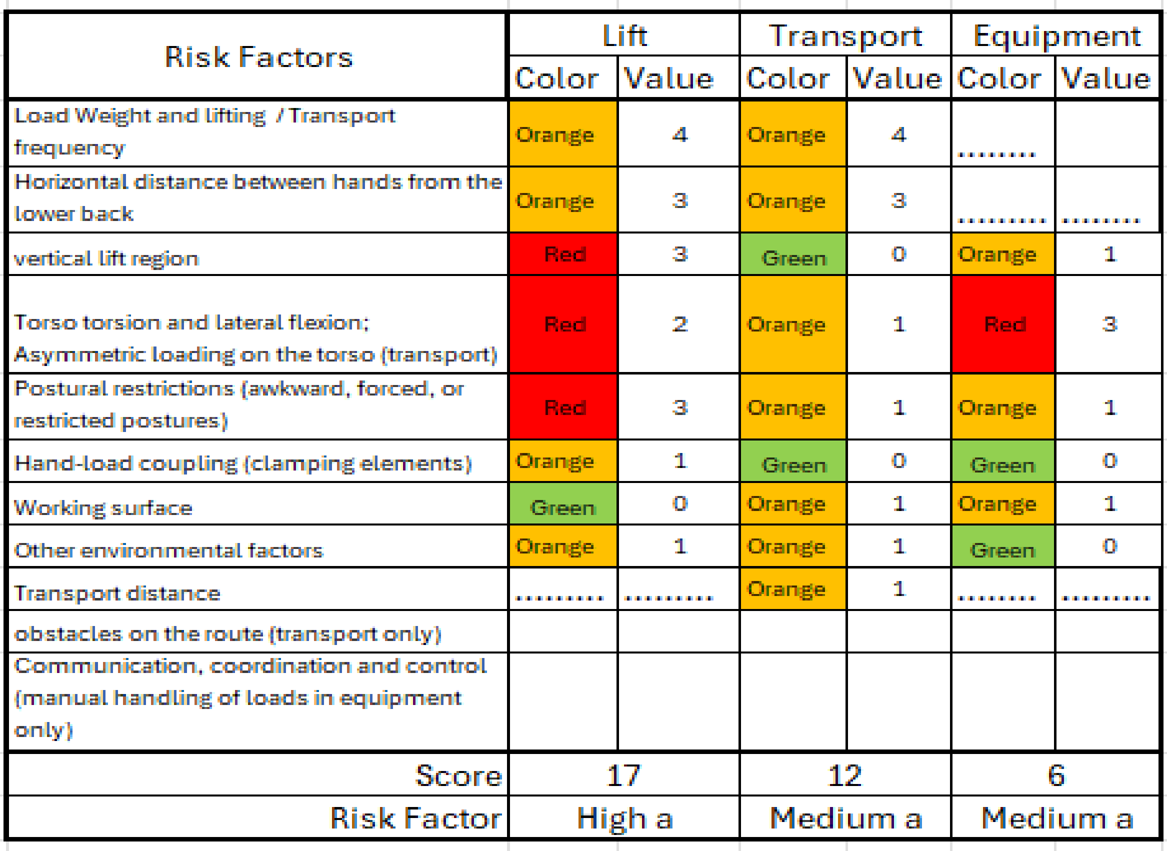
Figure 3. LEST Results.

4.3 NOM-036-1-STPS-2018 Results

Mexican regulation aims to establish the elements to identify, analyze, prevent, and control ergonomic risk factors in the workplace derived from the manual handling of loads, to avoid alterations to the worker's health.

The man on whom the analysis was carried out is an apple loader, who is responsible for lifting apple boxes of approximately 22 kg, transporting them, placing them in another station, and carrying out the corresponding packaging. The results obtained in a specific way can be seen in Figure 4.

As can be seen, there is a high to significant risk to the lifting area, so changes must be made to the area of lifting boxes quickly. In the transport of the boxes, there is a medium to possible risk, so it is recommended that administrative control measures be implemented, and investment be made in transfer equipment such as hand trolleys, which would affect not only the load part but also the postural part, preventing injuries or pain in the back of the workers.



Risk Factors	Lift		Transport		Equipment	
	Color	Value	Color	Value	Color	Value
Load Weight and lifting / Transport frequency	Orange	4	Orange	4	....	
Horizontal distance between hands from the lower back	Orange	3	Orange	3	....	....
vertical lift region	Red	3	Green	0	Orange	1
Torso torsion and lateral flexion; Asymmetric loading on the torso (transport)	Red	2	Orange	1	Red	3
Postural restrictions (awkward, forced, or restricted postures)	Red	3	Orange	1	Orange	1
Hand-load coupling (clamping elements)	Orange	1	Green	0	Green	0
Working surface	Green	0	Orange	1	Orange	1
Other environmental factors	Orange	1	Orange	1	Green	0
Transport distance	....	....	Orange	1	....	....
obstacles on the route (transport only)						
Communication, coordination and control (manual handling of loads in equipment only)						
Score	17		12		6	
Risk Factor	High a		Medium a		Medium a	

Figure 4. Risk Level Estimation.

5. CONCLUSION

By analyzing the activity of Apple´s packing, packaging, and storage, it was possible to verify the problems that exist in the workstation, through the application of some ergonomic methodologies such as BRIEF, LEST, and the NOM-036-1-STPS-2018.

At present, in most of the apple packing plants of the 5 municipalities mentioned above, importance has not been given to the activities carried out by the workers, of which a large number of tasks are carried out manually, causing accidents and musculoskeletal injuries in them, hence the importance of performing, improve and adapt the manual activities that are being used in the different packing houses, since there is a high demand for apples throughout the country.

As a preliminary recommendation, it is important to establish the use of hand trolleys for the apple cage loading, as well as ergonomic mats that allow the worker’s comfort in the different areas.

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SENSOR TECHNOLOGY AND NEURAL NETWORKS FOR SITTING POSTURE CLASSIFICATION: A SYSTEMATIC REVIEW

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Resumen: En los últimos años ha aumentado el número de personas que pasan largos periodos de tiempo sentadas, tanto en el trabajo como en casa. Aproximadamente el 75% de los empleados de centros de llamadas, empresas de software y otros lugares de trabajo industriales pasan el 90% de su jornada laboral sentados. Estar sentado mucho tiempo en una mala postura puede causar molestias y dolores musculoesqueléticos. Los métodos tradicionales analizan la postura sentada mediante la observación y las respuestas autodeclaradas a un cuestionario. Desafortunadamente, estos métodos son sesgados y subjetivos, como resultado, los datos no eran fiables. Los avances en los sistemas micro y nanoelectromecánicos han llevado a la disponibilidad de varias tecnologías de sensores miniaturizados en el mercado. Estos pueden clasificar de forma objetiva y precisa las posturas al sentarse. El objetivo de esta revisión bibliográfica es evaluar los trabajos publicados sobre tecnología de sensores y redes neuronales para la clasificación de posturas sentadas. Para realizar esta revisión bibliográfica sistemática se siguió el enfoque PRISMA (Preferred Reporting Items for Systematic

Reviews and Meta-Analyses). La búsqueda inicial consideró cinco bases de datos (ScienceDirect, PubMed, Web of science, IEEE Xplore, MDPI). Sólo se buscaron estudios en inglés. Esta revisión bibliográfica sienta las bases para una exploración detallada de las metodologías, tecnologías y retos encontrados en los estudios centrados en la clasificación de la postura sentada. Según los resultados de la revisión, la mayoría de los estudios se desarrollaron en el contexto científico (n = 7, 58,33%), y el resto abarcó otras áreas. En cuatro estudios los sensores de presión se colocaron en el respaldo. En cinco estudios se utilizaron sensores comerciales. En dos artículos la precisión del algoritmo disminuía a medida que aumentaban las posturas, parece que la diferenciación entre posturas era un reto.

La revisión de los estudios sobre clasificación de posturas sentadas pone de relieve los factores críticos que influyen en la precisión de los algoritmos de clasificación. La naturaleza experimental de la mayoría de los estudios, en los que se pide a los participantes que adopten posturas específicas, subraya la importancia de los entornos controlados para una recogida de datos fiable. Entre los factores determinantes del rendimiento de los algoritmos se encuentran el tipo de características extraídas, la colocación de los sensores, el número de sujetos implicados, el tamaño de la muestra de los datos de entrenamiento y el número de posturas clasificadas. Entre los diversos algoritmos probados, las redes neuronales artificiales y los modelos de bosque aleatorio demostraron las mayores precisiones, alcanzando el 80,9% y el 90%, respectivamente. Estos resultados sugieren que, si bien los métodos actuales son eficaces, la optimización de la ubicación de los sensores y de las características algorítmicas podría mejorar aún más la precisión de los sistemas de clasificación de posturas y, en última instancia, contribuir a mejorar las soluciones ergonómicas para reducir los riesgos asociados a la sedestación prolongada.

Palabras clave: postura sedente, sensores, redes neuronales, monitoreo, revisión.

Relevancia para la ergonomía: Esta revisión bibliográfica contribuye al campo de la ergonomía al abordar la creciente preocupación que suscita la sedestación prolongada y los riesgos musculoesqueléticos que conlleva. La revisión pone de relieve las limitaciones de los métodos tradicionales de evaluación de la postura, como la observación y la autoevaluación, que suelen ser sesgados y poco fiables. Destaca la importancia de la tecnología de sensores avanzados, en particular los sensores miniaturizados, para proporcionar una clasificación objetiva y precisa de las posturas al sentarse. Mediante la evaluación de diversas tecnologías -como el mapeo de presión, el escaneo láser y la localización ultrasónica-, la revisión identifica tanto los puntos fuertes como las limitaciones de los métodos existentes, especialmente en términos de precisión, comodidad y viabilidad para las aplicaciones del mundo real. Además, la revisión explora la integración de la tecnología de sensores con las redes neuronales, reflejando las tendencias actuales en el uso del aprendizaje automático para la clasificación de la postura. Este enfoque ofrece la posibilidad de desarrollar sistemas no invasivos, eficientes y precisos que pueden controlar y prevenir mejor los problemas de salud relacionados con la postura, especialmente en entornos industriales y de oficina. Al identificar las

lagunas de la investigación, la revisión aporta valiosas ideas para el futuro desarrollo de soluciones ergonómicas destinadas a mitigar los efectos negativos de la sedestación prolongada, contribuyendo en última instancia a mejorar la salud y la seguridad en el lugar de trabajo.

Abstract: In recent years, the number of people who spend long periods of time sitting has increased, both at work and at home. Approximately 75% of employees in call centers, software companies, and other industrial workplaces spend 90% of their workday sitting. Sitting for long periods of time in a bad posture can cause musculoskeletal discomfort and pain. Traditional methods analyze sitting posture through observation and self-reported questionnaire responses. Unfortunately, these methods are biased and subjective, as a result, the data was not reliable (Xu et al., 2013). According to Ma et al (2016) the advances in micro- and nano-electromechanical systems have led to the availability of several miniaturized sensor technologies on the market. They can objectively and accurately classify sitting postures. This literature review aims to evaluate published work on sensor technology and neural network for sitting posture classification.

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) approach was followed to conducting this systematic literature review. The initial search considered five databases (ScienceDirect, PubMed, Web of science, IEEE Xplore, MDPI). Only studies in English were searched. This literature review sets a stage for a detailed exploration of the methodologies, technologies, and challenges encountered in studies focused on sitting posture classification. According to review results, most studies were developed in scientific context (n = 7, 58.33%), and the rest covered other areas. In four studies the pressure sensors were placed in the back rest. Five studies used commercial sensors. In two articles the accuracy of the algorithm decreased as postures increased, it seems that the differentiation between postures was a challenging. The review of studies on sitting posture classification highlights the critical factors that influence the accuracy of classification algorithms.

The experimental nature of most studies, where participants are asked to assume specific postures, underscores the importance of controlled settings for reliable data collection. Key determinants of algorithm performance include the type of features extracted, sensor placement, the number of subjects involved, the sample size of the training data, and the number of classified positions. Among the various algorithms tested, Artificial Neural Networks and Random Forest models demonstrated the highest accuracies, achieving 80.9% and 90%, respectively. These findings suggest that while current methods are effective, optimizing sensor location and algorithmic features could further enhance the precision of posture classification systems, ultimately contributing to better ergonomic solutions for reducing the risks associated with prolonged sitting.

Keywords: sitting, posture, sensor, neural network, monitoring, review

Relevance to Ergonomics: This literature review provides a significant contribution to the field of ergonomics by addressing the growing concern of prolonged sitting

and its associated musculoskeletal risks. The review highlights the limitations of traditional posture assessment methods, such as observation and self-reporting, which are often biased and unreliable. It emphasizes the importance of advanced sensor technology, particularly miniaturized sensors, in providing objective and accurate classification of sitting postures. By evaluating various technologies—such as pressure mapping, laser scanning, and ultrasonic localization—the review identifies both the strengths and limitations of existing methods, particularly in terms of accuracy, comfort, and practicality for real-world applications. Furthermore, the review explores the integration of sensor technology with neural networks, reflecting current trends in the use of machine learning for posture classification. This approach offers the potential for developing non-invasive, efficient, and precise systems that can better monitor and prevent posture-related health issues, especially in office and industrial settings. By identifying research gaps, the review provides valuable insights for the future development of ergonomics solutions aimed at mitigating the negative impacts of prolonged sitting, ultimately contributing to improved workplace health and safety.

1. INTRODUCTION

In recent years, the number of people who spend long periods of time sitting has increased, both at work and at home. Approximately 75% of employees in call centers, software companies, and other industrial workplaces spend 90% of their workday sitting (Bontrup et al., 2019). Sitting for long periods of time in a bad posture can cause musculoskeletal discomfort and pain (Huang et al., 2022). Prolonged sitting behavior have been reported to act negatively, increasing the likelihood of developing low back pain (Loyen et al., 2018). The Bulletin of the World Health Organization (WHO) emphasizes the importance of identifying postural risk factors for sitting postures in office settings to implement effective back pain intervention and prevention programs. Traditional methods analyze sitting posture through observation and self-reported questionnaire responses.

Unfortunately, these methods are biased and subjective, as a result, the data was not reliable (Xu et al., 2013). According to Ma et al (2016) the advances in micro- and nano-electromechanical systems have led to the availability of several miniaturized sensor technologies on the market. They can objectively and accurately classify sitting postures. Over the past decade, researchers have explored miniaturized pressure sensors made of piezoelectric materials, yarn-coated fibers, force sensors, and resistors to provide the necessary signals to classify seated postures (Noh and Jeong, 2018). A variety of techniques for assessing posture have emerged, some of them include radiography (Simmons et al., 2013), structured light methods, laser scanning, pressure mapping systems, mechanical displacement sensors, and ultrasonic localization Some of these methods are time-consuming and may cause discomfort to individuals. Additionally, these methods tend to be more accurate and often provide three-dimensional shape information. However, the need for direct access to individual body parts is a major limitation of these methods, especially when assessing sitting posture.

This literature review aims to evaluate published work on sensor technology and neural network for sitting posture classification. By examining existing studies, it is possible to analyze current trends in the use of sensors and machine learning algorithms, as well as potential research gaps. This review aims to provide valuable insights into the development of non-invasive sensor technology systems assisted by neural networks.

2. OBJECTIVES

This systematic literature review aimed to achieve several key objectives: a) To evaluate sensor technology for sitting posture classification: The review seeks to assess the current state of sensor technology, particularly the advancements in miniaturized sensors, for accurately and objectively classifying sitting postures. This includes examining various types of sensors, such as pressure sensors, force sensors, and piezoelectric materials, that have been developed over the past decade; b) To analyze integration with neural networks to explore how neural networks and machine learning algorithms are being integrated with sensor technology to improve the accuracy and reliability of posture classification. This includes identifying trends in the application of these technologies and assessing their effectiveness in real-world settings; c) To identify research gaps in the existing literature, particularly in the areas where current methods fall short, such as the discomfort caused by traditional techniques or the limitations in accessing body parts for posture assessment. This objective is crucial for guiding future research efforts toward developing more user-friendly and effective solutions; d) To provide insights for Non-Invasive Solutions: Ultimately, the review seeks to provide valuable insights into the development of non-invasive sensor systems that can be used in various settings, such as offices and industrial workplaces, to monitor and improve sitting posture. These insights are intended to inform the design of intervention and prevention programs aimed at reducing the risk of musculoskeletal disorders and promoting better ergonomics.

3. METHODOLOGY

3.1 Search strategy

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) approach was followed to conducting this systematic literature review. Below is the search strategy aligned with the PRISMA guidelines. For the review, articles published within the last 10 years were prioritized, reflecting recent advancements in the field. The initial search considered five databases (ScienceDirect, PubMed, Web of science, IEEE Xplore, MDPI). Only studies in English were searched. The search considered a combination of keywords and

Boolean operators to cover the relevant topics: Primary keywords: "sitting posture," "posture classification," "ergonomics," "sensor technology," "inertial sensors"; and Secondary keywords: "neural networks," "machine learning," "micro-electromechanical systems," "pressure sensors," "postural assessment". They were used Boolean operators: ["seated posture" OR "sitting posture” OR “position” OR “Behavior”] AND ["sensor technology" OR "inertial measurement unit" OR "IMU” OR “pressure sensors" OR “piezoresistive” OR “accelerometer” OR “gyroscope”] AND ["neural networks" OR "machine learning" OR "algorithm" OR "supervised” OR “Classif” OR “detection” OR “identification” OR “recognition”].

3.2 Inclusion criteria

Inclusion criteria considered the following: Studies that focus on the use of sensor technology for classifying sitting posture; studies that integrate neural networks or machine learning algorithms with sensor data, and research conducted in both laboratory and real-world settings, articles published in English, publications from the past 10–15 years to ensure relevance.

3.3 Exclusion criteria

The exclusion criteria considered studies that do not specifically address sitting posture; research focusing solely on traditional methods like observation or self-reported data.

3.4 Search and study selection

The selected databases were searched articles using the search terms developed. Filters were used to refine the results by publication date, language, and study type. Titles and abstracts were screened to identify potentially relevant studies. Study selection involved importing search results into a reference management tool (Zotero) to organize and manage references. An initial screening based on titles and abstracts was performed to exclude irrelevant studies. There was performed full-text screening of the remaining studies to confirm their eligibility based on inclusion and exclusion criteria. Finally, a PRISMA flowchart was used to document the study selection process, including the number of studies identified, screened, excluded, and included. The initial search identified a total of 321 studies based on title, abstract, and keywords. After discarding duplicate articles, the count was 286 papers. Review articles were excluded according to exclusion criteria. The chosen studies (n = 81) were examined in their entirety based on the study's title, abstract, and full text (Step 1 in Fig 1), and they were disqualified from further analysis if they: not neural networks were within sitting posture (Step 2 in Fig 1). After full review were selected 12 articles.

3.5 Data extraction and analyses

The data extraction and analysis phase included the following: Technology (Sensor type, the number of sensors, sensor location), Study design (The environment in which these studies were performed, the number of subjects recruited, study protocol), classification algorithm (algorithms used, the type of features extracted, number of postures classified), algorithm performance (performance metrics, evaluation setup).

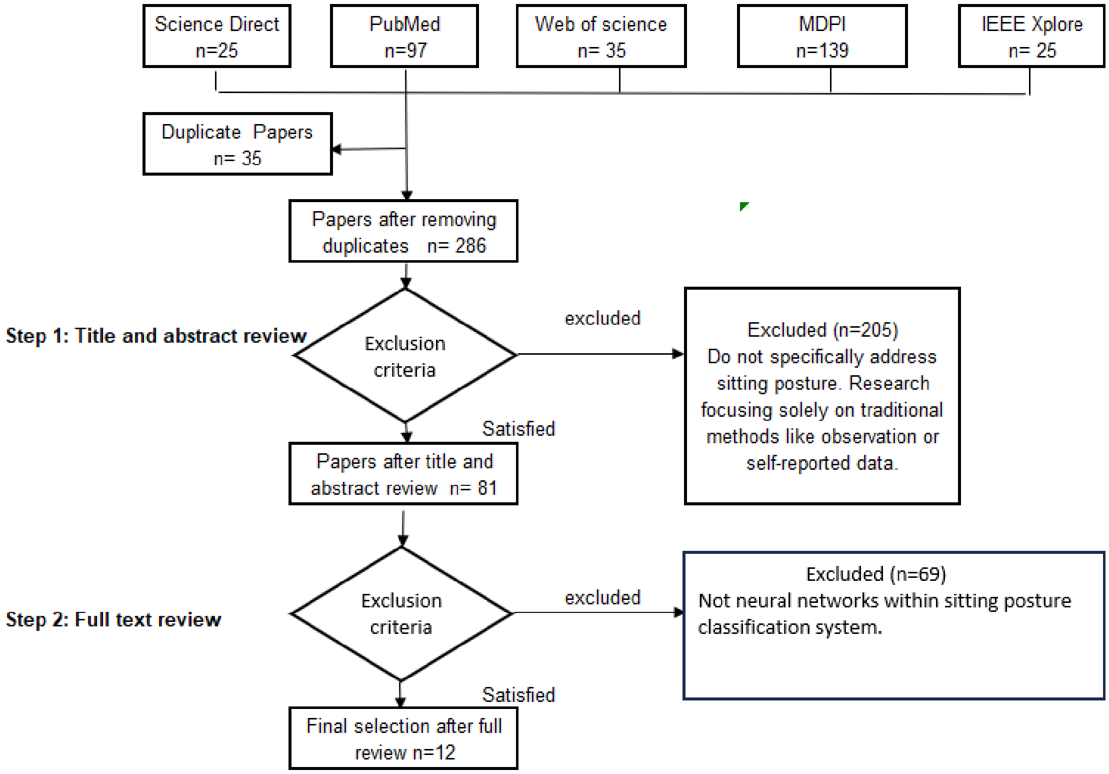

Fig 1. PRISMA flowchart of the document and selection process.

4 RESULTS

In recent years, the assessment and classification of sitting postures have gained significant attention due to the growing prevalence of sedentary lifestyles and their associated health risks. To address the challenges of prolonged sitting and poor posture, researchers have explored various sensor technologies and algorithms to accurately classify different sitting postures. Pressure sensors have emerged as a common tool in these studies, with their placement on chairs and backrests being critical for capturing the necessary data. The location and type of sensors, as well as the experimental context, significantly influence the effectiveness of posture classification systems. Additionally, the accuracy of the algorithms used, such as Artificial Neural Networks and Random Forest, is dependent on several factors, including sensor placement, the number of classified positions, and the data sample size. This literature review sets a stage for a detailed exploration of the methodologies, technologies, and challenges encountered in studies focused on sitting posture classification.

According to table 2, most studies reported the use of pressure sensors. The changes in pressure intensity were used to classify sitting postures. Some pressure sensors were placed in the backrest. According to literature (Martins et al., 2013) sensors must be placed on chair in direct contact with the ischial tuberosity, allowing the use of less sensors. The type of sensor and its location must be carefully considered while performing the study. Regarding the context of place to perform the study, most studies were developed in scientific context (n = 7, 58.33%), and the rest covered other areas. In four studies (Wang et al. (2017), Zemp et al. (2016), Mutlu et al. (2007), Zhu et al. (2003)) the pressure sensors were placed in the back rest. Five studies used commercial sensors (Bontrup et al. (2019), Zemp et al. (2016), Wang et al. (2017), Zhu et al. (2003)). Mutlu et al. (2007) used sensors from Tekscan. In two articles (Bontrup et al. (2019) y Zemp et al. (2016) the accuracy of the algorithm decreased as postures increased, it seems that the differentiation between postures was a challenging. Other study (Ma et al., 2016) an accelerometer was used, placed in the cervical spine to measure movements to classify postures. Most studies were experimental with participants being asked to sit in specific postures. The accuracy of the classification algorithms depends on the type of features, location of sensors, number of subjects and sample size of the data used for training algorithm and number of positions classified. Maximum accuracies were in Artificial Neural networks (80.9%) and random forest (90%). The main sitting postures are upright sitting, lean forward, lean backward, lean left, and lean right.

While the systematic review on sensor technology and neural networks for sitting posture classification provides valuable insights, several limitations must be acknowledged. First, the experimental design of most studies, which often involved participants assuming specific postures, may not fully capture the variability of real-world sitting behaviors. This controlled environment may limit the generalizability of the findings to more natural, dynamic settings. Second, the accuracy of classification algorithms is highly dependent on the specific features selected, the number and location of sensors, and the sample size used for training. Inconsistent sensor placement and small sample sizes can introduce biases, potentially reducing the robustness of the algorithms across diverse populations. Additionally, the algorithms' performance varied significantly, with Artificial Neural Networks and Random Forest models showing the highest accuracies, but their effectiveness in real-time applications and across different postural scenarios remains uncertain. Finally, the reliance on a limited number of classified postures may oversimplify the complexity of human sitting behavior, suggesting that future research should explore more comprehensive posture categories to improve overall accuracy and applicability.

5. CONCLUSIONS

The review of studies on sitting posture classification highlights the critical factors that influence the accuracy of classification algorithms. The experimental nature of most studies, where participants are asked to assume specific postures, underscores the importance of controlled settings for reliable data collection. Key determinants of algorithm performance include the type of features extracted, sensor placement, the number of subjects involved, the sample size of the training data, and the number of classified positions. Among the various algorithms tested, Artificial Neural Networks and Random Forest models demonstrated the highest accuracies, achieving 80.9% and 90%, respectively. These findings suggest that while current methods are effective, optimizing sensor location and algorithmic features could further enhance the precision of posture classification systems, ultimately contributing to better ergonomic solutions for reducing the risks associated with prolonged sitting.

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.

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Table2 Selected publicatiosafter review

Study	Authors (Year)	n	Sensor type	Number of sensors	Sensor location	Postures assessed	Approach	Accuracy
1	Noh et al. (2019)	10	pressure sensors	8	seat pan of the chair	Upright sitting, lean forward, lean backward, lean right, lean left, left leg trembling, right leg thrembling, left leg twisted, right leg twisted	Triangle center	90%
2	Bontrup et al. (2019)	64	pressure sensors	196	seat pan of the chair	Upright sitting, lean forward, lean backward, lean right, lean left, crossed legs right over, crossed legs left over right	Random forest	90%
3	Liu et al. (2019)	25	pressure sensors	1024	array in seat pan	Upright sitting, lean forward, lean backward, lean right, lean left, crossed legs over left, crossed legs over right and slouching	Convolutional network	98%
4	Wang et al. (2017)	5	pressure sensors	8	seat and backrests of the chair	Upright sitting, lean forward, lean backward, left leg crossed, right leg crossed, astride sitting	Decission tree	99%
5	Ma et al. (2016)	6	triaxial accelerometer	1	Cervical spine	Upright sitting, lean forward, lean backward, lean right	Suppor vector machine/k-means clustering	95.33%/89.35%
6	Zemp et al. (2016)	41	pressure sensors	17	seat pan, back rest, armrest	Upright sitting, lean forward, lean backward, lean right, lean left	Neural networks	90.80%
7	Zemp et al. (2016)	20	pressure sensors	6	seat pan of the chair	Upright sitting, lean forward, lean backward, lean right, lean left, crossed legs right over, crossed legs left over right	Random forest	82.70%
8	Pereira et al. (2015)	72	pressure sensors	8	seat and backrests of the chair	Upright sitting, lean forward, lean backward, lean right, lean left, lean backward	Artificial network	80.90%
9	Xu et al. (2013)	25	pressure sensors	256	cushion placed on the seat of chair	Upright sitting, lean forward, lean backward, lean right, lean left	Dynamic time warping	85.90%
10	Kamiya et al. (2008)	10	pressure sensors	64	seat pan of the chair	Upright sitting, lean forward, lean backward, lean right, lean left, right leg crossed, left leg crossed	Support vector machine	98.90%
11	Mutlu et al. (2007)	20	pressure sensors	2016	seat and backrests of the chair	Upright sitting, lean forward, lean backward, lean right, lean left, left leg crossed with lean right, right leg crossed, slouching, the left crossed, lean left	Tekscan	87%
12	Zhu et al. (2003)	50	pressure sensors	2016	seat and backrests of the chair	Upright sitting, lean forward, lean backward, lean right, lean left, the right leg crossed, the left leg crossed, lean right with the left leg crossed, slouching	K-nearest neighbor	81%

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ERGONOMIC INTERVENTIONS IMPLEMENTED IN CALL CENTERS: A SYSTEMATIC

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Resumen: Los call centers son esenciales en la estructura de muchas empresas, proporcionando soporte y servicios al cliente a través de la gestión de un gran volumen de interacciones diarias. Sin embargo, los trabajadores de estos centros enfrentan altos niveles de estrés, fatiga y problemas musculoesqueléticos, originados por las largas horas frente a la computadora y las exigencias del trabajo. Este estudio busca identificar y evaluar intervenciones ergonómicas que se proponen mejorar las condiciones laborales en estos centros. Se tiene como objetivo principal identificar y evaluar las intervenciones ergonómicas en los call centers, clasificándolas según sus características y métodos de implementación, y evaluando su efectividad en la mejora de las condiciones laborales. La investigación se centra en estudios publicados entre 2020 y 2024, y utiliza una estrategia de búsqueda en bases de datos académicas como Google Académico, Redalyc, Scopus y Ebsco. Los estudios seleccionados debían estar disponibles en inglés o español y presentar resultados empíricos o teóricos sobre la efectividad de las intervenciones ergonómicas. La revisión siguió el protocolo PRISMA, identificando un total de 62 registros, de los cuales, se identificaron cinco estudios clave que demuestran la efectividad de diversas intervenciones ergonómicas en la reducción de síntomas físicos y mentales, mejorando la salud, el bienestar y la productividad de los empleados. Los cinco estudios seleccionados abordan una variedad de enfoques y métodos para implementar intervenciones ergonómicas en los call centers. Estas intervenciones incluyen mejoras en el diseño de los puestos de trabajo y equipos ergonómicos para reducir los síntomas musculoesqueléticos, intervenciones cognitivas como juegos mentales y pausas activas para disminuir la carga mental y la fatiga, y programas de bienestar enfocados en la productividad y satisfacción laboral. En conclusión, las intervenciones ergonómicas en los call centers son efectivas para mejorar la salud y el bienestar de los empleados, así como para aumentar la productividad. La implementación de estas intervenciones debe ser integral y adaptativa, considerando tanto aspectos físicos como cognitivos del trabajo. Además, se subraya la importancia de continuar investigando y desarrollando prácticas ergonómicas innovadoras para seguir mejorando las condiciones laborales en este sector.

Palabras clave: Revisión sistemática, ergonomía, call centers, intervenciones ergonómicas.

Relevancia para la ergonomía: Este estudio aporta valiosas evidencias sobre la efectividad de las intervenciones ergonómicas en el ámbito de los call centers, un sector caracterizado por altos niveles de estrés, fatiga y trastornos musculoesqueléticos, y también proporciona una base sólida para la implementación de intervenciones ergonómicas efectivas en los call centers, subrayando la importancia de un enfoque integral y adaptativo para mejorar el bienestar y la productividad de los empleados. Las evidencias presentadas no solo contribuyen al campo de la ergonomía debido a la síntesis actualizada de las investigaciones más recientes (2020-2024) que proporciona, la identificación de prácticas ergonómicas más efectivas y la reafirmación de la importancia de la ergonomía en la mejora de las condiciones laborales y la reducción de problemas de salud relacionados con el trabajo en ambientes de alta presión, sino que también ofrecen una guía práctica para la mejora continua de las condiciones laborales en este sector crítico. Con estas aportaciones, se espera inspirar futuras investigaciones y prácticas innovadoras que sigan avanzando en el bienestar y la eficiencia en los ambientes de trabajo modernos.

Abstract: Call centers are essential to the structure of many companies, providing customer support and services through the management of a large volume of daily interactions. However, workers in these centers face high levels of stress, fatigue, and musculoskeletal problems due to long hours at the computer and the demands of the job. This study aims to identify and evaluate ergonomic interventions designed to improve working conditions in these centers. The main objective is to identify and evaluate ergonomic interventions in call centers, classifying them according to their characteristics and methods of implementation, and assessing their effectiveness in improving working conditions. The research focuses on studies published between 2020 and 2024, using a search strategy in academic databases such as Google Scholar, Redalyc, Scopus, and Ebsco. The selected studies had to be available in English or Spanish and present empirical or theoretical results on the effectiveness of ergonomic interventions. The review followed the PRISMA protocol, identifying a total of 62 records, from which five key studies were identified that demonstrate the effectiveness of various ergonomic interventions in reducing physical and mental symptoms, improving employees' health, well-being, and productivity. The five selected studies address a variety of approaches and methods for implementing ergonomic interventions in call centers. These interventions include improvements in workstation design and ergonomic equipment to reduce musculoskeletal symptoms, cognitive interventions such as mental games and active breaks to reduce mental load and fatigue, and wellness programs focused on productivity and job satisfaction. In conclusion, ergonomic interventions in call centers are effective in improving employees' health and well-being, as well as increasing productivity. The implementation of these interventions should be comprehensive and adaptive, considering both the physical and cognitive aspects of work. Furthermore, the importance of continuing to research and develop innovative ergonomic practices to further improve working conditions in this sector is emphasized.

Keywords: Systematic review, ergonomics, call centers, ergonomic interventions.

Relevance to Ergonomics: This study provides valuable evidence on the effectiveness of ergonomic interventions in the call center environment, a sector characterized by high levels of stress, fatigue, and musculoskeletal disorders. It also provides a solid foundation for the implementation of effective ergonomic interventions in call centers, emphasizing the importance of a comprehensive and adaptive approach to improving employee well-being and productivity. The evidence presented not only contributes to the field of ergonomics by providing an updated synthesis of the most recent research (2020-2024), identifying the most effective ergonomic practices, and reaffirming the importance of ergonomics in improving working conditions and reducing work-related health problems in high-pressure environments but also offers practical guidance for the continuous improvement of working conditions in this critical sector. With these contributions, it is expected to inspire future research and innovative practices that continue to advance well-being and efficiency in modern work environments.

1. INTRODUCTION

In recent years, call centers have experienced significant growth as essential components in the structure of many companies; these centers are crucial for providing customer support and services, managing a large volume of daily interactions (Mexican Institute of Teleservices [IMT], 2024). However, the work environment in call centers presents various challenges for workers, who, within a short period of time, are experiencing high levels of stress, fatigue, and/or musculoskeletal problems (Bagnara & Marti, 2001; Crawford et al., 2008; Kim & Choo, 2016; Kim & Cha, 2015). These issues primarily arise due to the sedentary nature of the work, long hours in front of the computer, and the intense cognitive and emotional demands (Flores et al., 2020; Kim & Choo, 2016; Rocha et al., 2005).

A call center is a centralized office used to receive and transmit a large volume of telephone requests. Depending on their function and operation, call centers can be classified into various types: in-house, operated directly by the company providing the service, allowing greater control over agent quality and performance; and outsourced, where a company contracts a third party to handle its calls, an option that may be more cost-effective and flexible (Hualde & Micheli, 2018; IMT, 2024; Poochada & Chaiklieng, 2015; Saberi et al., 2017).

Call center workers are exposed to various occupational risks that can negatively affect their health and well-being. Among the most common problems are stress, resulting from high work demands, pressure to meet targets, and constant interaction with customers (Kim & Choo, 2016; Martínez, 2019; McFarlane et al., 2018; Sprigg et al., 2003); fatigue, caused by long working hours and the repetitive nature of the work (Delgado-Martínez et al., 2020; Kim & Cha, 2015; Piedra Guillén, 2019; Rameshbabu et al., 2013; Sharifi et al., 2022); and musculoskeletal problems, caused by prolonged and static posture, repetitive use of the keyboard and mouse, and improper workstation setup (Cohen & Cohen, 2005; Crawford et al., 2008; Kim & Choo, 2016; Rocha et al., 2005).

To mitigate these issues, various ergonomic interventions have been proposed in call centers (Garrett et al., 2016; Khattak, 2019; Saberi et al., 2017). These interventions can be classified into two main categories: micro-ergonomic, focused on improving the direct interaction between the worker and their workstation, including adjustments in furniture design, the use of ergonomic equipment, and the implementation of active breaks; and macro-ergonomic, aimed at improving the work environment and organization, involving changes in workspace layout, modification of work schedules, and promotion of a healthy and collaborative work environment.

The purpose of this systematic review is to identify and evaluate the various ergonomic interventions that have been implemented in call centers and to analyze their outcomes in terms of effectiveness and benefits for workers. This review seeks to provide a comprehensive view of the most effective strategies for improving working conditions in this sector and contributing to the well-being of employees.

2. OBJECTIVES

The overall objective of this systematic review is to identify and evaluate the various ergonomic interventions that have been implemented in call centers. To achieve this main objective, the following specific objectives have been defined:

1. To classify the ergonomic interventions according to their characteristics and methods of implementation.
2. To evaluate the reported outcomes of the interventions in terms of their effectiveness.

3. METHODOLOGY

3.1 Delimitation

This research focused on analyzing ergonomic interventions implemented in call centers, covering studies published between 2020 and 2024. Ergonomic practices aimed at improving working conditions and reducing health and well-being issues for employees in this sector were investigated.

The geographic scope was global, including studies in English or Spanish from various regions of the world.

Priority was given to academic sources and publications specializing in ergonomics and occupational health, while unverified or informal sources were excluded. A wide range of ergonomic interventions was analyzed to provide a comprehensive view of the most effective strategies. The study population includes call center workers from different companies and regions, with no restrictions based on age, gender, or level of work experience, ensuring diverse representation of working conditions in this sector.

This delimitation will allow for an exhaustive and detailed evaluation of ergonomic interventions in call centers, providing a solid foundation for recommendations and improvements in ergonomic practice and employee well-being in this field.

3.2 Academic Literature Search Strategy

To conduct this systematic review, a search strategy was developed in collaboration with the university library, aimed at identifying relevant studies on ergonomic interventions in call centers. The search was conducted using the terms "ergonomics intervention" AND "call center" in academic databases such as Google Scholar, Redalyc, Scopus, and Ebsco. These databases were selected for their relevance to the research objectives. A time frame between 2020 and 2024 was defined, allowing the capture of the most recent practices and innovations in ergonomic interventions. The search was conducted in June 2024.

3.2.1 Exclusion and Inclusion Criteria

Studies published in English or Spanish between 2020 and 2024, peer-reviewed journal articles, and research addressing ergonomic interventions in call centers that present empirical or theoretical results on the effectiveness of these interventions were included.

Studies not directly related to ergonomic interventions in call centers, opinion articles, editorials, comments without empirical data, and duplicate publications were excluded.

3.2.2 Review Protocol

The PRISMA protocol for systematic literature reviews was used (Page et al., 2021). The initial search identified a total of 51 records in Google Scholar, 0 in Redalyc, 9 in Scopus, and 2 in Ebsco. After removing duplicates, the remaining records were reviewed using advanced search in each database. In addition to direct searches in academic databases, the references of the found articles were also reviewed, leading to the identification of 5 additional studies (Figure 1).

The PRISMA 2020 Checklist (Page et al., 2021) was used to guide the review. Although it is not possible to eliminate the risk of bias entirely, protocols were implemented to minimize it and improve consistency, which were reviewed and approved with the assistance of another researcher. The titles and abstracts of the records were independently examined to determine their relevance according to the inclusion criteria. In case of doubt about the inclusion of an article, it was discussed with another researcher to resolve it by consensus. The selected articles underwent a full review, and additional records were identified from the reviewed references, which were also subjected to the same evaluation process. Articles that did not meet the inclusion criteria or did not address ergonomic interventions were excluded, resulting in a total of five academic records included in the review.

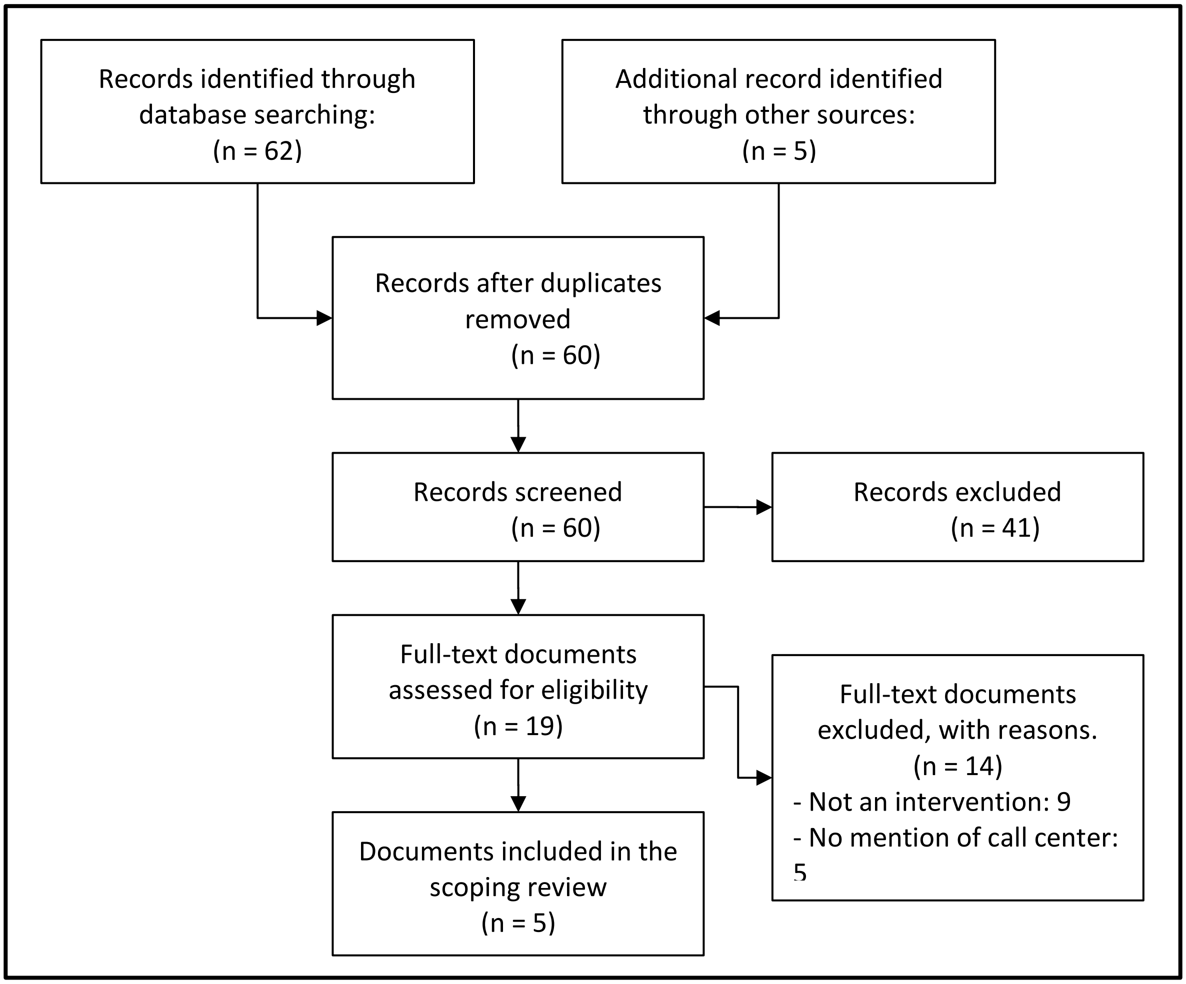

Figure 1. PRISMA 2020 Flow Diagram for Systematic Reviews

3.3. Data Extraction and Synthesis

Data extraction was carried out using a structured spreadsheet to capture relevant information from each study, such as author, publication year, country, objective, study design, sample size, methodology, instruments used, type of ergonomic intervention, study duration, results, conclusions, limitations or biases, and level of evidence.

The validity of the instruments used in the studies was assessed through a review of previous studies that supported their construct and content validity. The impact of the interventions was evaluated by considering the reported outcomes in terms of improvement in working conditions and employee well-being.

Data synthesis was based on a qualitative analysis that allowed for the identification of patterns and trends in ergonomic interventions, as well as their effectiveness in improving working conditions and employee well-being in call centers. Additionally, recurrent trends were identified both in the positive effects of interventions and in the methodological limitations noted by the authors or discovered during the review process.

3.4. Ethical Considerations

The article, by its nature, has no ethical implications.

4. RESULTS

4.1. Full Text Review

In the full text review, five studies selected for their relevance and quality were evaluated (Table 1). These studies provided detailed information on various ergonomic interventions implemented in call centers, focusing on the reduction of musculoskeletal symptoms, mental workload, fatigue, and improvement in productivity and job satisfaction.

Table 1. Reviewed Full Text

Title	Year	Country	Keywords
Ergonomics risk factor model in business process outsourcing industry (Malapascua et al., 2020)	2020	Philippines	business data processing; call centres; ergonomics; occupational health; occupational safety; outsourcing; personnel; risk management; statistical analysis
Call centre employee's reasons for variation in objective productivity during a cognitive ergonomics intervention (Khattak et al., 2021)	2021	UK	call centres; cognitive ergonomics; Mental games; productivity; work breaks
Effectiveness of ergonomic intervention in work-related postures and musculoskeletal disorders of call center workers: A case-control study (Amit & Song, 2021)	2021	Philippines	Call center; Ergonomic intervention; Musculoskeletal disorders; Philippines; Posture; Workplace design
Sit Less and Move More-A Multicomponent Intervention With and Without Height-Adjustable Workstations in Contact Center Call Agents: A Pilot Randomized Controlled Trial (Morris et al., 2021)	2021	UK	Intervention development; Feasibility; Adults, Occupational; Health; Sedentary behaviour; Physical activity.

Improvements in musculoskeletal symptoms, mental workload and mental fatigue: Effects of a multicomponent ergonomic intervention among call center workers (Sharifi et al., 2022)	2022	Iran	mental demand; occupational fatigue; office work; WRMSDs

4.2. Literature Review

The five reviewed studies were published between 2020 and 2024, covering a range of approaches and research methods. They were identified on platforms such as Scopus and EBSCO, and all were available in English or Spanish. The selected studies used a combination of physical and cognitive interventions to address ergonomic issues in call centers (Table 2).

The interventions studied focused on implementing improvements in workstation design and ergonomic equipment to reduce musculoskeletal symptoms, cognitive interventions such as mental games and active breaks to decrease mental workload and fatigue, and sustainable ergonomics models and wellness programs aimed at productivity and job satisfaction.

Table 2. Details of the Studies Conducted

Study	Objective	Methodology	Instruments	Intervention Implemented
Malapascua, Manazanilla, Mendoza, Terrones, Mendoza y Curbano, 2020.	Identify the demographic profile of the respondents and determine ergonomic risk factors to develop an intervention plan in the BPO industry.	Descriptive study with 300 participants. Quantitative approach including observations and surveys.	Questionnaires and surveys based on the Likert scale to assess ergonomic risk factors.	A continuous intervention plan was designed to reduce ergonomic risk factors. The intervention included promoting ergonomics in the workplace, seminars and training on new technologies, proper task distribution, and communication skills training.
Khattak, Fray y Clift, 2021.	Investigate the impact of mental games on employee productivity and engagement through recreational activities during	Quasi-experimental study with 15 participants (6 from one call center and 9 from another). Use of focus group discussions and qualitative analysis with NVivo 11.	Open-ended questions and sticky notes for collecting responses.	Mental games were implemented mandatorily during work breaks, lasting 4 weeks.

	work hours.			
Amit y Song, 2021.	Measure the level of Musculoskeletal Disorders (MSDs) in call center workers and evaluate the effectiveness of an ergonomic intervention on their posture and MSD symptoms.	Case-control study with 32 participants. Ergonomic intervention program with posture observations and evaluations.	RULA, REBA, and Body Part Discomfort (BPD) questionnaire.	An ergonomic program was implemented focusing on workstation design and proper postures. An informational brochure on the use of visual display terminals (VDTs), ergonomic criteria, correct postures, benefits and frequency of micro-breaks, and exercise recommendations was distributed. The intervention lasted 4 weeks, with follow-up visits and surprise observations.
Morris, Murphy, Hopkins, Low, Healy y Edwardson, 2021.	Evaluate the effectiveness of an intervention focused on reducing sedentary time and increasing physical activity in the workplace.	Randomized controlled trial. Pilot study with a mixed approach to assess feasibility and effectiveness.	Adapted questionnaire to assess smoking status, diet, alcohol consumption, Pittsburgh Sleep Quality Index (PSQI), and activPAL accelerometer.	A multifaceted intervention with an Intensive Phase of 3 months focused on immediate behavior changes, followed by a 7-month Maintenance Phase of follow-up and continuous support.
Sharifi, Danesh y Gholamnia, 2022.	Evaluate the effectiveness of a multifaceted ergonomic intervention in improving musculoskeletal symptoms, mental workload, and fatigue.	Quasi-experimental descriptive study with 84 participants. Pretest-posttest design with ergonomic training and exercise program.	Nordic Musculoskeletal Symptoms Questionnaire, Swedish Occupational Fatigue Inventory (SOFI-20), and NASA-TLX (Task Load Index).	The intervention included 4 components: (1) Ergonomic Training with two 90-minute sessions on basic principles and workspace design; (2) Workspace Design Improvement with physical adjustments and furniture, such as adjustable chairs and footrests; (3) Daily Supervised Visits to monitor the application of ergonomic principles; and (4) Exercise

				Program during breaks to improve physical and mental health.

The review of the studies reveals various ergonomic interventions implemented in call centers, each with distinct approaches and methodologies but with the common goal of improving employee health and productivity.

Malapascua et al. (2020) first identified ergonomic risk factors and then developed an intervention plan in the BPO industry; on the other hand, Khattak, Fray, and Clift (2021) investigated the impact of mental games during work breaks; Amit and Song (2021) conducted a case-control study to evaluate the effectiveness of an ergonomic intervention in reducing Musculoskeletal Disorders (MSDs); following a similar line, Morris et al. (2021) carried out an intervention focused on reducing sedentary time and increasing physical activity; and finally, Sharifi, Danesh, and Gholamnia (2022) implemented a multifaceted ergonomic intervention.

These studies highlight the importance of a comprehensive ergonomic intervention that addresses multiple aspects of the work environment to improve both the physical and mental health of employees.

4.3. Intervention Results

The reviewed articles included various ergonomic and cognitive interventions. The intervention studies provided quantitative and qualitative data on the effectiveness of the interventions, particularly in terms of reducing stress and fatigue; Sharifi et al. (2022) and Amit & Song (2021) reported significant decreases in these indicators. Additionally, in terms of improving posture and musculoskeletal health, Khattak et al. (2021), Morris et al. (2021), and Malapascua et al. (2020) demonstrated improvements in work postures and a reduction in musculoskeletal disorders. The studies employed various designs, including case-control studies and pilot studies. intervention.

The interventions proved effective, especially when combining physical and cognitive improvements. Sharifi et al. (2022) emphasized the importance of a comprehensive approach for achieving lasting results. These studies underscore the importance of a comprehensive ergonomic intervention that addresses multiple aspects of the work environment to enhance both physical and mental health of employees.

Table 3. Evaluation of Intervention Results

Type of Intervention	Results and Conclusions	Limitations, Biases, and Level of Evidence
Continuous intervention plan to reduce ergonomic risks (Malapascua et al., 2020)	A significant relationship was found between ergonomic risk factors and demographic profile	Efficiency and effectiveness of the intervention were not evaluated. No specific

	(age, marital status, and educational level), particularly in mental workload and posture. The intervention improved worker health and productivity.	limitations are mentioned in the document. The level of evidence is not classified.
Cognitive (mental games during breaks) (Khattak et al., 2021)	The games increased productivity at certain times but were also distractions. Productivity improved mid-week, though some participants found the games distracting.	Initial resistance and lack of significant improvement. Lack of daily feedback and the nature of the games as distractions affected the results. Moderate level of evidence due to the quasi-experimental design.
Ergonomic intervention focused on posture and workplace design (Amit & Song, 2021)	There was an improvement in posture, but MSD symptoms did not improve significantly. Short duration and inadequate conditions limited effectiveness.	Limited duration and inadequate working conditions. Lack of adjustable ergonomic equipment. Moderate level of evidence due to case-control design and small sample size.
Multifaceted intervention focused on reducing sedentary time and increasing physical activity in the workplace (Morris et al., 2021)	Potential reduction in sitting time with adjustable workstations was observed. Future trials are supported to assess the effectiveness of the intervention in reducing sedentary behavior.	Staff turnover hindered retention. Level of evidence not specified.
Multifaceted ergonomic intervention including physical and cognitive training (Sharifi et al., 2022)	Significant improvements in musculoskeletal symptoms, mental workload, and fatigue. Multicomponent interventions were effective in both physical and cognitive aspects.	Lack of a control group, non-randomized design, and self-reported evaluations. Moderate level of evidence due to the lack of robust experimental design.

4.4. Assessment of Study Quality

The assessment of study quality was conducted following established criteria for systematic reviews, considering key aspects such as the internal and external validity of the studies, the methodology employed, sample selection, and the instruments used for data collection. Internal validity refers to the accuracy with which a study measures what it intends to measure, that is, how well variables were controlled to establish a causal relationship between the intervention and the observed outcomes. On the other hand, external validity refers to the generalizability of the results to other contexts and populations beyond the specific environment studied.

In the reviewed studies, some demonstrated good internal validity by using reliable instruments such as the Nordic Musculoskeletal Symptoms Questionnaire, the NASA-TLX scale for measuring mental workload, and qualitative analysis using NVivo software. However, in several cases, external validity was limited due to the small sample size, lack of a control group, and the short duration of the interventions, which reduces the ability to apply findings to other call centers or industries.

Despite these limitations, the reviewed studies provided relevant evidence on the effectiveness of ergonomic interventions in improving the health and well-being of workers in call centers. However, most studies had a moderate level of evidence, highlighting the need for further research with more rigorous methodologies and longer durations to consolidate conclusions and recommendations in this field.

5. DISCUSSION/CONCLUSION

The results of this systematic review confirm that ergonomic interventions in call centers can be effective in addressing issues related to musculoskeletal disorders (MSDs), mental workload, and fatigue, thereby improving productivity and job satisfaction in some cases. However, it is important to note that the effects varied depending on the type of intervention and study conditions.

According to the findings of this review, studies such as those by Sharifi et al. (2022) demonstrated significant improvements in reducing musculoskeletal symptoms, mental workload, and fatigue due to a multifaceted ergonomic intervention that included physical and cognitive training. Similarly, the study by Amit & Song (2021) showed improvements in workers' posture, although MSD symptoms did not significantly improve, possibly due to the short duration of the intervention and the lack of adjustable ergonomic equipment. These results highlight the need to design more extensive and customized interventions to achieve greater effectiveness in reducing MSDs.

Additionally, the study by Khattak et al. (2021), which introduced mental games during work breaks, highlighted both productivity benefits and distracting effects, depending on the context and implementation. On the other hand, the research by Morris et al. (2021) demonstrated a potential reduction in sedentary time through adjustable workstations, although limitations such as staff turnover and study duration were encountered.

These findings underscore the importance of ergonomic interventions in managing call centers, especially those that combine improvements in workstation design with structured breaks and cognitive activities. These strategies can not only reduce stress and fatigue among employees but also improve productivity and job satisfaction, thus contributing to decreased absenteeism and staff turnover.

However, this review has some limitations. Firstly, the temporal range considered (2020-2024) may have excluded earlier studies that could provide additional perspectives. Additionally, the review was limited to articles in English and Spanish, which may have excluded relevant research in other languages. Lastly, the methodology did not include automated software for screening and selecting studies, which may have affected the thoroughness of the process.

Future research should extend the temporal range and consider studies in multiple languages to offer a more comprehensive view. Furthermore, it would be useful to explore cognitive interventions more thoroughly and their long-term impact on the health and well-being of call center employees to develop more sustainable and effective ergonomic models.

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A SYSTEMATIC REVIEW OF THE METHODOLOGIES USED TO VALIDATE INERTIAL SENSORS FOR JOINT ANGLE ESTIMATION

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Resumen: anto los médicos como los investigadores utilizan ampliamente las mediciones del ángulo articular; dichas medidas se han empleado para cuantificar posturas neutrales y no neutrales, para evaluar el grado de deterioro, planificar estrategias de rehabilitación y evaluar el efecto de diversas intervenciones. Los sistemas convencionales de estimación de ángulos articulares (goniómetros) suelen ser sencillos de utilizar, pero es posible que no proporcionen toda la gama de datos necesarios. Además, los goniómetros proporcionan información en planos únicos y sólo para posiciones estáticas. Además, estos sistemas no son adecuados para su uso en entornos no controlados debido a su falta de portabilidad y la falta de experiencia técnica requerida. Esto puede limitar sus posibles aplicaciones de investigación. Como resultado, puede resultar complicado para los investigadores obtener datos sobre las posturas tridimensionales de los segmentos corporales.

Se ha demostrado que los acelerómetros son un método de medición válido y fiable. Sin embargo, se ha observado que los datos del ángulo de la articulación pueden no ser tan precisos como se desea, debido a la influencia de una mayor aceleración del segmento o la presencia de derivas. En respuesta a esto, la validación de los sensores garantiza que los datos que recopilan sean precisos y comparables con los métodos estándar. Esta revisión sistemática examina y sintetiza la literatura actual sobre los métodos y resultados utilizados para probar la validez y confiabilidad de los sensores inerciales cuando se usan para estimar los ángulos de las articulaciones. Este enfoque de revisión sistemática siguió la metodología PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) para realizar e informar revisiones sistemáticas en ciencias de la salud.

Para la revisión, se buscaron artículos publicados hasta junio de 2024 en cuatro bases de datos (ScienceDirect, PubMed, Web of science, MDPI), incluidas bases de datos específicas de ergonomía, biomecánica e ingeniería para garantizar una cobertura integral del tema. Los criterios de inclusión consideraron lo siguiente: estudios enfocados a la validación de IMU en evaluaciones ergonómicas; artículos de investigación publicados en revistas revisadas por pares o actas de congresos, estudios que comparan las IMU con los métodos estándar (por ejemplo, captura de movimiento óptico), artículos publicados en inglés, publicaciones de los últimos 10 a 15 años para garantizar su relevancia. Los criterios de exclusión consideraron estudios no directamente relacionados con validaciones de IMUS para la estimación de la articulación angular, artículos, editoriales o artículos de opinión no revisados por pares, así como estudios sin suficientes detalles metodológicos. Se seleccionaron diecinueve estudios para la revisión final. La revisión incluyó el tamaño y la composición de la muestra para cada muestra, el tamaño de la muestra, el sistema estándar de oro y los índices de validación calculados. Metodología para validar sensores inerciales al aplicarlos para estimar ángulos articulares. Los hallazgos destacan que la mayoría de los estudios (94,7%) utilizaron software comercial de captura de movimiento para analizar la postura y el movimiento, lo que subraya la dependencia de herramientas estandarizadas para la recopilación de datos precisos. La tendencia creciente en el uso de sensores inerciales durante la última década, con más de la mitad de los estudios (57,8%) publicados en los últimos cinco años, refleja el creciente reconocimiento del potencial de esta tecnología en las evaluaciones ergonómicas. El uso de métodos estadísticos avanzados, como coeficientes de correlación, RMSE y gráficos de Bland-Altman, confirma aún más el enfoque para evaluar la validez y confiabilidad de estos sensores.

Palabras clave: sensores, validación, confiabilidad, revisión.

Relevancia para la ergonomía: Las unidades de sensores inerciales (IMU), que incluyen acelerómetros, giroscopios y magnetómetros, son utilizadas con mayor frecuencia en las evaluaciones ergonómicas para medir los movimientos y posturas corporales. Estos sensores proporcionan datos valiosos y objetivos, en tiempo real,

que pueden ser fundamentales para evaluar ergonómicamente una estación de trabajo, identificar factores de riesgo y mejorar el diseño de tareas y herramientas. Sin embargo, la precisión y fiabilidad de estas mediciones son cruciales para tomar decisiones informadas en ergonomía. La validación de las IMU garantiza que los datos que recopilan son precisos y comparables a los métodos de referencia, como los sistemas ópticos de captura del movimiento. Sin una validación adecuada, los datos de las IMU podrían dar lugar a evaluaciones incorrectas que podrían generar intervenciones ergonómicas ineficaces o incluso perjudiciales. El proceso de validación consiste en comparar los datos del sensor inercial con estándares conocidos o utilizarlos en experimentos controlados cuyos resultados se conocen bien. Este proceso permite descubrir problemas como la deriva del sensor, la sensibilidad a factores ambientales o imprecisiones en la medición de movimientos complejos. Una vez validadas, los sensores inerciales pueden utilizarse con confianza en diversos entornos, desde estudios de campo en lugares de trabajo reales hasta experimentos de laboratorio controlados, proporcionando datos fiables que mejoran la precisión y eficacia de las evaluaciones ergonómicas. La principal ventaja de las metodologías cuando se utilizan para validar sensores inerciales en cuestiones de ergonomía es que la calidad de las medidas parece ser superior a la obtenida mediante goniómetros y otros instrumentos. Esto permite realizar evaluaciones ergonómicas más objetivas y precisas. Por otra parte, en cuanto al proceso de revisión sistemática de literatura, es preciso señalar su potencial para identificar oportunidades para futuras investigaciones en el campo de la validación de instrumentos para propósitos de estudios ergonómicos.

Abstract: Joint angle measurements are used extensively by clinicians and researchers alike, such measures have been employed to quantify both neutral and no-neutral postures, to assess the degree of impairment, to plan rehabilitation strategies, and to assess the effect of various interventions. Conventional systems of joint angle estimation (goniometers) are often straightforward to use, but they may not provide the full range of data that is needed. Addionally, goniometers provide information in single planes and only for static positions. Besides, these systems are not suitable for use in uncontrolled environments due to their lack of portability and the technical expertise required. This may limit their potential research applications. As a result, it can be challenging for researchers to obtain data about three-dimensional body segment postures.

It has been demonstrated that accelerometers are a valid and reliable method of measurement. However, it has been observed that joint angle data may not be as precise as desired, due to the influence of increased segment acceleration or the presence of drifts. In response to this, the validation of the sensors ensures that the data they collect is accurate and comparable to gold-standard methods. This systematic review examines and synthesizes the current literature on the methods and outcomes used to test the validity and reliability of the inertial sensors when used to estimate joint angles. This systematic review approach followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology for conducting and reporting systematic reviews in health sciences.

For the review, articles published through June 2024 were looked up in four databases (ScienceDirect, PubMed, Web of science, MDPI), included databases specific to ergonomics, biomechanics, and engineering to ensure comprehensive coverage of the topic. Inclusion criteria considered the following: studies focused on the validation of IMUs in ergonomic assessments; research articles published in peer-reviewed journals or conference proceedings, studies that compare IMUs to gold-standard methods (e.g., optical motion capture), articles published in English, publications from the past 10–15 years to ensure relevance. The exclusion criteria considered studies not directly related to validations of IMUS for angle joint estimation, non-peer-reviewed articles, editorials, or opinion pieces, as well as studies without sufficient methodological details. Nineteen studies were selected for final review. The review included the sample size and composition for each sample, sample size, gold-standard system, and validation indexes calculated. methodology to validate inertial sensos when applying them to estimate joint angles. The findings highlight that most studies (94.7%) utilized commercial motion capture software to analyze posture and movement, underscoring the reliance on standardized tools for accurate data collection. The increasing trend in the use of inertial sensors over the past decade, with more than half of the studies (57.8%) published in the last five years, reflects the growing recognition of this technology's potential in ergonomic assessments. The use of advanced statistical methods, such as correlation coefficients, RMSE, and Bland-Altman plots, further confirms the approach to evaluating the validity and reliability of these sensors.

Keywords: sensor, validity, reliability, review

Relevance to Ergonomics:

Inertial sensor units (IMUs), comprising accelerometers, gyroscopes, and sometimes magnetometers, are increasingly used in ergonomic assessments to measure body movements and postures. These sensors provide valuable, objective data in real-time, which can be critical in evaluating workplace ergonomics, identifying risk factors for musculoskeletal disorders, and improving the design of tasks and tools. However, the accuracy and reliability of these measurements are crucial for making informed decisions in ergonomics. Validating IMUs ensures that the data they collect is accurate and comparable to gold-standard methods, such as optical motion capture systems. Without proper validation, the data from IMUs could lead to incorrect assessments, potentially resulting in ineffective or even harmful ergonomic interventions. Validation typically involves comparing the IMU data against known standards or using them in controlled experiments where the outcomes are well understood. This process can uncover issues like sensor drift, sensitivity to environmental factors, or inaccuracies in measuring complex movements. Once validated, IMUs can be confidently used in various settings, from field studies in real workplaces to controlled laboratory experiments, providing reliable data that enhances the precision and effectiveness of ergonomic assessments. The primary benefit of methodologies when used to validate inertial sensors in ergonomics issues is that the quality of measures appears to be superior to that obtained through goniometers and other instruments. This allows for more objective and precise ergonomic evaluations. In addition, this systematic review can help identify potential avenues for further research in the field of ergonomics. Overall, the findings suggest that inertial sensor technology has become a critical tool in ergonomic research, with proven reliability and precision for estimating joint angles. As the technology continues to evolve, its application is likely to expand further, offering new insights and improving workplace safety and health outcomes.

4. INTRODUCTION

Joint angle measurements are used extensively by clinicians and researchers alike. Ceseracciu et al. (2014) indicates that such measures have been employed to quantify both neutral and no-neutral postures, to assess the degree of impairment, to plan rehabilitation strategies, and to assess the effect of various interventions. Conventional systems of joint angle estimation (goniometers) are often straightforward to use, but they may not provide the full range of data that is needed (Godfrey et al., 2008). Goniometers provide information in single planes and only for static positions. According to Fong and Chan (2008) electro goniometers and inclinometers may offer solutions for more than one plane, as well as provide dynamic data. However, the physical design of such sensors can restrict motion, which is something to consider. Besides, these systems are not suitable for use in uncontrolled environments due to their lack of portability and the technical expertise required (Walmsley et al., 2018). This may limit their potential research applications. As a result, it can be challenging for researchers to obtain data about three-dimensional body segment postures. It has been demonstrated that accelerometers are a valid and reliable method of measurement (Grimaldi et al.,2010). However, it has been observed that joint angle data may not be as precise as desired, due to the influence of increased segment acceleration or the presence of drifts. In response, several algorithms have been developed to address this issue. According to Abyarjoo et al. (2015) a possible solution to this problem is to combine a gyroscope and a magnetometer with an accelerometer in a sensor, which is called an inertial measurement unit (IMU; sensors combining accelerometer and gyroscope) and sensors combining accelerometer, gyroscope, and magnetometer (Magneto-inertial measurement units). It is proposed by Kok et al. (2016) that gyroscopes could be used to estimate sensor orientation by integration of signals (angular velocity relative to the sensor XYZ axis), accelerometers could be used to provide a static orientation measurement relative to gravity by analyzing the acceleration signal, and magnetometers could be used to provide heading using sensor orientation relative to Earth’s magnetic field (Sabatini, 2008).

The psychometric properties, such as validity and reliability of sensors for joint angle estimation have been extensively studied during the past few years. Two systematic reviews have been conducted to report on the psychometric evidence relating to IMU validity. The first systematic review, published in 2019 (Poitras, 2019), indicated that sensor technologies have been validated through several different methods, including coefficient of multiple correlation (CMC), intraclass correlation coefficient (ICC) and root mean square error (RMSE). The other systematic review, published in 2021, considered the use of ICC and Kappa Index, in addition to RMSE, as a means of evaluating the validity of the tests.

This systematic review examines and synthesize the current literature on the methods and outcomes used to test the validity and reliability of the inertial sensors when used to estimating joint angles. It is possible that some studies may have been missed because of the search keywords used. These may have been studies focusing on other applications.

5. OBJECTIVES

Several objectives have been considered in this systematic review, namely: To Identify and Synthesize Existing Research, which considers to gather and analyze existing studies and literature on the validation of inertial sensor units (IMUs) in the context of estimating joint angles, providing a comprehensive overview of current knowledge and methodologies; to assess validation methods and critically evaluate the different methods used to validate IMUs, including comparisons with gold-standard techniques, to determine their effectiveness, strengths, and limitations; to determine accuracy and reliability of IMU's in measuring ergonomic variables such as posture, movement, and force, identifying factors that may influence these parameters; to identify gaps in the literature; highlighting areas where research is lacking or inconsistent, identifying gaps that need to be addressed in future studies to enhance the understanding and application of IMUs in ergonomics; to provide recommendations for best practices, developing evidence-based recommendations for the use and validation of IMUs in ergonomic assessments, guiding researchers and practitioners in selecting and applying these tools effectively; to evaluate the applicability in real-world settings, exploring the feasibility and practicality of using validated

IMUs in various workplace environments, assessing their potential to improve ergonomic interventions and reduce injury risks; to analyze the impact on ergonomic interventions, reviewing how the use of validated IMUs influences the outcomes of ergonomic interventions, determining their role in improving worker safety, comfort, and productivity; to establish a framework for future research, proposing a structured framework for future research efforts aimed at improving the validation and application of IMUs in ergonomic assessments, ensuring continued advancements in this field.

6. METHODOLOGY

3.3 Search strategy

This systematic review approach followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology for conducting and reporting systematic reviews in health sciences. For the review, articles published through June 2024 were looked up in four databases (ScienceDirect, PubMed, Web of science, MDPI), included databases specific to ergonomics, biomechanics, and engineering to ensure comprehensive coverage of the topic. Only studies in English were searched. A list of primary keywords and search terms related to the validation of inertial measurement units (IMUs) for joint angle estimation was developed. Primary key words included: "Inertial sensor units”, “IMUs", "Ergonomics”, "Validation", "Accuracy", "Reliability", "Posture assessment", "Movement analysis" and "Biomechanics". The search keywords used to identify studies on validation of inertial sensor technology for joint angle estimation included ["Inertial sensor units" OR "IMUs"] AND ["validation" OR "accuracy" OR "reliability"] AND ["ergonomics" OR "posture assessment" OR "movement analysis" OR "biomechanics"].

3.2 Inclusion criteria

Inclusion criteria considered the following: studies focused on the validation of IMUs in ergonomic assessments; research articles published in peer-reviewed journals or conference proceedings, studies that compare IMUs to gold-standard methods (e.g., optical motion capture), articles published in English, publications from the past 10–15 years to ensure relevance.

3.6 Exclusion criteria

The exclusion criteria considered studies not directly related to validations of IMUS for angle joint estimation, non-peer-reviewed articles, editorials, or opinion pieces, as well as studies without sufficient methodological details.

3.7 Search and study selection

The selected databases were searched using the search terms developed. Filters were used to refine the results by publication date, language, and study type. Titles and abstracts were screened to identify potentially relevant studies. Study selection involved importing search results into a reference management tool (Zotero) to organize and manage references. An initial screening based on titles and abstracts was performed to exclude irrelevant studies. There was performed full-text screening of the remaining studies to confirm their eligibility based on inclusion and exclusion criteria. Finally, a PRISMA flowchart was used to document the study selection process, including the number of studies identified, screened, excluded, and included. The initial search identified a total of 275 studies based on title, abstract, and keywords, and after discarding duplicate articles. Review articles were excluded according to exclusion criteria. The chosen studies (n = 58) were examined in their entirety based on the study's title, abstract, and full text (Step 1 in Fig 1), and they were disqualified from further analysis if they: did not use human subjects; used inertial sensing for purposes other than measuring a particular aspect of body posture (Step 2 in Fig 1), studies that used accelerometers to measure the vibration or movement of inanimate objects or machinery, for instance, were not included. After full review were selected 19 articles.

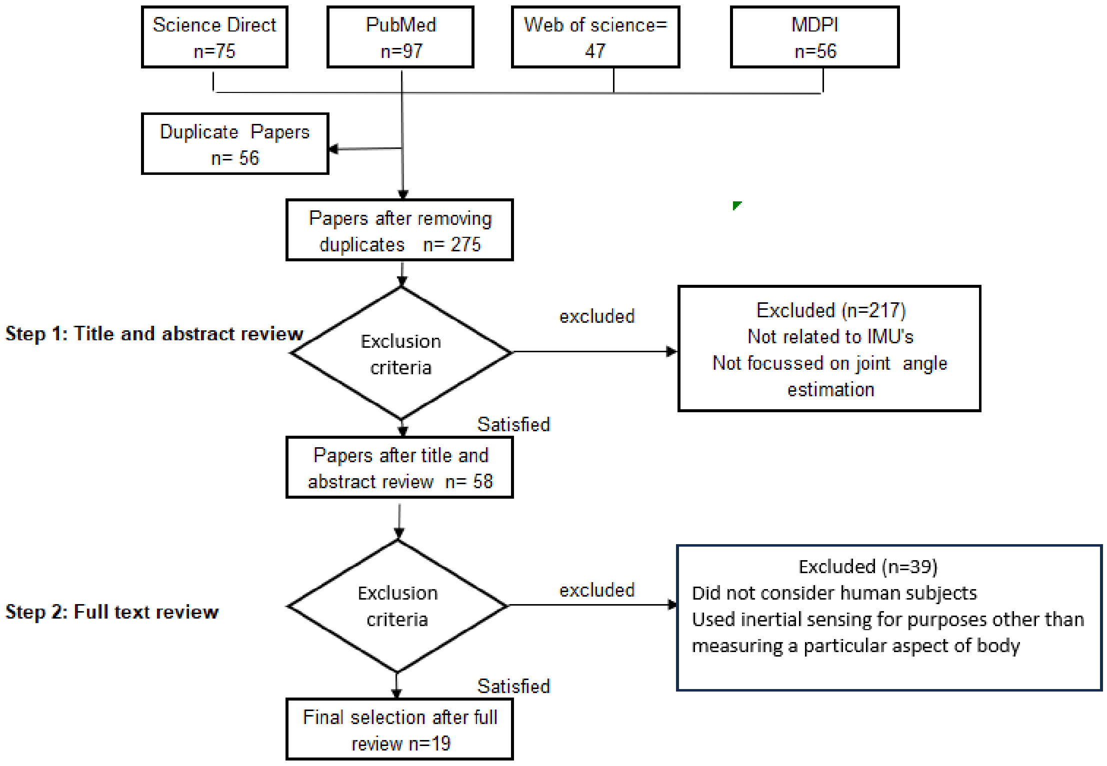


Fig 1. PRISMA flowchart of the document and selection process.

3.8 Data extraction and analyses

The data extraction and analysis phase included the following: author (s), year of publication, title, journal, study objective, study sample, study location, location of sensor in body, type of tasks performed, exposure characteristics, type of statistical technique used for validation, gold-standard system, and validation indexes calculated.

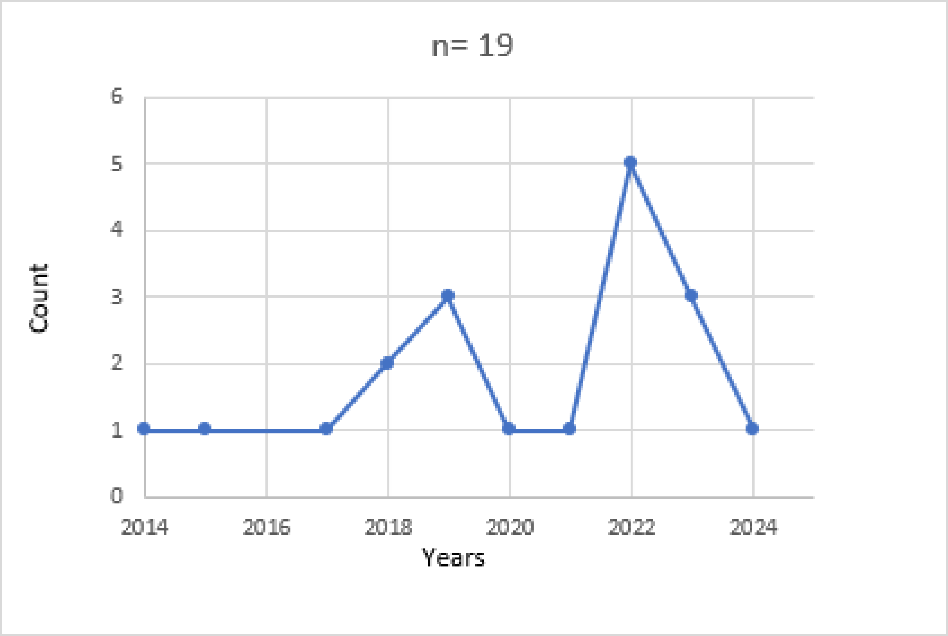
7 RESULTS

The growing adoption of inertial sensor technology in ergonomics research reflects a shift towards more precise and accessible methods for assessing their validity and reliability. In recent years, these sensors have become increasingly valuable in both laboratory and field settings, offering detailed measurements of body kinematics that are crucial for understanding and mitigating occupational hazards. This review examines 19 studies that present methodologies to validate and examine reliability of inertial sensors to estimate joint angles, providing insights into their effectiveness and reliability across various applications. The analysis focuses on the validation of inertial sensors against gold-standard systems, the statistical methods employed to assess their accuracy, and the contexts in which these studies were conducted. The review also highlights the trends in research over the past decade, revealing a significant increase in the use of these sensors, particularly in scientific and healthcare environments. Table 2 gives a general overview of the 19 studies that were examined, including the sample size and composition for each sample, sample size, gold-standard system, and validation indexes calculated.

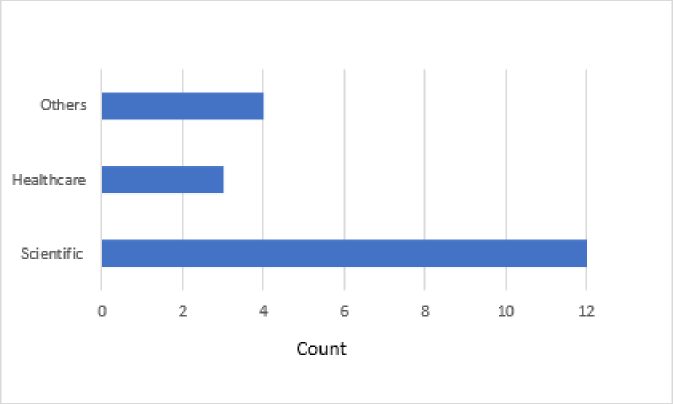
Table 2 Publications selected after final review.

Study	Authors (Year)	Participants	n	Gold-sample system	Validation index
1	Thompson et al. (2024)	Cyclists	17	Marker-based three-	Intra-class Correlation Coefficients (ICC)
2	Zahn et al. (2023)	Hospital patients	39	A marker based system	Correlation coefficient
3	Riek et al. (2023)	Healty adults	12	Motion capture	Bland–Altman and intraclass correlation (ICC) analysis
4	Ortigas et al. (2023)	arthroplasty patients	N/E	ground truth simulator values	RMSE
5	Lewin et al. (2022)	adults	20	Qualisys motion capture, AMTI	Intra-class Correlation Coefficients (ICC)
6	Evans et al. (2022)	cyclists	4	MoCap System	Pearson's correlation coefficient ® and Root Mean Square Error (RMSE)
7	Blandeau et al. (2022)	Healty adults	15	Optoelectronic reference system	Bland–Altman plots and Lin's concordance correlation coefficient
8	Piche et al. (2022)	Young adults	22	optoelectronic motion capture	Root Mean Square Deviation (RMSD) and Lin's Concordance Correlation (LCC)
9	Cudejko et al. (2022)	Young adults	21	Xsens motion tracking system	R-squared values
10	Park and Yoon (2021)	Healty adults	10	statsitical parametric	Hypothesis testing for diffences in mean values
11	Aqueveque et al. (2020)	Healty adults	20	Motion capture system	Correlation coefficient
12	Teufl et al. (2019)	College students	28	A marker based OMC System	Root mean squared error (RMSE), range of motion error (ROME), Bland-Altman (BA) analysis, and the coefficient of multiple
13	Bessone et al. (2019)	College students	14	Optoelectronic system	Coefficient of repeatability and RMSE
14	Abhayasinghe et al. (2019)	Not specified	N/E	Vicon Optical Motion Capture	Root Mean Square Error (RMSE)
15	Cho et al. (2018)	Hospital patients	3	Camera based system	Root mean squared error (RMSE) and intraclass correlation coefficient (ICC)
16	Parrington et al. (2018)	Young adults	10	Motion capture	Intra-class Correlation Coefficients (ICC), root mean square error (RMSE), and percent error
17	Lanovaz et al. (2017)	Children	10	3D motion capture system	Overal partial R squared, RMS, Bland-Altman plots
18	Winter et al. (2015)	Runners	10	Motion analysis system	Correlation coefficient
19	Leardini et al. (2014)	Healty adults	17	stereophotogrammetry	Root mean square deviation

Ten of the 19 studies collected data in field settings, with 9 (47.3%) of the studies taking place in laboratory settings. Scientific in laboratory ambiance and health services, were the most frequently studied (18 of the 19 studies). Three of the studies (15.8%) used measurements of angular displacement, as well as acceleration. Joint angle kinematics for upper arms, neck and trunk was calculated using various pairs of sensors. All the studies performed in lab settings validated inertial sensor measurements for accuracy and precision in ergonomics applications. By statistically comparing kinematic measurements obtained using inertial sensing to equivalent measurements obtained from a reference gold-sample system, Root mean square error (RMSE) was assessed by Ortigas et al. (2023), Evans et al. (2022), Blandeau et al. (2022), Teufl et al. (2019), Abhayasinghe et al. (2019), Cho et al. (2018), and Parrington et al. (2018). Correlation coefficients paired and independent sample t-tests, summary statistics on root mean squared errors (RMSE), and limits of agreement were among the statistical techniques were used to evaluate the accuracy of inertial sensor-derived measures in comparison to reference instrumentation measures (Park and Yoon, 2021. By measuring inter-rater reliability and intra-rater repeatability, the precision of sensor measurements was evaluated (Thompson et al., (2024); Lewin et al. (2022), and Parrington et al. (2018). Correlation coefficient was evaluated by Zahn et al. (2023), Evans et al. (2022), Piche et al. (2022), and Aqueveque et al. (2020). Bland-Altman plots were used by Riek et al. (2023), Blandeau et al. (2022), and Teufl et al. (2019). To compare the measurements obtained after multiple attachments of sensors to the same participant by the same examiner, intra-rater repeatability was typically investigated Thompson et al. (2024) and Lewin et al. (2022). A 94.7% of the studies used commercial software, such as MoCap system, Vicon Optical motion capture, Xsens motion MTS) to categorize various postures from inertial sensor data over time. According to the review's findings, over the past ten years, an increasing number of studies have used inertial sensors to evaluate the risk of MD. Over 57.8% of the studies examined (n=11 of 19) were published in the five years prior to the current year (2024); Fig 2 a). Most studies were developed in scientific context (63.15%), a 15.7% took place in healthcare service, and 21.1% covered other areas (cycling children, runners); fig 2 b).



a)



b)

Fig 2 Summary of the review results in terms of the number of studies by publication year between 2014 and 2024 (a), by field study site where the data collection was performed (b)

When using body-worn inertial sensors for ergonomics applications, the location of the sensors on the body must be carefully considered. Most studies used were focused on the sensor placement on upper body segments (Table 3) (65.8%). The placement decision was related to the study main research question. However, the locations varied according to postural models considered. Most studies reported segment or joint angular displacement in terms of flexion/extension, abduction/adduction, rotation using the sensor frame reference, but they were not standardized making the comparisons undetermined.

Table 3 Sensor placement

Body segment	Quantity	Upper body	Lower body	Study number from table
Head	3	x		1,5,17,19
Forehead	1	x		6,9
Cervical	1	x		16
Chest/Sternum	6	x		15,18
Scapular	3	x		1
Thoracic	4	x		7,8,9,11,15,18
Upper Arm	7	x		1,2,3,4,5,8,9,13,14
Lumbar	1	x		5,9,11,12,17,18
Sacral	1	x		8,11
Lower Arm	8		x	4,5,8,9,10,11,12
Pelvis	1		x	13,14
Hand	2	x		1

Thigh	3		x	12,13,15

It was identified the need to demonstrate the validation process for the sensor attachment placements.

8. CONCLUSIONS

This literature review underscores the role that inertial sensor technology plays in modern ergonomics research. This systematic review of 19 studies assessed the available evidence on the psychometric properties of the use of inertial sensors to estimate joint angles. The widespread use of these sensors across various settings—both laboratory and field—demonstrates their versatility and growing importance in capturing detailed kinematic data. The studies consistently validated the accuracy and precision of inertial sensors against gold-standard systems, employing robust statistical methods such as RMSE, correlation coefficients, and Bland-Altman plots. The focus on joint angle kinematics for key body regions, such as the upper arms, neck, and trunk, further highlights the applicability of these sensors in evaluating complex postural and movement dynamics. Regarding validity, inertial sensors appear to provide a suitable alternative measure angles for flexion/extension postures at the upper limb joints. The review provides a comprehensive overview of the recent advancements and applications of inertial sensor technology in ergonomics research, particularly in assessing the methodology to validate inertial sensos when applying them to estimate joint angles. The findings highlight that most studies (94.7%) utilized commercial motion capture software to analyze posture and movement, underscoring the reliance on standardized tools for accurate data collection. The increasing trend in the use of inertial sensors over the past decade, with more than half of the studies (57.8%) published in the last five years, reflects the growing recognition of this technology’s potential in ergonomic assessments. The research predominantly focuses on laboratory settings (47.3%), with scientific and healthcare contexts being the most frequently studied environments. This suggests a strong interest in validating inertial sensor measurements for their accuracy and precision in controlled conditions before wider application in more complex, real-world environments. The use of advanced statistical methods, such as correlation coefficients, RMSE, and Bland-Altman plots, further confirms the approach to evaluating the validity and reliability of these sensors. Moreover, the review identifies key areas of focus, such as joint angle kinematics and the assessment of inter-rater reliability and intra-rater repeatability, indicating a comprehensive effort to ensure the robustness of inertial sensor data in ergonomic applications. The involvement of diverse fields, including scientific research, healthcare, and sports, demonstrates the versatility of inertial sensors in monitoring posture and movement across various contexts. Overall, the findings suggest that inertial sensor technology has become a critical tool in ergonomic research, with proven reliability and precision for estimating joint angles. As the technology continues to evolve, its application is likely to expand further, offering new insights and improving workplace safety and health outcomes.

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.

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IMPORTANCE OF ERGONOMICS IN THE WORKPLACE HEALTH OF A WORKER WITH DIABETES MELLITUS

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Summary. This research shows the relationship that diabetes mellitus has with ergonomics, since there are impactful occupational risks that must be recognized, evaluated and controlled to preserve the health of workers under this health condition. At the same time, an overview of the existing situation in Mexico regarding diabetes by various health institutions in the country is given, as well as the possible damages that a worker may have. A worker with diabetes mellitus was contacted who, due to manual handling of loads (MMC), presented an injury and it is related to the importance of the application of NOM-036-1-STPS-2018, Ergonomic risk factors in the Work-Identification, analysis, prevention and control. Part 1: Manual handling of loads to prevent this condition from becoming complicated in workers who have this medical condition.

Keywords: ergonomics, diabetes, MMC

Relevance to ergonomics: Various factors must be analyzed for manual handling of loads. In Mexico, NOM-036-1-STPS-2018, Ergonomic risk factors at work-Identification, analysis, prevention and control. Part 1: Manual handling of loads, must have greater dissemination and application, as well as ensure that companies recognize the importance of medical examinations, the use of personal protective equipment and elements for manual handling of loads (MMC) to identify , prevent and control risk factors that related to work activity may aggravate a medical condition for workers.

Abstract: This research shows the relationship that diabetes mellitus has with ergonomics, since there are impactful occupational risks that must be recognized, evaluated and controlled to preserve the health of workers under this health condition. At the same time, an overview of the existing situation in Mexico regarding diabetes by various health institutions in the country is given, as well as the possible damages that a worker may have. A worker with diabetes mellitus was contacted who, due to manual handling of loads (MMC), presented an injury and it is related to the importance of the application of NOM-036-1-STPS-2018, Ergonomic risk factors in the Work- Identification, analysis, prevention and control. Part 1: Manual handling of loads to prevent this condition from becoming complicated in workers who have this medical condition.

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Relevance to Ergonomics: Various factors must be analyzed for manual load handling. In Mexico, NOM-036-1-STPS-2018, Ergonomic risk factors at work-Identification, analysis, prevention and control. Part 1: Manual handling of loads, must have greater dissemination and application, as well as ensure that companies recognize the importance of medical examinations, the use of personal protective equipment and elements for manual handling of loads to identify, prevent and control risk factors that related to work activity may aggravate a medical condition for workers.

1. INTRODUCTION

The present work tries to emphasize the impact that diabetes mellitus could have on workers who suffer from a chronic-degenerative disease such as diabetes mellitus and the way in which a work accident could complicate this condition. Using ergonomics could reduce the possibility of suffering an injury or accident that complicates this type of condition. In Mexico, and according to the National Health and Nutrition Survey (ENSANUT) 2021, it was pointed out that 12 million 400 thousand people suffer from diabetes mellitus, a chronic disease that can cause irreversible damage to eyesight, kidneys or skin. Likewise, the International Diabetes Federation places Mexico in 7th place. Place with 14.1 million people with diabetes and predicts that this figure will increase to 21.2 million by 2045. The National Institute of Statistics and Geography (INEGI), in Mexico, 10.3% of the population aged 20 years and over reported having a diagnosis previous diabetes mellitus and the increase in the diagnosis of the disease as people's age increases. Given these figures, it must be considered that the care of the disease must be considered within the environments where a worker develops, and this includes the workplace, so that the company establishes safe work procedures, provides protective equipment personnel to workers, as well as elements for manual handling of loads and provide timely follow-up on safety and health at work towards people who suffer from this disease.

The Ministry of Health of the Government of Mexico mentions on its electronic portal that a patient with controlled diabetes has an absenteeism from work per year of 1.2 days, while those people who present complications due to lack of control of the disease lose up to 44.3 days. These levels of absenteeism directly impact the productivity of various companies. On the other hand, the Mexican Social Security Institute (IMSS) mentions that diabetes is one of the main causes of absenteeism and disability among Mexican workers and that it is also the main cause of death in its health centers and the second cause of queries. In addition, it is the main cause of disability pensions, with thousands of workers receiving pensions due to complications of this disease.

Due to the aforementioned statistics, it is important that, in Mexican companies, the importance of industrial safety and hygiene, as well as ergonomics, is taken into account to help the health of workers who suffer from chronic-degenerative diseases, such as the case of diabetes mellitus.

The delimitation of this investigation focuses on a worker from an animal food company, who handles loads manually and who also suffers from diabetes mellitus. Showing an analysis where an injury suffered by the worker, who suffers from diabetes mellitus, was generated; This injury was due to the ergonomic risk factor: manual handling of loads.

2. OBJECTIVE

Show the impact that the lack of application of NOM-036-1-STPS-2018, Ergonomic risk factors at Work-Identification, analysis, prevention and control, can have. Part 1: Manual handling of loads, personal protective equipment and elements for manual handling of loads, on the health of a worker with diabetes mellitus.

3. METHODOLOGY

In the first instance, a review of existing data on diabetes mellitus in Mexico was carried out, its definition and risk conditions, ergonomic risk factor: manual handling of loads as well as its applicable regulations in companies.

The worker was later interviewed personally, who did not allow him to be recorded due to confidentiality issues and was not allowed to enter the company where the accident occurred. Information was collected about his condition, as well as the workplace and the activities he carries out there.

Once the previous information has been collected, it is concentrated in this document for analysis and to show the importance of the application of ergonomics in this and other workers to the manual handling of loads in a safer way.

4. RESULTS

According to data obtained from various sources such as ENSANUT, INEGI, Ministry of Health and IMSS of Mexico, unfortunately the population suffering from diabetes mellitus is increasing. The Ministry of Health defines it as a disease characterized by maintaining high blood glucose levels, which is associated with insulin deficiency, affecting the heart, eyes, kidneys and nervous system. It is a disease that does not respect gender, age or even social status, many people suffer from it without knowing it, it has even become a health emergency.

The main cause of diabetes is bad eating habits full of refined sugars, saturated fats and sodium, we add to this a sedentary lifestyle, obesity and the genetic factor. Currently in Mexico, diabetes is the third cause of death; It is possible that more than one hundred thousand people die each year from this disease and within these figures, people over 65 years of age occupy the first place in deaths. Children are not exempt, and they can even be born with this disease due to the famous gestational diabetes that the mother usually gets during pregnancy. Specifically, in diabetes mellitus or type 2 diabetes, it happens when the body is unable to produce insulin and therefore glucose accumulates in the blood. This disease represents the majority of cases and manifests itself in adults, generally with obesity or hypertension. When knowing these data, the importance of investigating the impact that this disease can have on the occupational health of workers arises, since occupational risk agents, as well as unsafe conditions and acts, can generate complications of this condition. For this research, we seek to begin to emphasize the importance that various work aspects may have on the health of workers who suffer from this chronic-degenerative disease, exposing the situation described below.

According to the encyclopedia of the International Labor Organization (ILO), in its chapter 29 “Ergonomics”, the objective of ergonomics is to ensure that the work environment is in harmony with the activities carried out by the worker. This objective is valid in itself, but its achievement is not easy for a number of reasons. The human operator is flexible and adaptable and continually learns, but individual differences can be very large. Some differences, such as those in physical build and strength, are obvious, but there are others, such as differences in culture, style or skills that are more difficult to identify.

On the other hand, ergonomic risk factors according to the Mexican Official Standard-036-1-STPS-2018, Ergonomic risk factors-Identification, analysis, prevention and control. Part 1: Manual handling of loads, are those that can lead to physical effort, repetitive movements or forced postures in the work carried out, with the consequent fatigue, errors, accidents and work-related illnesses, derived from the design of the facilities, machinery, equipment. , tools or workplace; This is why the importance of the analysis in this research focused on this standard is mandatory, at least in this work center, since the field of application stipulates that it governs the entire national territory and applies in all countries. work centers where there are workers whose activity involves manual handling of loads on a daily basis (more than once a day).

Occupational risks related to diabetes mellitus should be considered an important issue, as workers with this condition may face additional challenges in the workplace. How can they be:

1. **Hypoglycemic episodes**: Hypoglycemia (low blood glucose levels) can be a risk at work, especially in tasks that require constant attention, precision or use of heavy machinery, as they can cause dizziness, confusion or even loss of consciousness. causing the probability of suffering an injury or accident to increase.
2. **Control of the work environment**: Changes in work schedules, night shifts, and stress can affect diabetes control. It is important that companies provide a work environment that allows workers to attend to their health needs (for

example, having time to take medications, eat properly, and measure their blood glucose levels).

3. **First aid**: It is necessary for there to be a medical service area in companies, and also for co-workers and supervisors or area heads to be informed about diabetes and know how to respond in the event of an emergency related to this disease.
4. **Adaptations in processes or tasks**: Companies should consider adjusting or modifying tasks that may be particularly risky for employees with diabetes, ensuring that they can perform their work safely and allowing work hazards to be eliminated or controlled to reduce the likelihood of suffering an accident.
5. **Education and awareness**: Workers with diabetes and their colleagues should be educated about diabetes, its symptoms and proper management to reduce stigma and foster a supportive environment, which will help increase productivity in the company as well as the quality of life of people who suffer from this condition.

Effective management of these occupational risks can significantly improve the safety and productivity of workers with diabetes.

Likewise, the relationship that this disease has with occupational risks is:

a) **Affections to the nervous and vascular system**: Diabetes can cause neuropathy (nerve damage) and vascular problems, which can reduce sensation in the extremities. This could prevent a worker from feeling a pain or injury, such as a cut or burn, which could result in a worsening of the injury or additional accidents.

b) **eye damage**: Diabetic retinopathy and other diabetes-related eye problems can reduce vision, which can be particularly dangerous in environments where visual precision is required, such as operating heavy machinery or driving vehicles.

c) **Responsiveness**: Fluctuations in blood glucose levels can affect an individual's cognitive and responsiveness, which could delay their ability to appropriately respond to emergency situations or unexpected dangers.

Given the previous points, it is important that workers with diabetes carry out collaborative work with their doctors and employers to properly manage their condition in the workplace and reduce the presence of possible injuries and workplace accidents.

Ergonomics and diabetes can be related considering that ergonomics is responsible for optimizing the work environment and tools to improve the health and performance of workers, this relationship is shown as follows:

Stress Control: A well-designed work environment can reduce stress, which is important for people with diabetes, as stress can increase blood glucose levels.

Physical Activity: Workplaces that encourage movement and active breaks can help employees with diabetes maintain adequate physical activity levels, which is crucial for controlling blood glucose levels.
Ease of Access: Ergonomics involves designing environments that are accessible to everyone, including those with physical limitations that may result from complications of diabetes, such as neuropathy or vision problems.
Proper Postures: Good ergonomics helps prevent awkward postures, which is essential for people with diabetic neuropathy who may have reduced sensation in the extremities and be more prone to injury.

Ergonomics not only improves comfort and efficiency at work, but also plays an important role in supporting the health and well-being of people with diabetes. Implementing appropriate ergonomic practices can help mitigate the risks of complications and promote better disease control.

Relating the above to the objective for this research, the following case is presented, where one of the authors of this work was the first line of contact to be able to schedule and execute the interview with the analyzed worker.

When interviewing the worker, it was found that he is male, is 51 years old, has been working in that company for 3 years and was diagnosed with diabetes mellitus in 2001, stating that he attends his control appointments at his IMSS family medical unit. , considering that his condition is under control, although sometimes he has fatigue and headaches but with a low frequency. Likewise, he works in an animal food company, located in the State of Mexico. Inside it, there is also a small farm with birds and horses. His activities consist of daily moving 5 drums with dog food and 5 drums with horse food weighing 10 kg each; However, he also has to prune trees with a chainsaw and sweep gardens, as well as remove animal excrement from the small farm, emptying all this waste into drums that can weigh up to 15 kg, handling these loads alone, without the help of other colleagues or some element for manual handling of loads that would facilitate this activity; They provide you with personal protective equipment, specifically a helmet, goggles, gloves and a mask.

On January 5, 2024, the worker was moving a drum with garden waste and animal excrement, when while trying to empty the drum into a container, with the movement, the drum hit his left shin; The worker went to the company's medical service and when asked about what happened and his condition as a person with diabetes, they sent him to his corresponding IMSS clinic, who gave him disability, classifying it as a work risk. Given the history of his illness, the IMSS gave alarm signals and a procedure for washing and healing, to prevent the wound from becoming infected or complicated. Figure 1 shows the conditions of the injury.

Figure1. Injury in the process of healing

The worker states that he was afraid that his wound would not heal, that it would become infected and that his leg would be amputated, since his condition is somewhat delicate and he must be careful in carrying out his work activities so that it does not happen again. He also comments that the company had not conducted any medical examination or interview about his medical history to hire him, therefore, the company did not know about his illness until the accident occurred.

Given the previous situation and what exists about the MMC, Figure 2 shows the criteria requested by NOM-036-1-STPS-2018, Ergonomic risk factors at work-Identification, analysis, prevention and control so that implement and help eliminate or control this ergonomic risk, and must consult the standard in its entirety for successful compliance with it.

Analysis of ergonomic risk factors

Security procedure to carry out activities with MMC

Reduce or eliminate ergonomic risk factors

Workers' health surveillance program

Inform workers about the risks due to MMC

Record of preventive measures and medical examinations performed

Figure2. Criteria for compliance with NOM-036-1-STPS-2018, Ergonomic risk factors at work-Identification, analysis, prevention and control.

5. CONCLUSIONS

The situation explained above serves to raise awareness that there are occupational risks that can significantly affect the health of workers when they suffer from diabetes mellitus.

The application of ergonomics, specifically the issue related to manual handling of loads (MMC), is very important for all workers, also considering the health conditions that arise, since a work accident can aggravate a medical condition such as diabetes mellitus. For all cases, in addition to carrying out the corresponding medical examinations as part of a control for the occupational health of the workers, an analysis is recommended to determine the characteristics of the load, the physical effort necessary to move the load, the demands of the activity, individual factors and characteristics of the work environment, so that in this way, there is recognition, evaluation and control of ergonomic risk agents and safety and health at work is guaranteed for people involved in any work activity.

To reduce the risk of diabetes in industrial workers, measures such as promoting active breaks during the day, improving healthy food options in canteens, diabetes education programs and regular health checks can be implemented. Additionally, addressing job stressors and providing a healthier and safer work environment can help minimize the risk of chronic diseases, regardless of the implementation of NOM-036-1-STPS-2018, Ergonomic risk factors in the workplace. Work-Identification, analysis, prevention and control.

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IDENTIFICATION, EVALUATION AND CONTROL OF PSYCHOSOCIAL RISK FACTORS AND ORGANIZATIONAL ENVIRONMENT IN A BREWING INDUSTRY IN MEXICO CITY.

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Resumen Se realizó una evaluación de los Factores de Riesgo Psicosocial y el entorno organizacional en una industria cervecera, por medio del cuestionario de la Guía de referencia III de la NORMA Oficial Mexicana NOM-035-STPS-2018, Factores de riesgo psicosocial en el trabajo-Identificación, análisis y prevención; el nivel de riesgo global en todas las evaluaciones fue bajo, sin embargo se presentaron niveles de riesgo medio y alto en la categoría de factores propios de la actividad, con sus respectivos dominios: carga de trabajo y la falta de control sobre el trabajo; mientras que el nivel de riesgo más bajo se obtuvo en las categorías de entorno organizacional, liderazgo y relaciones en el trabajo.

Palabras clave: Factores de riesgo psicosocial, entorno organizacional, salud mental, salud ocupacional, industria cervecera.

Relevancia para la ergonomía: Los factores psicosociales forman parte de la ergonomía cognitiva; estos siempre se encuentran presentes dentro del entorno laboral del trabajador, su evaluación nos permite implementar medidas de control para favorecer que el trabajador desarrolle sus actividades de manera óptima procurando el cuidado de su salud mental; esto favorece a su vez la productividad al sentirse en un ambiente adecuado y el sentido de pertenencia a la empresa. También se han identificado y analizado con mayor frecuencia los factores de riesgo psicosocial en el área médica respecto a las áreas industriales, por lo tanto, el presente estudio en la industria cervecera nos permite conocer el nivel de riesgo de los factores psicosociales considerando las actividades desarrolladas.

Abstract: An evaluation of the Psychosocial Risk Factors and the organizational environment in a brewing industry was carried out, through the questionnaire of the Reference Guide III of the Mexican Official STANDARD NOM-035-STPS-2018, Psychosocial risk factors at work- Identification, analysis and prevention; The global risk level in all evaluations was low, however, medium and high risk levels were presented in the category of factors specific to the activity, with their respective domains: workload and lack of control over work; while the lowest risk level was obtained in the categories of organizational environment, leadership and relationships at work.

Keywords. Psychosocial risk factors, organizational environment, mental health, occupational health, brewing industry.

1. INTRODUCTION

A favorable organizational environment can contribute positively to the mental health of workers, triggering a series of consequences that help both the worker's performance and favor the productive process of companies (WHO, 2022). This favorable organizational environment makes the worker feel part of the company and that their work is valued. It also takes into consideration the relationships they have with their co-workers and how they develop in the work environment (Fernandes, 2016). The actions to generate it are aimed at promoting communication between workers, promoting healthy coexistence, avoiding workplace violence, etc.

In Mexico, the legislation includes, from the Federal Labor Law (FLL), the figures of sexual harassment and harassment (DOF, 2012); There is a table of work-related illnesses; in its latest modification, psychosocial illnesses were integrated for the first time (DOF, 2024); and there is NOM-035-STPS-2018 Psychosocial risk factors at work-Identification, analysis and prevention.

In NOM-035-STPS-2018 Psychosocial risk factors at work-Identification, analysis and prevention, Psychosocial Risk Factors (PRF) are defined as those that can cause anxiety disorders, not organic to the sleep-wake cycle and of serious stress and adaptation, derived from the nature of the functions of the job, the type of work day and the exposure to Severe Traumatic Events (STE) or acts of workplace violence to the worker, due to the work carried out affecting his or her life. staff. (Behere, 2021) and labor (Kocatepe, 2022), both even with fatal outcomes.

2. OBJETIVES.

Analyze the PRF and the organizational environment in a brewing industry carried out to identify the control measures that must be implemented, aimed at improving working conditions related to the mental health of workers.

3. METODOLOGY.

To obtain data on the working population, a socio-labor survey was carried out. Identification of exposure to STE was carried out with Reference Guide I; and the analysis of the PRF and the evaluation of the organizational environment was carried out through Reference Guide III, both of the Mexican Official STANDARD NOM-035-STPS-2018. From April to May 2024.

4. RESULTS.

The brewing company where the study was carried out has a staff of 1,500 workers. The study was carried out with a convenience sample, which exceeded the minimum estimated sample to carry out the analysis in accordance with formula (1) established in the NOM. -035-STPS-2008, the responses of 1171 workers were analyzed.

$$n = \frac{0.9604N}{0.0025(N-1)+0.9604} \quad (1)$$

In the socio-labor survey, the characteristics of the studied population were obtained; it is observed that the average age is around 41 years; the majority of workers are men; they report working overtime; they report not having another job; they do not use tobacco, medications or have illnesses; alcohol consumption was greater than tobacco consumption; The majority refers to exercising, among the most prominent sports are cardio, soccer and gym activities. Table 1.

Table 1. Socio-labor data of the workers.

Feature		**Data**
Age (years)	Average	41
	Standard deviation	+ 12.0
Sex %	Men	89
	Woman	11
Overtime%	No	70
	Yes	30
Other work%	No	97
	Yes	3
Exercise%	No	38
	Yes	62
Alcohol %	No	34
	Yes	66
Tobacco%	No	73
	Yes	27
Medications%	No	78
	Si	22
Illness%	No	87
	Si	13

4.1 Psychosocial Risk Factors and Organizational Environment.

The analysis of the PRF and the evaluation of the organizational environment according to the method used is structured in 5 categories divided into 10 domains, which in turn are classified into 25 dimensions.

It is observed that the categories: organizational environment and leadership and relationships at work, show the lowest levels of risk. The category: factors specific to the activity and its workload domain, present a medium and high risk level; as well as the category of organization of working time due to the working day. Table 2.

Table 2. Results of Psychosocial Risk Factors and Organizational Environment.

Category	Domain	Null	Low	Medium	High	Very high
Work environment	Conditions of the work environment	22%	43%	20%	13%	2%
Factors inherent to the activity	Workload	16%	23%	28%	25%	8%
	lack of control over work	23%	37%	22%	10%	8%
Organization of working time	Workday	12%	8%	40%	30%	10%
	work-family intervention	46%	22%	15%	9%	8%
Leadership and working relationships	Leadership	86%	7%	4%	3%	0%
	relationships at work	91%	4%	3%	2%	0%
	Workplace violence	62%	19%	11%	5%	3%
Organizational Environment	Performance recognition	78%	11%	5%	4%	2%
	Insufficient sense of belonging	70%	25%	3%	1%	1%

A global risk level was obtained, considering the results of all categories for psychosocial risk factors and organizational environment, and it is observed that the risk level was predominantly low. Table 3.

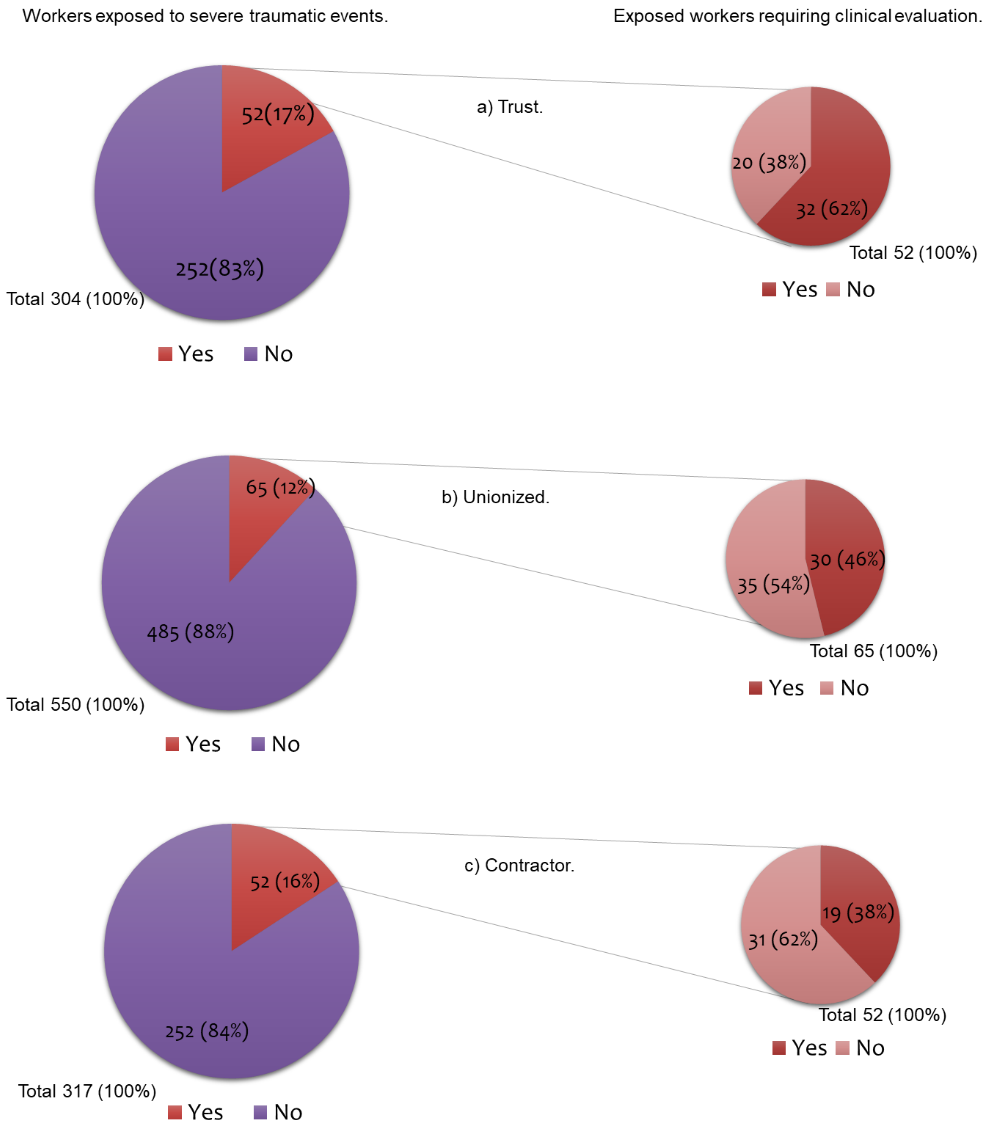
Table 3. Overall workplace rating

Risk level				
Null	Low	Medium	High	Very high
24%	35%	26%	13%	2%

PRF risk levels were most detrimental in the water plant and cleaning departments. According to the type of worker, the highest levels of risk were observed in trusted personnel.

2. SEVERE TRAUMATIC EVENTS

STE identification was carried out, where 167 (14%) workers have been exposed to situations such as assaults, accidents that result in death and loss of a limb or serious injury. Of the 167 workers, 81 (49%) need to rule out Post-Traumatic Stress Disorder (PTSD). Figure 1.



Severe traumatic events.

Figure 1. Exposed workers and those requiring clinical evaluation.

It is observed that, according to the type of worker, 32 (62%) of the trusted personnel exposed to STE require a specific evaluation to rule out PTSD; In this regard, the application of the Davidson scale was recommended, which allows the severity of PTSD symptoms to be evaluated so that the company's medical area is responsible for the clinical assessment and follow-up if necessary for each worker.

It was also observed in the three types of workers who were exposed to STE, 123 (74%) consume alcohol, this variable is important to consider, since it is known that substance consumption is related to some consequences of psychosocial risk factors like stress. (World Health Organization, 2010).

3. DISCUSSION

It is important to evaluate the perception of the PRF in the workplace, since it differs according to the department, job position and type of worker; In this study it is observed that the highest level of risk for PRF was found in the cleaning department, which has to carry out monotonous activities with excessive physical load, which may result in a greater risk of stress; This situation is also observed for the identification of STE, since trusted personnel are the ones who in the highest percentage require specialized clinical care to rule out PTSD. In this regard, some studies also refer to the fact that the risk level of the PRF categories may vary depending on the job in which the workers are found (Martín, 2015).

For its part, the identification of STE that workers have experienced or witnessed must have a follow-up for those who are considered for a clinical evaluation and PTSD is ruled out, as well as preventing substance consumption due to these STE; In this study, it is observed that alcohol consumption is high in exposed workers and that they require clinical evaluation, which may result in codependency on this substance; In this regard, some studies also refer to substance use in relation to experienced or witnessed STE (Bonumwezi, 2022).

Most of the studies that analyze PRF at work have been carried out on health personnel, which highlights the importance of conducting them in the industrial sector.

Conclusions: The categories with the highest level of risk were the organization of work time and the factors inherent to the activity, while the categories with the lowest level of risk were leadership, relationships at work and the organizational environment.

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WORK POSTURES EVALUATION WITH RULA AND OWAS IN A COSMETIC DEPARTMENT STORE

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Resumen: La evaluación de posturas en el contexto de ergonomía ocupacional se centra en analizar y cuantificar las posturas adoptadas por un trabajador durante su jornada laboral. Este proceso comienza con la observación de las tareas desempeñadas por el trabajador, identificando las posturas más frecuentes y potencialmente dañinas. Para ello, se registran las posturas en distintos intervalos de tiempo establecido, utilizando métodos como la observación directa como el análisis de fotografías o videos.

Cada postura observada se codifica según la posición de la espalda, brazos, piernas y la carga manipulada, utilizando tablas específicas para asignar códigos a estas posiciones. A partir de estos códigos, se determina la categoría de riesgo de cada postura, identificando aquellas que presentan un mayor riesgo para el trabajador. Se calcula la frecuencia relativa de cada postura para identificar patrones repetitivos que puedan contribuir a riesgos ergonómicos.

En función de los resultados obtenidos, se evalúa la necesidad de acciones correctivas o el rediseño de la tarea. Las categorías de riesgo varían desde posturas aceptables hasta aquellas que requieren cambios urgentes. En el documento se utilizan métodos como OWAS y RULA para realizar esta evaluación, permitiendo una valoración detallada de las posturas y ayudando a identificar áreas donde se necesitan cambios en la tarea para mejorar la ergonomía del puesto y a su vez para reducir el riesgo de lesiones musculoesqueléticas.

El uso de esta metodología es fundamental para garantizar la salud y seguridad del trabajador, minimizando y mitigando los riesgos ergonómicos en el lugar de trabajo asociados a posturas inadecuadas y repetitivas, puesto que se favorece al bienestar de los empleados y a su vez también puede aumentar la eficiencia y productividad al reducir el tiempo perdido por futuras lesiones relacionadas con el trabajo.

Palabras claves: Fatiga, posturas, rendimiento

Relevancia para la ergonomía: El estudio proporciona recomendaciones prácticas basadas en el análisis ergonómico para optimizar las estaciones de trabajo en tiendas departamentales. Destaca la importancia de integrar prácticas ergonómicas en el diseño del lugar de trabajo, tales como ajustar la altura de los mostradores, proporcionar sillas ergonómicas para tareas que lo permitan, y promover la

educación sobre posturas correctas y técnicas de manejo seguro. También subraya la necesidad de un monitoreo y evaluación continua para mantener un entorno de trabajo saludable. Implementar un sistema de revisión periódica y ajustes basados en observaciones permitirá prevenir problemas de salud a largo plazo. Estas sugerencias no solo pueden servir de base para futuras investigaciones, sino que también facilitan la implementación de mejoras en otros establecimientos con condiciones laborales similares. Además, contribuyen a la prevención de lesiones musculoesqueléticas entre los trabajadores del sector minorista, promoviendo así la salud ocupacional

Abstract: The postures evaluation in the context of occupational ergonomics focuses on analyzing and quantifying the postures adopted by a worker during their work day. This process begins with observing the tasks performed by the worker, identifying the most frequent and potentially harmful postures. To do this, postures are recorded at different established time intervals, using methods such as direct observation and analysis of photographs or videos.

Each posture observed is coded according to the position of the back, arms, legs and the load manipulated, using specific tables to assign codes to these positions. From these codes, the risk category of each position is determined, identifying those that present a higher risk to the worker. The relative frequency of each posture is calculated to identify repetitive patterns that may contribute to ergonomic risks.

Based on the results obtained, the need for corrective actions or redesign of the task is evaluated. Risk categories change from acceptable postures to those requiring urgent changes. The document uses methods such as OWAS and RULA to carry out this evaluation, allowing a detailed assessment of postures and helping to identify areas where changes in the task are needed to improve the ergonomics of the position and in turn to reduce the risk of musculoskeletal injuries.

The use of this methodology is essential to guarantee the health and safety of the worker, minimizing and mitigating ergonomic risks in the workplace associated with inappropriate and repetitive postures, since it favors the well-being of employees and in turn can also increase the efficiency and productivity by reducing time lost due to future work-related injuries.

Introduction:

Ergonomic assessment is a critical component in designing safe and healthy workplaces. An example of this process involves closely observing specific postures and assigning scores to different parts of the body, such as arms, forearms, wrists, neck, trunk, and legs. These scores are added to determine the level of risk associated with each posture, allowing informed decisions to be made about the need to adjust improve the ergonomics of the position.

Keywords: Fatigue, postures, performance

Relevance to ergonomics: The study provides practical recommendations based on ergonomic analysis to optimize workstations in department stores. It emphasizes the importance of integrating ergonomic practices into workplace design, such as adjusting counter heights, providing ergonomic chairs for tasks that allow it, and promoting education on correct postures and safe handling techniques. It also underscores the need for continuous monitoring and evaluation to maintain a healthy work environment. Implementing a system of periodic review and adjustments based on observations will prevent long-term health problems. These suggestions can not only serve as a basis for future research, but also facilitate the implementation of improvements in other facilities with similar working conditions. In addition, they contribute to the prevention of musculoskeletal injuries among retail workers, thus promoting occupational health.

1. INTRODUCCTION

In the department store environment, ergonomics plays a crucial role in employee health and well-being. This is especially relevant in the cosmetics sector, where sales associates spend long days interacting with customers and handling products. These activities, which often involve postures held for long periods and repetitive movements, can significantly increase the risk of developing musculoskeletal disorders. Therefore, posture evaluation becomes a fundamental aspect to prevent these risks and improve work quality.

According to (EU-OSHA, 2020), work-related MSDs mainly affect the back, neck, shoulders and extremities - both upper and lower - and include any damage or disorder of joints or other tissues. Health problems range from mild aches and pains to more serious conditions requiring sick leave or medical treatment. In chronic cases, these disorders can lead to disability and prevent the affected person from continuing to work.

The (World Health Organization, 2021) defines the scope of musculoskeletal disorders as comprising more than 150 disorders affecting the locomotor system. They range from sudden, short-term disorders, such as fractures, sprains and strains, to chronic diseases that cause limitations of functional abilities and permanent disability.

During a period of two weeks, continuous monitoring of the employees was carried out, recording their postures and activities in order to detect patterns that could represent ergonomic risks and to increase efficiency and productivity by minimizing time lost due to injuries related to work. the work.

This study not only seeks to contribute to the improvement of working conditions at the Exótica store, but also aims to serve as a model for other department stores in Los Mochis and beyond, demonstrating the importance of ergonomics in promoting a safe environment. safe and healthy work.

2. OBJECTIVES

General objective:

Evaluate and improve the ergonomic conditions of the clerks who work in a department store through observation of the work environment, evaluation of postures, risks and continuous monitoring to modify the work environment.

Specific objectives;

- Identify the most frequent postures adopted by shop assistants during their daily activities in the store and evaluate these postures to determine if there are potential risks of musculoskeletal injuries in the short and long term.
- Evaluate how the physical layout of the store, including the arrangement of shelves and counters, affects the postures adopted by shop assistants.
- Collect data on the specific tasks performed by shop assistants to better understand the contexts and ergonomic demands of working in the store.

3. METHODOLOGY

It focused on the ergonomic evaluation of a saleswoman who works at the Exótica department store in Los Mochis, Sinaloa. A single 20-year-old working woman was evaluated because she is the main person responsible for the tasks in the establishment within her 8-hour work day.

The workstation is characterized by a large space, where the worker must stand for long hours. The height of the counter is fixed, which can force the worker to adopt uncomfortable positions. Additionally, the dependent will be observed performing repetitive movements, such as reaching for products located on shelves both at waist level and above the head, which could increase the risk of injuries.

3.1 RULA (Rapid Upper Limb Assessment)

To realize the evaluation, the RULA (Rapid Upper Limb Assessment) methodology was used, which is used to evaluate the risk of musculoskeletal injuries in the upper extremities, derived from forced postures and repetitive movements. Since work at the cosmetics station involves repetitive tasks and the adoption of postures that can compromise the health of the worker, RULA turns out to be a suitable method to identify problem areas that require immediate attention.

A detailed observation of the dependent's postures was carried out, focusing on aspects such as the inclination of the trunk, the flexion angles of the upper and lower extremities and the position of the neck. Likewise, the guide and scoring scale provided by RULA was used to evaluate each of the observed postures and determine the level of risk associated with the observed postures

Position 1: Evaluation of the right side

Figure 1. Position 1RULA.

Group A evaluation:

1. Arm score.

Its score is 1, since its posture ranges from 20° of extension to 20° of flexion. (14°).

Figure 2. Position 1 RULA.

2. Forearm scoring

Its score is 2, since forearm flexion <60° or >100° (113°).

Figure 3. Position 1RULA.

4. Hand doll score

The score is 1 since your wrist is in position. Furthermore, we add 1 since the wrist has a slight ulnar deviation and, in the same way, we added another point since it has a medium supination. Being a total of 3 points.

Figure 4. Position 1 RULA.

Group B evaluation:

1. Neck score

Its score is 3 since it has >20° (28°) flexion.

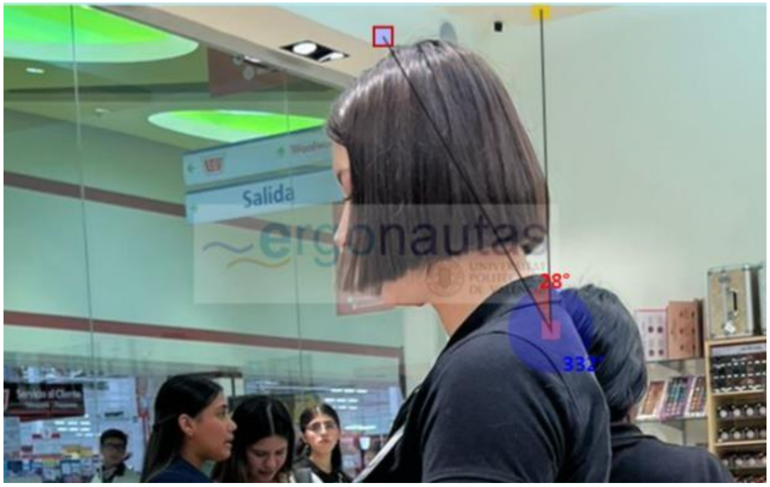


Figure 5. Position 1 RULA.

2. Trunk scoring

Its score is 1, because it is standing without any inclination of the trunk.

Figure 6. Position 1 RULA.

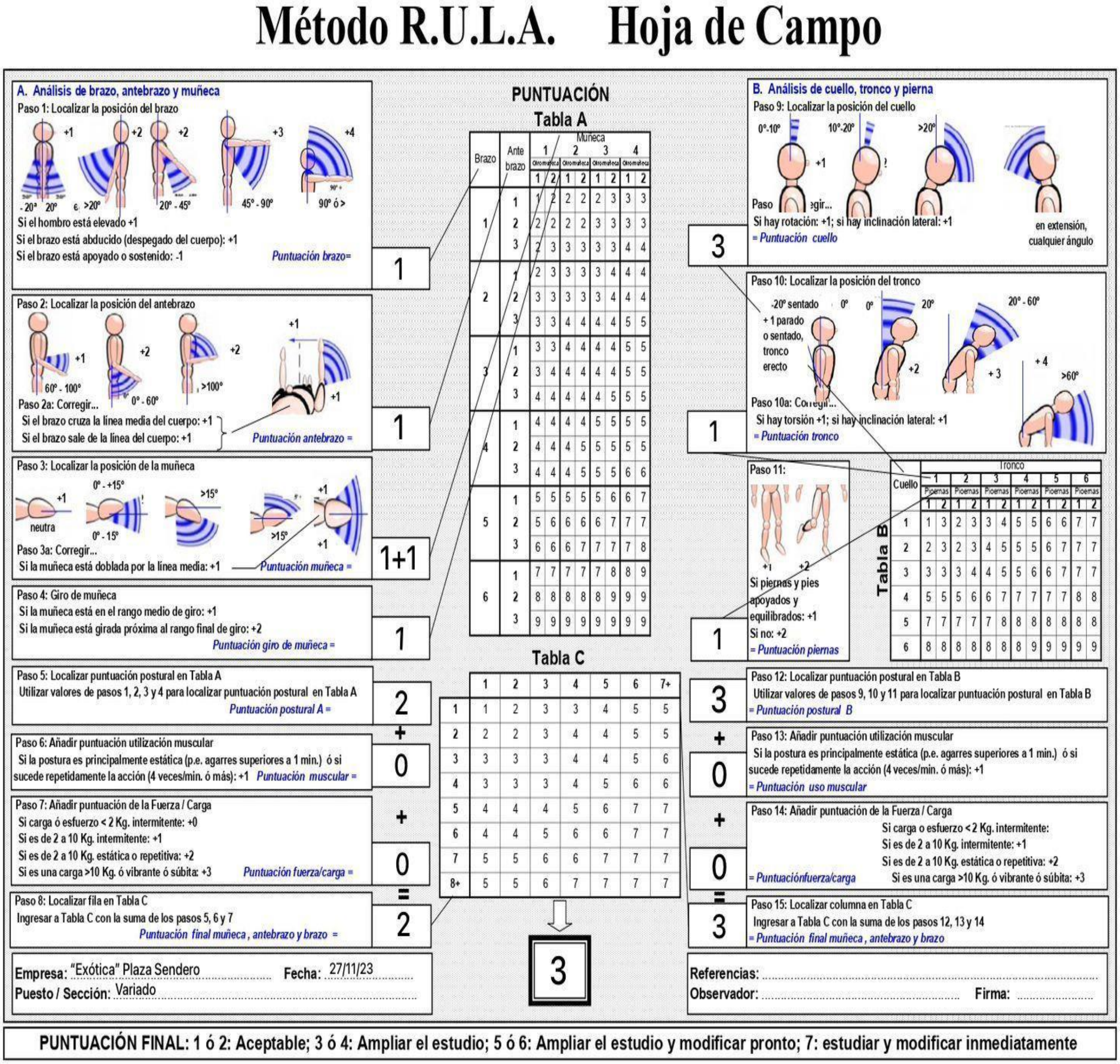
3. Leg scoring
Its score is 1 since the worker is standing with her weight symmetrically distributed and room to change position

Figure 7. Position 1RULA.

Table 1. Level of performance

Score	Level	Performance
1 o 2	1	Acceptable risk
3 o 4	2	Changes in the task may be required;
5 o 6	3	Task redesign is required
7	4	Urgent changes are required in the task

The total score for this position is 3. Therefore, it is at level 2 of the table, which indicates that changes may be required in the task and that it is advisable to study it in depth in search of improvements.



Método R.U.L.A. Hoja de Campo

A. Análisis de brazo, antebrazo y muñeca

Paso 1: Localizar la posición del brazo

Si el hombro está elevado +1

Si el brazo está abducido (despegado del cuerpo): +1

Si el brazo está apoyado o sostenido: -1

Puntuación brazo= 1

Paso 2: Localizar la posición del antebrazo

Paso 2a: Corregir...

Si el brazo cruza la línea media del cuerpo: +1

Si el brazo sale de la línea del cuerpo: +1

Puntuación antebrazo = 1

Paso 3: Localizar la posición de la muñeca

Paso 3a: Corregir...

Si la muñeca está doblada por la línea media: +1

Puntuación muñeca = 1+1

Paso 4: Giro de muñeca

Si la muñeca está en el rango medio de giro: +1

Si la muñeca está girada próxima al rango final de giro: +2

Puntuación giro de muñeca = 1

Paso 5: Localizar puntuación postural en Tabla A

Utilizar valores de pasos 1, 2, 3 y 4 para localizar puntuación postural en Tabla A

Puntuación postural A = 2

\+

Paso 6: Añadir puntuación utilización muscular

Si la postura es principalmente estática (p.e. agarres superiores a 1 min.) ó si sucede repetidamente la acción (4 veces/min. ó más): +1 *Puntuación muscular =* 0

\+

Paso 7: Añadir puntuación de la Fuerza / Carga

Si carga ó esfuerzo < 2 Kg. intermitente: +0

Si es de 2 a 10 Kg. intermitente: +1

Si es de 2 a 10 Kg. estática o repetitiva: +2

Si es una carga >10 Kg. ó vibrante ó súbita: +3

Puntuación fuerza/carga = 0

=

Paso 8: Localizar fila en Tabla C

Ingresar a Tabla C con la suma de los pasos 5, 6 y 7

Puntuación final muñeca , antebrazo y brazo = 2

PUNTUACIÓN

Tabla A

Brazo	Ante brazo	Muñeca 1 Giro muñeca 1	2	Muñeca 2 Giro muñeca 1	2	Muñeca 3 Giro muñeca 1	2	Muñeca 4 Giro muñeca 1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	3	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	5	5	5	5
	2	4	4	4	5	5	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Tabla C

	1	2	3	4	5	6	7+
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8+	5	5	6	7	7	7	7

3

B. Análisis de cuello, tronco y pierna

Paso 9: Localizar la posición del cuello

Paso ...egir...

Si hay rotación: +1; si hay inclinación lateral: +1

= Puntuación cuello 3

Paso 10: Localizar la posición del tronco

Paso 10a: Corregir...

Si hay torsión +1; si hay inclinación lateral: +1

= Puntuación tronco 1

Paso 11:

Si piernas y pies apoyados y equilibrados: +1

Si no: +2

= Puntuación piernas 1

Tabla B

Cuello	Tronco 1 Piernas 1	2	Tronco 2 Piernas 1	2	Tronco 3 Piernas 1	2	Tronco 4 Piernas 1	2	Tronco 5 Piernas 1	2	Tronco 6 Piernas 1	2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Paso 12: Localizar puntuación postural en Tabla B

Utilizar valores de pasos 9, 10 y 11 para localizar puntuación postural en Tabla B

= Puntuación postural B 3

\+

Paso 13: Añadir puntuación utilización muscular

Si la postura es principalmente estática (p.e. agarres superiores a 1 min.) ó si sucede repetidamente la acción (4 veces/min. ó más): +1

= Puntuación uso muscular 0

\+

Paso 14: Añadir puntuación de la Fuerza / Carga

Si carga o esfuerzo < 2 Kg. intermitente:

Si es de 2 a 10 Kg. intermitente: +1

Si es de 2 a 10 Kg. estática o repetitiva: +2

Si es una carga >10 Kg. ó vibrante ó súbita: +3

= Puntuaciónfuerza/carga 0

=

Paso 15: Localizar columna en Tabla C

Ingresar a Tabla C con la suma de los pasos 12, 13 y 14

= Puntuación final muñeca , antebrazo y brazo 3

Empresa: "Exótica" Plaza Sendero Fecha: 27/11/23

Puesto / Sección: Variado

Referencias: ....

Observador: .... Firma: ....

PUNTUACIÓN FINAL: 1 ó 2: Aceptable; 3 ó 4: Ampliar el estudio; 5 ó 6: Ampliar el estudio y modificar pronto; 7: estudiar y modificar inmediatamente

Figure 8. RULA worksheet position 1

Position 2: Evaluation of the left side

Figure 9. Position 2 RULA.

Group A evaluation:
1. arm score.
Your score is 3 as the arm has flexion >45° and 90° (64°).

Figure 10. Position 2 RULA.

2. Forearm scoring
Its score is 1 since it has a flexion between 60° and 100° (64°).

Figure 11. Position 2 RULA.

3. Hand doll score
Its score is 2 since the wrist has an extension > 0° and <15° (approximately 8°). In addition, we add 1 point since the wrist has ulnar deviation and, in the same way, we add another point since it has medium supination. This section has a total of 4 points.

Figure 12. Position 2 RULA.

Group 2 evaluation:

1. Neck Score

Its score is 2 as the neck has a flexion >10° and ≤20° (13°).

Figure 13. Position 2 RULA.

2. Trunk Scoring

Score is 4 as his trunk posture has a flexion >60° (86°).

Figure 14. Position 2 RULA.

3. Leg Scoring

Its score is 2 cause her feet are not supported and the weight is not symmetrically distributed.

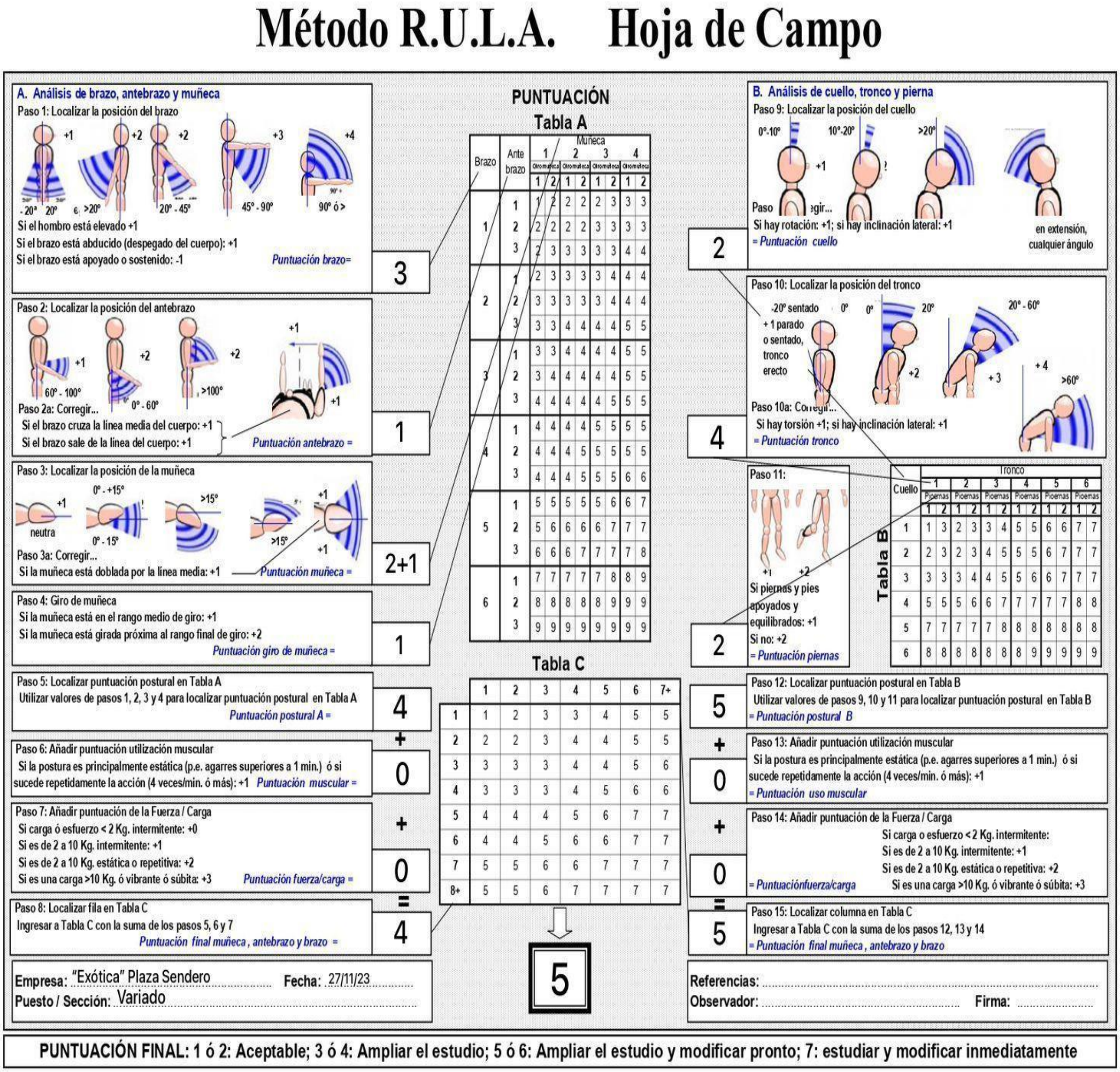
Figure 15. Position 2 RULA.

Table 2. Level of performance.

Score	Level	Performance
1 o 2	1	Acceptable risk
3 o 4	2	Changes in the task may be required;
5 o 6	3	Task redesign is required
7	4	Urgent changes are required in the task

The total score for this posture is: 5

Therefore, it is at level 3 of the table, which indicates that a redesign of the task is required, so that it does not affect the worker's health in the short and long term.



Método R.U.L.A. Hoja de Campo

A. Análisis de brazo, antebrazo y muñeca

Paso 1: Localizar la posición del brazo

Si el hombro está elevado +1
Si el brazo está abducido (despegado del cuerpo): +1
Si el brazo está apoyado o sostenido: -1
Puntuación brazo= 3

Paso 2: Localizar la posición del antebrazo

Paso 2a: Corregir...
Si el brazo cruza la línea media del cuerpo: +1
Si el brazo sale de la línea del cuerpo: +1
Puntuación antebrazo = 1

Paso 3: Localizar la posición de la muñeca

Paso 3a: Corregir...
Si la muñeca está doblada por la línea media: +1
Puntuación muñeca = 2+1

Paso 4: Giro de muñeca
Si la muñeca está en el rango medio de giro: +1
Si la muñeca está girada próxima al rango final de giro: +2
Puntuación giro de muñeca = 1

Paso 5: Localizar puntuación postural en Tabla A
Utilizar valores de pasos 1, 2, 3 y 4 para localizar puntuación postural en Tabla A
Puntuación postural A = 4

\+

Paso 6: Añadir puntuación utilización muscular
Si la postura es principalmente estática (p.e. agarres superiores a 1 min.) ó si sucede repetidamente la acción (4 veces/min. ó más): +1 *Puntuación muscular =* 0

\+

Paso 7: Añadir puntuación de la Fuerza / Carga
Si carga ó esfuerzo < 2 Kg. intermitente: +0
Si es de 2 a 10 Kg. intermitente: +1
Si es de 2 a 10 Kg. estática o repetitiva: +2
Si es una carga >10 Kg. ó vibrante ó súbita: +3
Puntuación fuerza/carga = 0

=

Paso 8: Localizar fila en Tabla C
Ingresar a Tabla C con la suma de los pasos 5, 6 y 7
Puntuación final muñeca , antebrazo y brazo = 4

PUNTUACIÓN

Tabla A

Brazo	Ante brazo	Muñeca 1		Muñeca 2		Muñeca 3		Muñeca 4	
		Giro muñeca		Giro muñeca		Giro muñeca		Giro muñeca	
		1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	3	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	5	5	5	5
	2	4	4	4	5	5	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Tabla C

	1	2	3	4	5	6	7+
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8+	5	5	6	7	7	7	7

5

B. Análisis de cuello, tronco y pierna

Paso 9: Localizar la posición del cuello

Paso ...egir...
Si hay rotación: +1; si hay inclinación lateral: +1
= Puntuación cuello 2

Paso 10: Localizar la posición del tronco

Paso 10a: Corregir...
Si hay torsión +1; si hay inclinación lateral: +1
= Puntuación tronco 4

Paso 11:

Si piernas y pies apoyados y equilibrados: +1
Si no: +2
= Puntuación piernas 2

Tabla B

Cuello	Tronco 1		Tronco 2		Tronco 3		Tronco 4		Tronco 5		Tronco 6	
	Piernas		Piernas		Piernas		Piernas		Piernas		Piernas	
	1	2	1	2	1	2	1	2	1	2	1	2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Paso 12: Localizar puntuación postural en Tabla B
Utilizar valores de pasos 9, 10 y 11 para localizar puntuación postural en Tabla B
= Puntuación postural B 5

\+

Paso 13: Añadir puntuación utilización muscular
Si la postura es principalmente estática (p.e. agarres superiores a 1 min.) ó si sucede repetidamente la acción (4 veces/min. ó más): +1
= Puntuación uso muscular 0

\+

Paso 14: Añadir puntuación de la Fuerza / Carga
Si carga o esfuerzo < 2 Kg. intermitente:
Si es de 2 a 10 Kg. intermitente: +1
Si es de 2 a 10 Kg. estática o repetitiva: +2
Si es una carga >10 Kg. ó vibrante ó súbita: +3
= Puntuaciónfuerza/carga 0

=

Paso 15: Localizar columna en Tabla C
Ingresar a Tabla C con la suma de los pasos 12, 13 y 14
= Puntuación final muñeca , antebrazo y brazo 5

Empresa: "Exótica" Plaza Sendero **Fecha:** 27/11/23
Puesto / Sección: Variado

Referencias: ……
Observador: …… **Firma:** ……

PUNTUACIÓN FINAL: 1 ó 2: Aceptable; 3 ó 4: Ampliar el estudio; 5 ó 6: Ampliar el estudio y modificar pronto; 7: estudiar y modificar inmediatamente

Figure 16. RULA worksheet Position 2.

Position 3 : evaluation of the right side

Figure 17. Position 3 RULA.

Group A evaluation:

1. Arm Score:

Its score is 2 as it has a flexion >20° and <45° (32°).

Figure 18. Position 3 RULA.

2. Forearm Scoring

Its score is 2 as it has a flex <60° or >100° (73°).

Figure 19. Position 3 RULA .

3. Hand doll Score

Its score is 2 as it has a slight extension > 0° and <15°. We will also add a 1 to it because it has a medium supination. Giving a total of 3 points for the wrist area

Figure 20. Position 3 RULA.

Group B evaluation

1. Neck Score

Its score is 3 as it has a flexion >20° (24°).

Figure 21. Position 3 RULA .

2. Trunk Scoring

Her score is 1 since she is standing correctly.

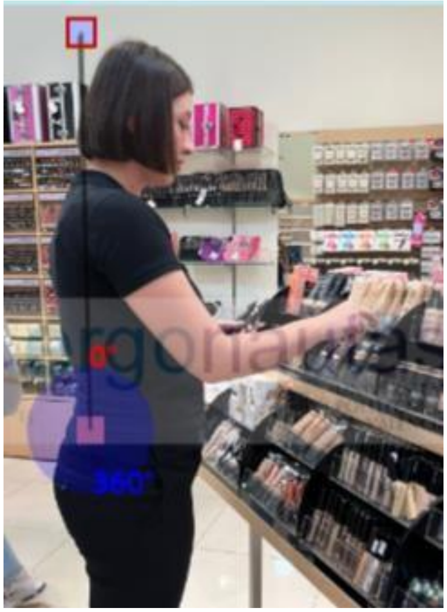
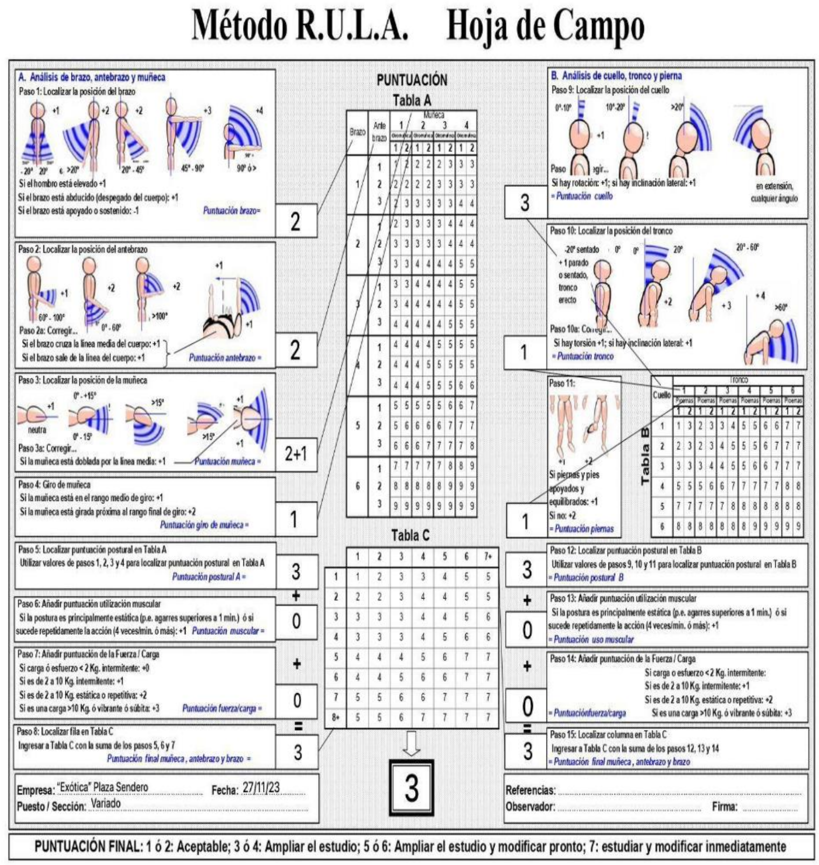


Figure 22. Position 3 RULA.

Table 3. Level of performance.

Score	Level	Performance
1 o 2	1	Acceptable risk
3 o 4	2	Changes in the task may be required;
5 o 6	3	Task redesign is required
7	4	Urgent changes are required in the task

The total score for this posture is: 3, therefore, it is at level 2 of the table, which indicates that changes to the task may be required; It is advisable to deepen the study to avoid future wear and tear on the health of our worker.



Método R.U.L.A. Hoja de Campo

A. Análisis de brazo, antebrazo y muñeca

Paso 1: Localizar la posición del brazo

Si el hombro está elevado +1
Si el brazo está abducido (despegado del cuerpo): +1
Si el brazo está apoyado o sostenido: -1
Puntuación brazo= 2

Paso 2: Localizar la posición del antebrazo
Paso 2a: Corregir...
Si el brazo cruza la línea media del cuerpo: +1
Si el brazo sale de la línea del cuerpo: +1
Puntuación antebrazo = 2

Paso 3: Localizar la posición de la muñeca
Paso 3a: Corregir...
Si la muñeca está doblada por la línea media: +1
Puntuación muñeca = 2+1

Paso 4: Giro de muñeca
Si la muñeca está en el rango medio de giro: +1
Si la muñeca está girada próxima al rango final de giro: +2
Puntuación giro de muñeca = 1

Paso 5: Localizar puntuación postural en Tabla A
Utilizar valores de pasos 1, 2, 3 y 4 para localizar puntuación postural en Tabla A
Puntuación postural A = 3

\+

Paso 6: Añadir puntuación utilización muscular
Si la postura es principalmente estática (p.e. agarres superiores a 1 min.) ó si sucede repetidamente la acción (4 veces/min. ó más): +1 *Puntuación muscular =* 0

\+

Paso 7: Añadir puntuación de la Fuerza / Carga
Si carga ó esfuerzo < 2 Kg. intermitente: +0
Si es de 2 a 10 Kg. intermitente: +1
Si es de 2 a 10 Kg. estática o repetitiva: +2
Si es una carga >10 Kg. ó vibrante ó súbita: +3
Puntuación fuerza/carga = 0

=

Paso 8: Localizar fila en Tabla C
Ingresar a Tabla C con la suma de los pasos 5, 6 y 7
Puntuación final muñeca , antebrazo y brazo = 3

Empresa: "Exótica" Plaza Sendero Fecha: 27/11/23
Puesto / Sección: Variado

PUNTUACIÓN

Tabla A

Brazo	Antebrazo	Muñeca 1		2		3		4	
		1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	3	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	5	5	5	5
	2	4	4	4	5	5	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Tabla C

	1	2	3	4	5	6	7+
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8+	5	5	6	7	7	7	7

3

B. Análisis de cuello, tronco y pierna

Paso 9: Localizar la posición del cuello

Paso ...egir...
Si hay rotación: +1; si hay inclinación lateral: +1
en extensión, cualquier ángulo
= Puntuación cuello 3

Paso 10: Localizar la posición del tronco
+ 1 parado o sentado, tronco erecto
Paso 10a: Corregir...
Si hay torsión +1; si hay inclinación lateral: +1
= Puntuación tronco 1

Paso 11:
Si piernas y pies apoyados y equilibrados: +1
Si no: +2
= Puntuación piernas 1

Tabla B

Cuello	Tronco 1		2		3		4		5		6	
	Piernas		Piernas		Piernas		Piernas		Piernas		Piernas	
	1	2	1	2	1	2	1	2	1	2	1	2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Paso 12: Localizar puntuación postural en Tabla B
Utilizar valores de pasos 9, 10 y 11 para localizar puntuación postural en Tabla B
= Puntuación postural B 3

\+

Paso 13: Añadir puntuación utilización muscular
Si la postura es principalmente estática (p.e. agarres superiores a 1 min.) ó si sucede repetidamente la acción (4 veces/min. ó más): +1
= Puntuación uso muscular 0

\+

Paso 14: Añadir puntuación de la Fuerza / Carga
Si carga o esfuerzo < 2 Kg. intermitente:
Si es de 2 a 10 Kg. intermitente: +1
Si es de 2 a 10 Kg. estática o repetitiva: +2
Si es una carga >10 Kg. ó vibrante ó súbita: +3
= Puntuaciónfuerza/carga 0

=

Paso 15: Localizar columna en Tabla C
Ingresar a Tabla C con la suma de los pasos 12, 13 y 14
= Puntuación final muñeca , antebrazo y brazo 3

Referencias:
Observador: Firma:

PUNTUACIÓN FINAL: 1 ó 2: Aceptable; 3 ó 4: Ampliar el estudio; 5 ó 6: Ampliar el estudio y modificar pronto; 7: estudiar y modificar inmediatamente

Figure 23. RULA worksheet position 3

4.2 OWAS(Ovako Working Posture Analyzing System)

On the other hand, OWAS is a comprehensive methodology that allows analyzing global body postures, including the position of the back, arms, legs and physical load in general. This tool is particularly useful for evaluating the impact of prolonged postures on the general health of workers. In the context of this study, OWAS provided a holistic view of the ergonomic risks associated with the work environment, allowing for a more complete and accurate assessment.

The OWAS table was used to assign risk categories to the observed postures, considering aspects such as the inclination of the trunk, the position of the legs and the elevation of the arms. These data allow us to identify high-risk postures and analyze recommendations aimed at reducing the risk of physical fatigue and musculoskeletal injuries in the worker.

Position 1

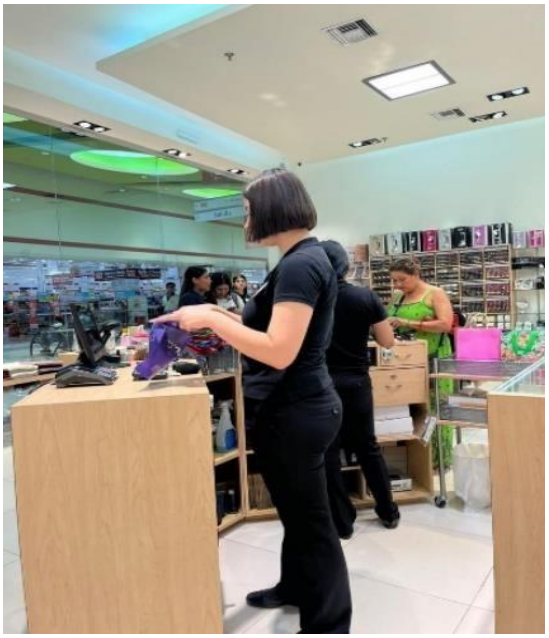


Figure 24. Posture 1 OWAS.

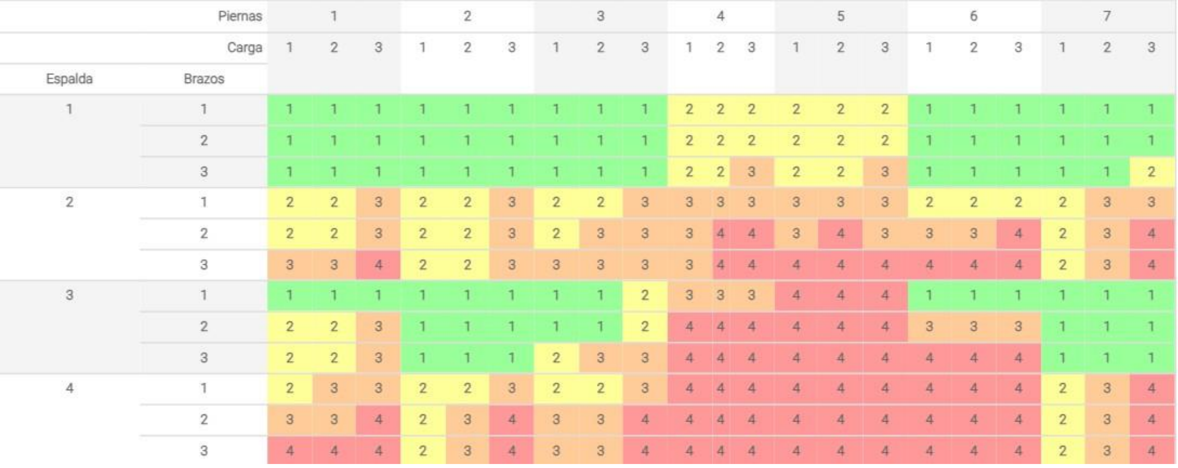
Table 4. Risk categories.

P1. Cash desk	**Back**	**Arms**	**Leg**	**Load**
Code	1	1	2	1
Posture	Straight back	Both arms below the shoulders.	Standing with both legs straight .	<10 kg
Risk	1	Normal posture No harmful effects on the musculoskeletal system.	No action required.	

Table 5. Actions required.

Category Risk	**Effect of posture**	**Action Required**
1	Normal, natural posture with no harmful effects on the muscular system skeletal.	No action required.
2	Posture with the possibility of causing damage to the musculoskeletal system.	Corrective actions are required in the near future.
3	Posture with harmful effects on the musculoskeletal system.	Corrective actions are required as soon as possible.
4	The burden caused by this posture has extremely harmful effects	Corrective action needs to be taken immediately

Table 6: Risk Categories by posture codes.



	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

In this posture he has a risk of 1 since his compound positions are shown by the OWAS method and says that he has a normal posture without damage to the musculoskeletal system and does not require action.

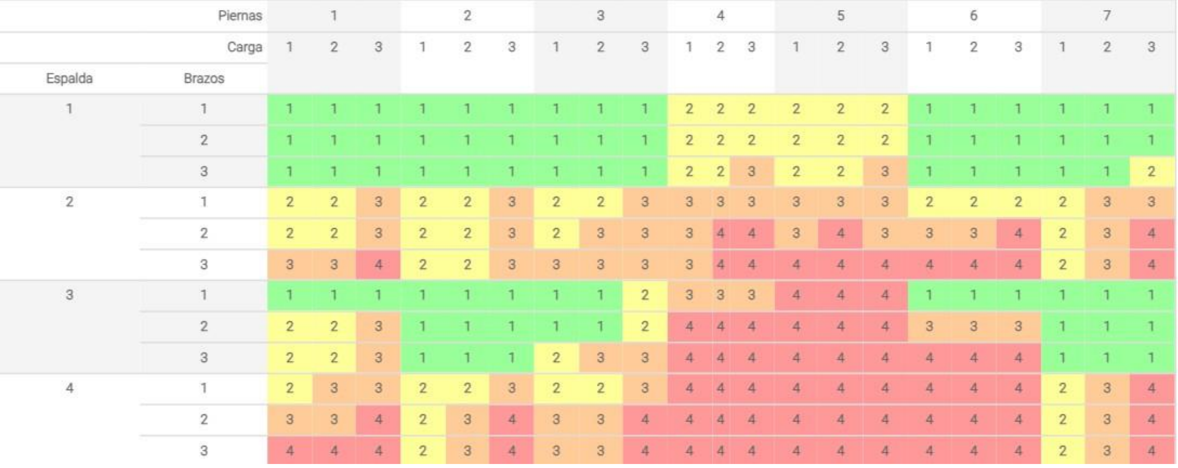
Position 2:

Figure 25. Position 2 OWAS.

Table 7. Risk categories.

P2. Taking merchandise.	**Back**	**Arms**	**Leg**	**Load**
Code	2	1	6	1
Posture	Folded back.	Both arms below the shoulders.	Kneeling.	<10 kg
Risk	2	Posture with the potential to cause damage to the system musculoskeletal	Corrective actions are required in the near future.	

Table 8: Risk Categories by posture codes.



	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

In this posture number 2 he has a risk of 2 since due to his compound positions shown by the OWAS method he says that he has a posture with the possibility of causing damage to the musculoskeletal system and corrective actions are required in the future due to his effort in the spade and legs.

Position 3:

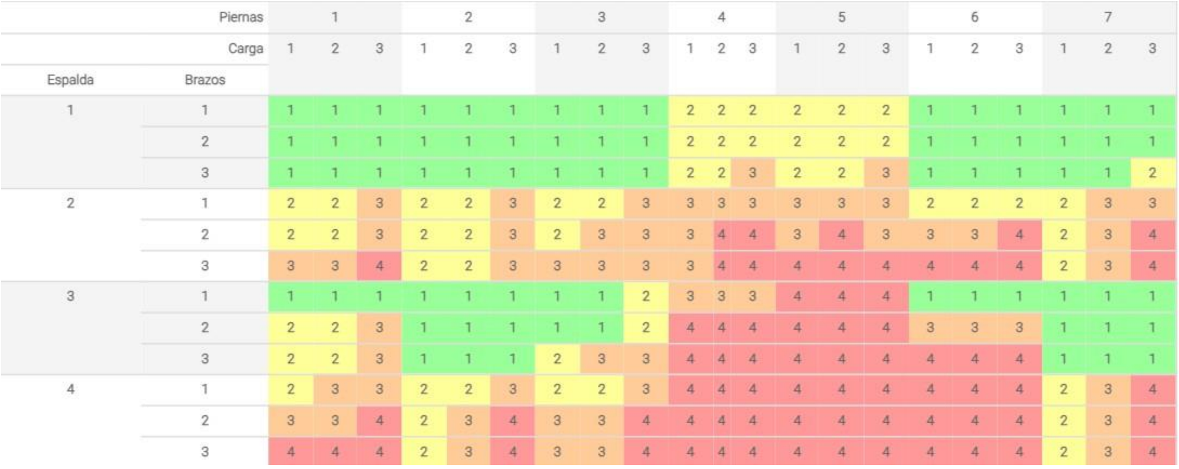
Figure 26. Position 3 OWAS.

Table 9. Risk categories.

P3. Placing merchandise	**Back**	**Arms**	**Leg**	**Load**
Code	1	1	2	1

Posture	Straight back	Both arms Below the shoulders.	Standing with both straight legs.	<10 kg
Risk	1	Normal posture No harmful effects on the ethical musculoskeletal system.	No action required.	

Table 10: Risk Categories by posture codes



	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

In this posture he has a risk of 1 since by his compound positions shown by the OWAS method he says that he has a normal posture without damage to the musculoskeletal system and does not require action.

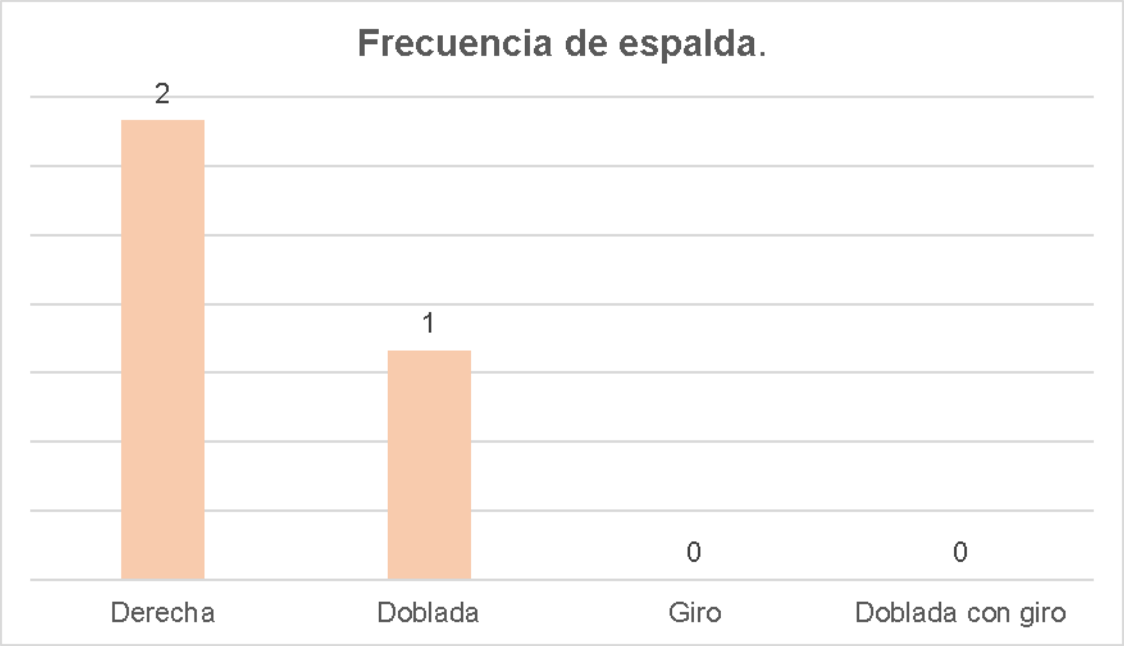


Figure 27. Back frequency.

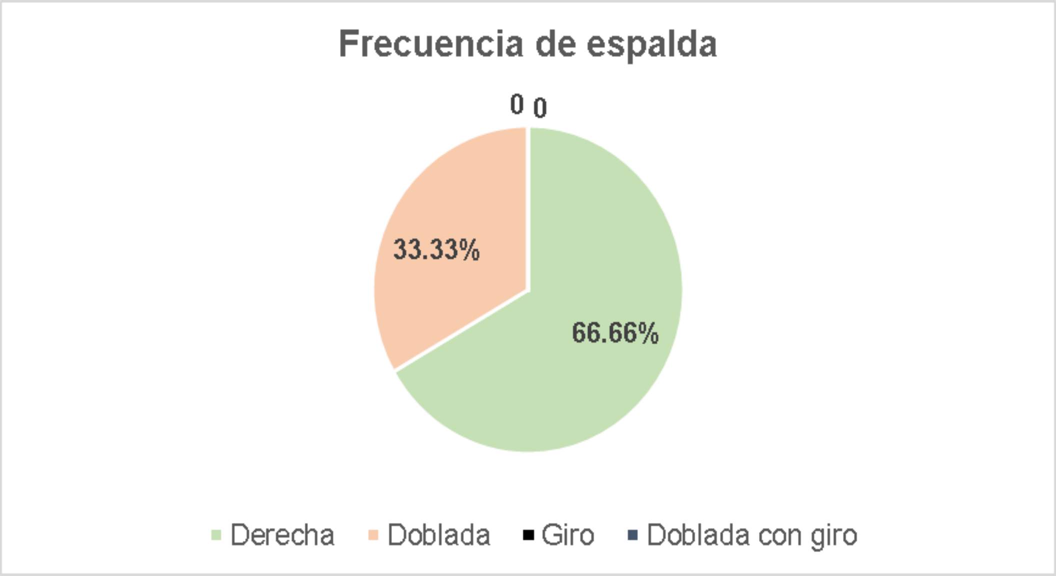
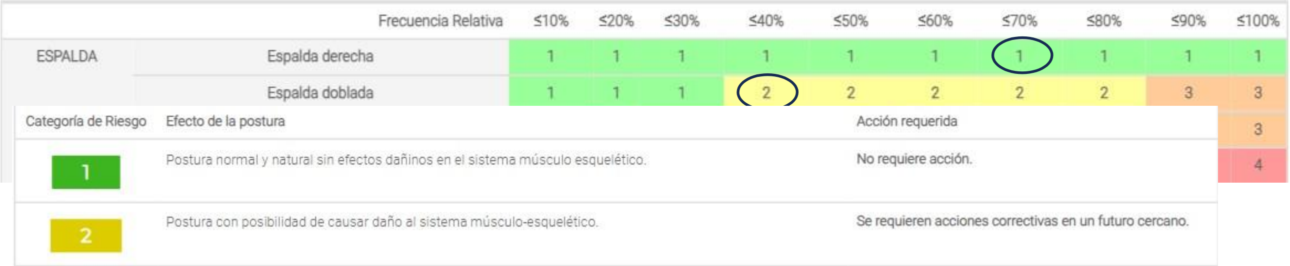


Figure 28. Back frequency.

Table 10. Risk category of body positions according to their relative frequency. Back.



	Frecuencia Relativa	≤10%	≤20%	≤30%	≤40%	≤50%	≤60%	≤70%	≤80%	≤90%	≤100%
ESPALDA	Espalda derecha	1	1	1	1	1	1	1	1	1	1
	Espalda doblada	1	1	1	2	2	2	2	2	3	3
											3
											4

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.

This frequency marks that most of the working hours are with the back straight, but this can also generate long-term damage, it should also be emphasized that in the bent back position corrective actions have to be taken in the near future.

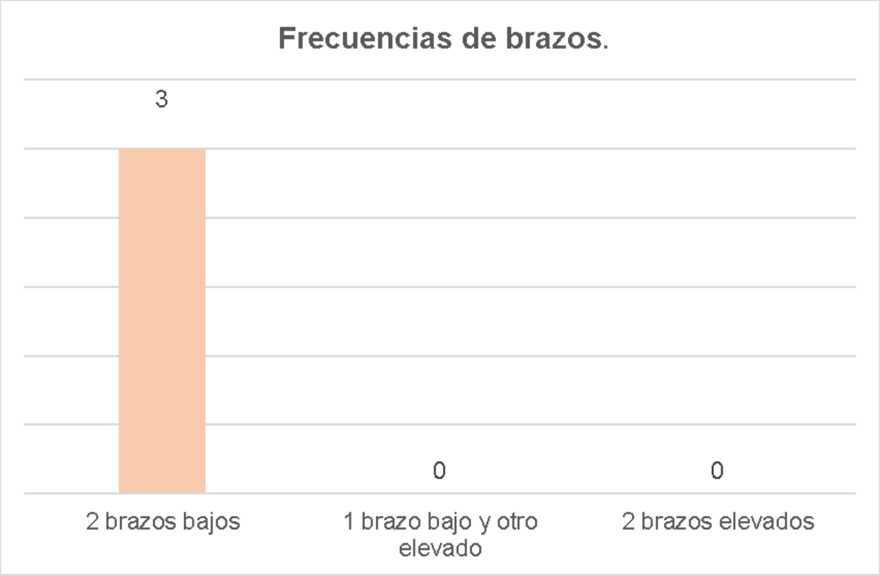


Figure 29. Arms frequencies.

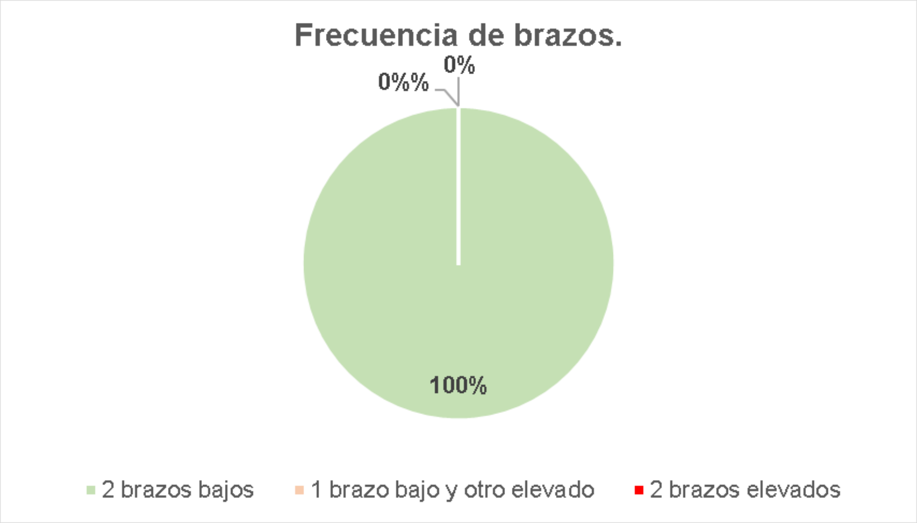
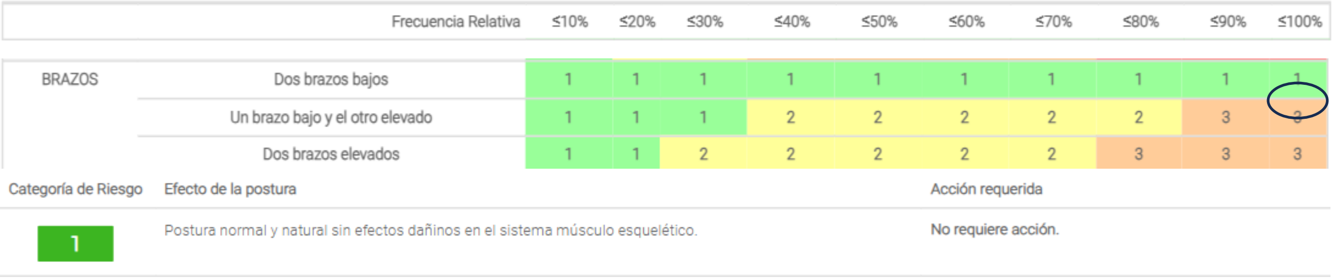


Figure 30. Arms frequencies.

Table 11. Risk category of body positions according to their relative frequency. Arms.



	Frecuencia Relativa	≤10%	≤20%	≤30%	≤40%	≤50%	≤60%	≤70%	≤80%	≤90%	≤100%
BRAZOS	Dos brazos bajos	1	1	1	1	1	1	1	1	1	1
	Un brazo bajo y el otro elevado	1	1	1	2	2	2	2	2	3	3
	Dos brazos elevados	1	1	2	2	2	2	2	3	3	3

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.

This frequency marks that most of the working hours he is with his arms under his shoulders and has a good posture of these.

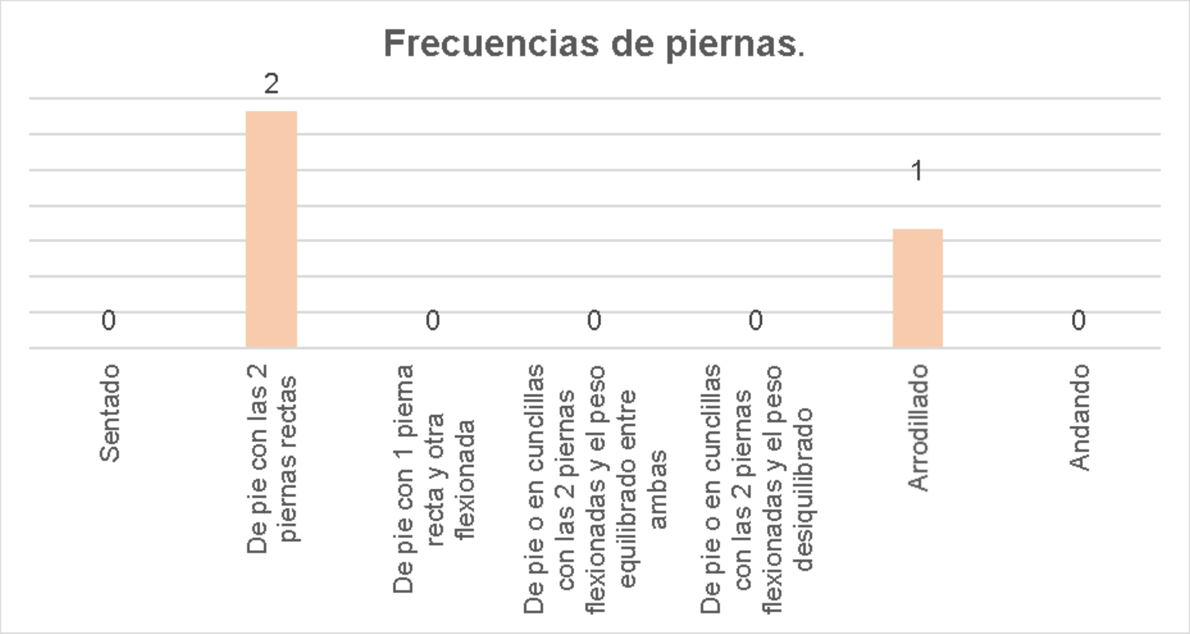


Figure 31. Legs frequencies.

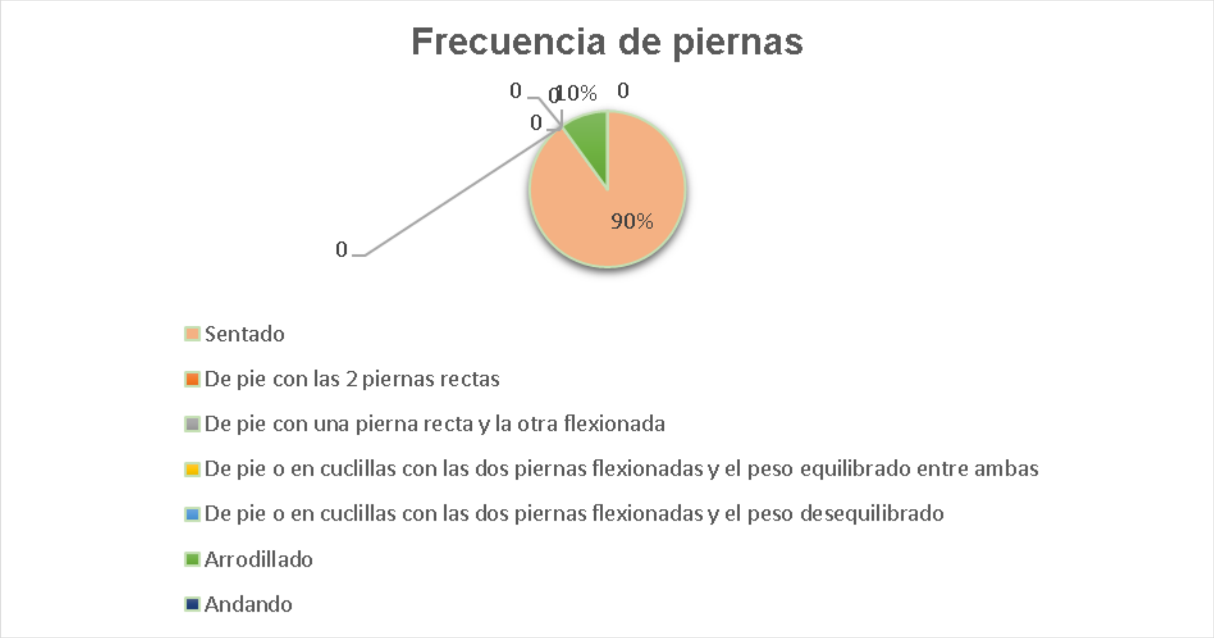
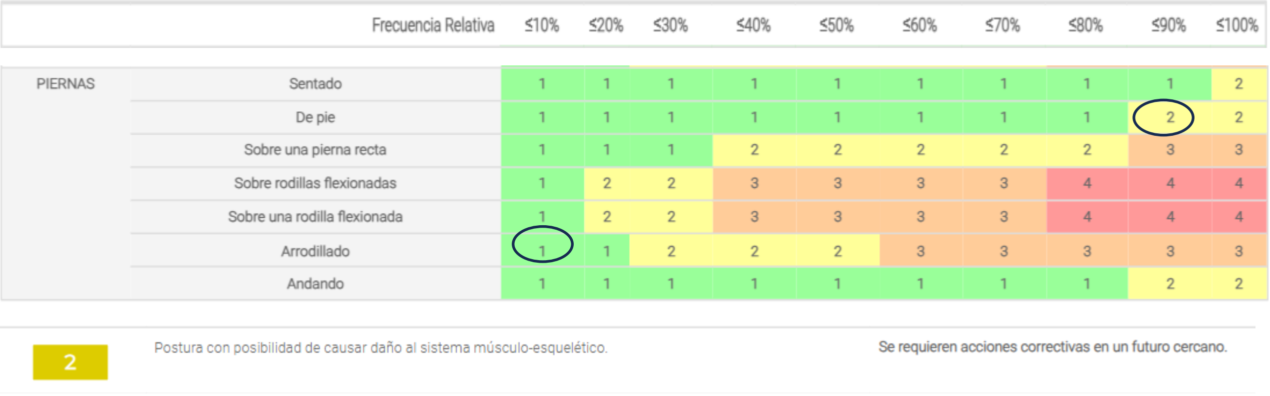


Figure 32. Legs frequencies.

Table 12. Risk category of body positions according to their relative frequency. Legs.



	Frecuencia Relativa	≤10%	≤20%	≤30%	≤40%	≤50%	≤60%	≤70%	≤80%	≤90%	≤100%
PIERNAS	Sentado	1	1	1	1	1	1	1	1	1	2
	De pie	1	1	1	1	1	1	1	1	2	2
	Sobre una pierna recta	1	1	1	2	2	2	2	2	3	3
	Sobre rodillas flexionadas	1	2	2	3	3	3	3	4	4	4
	Sobre una rodilla flexionada	1	2	2	3	3	3	3	4	4	4
	Arrodillado	1	1	2	2	2	3	3	3	3	3
	Andando	1	1	1	1	1	1	1	1	2	2

2	Postura con posibilidad de causar daño al sistema músculo-esquelético.	Se requieren acciones correctivas en un futuro cercano.

This frequency marks that most of the working hours are with the legs straight and little time kneeling, this marks that the position of right legs is more harmful than even kneeling, based on the frequency of their activities.

5. RESULTS

The results of RULA allowed us to identify high-risk postures which were located on the wrist, neck and trunk. Among the results obtained from the 3 postures evaluated by the RULA method, we have that postures 1 and 3 are at level 2 of the Performance Level table, which indicates that "changes may be required in the task and that it is advisable to deepen its study in search of improvements", Therefore, both postures need to be studied further in search of possible movements or positions that may generate a potential risk to the worker's musculoskeletal health and, if necessary, make changes in the activity for a better performance of the employee.

In posture 1, we realize that the parts of the body where there is a higher score, and that, therefore, we must pay more attention to them, are in the wrist, which has a flexion of 38° equivalent to 3 points and also has a medium wrist rotation so another point is added, giving a total of 4 points in this part of the body. The other area to highlight would be in the neck, since it has a flexion of 28°, which gives it a total of 3 points. Both parties require a more in-depth study to determine if a change in activity is necessary.

On the other hand, we have position 2 that is found at level 3 of the Table of Action Level, where it is established that "the redesign of the task is required". Therefore, a redesign of this activity is necessary to avoid or reduce possible damage to the physical health of the worker. Most of the scores of this posture express an imminent risk to health, and seem visually uncomfortable, within the parts of the body we can highlight the arm, wrist and trunk, all with a score of 3 within the standards established by the RULA method.

In general, the three postures evaluated are occasional and of short duration, in addition, their additional weight load is below 2kg, which indicates that the possibility of serious or permanent damage to the physical health of the worker is relatively low. On the other hand, the results in the level of performance of the activities, especially position 2, express that it is necessary to monitor work activities and should be corrected if possible, since they can generate fatigue and represent a potential risk to the employee's health in the long term.

Given the results, based on the OWAS method, this indicates that his postures are normal and natural with no harmful effects on the musculoskeletal system and do not require major action, but in posture number 2 he has a risk of 2 since due to his compound positions shown by the OWAS method he says that he has a posture with the possibility of causing damage to the musculoskeletal system and corrective actions are required in the future for his effort in the spade and legs. Based on weight, it was not a problem for the worker since 100% of the time she carries things less than 10 kg and did not require maximum effort.

A key point to emphasize is that it can be observed that in the long term standing for so long can damage the musculoskeletal system much more and in turn affect more than kneeling for a short time. It could be said that this work is not 100% recommended based on the OWAS method.

6. CONCLUSIONS

The application of the RULA and OWAS methodologies in the ergonomic assessment of the worker made it possible to effectively identify the postural risks associated with her work environment. Through these tools, it was possible to highlight critical areas that require intervention to prevent future musculoskeletal injuries and improve occupational health.

The RULA results identified high-risk postures, especially in the wrist, neck, and trunk. Postures 1 and 3, which are at level 2 of the Performance Level table, indicate the need for further study and possible adjustments to tasks to avoid health damage. In posture 1, flexion of 38° at the wrist and 28° at the neck are areas that require more attention. In posture 3, the 24° flexion in the neck stands out as an area of concern. Posture 2, on the other hand, is at level 3, suggesting the need to redesign the task due to the imminent risks identified, particularly in the arm, wrist, and trunk.

OWAS, on the other hand, offered a more global view, identifying not only dangerous postures, but also their cumulative impact throughout the working day. In general, the postures adopted by the shop assistants are normal and natural, with no significant harmful effects on the musculoskeletal system, except for posture 2, which presents a moderate risk and requires future corrective actions, especially due to the strain on the back and legs.

Although weight-bearing does not pose a significant risk, prolonged observation of static postures, such as standing for long periods, could, in the long term, cause damage to the musculoskeletal system. This suggests that although postures are not extremely dangerous in the short term, it is necessary to monitor and adjust working conditions to avoid long-term health problems.

Based on the results obtained, it is crucial to implement appropriate ergonomic interventions in the department store. This includes optimizing the design of the workstation, making use of adjustable stools and anti-fatigue mats, and continuing education on ergonomic practices among staff.

7. REFERENCES

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Comparison Using Electromyography in the Use of an Exoskeleton for Lifting Loads

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Resumen: El levantamiento de cargas, una actividad prevalente en múltiples industrias está asociado a un alto riesgo de trastornos musculoesqueléticos, particularmente en la región lumbar y las extremidades inferiores. Los exoesqueletos han sido propuestos como una solución innovadora para mitigar estos riesgos al proporcionar soporte estructural y reducir la carga física en tareas exigentes. Este estudio evalúa la efectividad de un exoesqueleto en la reducción de la carga muscular mediante electromiografía (EMG). Los resultados demuestran una reducción significativa en la activación muscular, lo que sugiere que el uso de exoesqueletos puede disminuir el riesgo de lesiones musculoesqueléticas y mejorar la ergonomía en entornos industriales.

Palabras clave: Exoesqueleto, EMG, Ergonomía, Levantamiento de cargas,

Relevancia para la ergonomía: Este artículo hace una contribución significativa a la ergonomía al proporcionar evidencia empírica sobre la efectividad de los exoesqueletos para reducir la carga muscular durante las tareas de levantamiento de carga, una actividad común y físicamente exigente en diversos sectores industriales. El estudio destaca el potencial de los exoesqueletos para mejorar la seguridad y la salud en el lugar de trabajo al mitigar una de las principales causas de trastornos musculoesqueléticos (TME) entre los trabajadores: el levantamiento de objetos pesados de forma repetitiva. Al demostrar una reducción sustancial en la activación muscular, particularmente en los cuádriceps, la investigación subraya los beneficios prácticos de la integración de exoesqueletos en entornos industriales como intervención ergonómica preventiva. El uso de electromiografía (EMG) para medir la actividad muscular ofrece una evaluación precisa y objetiva, lo que hace

que los hallazgos sean muy relevantes para investigadores y profesionales. Los resultados del estudio también podrían informar directrices y mejores prácticas para el despliegue de exoesqueletos, contribuyendo a entornos de trabajo más seguros y sostenibles.

Abstract: Load lifting, a prevalent activity in various industries, is associated with a high risk of musculoskeletal disorders, particularly in the lumbar region and lower extremities. Exoskeletons have been proposed as an innovative solution to mitigate these risks by providing structural support and reducing physical load in demanding tasks. This study evaluates the effectiveness of an exoskeleton in reducing muscle load using electromyography (EMG). The results demonstrate a significant reduction in muscle activation, suggesting that exoskeleton use may decrease the risk of musculoskeletal injuries and improve ergonomics in industrial settings.

Keywords: Exoskeleton, EMG, Ergonomics, Load Lifting

Relevance to Ergonomics: This article makes a significant contribution to ergonomics by providing empirical evidence on the effectiveness of exoskeletons in reducing muscle load during load-lifting tasks, a common and physically demanding activity in various industrial sectors. The study highlights the potential of exoskeletons to enhance workplace safety and health by mitigating one of the leading causes of musculoskeletal disorders (MSDs) among workers—repetitive heavy lifting. By demonstrating a substantial reduction in muscle activation, particularly in the quadriceps, the research underscores the practical benefits of integrating exoskeletons into industrial settings as a preventive ergonomic intervention. The use of electromyography (EMG) to measure muscle activity offers a precise and objective assessment, making the findings highly relevant for researchers and practitioners. The study's results could also inform guidelines and best practices for exoskeleton deployment, contributing to safer and more sustainable work environments.

1. INTRODUCTION

Load lifting is a fundamental and frequent activity across various industries, including but not limited to manufacturing, construction, and logistics. In these sectors, workers are routinely exposed to substantial physical loads, which, over time, can lead to the development of a range of musculoskeletal disorders (Botti & Melloni, 2024; Irawan et al., 2019; Pacifico et al., 2022). These disorders, such as lower back pain, shoulder strain, and joint injuries, are prevalent among workers who engage in repetitive and strenuous lifting tasks (Kinge et al., 2015; Mohd Nur et al., 2018; Theurel & Desbrosses, 2019a). The implications of these disorders are far-reaching, extending beyond the immediate discomfort and health issues faced by workers. They have a significant economic impact on both the individuals and the industries they serve, manifesting in decreased productivity, an increase in the number of sick days, and the subsequent costs associated with medical treatments and workers' compensation claims (Bevan, 2015; Fournier Daniel E. AND Yung, 2023; Haumaru Mahi, 2024).

In response to these challenges, the adoption of innovative technologies has become a focal point of interest. Among these, exoskeletons have been identified as a promising solution to mitigate the risks associated with heavy lifting (Alemi et al., 2019; Botti & Melloni, 2024; Li et al., 2021; Tadepalli et al., 2019). Exoskeletons are sophisticated, wearable devices designed to provide structural support to the body, thereby alleviating the physical strain experienced during demanding tasks. By redistributing the load and reducing the direct impact on key muscle groups, exoskeletons have the potential to enhance worker safety and well-being (Bao et al., 2019; Howard et al., 2020; Mohd Nur et al., 2018; Theurel & Desbrosses, 2019b),

However, despite the promising nature of these devices, their widespread adoption in the workplace requires rigorous, objective, and quantitative evaluations of their effectiveness. This is where electromyography (EMG) becomes invaluable. EMG is a crucial tool that measures the electrical activity of muscles during physical exertion, offering detailed insights into the muscle load and fatigue experienced by workers using exoskeletons (Lyu et al., 2019; Phinyomark et al., 2012; Raez et al., 2006). By leveraging EMG data, researchers can obtain a clear, evidence-based understanding of how exoskeletons impact muscle activity, enabling them to assess whether these devices genuinely reduce the risk of musculoskeletal disorders (Blanco et al., 2019). This study is therefore centered on exploring the effects of exoskeleton use on muscle load during load lifting activities, employing EMG measurements to ensure a thorough and scientifically robust evaluation.

2. OBJECTIVES

2.1 Evaluate the reduction of muscle load in workers using an exoskeleton during load lifting.

This objective focuses on measuring how the use of the exoskeleton influences muscle activity during load-lifting tasks. It is expected that the exoskeleton will provide significant support resulting in lower muscle activation, thereby reducing the risk of fatigue and injury.

2.2 Compare the levels of muscle activity, measured by EMG, in workers with and without the use of the exoskeleton.

Comparing EMG measurements under conditions with and without an exoskeleton will allow the establishment of quantitative differences in muscle load. This comparative analysis is crucial for understanding the extent of the exoskeleton's impact and validating its effectiveness as an ergonomic tool.

2.3 Determine the effectiveness of the exoskeleton in preventing musculoskeletal injuries in the long term.

While the focus of this study is on short-term muscle load analysis, it is important to consider the long-term implications of exoskeleton use. This objective involves a discussion of how the reduction in muscle load could translate into a decrease in the incidence of chronic musculoskeletal injuries.

3. METHODOLOGY

3.1 Participant Selection:

For this study, 3 workers from a manufacturing industry were recruited based on their experience in load-lifting tasks. Participants were informed about the study's purpose and provided with the necessary instructions for the tests. Inclusion and exclusion criteria were established to ensure group homogeneity and minimize external variables that could affect the results.

3.2 Instrumentation:

EMG data collection was carried out using surface electrodes placed on key muscles involved in load lifting, including the quadriceps and the gluteus maximus, and. These muscles were selected due to their relevance in the biomechanics of load lifting. EMG data were recorded using a high-precision data acquisition system, ensuring accurate capture of muscle electrical activity.

3.3 Procedure:

In this experiment, participants performed a series of standardized load-lifting tasks, both with and without the use of the exoskeleton. The lifting protocol was designed to replicate common workplace tasks where a load of 25 kg is lifting, ensuring the practical relevance of the results. The activity consisted of four repetitions of lifting and four repetitions of lowering a previously calculated weight, corresponding to each participant’s maximum load. Before each lifting session, a warm-up period was conducted to prevent injuries and ensure consistency in the measurements. Electromyography (EMG) sensors were placed on the participants' key muscles, recording electrical activity during each repetition, allowing for a detailed analysis of muscle response under maximum load conditions. The order in which participants performed tasks with and without the exoskeleton was randomized to control for potential learning or fatigue effects, thus ensuring the validity of the results obtained regarding muscle efficiency and effort during intense physical activities.

4. RESULTS

The results of the EMG analysis indicate a significant reduction in muscle activity among participants who used the exoskeleton, particularly in the quadriceps. This reduction is more pronounced during liftings, as it is in this phase where the quadriceps are primarily activated and maintain their activity throughout the execution of the cycles (Figure 1). Without the exoskeleton, the average maximum activation of the quadriceps during the lowering ranges from 544 to 652, whereas with the exoskeleton these values decrease to a range between 564 and 613, representing an average reduction of 9%. During the lifting, without the exoskeleton, activation values ranged from 542 to 641, but with the exoskeleton, they decrease to a range between 550 and 589, with a more significant reduction of 20%. The maximum values of the different muscles are shown in Table 1. These findings suggest that the exoskeleton provides effective support in situations of high physical demand, particularly during lifting, where muscle activation is more intense.

Figure 1 illustrates an example of the EMG signals from the quadriceps for a participant during load lifting with and without the exoskeleton, showing a clear decrease in the amplitude of the EMG signal when using the exoskeleton, confirming the observed reduction in muscle activation. The reduction in biomechanical load, especially during lifting, is consistent with the hypothesis that the exoskeleton decreases the muscular effort required to perform the task, which could have positive implications for reducing muscle fatigue and preventing injuries during repetitive or prolonged tasks. Although these results are promising, further studies are recommended to confirm these effects in the long term and to explore in greater depth the relationship between the reduction in muscle activity and the prevention of injuries. This analysis demonstrates that the exoskeleton is effective in reducing quadriceps muscle activation during load lifting, which could have positive implications for improving work efficiency and preserving musculoskeletal health.

Table 1. Maximum activation without and with the exoskeleton

Maximum activation					
Without exoskeleton		M1	M2	M3	M4
Lowering	Participant 1	697	717	545	541
	Participant 2	630	616	555	531
	Participant 3	605	623	562	561
	Average	644	652	554	544
Lifting	Participant 1	731	737	554	542
	Participant 2	573	576	544	527
	Participant 3	596	611	549	556
	Average	634	641	549	542
Maximum activation					
With exoskeleton		M1	M2	M3	M4
Lowering	Participant 1	630	616	555	531
	Participant 2	605	623	562	561

	Participant 3	605	601	601	601
	Average	613	613	573	564
Lifting	Participant 1	573	576	544	527
	Participant 2	596	611	549	556
	Participant 3	596	568	568	568
	Average	589	585	554	550

M1: left quadriceps, M2: right quadriceps, M3: left gluteus maximus, m4: right gluteus maximus. Muscle activation are showed in millivolts.

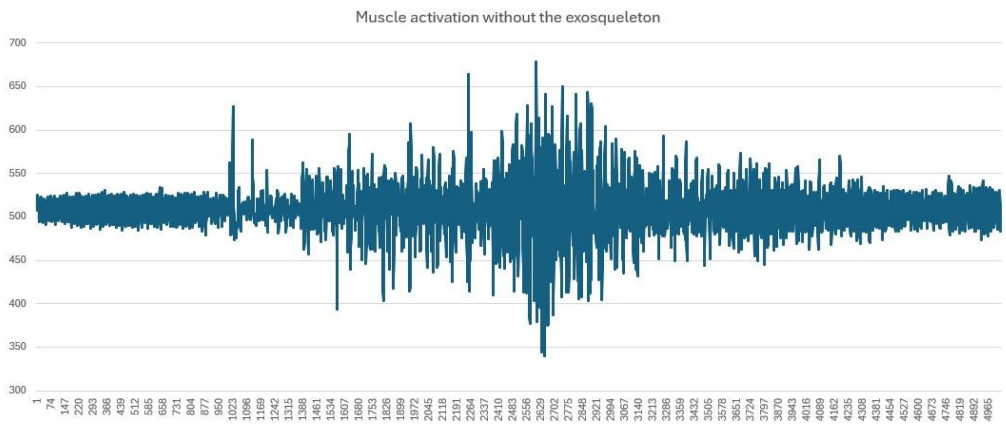

Figure 1. Muscle activation without the exoskeleton

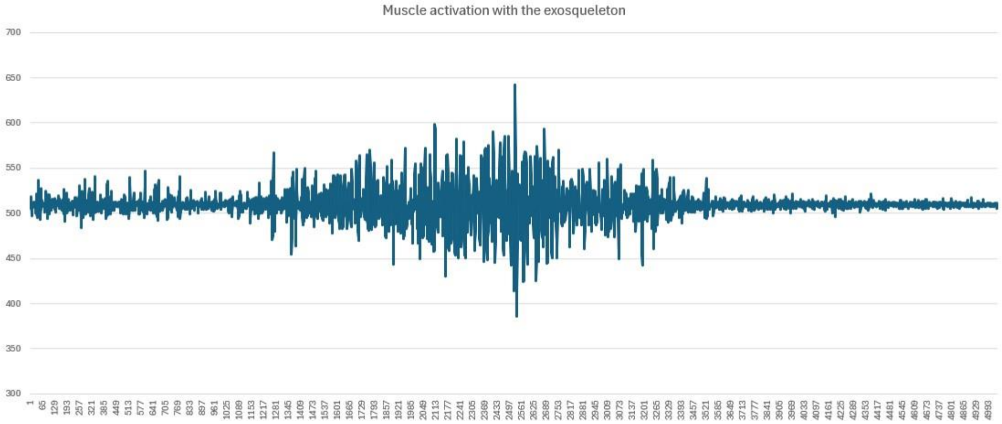

Figure 2. Muscle activation with the exoskeleton

5. DISCUSSION AND CONCLUSION

The findings of this study clearly demonstrate that the use of exoskeletons in load-lifting activities significantly reduces muscle activation, particularly in the quadriceps, as evidenced by EMG measurements. The observed reduction in muscle activity during both the lifting and lowering phases suggests that exoskeletons can effectively alleviate physical strain on workers, which is particularly beneficial in industries where repetitive lifting tasks are common. This reduction in muscle load not only enhances ergonomics but also potentially lowers the risk of musculoskeletal injuries over time, contributing to improved occupational health and safety.

The reduction in muscle activation by 9% during the lowering and up to 20% during the lifting highlights the exoskeleton's effectiveness in providing substantial support during physically demanding tasks. These results align with previous research suggesting that exoskeletons can redistribute load and reduce the direct impact on critical muscle groups, thereby mitigating the risk of fatigue and injury. The significant decrease in EMG signal amplitude when using the exoskeleton, as illustrated in Figure 1, further confirms its role in reducing the biomechanical load during load-lifting tasks.

However, this study is not without limitations. The small sample size of participants may limit the generalizability of the results. Additionally, the study focused on a specific type of exoskeleton and a limited range of load-lifting tasks, which may not fully represent the variety of conditions found in different industrial settings. Therefore, future research should include larger, more diverse participant groups and explore the effectiveness of different exoskeleton models across various industrial applications.

Moreover, while this study provides valuable insights into the short-term benefits of exoskeleton use, the long-term effects on muscle fatigue and overall occupational health remain to be fully understood. Future studies should investigate the impact of prolonged exoskeleton use, considering factors such as user comfort, adaptability to different tasks, and the potential for long-term reduction in injury rates

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EVALUATION OF NOISE LEVELS IN THE SHRIMP SPAWNING AREA OF AN AQUACULTURE COMPANY.

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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 that directly influences the health and performance of employees. According to the World Health Organization (WHO), prolonged exposure to high noise levels can cause irreversible hearing loss, as well as increase the risk of stress and cardiovascular disorders (WHO, 2021). In addition, the Occupational Safety and Health Administration (OSHA) highlights that excessive noise can reduce the ability to concentrate and increase the number of errors in the workplace (OSHA, 2020).

To conduct this study, acoustic measurements will be taken in different areas of the work environment, the main sources of noise will be identified, and the effects of these levels on employee productivity and well-being will be analyzed. The study is based on methodologies recommended by the Institute of Noise Control Engineering (INCE), which provide a structured approach for the assessment and mitigation of noise in work environments (INCE, 2019).

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 de-veining 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.

f) 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.

h) 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.

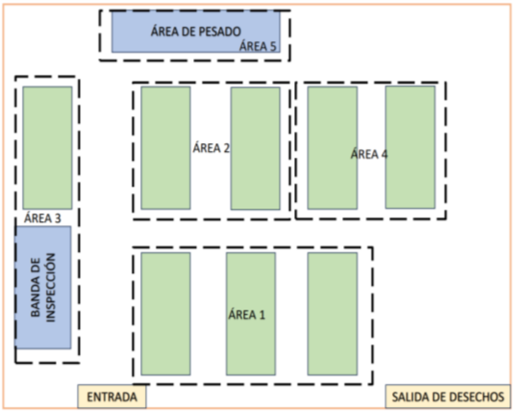


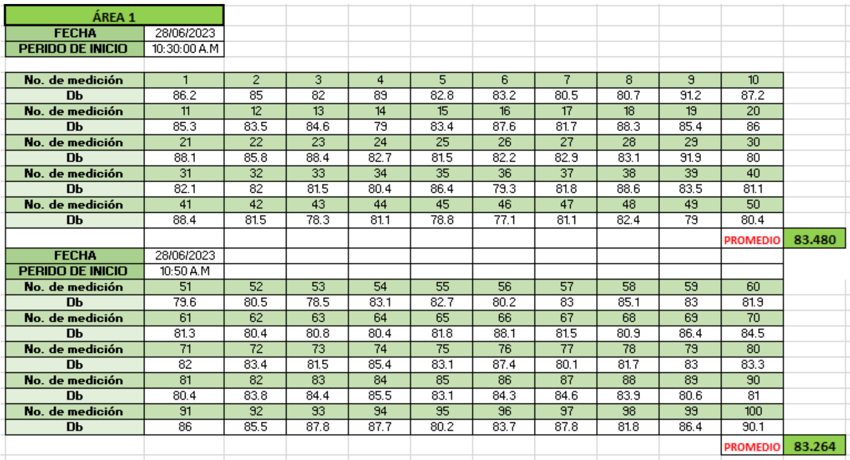
Figure 1. Sectioned area of decapitation

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

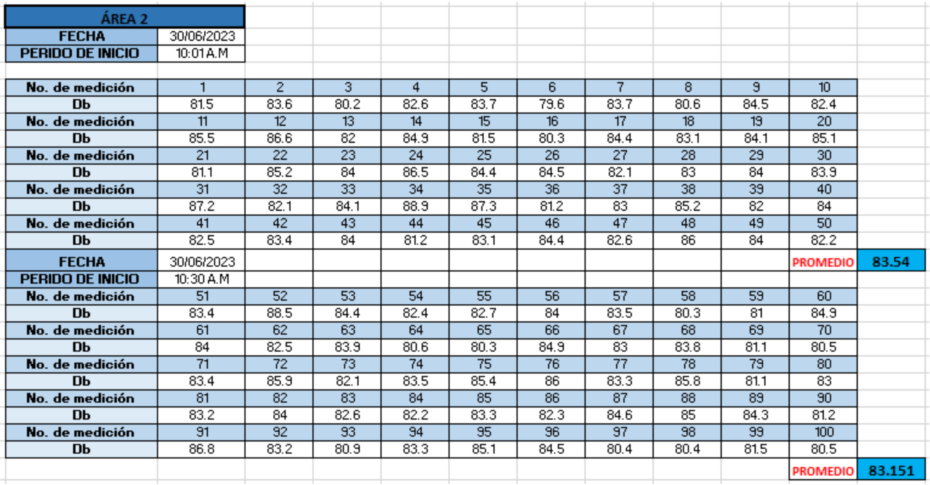


ÁREA 1											
FECHA	28/06/2023										
PERIDO DE INICIO	10:30:00 A.M										
No. de medición	1	2	3	4	5	6	7	8	9	10	
Db	86.2	85	82	89	82.8	83.2	80.5	80.7	91.2	87.2	
No. de medición	11	12	13	14	15	16	17	18	19	20	
Db	85.3	83.5	84.6	79	83.4	87.6	81.7	88.3	85.4	86	
No. de medición	21	22	23	24	25	26	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**

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

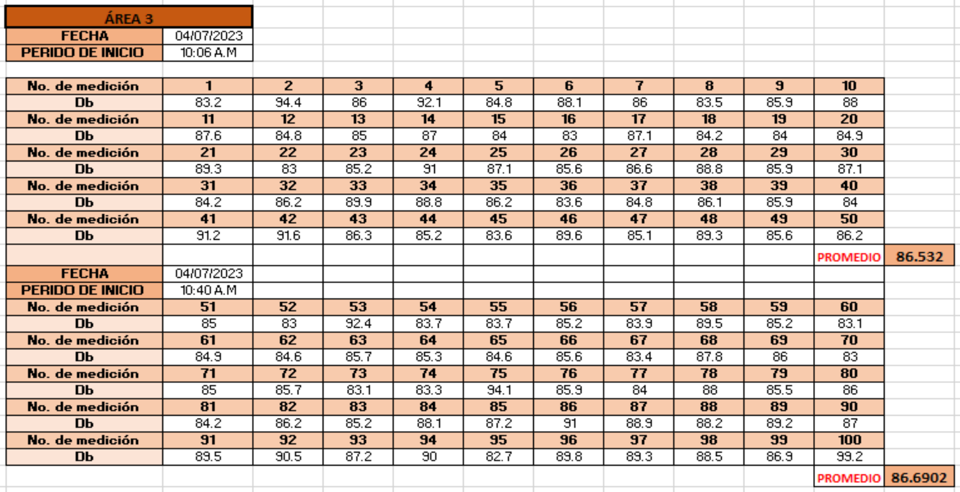
Table 2. Area 2 NSA sample record



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**

Figure 4. Area 2 shrimp de-scaling

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

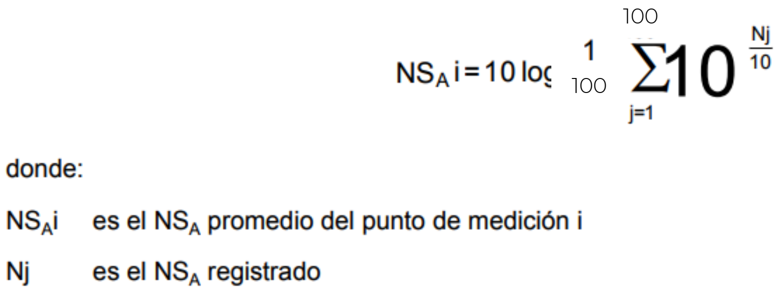
Figure 5 shows the samples taken in area 3, capturing the noise generated by one of the machines used by the company to inspect and fill the shrimp shrimp jars and then distribute them to the work tables.

Figure 5 sampling of work area 3

Figure 6 recording of NSA readings area 3

Average NSA calculation

The following formula was used to calculate the sound level:



$$NS_A i = 10 \log \frac{1}{100} \sum_{j=1}^{100} 10^{\frac{Nj}{10}}$$

donde:

$NS_A i$ es el NS_A promedio del punto de medición i

Nj es el NS_A registrado

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.

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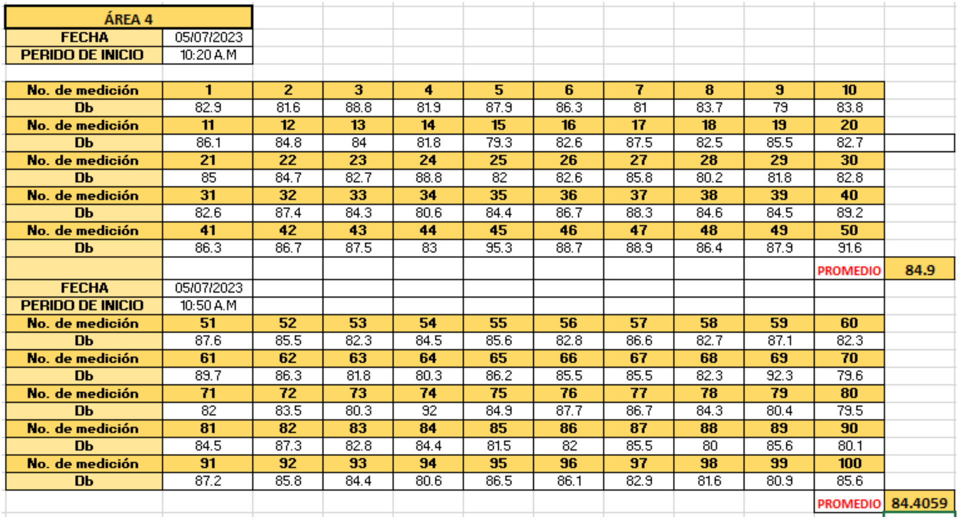
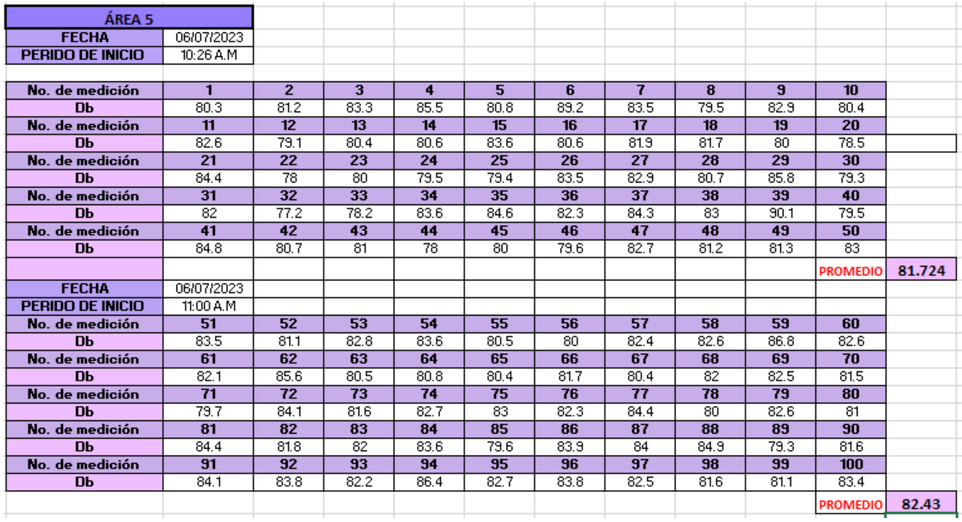
ANEXOS

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 DESIGN OF UNIVERSITY CLASSROOMS TO OPTIMIZE COMFORT AND REDUCE STUDENT FATIGUE AT UPVT

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Resumen Este trabajo se realizó con la finalidad de conocer los aspectos ergonómicos (postura, mobiliario, condiciones ambientales) que afectan la comodidad y fatiga de los estudiantes en el aula de la Universidad Politécnica del Valle de Toluca (UPVT). Se encontró lo siguiente: para los estudiantes la incomodidad, se manifiesto, específicamente en el material del asiento, la forma y el material del respaldar. Los resultados ameritan considerar nuevas aulas con diseño ergonómico ajustable a las dimensiones antropométricas de la población docente y estudiantil de nuestra máxima casa de estudios.

Palabras clave: Antropometría, comodidad, diseño ergonómico, fatiga.

Relevancia para la ergonomía: Es tan importante la investigación ergonómica que se hizo a través de este proyecto ya que proporciona las herramientas necesarias para minimizar los riesgos por una mala postura en el estudiante y así maximizar su eficiencia productiva.

Abstract This work was carried out with the purpose of knowing the ergonomic aspects (posture, furniture, environmental conditions) that affect the comfort and fatigue of students in the Universidad Politécnica del Valle de Toluca UPVT classroom. The following was found: for the students, the discomfort was manifested, specifically in the material of the seat, the shape, and the material of the backrest. The results warrant considering new classrooms with ergonomic designs adjustable to the anthropometric dimensions of the teaching and student population of our highest house of studies.

Keywords. Anthropometry, comfort, ergonomic design, fatigue.

1.

Relevance to Ergonomics: The ergonomic research that was done through this project is so important since it provides the necessary tools to minimize the risks of poor posture in the student and thus maximize their productive efficiency.

1. INTRODUCTION

This research work was carried out to provide favorable working conditions at the UPVT (Polytechnic University of the Valley of Toluca), where comfort can help the teacher and the student improve the teaching-learning process and their quality of life. The search for resistant and good-looking furniture and even the use of technology has led to the design of furniture that meets these demands and not the anthropometric measurements of the users and the functionality for the execution of their task in this maximum house of studies, causing forced postures, musculoskeletal disorders, stress and fatigue in its users.

2. GENERAL OBJECTIVE

Propose ergonomic conditions in the design of the classroom at the UPVT, to provide comfort to teachers and students, and reduce fatigue due to poor posture.

2.1 SPECIFIC OBJECTIVES

- Study and analyze ergonomic aspects in the classroom, which influence to provide comfort to students and reduce fatigue.
- Develop anthropometric measurements of a group of students, to find out if these measurements are related to the existing workspace.

3. METHODOLOGY

This research project that is presented uses an experimental method, the descriptive and explanatory method was also applied in our research project. In this sense, the causes perceived by the students as those that generate discomfort and fatigue are determined and it is explained if these are relevant to consider them within the design of the classroom, likewise, information is collected on the anthropometric measurements of students and contrasted with the measurements of the furniture in order to determine if these are related to the measurements of their users or not and if necessary make the recommendations relevant to improve their comfort and well-being in the classroom, for a better performance in this case study. The ergonomic aspects that have most influenced the discomfort of students in the university classroom are the standing and inclined posture, the measurements of the classroom furniture are not related to the anthropometric measurements of teachers and students.

Material: Scale, Anthropometer, Tape Measure. We start by taking the aforementioned bibliography as support, identify all the measures to be carried out and prepare a table to represent these data.

Figure 1. Anthropometric Measurement

Different measurements were then taken, which generated quantitative data to know the variation between measurements that exists between one and the other, these measurements were the following: Skinfold, Tricipital, Suprailiac, Abdominal, Weight, Height, Knee height, Body mass index, Abdominal circumference, Arm circumference.

For this study, 5 people (students of the University) were considered and the precentiles that the measurements yield were generated: sitting and standing based on the anatomy of the people chosen as a sample in this case study.

4. RESULTS

The information in the following tables was obtained by measuring 6 people, these measurements were taken in different positions (sitting and standing), the results are shown in the following table.

Table 1. Table of Anthropometric Measurements

	Person1	Person2	Person3
Body weight	55	62	61
Body height	1.66	1.54	1.71
Eye height	1.57	1.43	1.62
Height to shoulder	1.38	1.21	1.41
Height to shoulder	1.05	1.11	1.15
Height to hip	97	99	98

Height to buttock	88	90	88
Height to the wrist	82	86	70

5. CONCLUDED

El furniture in the university classroom must be able to be regulated or adpted to satisfy the different measurements of the users and prevent them from adopting forcerd postures. To relieve foot pain in teachers,it is recommended to place,on the platform where it is located, a rug or other material that cushions the tension when walking and gives comfort to the feet, in addition to being a thermal insulator that provides greater warmth than floors. hard like cement, not to mention that this gives the sensation of feeling comfortable.

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BEST PRACTICES OF TOP MANAGEMENT LEADERSHIP AND WORKERS' PARTICIPATION FOR ERGONOMICS MANAGEMENT IN SUPPLY CHAINS

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Resumen: La evaluación de la Gestión de Ergonomía (GE) en la Cadena de Suministro (CS) es un proceso en desarrollo, ya que existe la necesidad de evaluarla de forma integral y holísticamente. Es por ello, que las prácticas de liderazgo de la alta dirección y la participación de los trabajadores (PLYPT) es un constructo que juega un papel clave en este proceso. Tales prácticas han sido reconocidas en la literatura, ya que a través de la implementación de ellas se obtienen mejoras en la eficiencia y productividad, así como en la prevención y evaluación de riesgos ergonómicos. Esta investigación tiene como objetivo determinar las mejores PLYPT para la GE. Para ello, se desarrolló una revisión de literatura, posteriormente se diseñó un cuestionario digital con preguntas cerradas de escala Likert de 5 puntos (1-5), donde 1 = Totalmente en desacuerdo y 5 = Totalmente de acuerdo respecto al grado de acuerdo con las PLYPT en la CS para la GE. Se utilizó una muestra por conveniencia de expertos de Latinoamérica y se desarrolló un análisis descriptivo por medio de la obtención de las medianas y rangos intercuartílicos por ítem. Como resultados se diseñó y aplicó de manera electrónica un instrumento integrado por 17 ítems que miden cuatro dimensiones: 1) Liderazgo y compromiso, 2) Política de Ergonomía, 3) Roles, responsabilidades y autoridades en la organización, y 4) Consulta y participación de los trabajadores. El análisis descriptivo se realizó considerando la respuesta de 34 expertos. Las medianas más altas con menores rangos intercuartílicos determinan un alto grado de acuerdo con la aplicación de ciertas prácticas para la gestión de ergonomía, encontrándose que la mayoría de éstas están centradas en el actuar de la alta dirección. Entre las mejores prácticas se encuentran: el liderazgo y compromiso de la alta dirección al asumir la total responsabilidad de la prevención de lesiones, el deterioro de la salud, la rendición de cuentas, así como la provisión de actividades y lugares de trabajo seguro y saludables. Además de establecer la política y objetivos de ergonomía, apoyar la conformación de la comisión de seguridad e higiene y garantizar la disponibilidad de los recursos necesarios. Otra de ellas está relacionada con implementar y mantener una política de ergonomía documentada, comunicada y pertinente que incluya el compromiso de cumplir los requerimientos legales, así como eliminar o reducir los riesgos ergonómicos. Sin olvidar la promoción de los medios e invitar a los trabajadores a informar sobre incidentes, peligros, riesgos y oportunidades con libertad y confianza. Así, estas prácticas deben promoverse, implementarse y evaluarse de una manera efectiva en la GE en la CS. El instrumento diseñado y las dimensiones propuestas pueden considerarse pertinentes para la evaluación de estas prácticas en la industria.

Palabras clave: Gestión de Ergonomía, Cadena de suministro, Liderazgo de la alta dirección y participación de los trabajadores.

Relevancia para la ergonomía: Esta investigación contribuye a la caracterización de las prácticas en liderazgo de la alta dirección y participación de los trabajadores en la cadena de suministro para la gestión de ergonomía.

Abstract: Evaluating of Ergonomics Management (EM) in the Supply Chain (SC) is a developing process that must be conducted comprehensively and holistically. That is why top management leadership practices and worker participation (TML&WPPs) is a construct that play a crucial role in this process. Such practices have been recognized in the literature since, through their implementation, significant improvements in efficiency and productivity are obtained, as well as in the prevention and evaluation of ergonomic risks. This research aims to determine the best TML&WPPs for EM. A literature review was created for this purpose. After that, a digital instrument was created with closed-ended, 5-point Likert scale questions (1–5) regarding the degree of agreement with the TML&WPPs in SC for EM. 1 represents strongly disagree, and 5 represents strongly agree. Finding each item's median and interquartile ranges was the first step in performing a descriptive analysis on a convenience sample of Latin American experts. As a result, an instrument composed of seventeen items measuring four dimensions was designed and applied electronically: 1) leadership and commitment; 2) ergonomics policy; 3) roles, responsibilities, and authorities in the organization; and 4) consultation and participation of workers. The descriptive analysis was performed considering the responses of thirty-four experts. The highest medians with lower interquartile ranges determine a high degree of agreement with the relevance of the practice, identifying that most of these are centered on the actions of top management. Among the best practices are the leadership and commitment of top management to take full responsibility for injury prevention, health impairment, accountability, and the provision of safe and healthy workplaces and activities, in addition to establishing the ergonomics policy and objectives, supporting the formation of the health and safety committee, and ensuring the availability of the necessary resources. Another is related to implementing and maintaining a documented, communicated, and relevant ergonomics policy that includes the commitment to comply with legal requirements and eliminate or reduce ergonomic risks. It also promotes the means and invites workers to report incidents, hazards, risks, and opportunities freely and confidently. Thus, these practices should be promoted, implemented, and evaluated effectively in the SC. Therefore, the instrument designed, and the proposed dimensions can be considered pertinent for the evaluate these practices in the industry.

Keywords. Ergonomics Management, Supply Chain, Practices of top management leadership and worker participation

Relevance to Ergonomics: This research characterizes top management leadership and worker participation practices in the supply chain for ergonomics management.

1. INTRODUCTION

Organizations are adopting sustainable practices (Rocha et al., 2018) to contribute to the supply chain's (SC) profitability and eliminate or reduce negative impacts on environmental and social aspects. In this aspect, there is evidence suggesting that ergonomics management is a crucial aspect of achieving sustainability (Tortorella et al., 2017; Costa et al., 2018) since in these work systems, the leading actor is the human factor (Paillé y Boiral, 2013; Serdarasan, 2013). Thus, Ergonomics Management (EM) finds its most significant contribution to this purpose due to the need to perform comprehensive Ergonomics studies throughout the SC and propose a global assessment of all links through a holistic vision (Perttula, 2011). Therefore, it is essential to evaluate the ergonomic aspects inherent to the working conditions using an adequate ergonomics program and an ergonomics management system (EMS) that provides an assessment of good practices and requirements of EM in SC (Rodríguez-Gámez et al., 2023).

These considerations and the literature recognize top management leadership practices and worker participation as fundamental elements of EMS design (Rodríguez-Gámez et al., 2023); both elements contribute significantly to the success of ergonomic programs management and health and safety management (Rodríguez-Gámez et al., 2023; Hoque & Shahinuzzaman, 2021; Sadegh Amalnick & Zarrin, 2017; ISO, 2018; Shekari, 2020) and can have a positive impact on employee health, safety, and productivity. So, it is expected that TML&WPPs will be present on the SC links for ergonomics management. This research aims to identify the most significant practices in top manager leadership and workers' participation in the SC for this purpose.

1.1 Conceptual Development

One of the critical concepts of this research is Ergonomics Management (EM), which needs a more widely accepted definition in the literature. However, antecedents of the vision of continuous improvement and quality management applied to EM were found to build this concept. For example, Rowan & Wright (1994) established that EM is a complex and continuous process that should be integral to corporate strategy and culture. These authors further suggest that companies adopting a total quality management philosophy are well-positioned to adopt effective ergonomic management. In addition, management commitment, in attitude and resource allocation, is critical to the ergonomic management process. Thus, the human factors professional must have the support of those with the power and influence to bring about the required change. However, a cost-benefit analysis is crucial to lend credibility to the arguments in favor of implementing the ergonomic process and EM (Khon & Friend, 1993). They also state that EM requires the involvement and participation of all departments and all levels of employees. Awareness of ergonomic principles must permeate the entire organization. Each employee should feel comfortable pointing out ergonomic problems or indicators of problems affecting his or her work area since the employees most directly involved in the work often have the best ideas. Thus, the importance of leadership and employee participation in EM is recognized. Currently, Rodríguez-Gámez et al., 2024) define EM as the set of procedures and actions aimed at identifying ergonomic risk factors, planning and executing an ergonomics program, establishing risk and hazard control through good practices, as well as setting objectives to reduce or eliminate them in man-machine systems and work environments.

In the background and the new trends of the EM concept, even management systems governed by international standards such as ISO recognize that the construct of top management leadership and worker participation is a critical element of the model since the success of the management system depends on this, as ISO 45001 confirms in the particular case of safety and occasional health (ISO 45001, 2018).

The concepts and some of the practices that make up this construct are addressed below under the view of Sorensen et al. (2018), which states that leadership makes worker safety, health, and well-being a clear organizational priority. It drives accountability and provides the resources and environment necessary to create favorable working conditions. These authors recognize that top management is responsible for setting the priorities that define worker and workplace safety and health as part of the organization's vision and mission. Worker participation at all levels of an organization, including unions or other workers' organizations if present, helps to plan and conduct efforts to protect and promote safety and health. Many organizations have mechanisms to involve employees and managers in decision-making and planning. These mechanisms can be used to plan and implement policies and programs. Employee participation in decision-making facilitates a broader organizational health, safety, and well-being culture. Participation also includes encouraging employees to identify and report health and safety threats without fear of retaliation and expecting their concerns to be addressed.

Consequently, both, top management leadership and worker participation have historically been important to EM, so good practices must be defined, promoted, implemented, and evaluated to meet organizational and SC objectives regarding occupational health and safety.

2. OBJECTIVE

This research aims to determine the best practices of top management leadership and worker participation in the supply chain for ergonomics management.

3. DELIMITATIONS

As a delimitation, this research obtained a convenience sample of experts in the fields of ergonomics, occupational health and safety, management systems, and logistics will be studied.

4. METHODOLOGY

This research is a cross-sectional, non-experimental study with a convenience sample of experts. A four-phase methodology, shown in Figure 1, was considered:

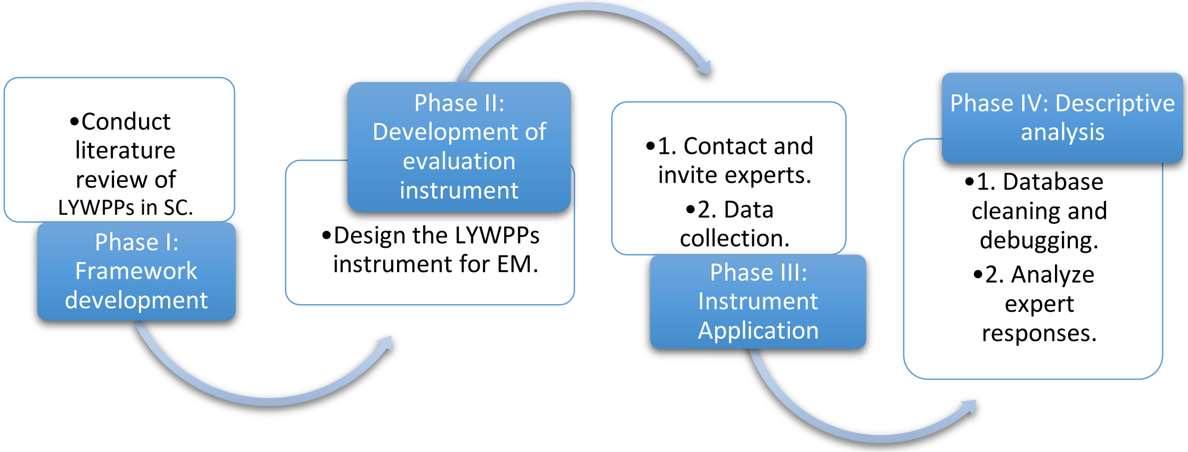

Figure 1. Phases of Methodology used in the research.

4.1 Phase I. Framework development

In this first phase, the theoretical framework was developed, obtained through a systematic literature review (SLR) to propose the dimensions and items that would evaluate leadership practices and worker participation in the supply chain. The PRISMA Statement (Liberati et al., 2009) can be consulted on their website: http://www.prismastatement.org/. Figure 2 shows the five stages that governed this process.

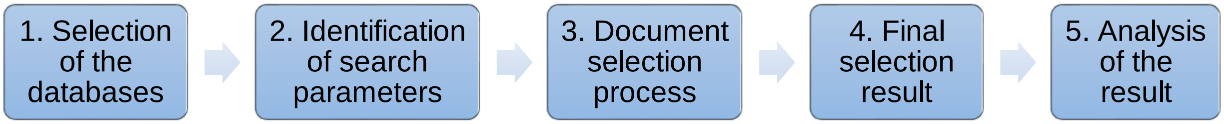

Figure 2. Overview of the approach used in the literature review.

4.2 Phase II. Development of evaluation instrument

For the design of the instrument, the aspects proposed by Hague (2006) and Arribas (2004) were considered, where first, the dimensions of the construct or aspects to be measured were determined, directly related to the research objectives and the information obtained from the literature review. Subsequently, the questionnaire's content, scope, and target population were established. A list of items to be evaluated for each dimension was drawn up, considering the type of question, either open or closed as appropriate, the measurement scale for each, and the coding of the responses (dichotomous, polychotomous, or analogical). The overall design of the instrument was finished once the questions had been defined or formulated and placed accordingly.

Finally, a content review of the instrument was conducted by six experts, as well as a pilot test, and the questions were redefined or eliminated based on the comments of these experts, resulting in a final version of the instrument. Once the design was completed, the form was developed in the online application Jotform®, for which all the sections included in the instrument were represented: 1) Cover page; 2) Introduction; 3) Informed consent; 4) Instructions; and 5) Content. This last section comprises two sections: the sociodemographic data of the expert, the top management leadership, and the workers' participation practices.

4.3 Phase III: Instrument application

This phase began with the invitation to experts to answer the digital instrument to establish the relevance of the leadership and participation practices of workers in SC for EM. Three invitation strategies were used: 1) sending emails to research network contacts, 2) promotion in international forums and congresses, and 3) through the LinkedIn platform. Those who chose to participate were given the evaluation instrument via a link provided by the Jotform® platform, distributed through email, WhatsApp, and social network chats.

4.4 Phase IV: Descriptive analysis

This phase used the SPSS 23® software. The data were explored as part of the cleaning process, which consists of identifying capture errors, extreme values, inadequate behavior, missing data, and unexpected variability. For the descriptive analysis, the median, quartiles, and interquartile range were used as description measures.

5. RESULTS

5.1 Phase 1. Framework development

The search was carried out in the ScienceDirect, ProQuest, and SpringerLink databases, which are the most widely used in the fields of engineering, supply chain, safety, and ergonomics (Rodríguez-Gámez et al., 2023). For this purpose, the search period was established from 2005 to 2022. In addition, the search focused on scientific articles that included keywords in their title and content, using logical operators to refine the search. These parameters are shown in Figure 3

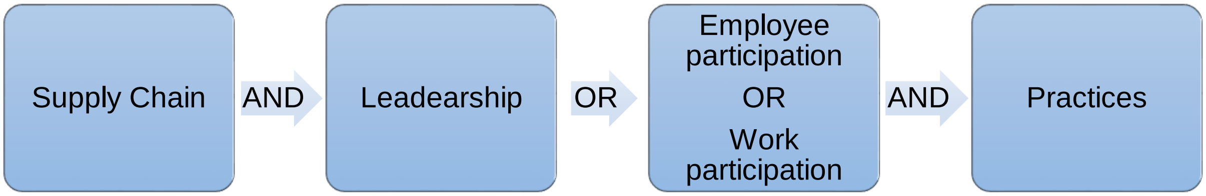

Figure 3. Relationship of keywords and logical operators used in the review.

After a thorough search, we identified 324 articles related to the specified keywords. Additionally, we found five documents from various other sources, including articles, theses, standards, and guides, bringing the total number of papers to 329. Subsequently, we applied inclusion and exclusion criteria to filter the papers.

Inclusion criteria:

1. The paper is published in a scientific journal.
2. The paper is available in English or Spanish.
3. The paper defines the concept of leadership or worker participation.
4. The paper addresses leadership or worker participation practices in the supply chain.

Exclusion criteria:

1. Duplicate papers.
2. Papers include conference posters, abstracts, short articles, and unpublished papers.

3. Articles that do not address SC or TML&WPPs.

Thirty-two documents were found to satisfy the inclusion criteria concerning worker participation and top management leadership. Table 1 shows the final selection of papers.

Table 1. The final selection of papers

Year	**Reference**	**Construct**	
		Leadership	**Work Participation**
2005	(Polanyi et al., 2005)	**X**	
2007	(Sutarjo, 2007)	**X**	
2009	(Mehrjerdi, 2009)	**X**	
	(ILO, 2009)		**X**
2010	(Closs et al., 2010)		
2012	(Hasle & Jensen, 2012)		**X**
2013	(Figueras, 2013)		**X**
	(Grillo Canelo, 2013)		**X**
2014	(Chiang-Vega et al., 2014)	**X**	
	(Bolis et al., 2014)	**X**	**X**
	(Mahmoudi et al., 2014)	**X**	
2015	(Yazdani et al., 2015)	**X**	
	(Hossain et al., 2015)	**X**	
	(Yorio et al., 2015)	**X**	
	(Samad, 2015)	**X**	
	(Fernandes et al., 2015)		**X**
2016	(Pilbeam et al., 2016)	**X**	
	(Sienkiewicz-Malyjurek, 2016)	**X**	
	(Hedlund et al., 2016)		**X**
2017	(Verma & Chaudhari, 2017)	**X**	

2018	(ISO 45001, 2018).	**X**	**X**
	(Sorensen et al., 2018)	**X**	
	(Prasad et al., 2018)	**X**	
	(Zeinalnezhad et al., 2018)	**X**	
2019	(Campailla et al., 2019)	**X**	**X**
	(Bayram & Üniversitesi İşletme Fakültesi Esentepe Kampüsü, 2019)		**X**
2020	(Yanar et al., 2020)	**X**	
	(Rodríguez-Ruíz et al., 2020)		**X**
2021	(Hoque & Shahinuzzaman, 2021)		**X**
	(Khalid et al., 2021)	**X**	**X**
	(García-Aranda et al., 2021)	**X**	
	(Markowski et al., 2021)	**X**	

These documents are evidence of the growing interest in the topic and the opportunity to address and study these aspects in greater detail in SC, ergonomics management, and even in the distinct types of management systems. On the other hand, the relevance of the topics of interest on the part of the authors is reflected in the thirty-two documents, since 68.75% addressed the topic of leadership, while 40.62% addressed the participation of workers. Thus, leadership is a practice of greater relevance for the authors.

5.2 Phase 2. Development of evaluation instrument

The dimensions were established based on the content of the literature, where four were determined: 1) Leadership and commitment, 2) Policy, 3) Organization roles, responsibilities, and authorities, and 4) Consultation and participation of workers, since these facilitated the grouping of the different TML&WPPs. It is important to note that considering these dimensions of the leadership and worker participation construct is based on adopting the ISO 45001 standard as a significant structural element, as proposed by Rodríguez-Gámez et al. (2023). This standard plays a crucial role in the development of the EMS, providing a comprehensive framework for environmental management. Furthermore, ergonomics is closely related to health and safety management systems, as both focus on risk analysis from their respective scopes of action. It is important to remember that, within its regulatory framework, the ISO standard establishes an opportunity for inclusion and improvement of working conditions and worker's health. Table 2 shows the relationship of the dimensions with the literature consulted for identifying the different TML&WPPs.

Table 2. Relationship of the dimensions with the literature.

Construct	Dimensions	Reference
Top management leadership and worker participation	Leadership and commitment	(Chiang-Vega et al., 2014) (Hossain et al., 2015) (Yorio et al., 2015) (Samad, 2015) (Prasad et al., 2018) (Closs et al., 2010) (Mehrjerdi, 2009) (Zeinalnezhad et al., 2018) (Sienkiewicz-Malyjurek, 2016) (Pilbeam et al., 2016) (Khalid et al., 2021) (Markowski et al., 2021) (García-Aranda et al., 2021) (Yanar et al., 2020) (Verma & Chaudhari, 2017) (Mahmoudi et al., 2014) (Campailla et al., 2019) (Sorensen et al., 2018) (ISO 45001, 2018).
	Ergonomics Policy	(Yazdani et al., 2015) (Sutarjo, 2007) (Polanyi et al., 2005) (Yanar et al., 2020) (Campailla et al., 2019) (Bolis et al., 2014) (ISO 45001, 2018).
	Organization roles, responsibilities, and authorities	(Yazdani et al., 2015) (Pilbeam et al., 2016) (Campailla et al., 2019) (ISO 45001, 2018).

	Consultation and participation of workers	(Rodríguez-Ruíz et al., 2020) (Fernandes et al., 2015) (Hasle & Jensen, 2012) (Figueras, 2013) (Grillo Canelo, 2013) (Hedlund et al., 2016) (ILO, 2009) (Khalid et al., 2021) (Campailla et al., 2019) (Bolis et al., 2014) (Bayram & Üniversitesi İşletme Fakültesi Esentepe Kampüsü, 2019) (Hoque & Shahinuzzaman, 2021) (ISO 45001, 2018).

The practices identified (see Table 3) in the literature were used as inputs for the design of the evaluation instrument. In addition, the practices and requirements of ISO 45001 were used as the basis for the instrument's design. Also, it was defined that the questions would be closed Likert scale questions, where 1 = Strongly disagree and 5 = Strongly agree concerning the degree of agreement with the leadership practice of top management and employee participation in the SC for EM. Once the instrument was finalized, a content review was conducted by six experts, as well as a pilot test. The questions posed were redefined or eliminated based on the comments of these experts in an iterative process that ensured the instrument's reliability. The last version of the instrument, composed of seventeen items, is shown in Table 3.

Table 3. Items of the last version of the instrument

Dimensions	Code	Practices / items
Leadership and commitment		**In your organization, regarding TOP MANAGEMENT LEADERSHIP AND WORKER PARTICIPATION in ergonomics management (EM):**
	TML&W P1	Top management demonstrates leadership and commitment by assuming full responsibility for injury prevention, health impairment, accountability, and the provision of safe and healthy workplaces and activities. They also promote worker consultation and participation without retaliation by directing and supporting them to improve EM's effectiveness.
	TML&W P2	Top management demonstrates leadership and commitment by establishing the ergonomics policy and objectives, supporting the formation of the health and safety committee, and ensuring the availability of the necessary resources.
	TML&W P 3	Top management's leadership and commitment are evident in their responsibility to ensure the achievement of planned results in the EM. They communicate the importance of effective management and promote continuous improvement.

	TML&W P15	Top management raises employee awareness and provides support and timely feedback.
Ergonomics Policy	TML&W P4	Top management is unwavering in their commitment to implementing and maintaining a documented, communicated, and relevant ergonomics policy. This policy includes a commitment to comply with legal and other relevant requirements and to eliminate or reduce ergonomic hazards.
	TML&W P5	The ergonomics policy is kept available (documented), communicated, and relevant.
Organization roles, responsibilities, and authorities	TML&W P6	Top management ensures that responsibilities and authorities for roles are assigned, communicated, and documented.
	TML&W P7	Workers at each level assume responsibility for those aspects of the business unit over which they have control.
Consultation and participation of workers	TML&W P8	Process(es) are in place for employee consultation and participation in the development, planning, implementation, performance evaluations, and actions to improve management.
	TML&W P9	Top management provides the mechanisms, time, training, and resources for consultation and participation.
	TML&W P10	Top management emphasizes employee consultation on stakeholder needs and expectations, establishing ergonomics policy and objectives, and assigning organizational roles, responsibilities, and authorities.
	TML&W P11	Top management emphasizes employee consultation on determining how to comply with legal requirements, applicable controls for outsourcing and purchasing, and what needs to be monitored, measured, and evaluated for performance.
	TML&W P12	Top management encourages employee consultation on planning, implementing, and maintaining audit programs and ensuring continual improvement.
	TML&W P13	Top management promotes workers' participation in determining mechanisms for their consultation, control measures, effective use, and training and evaluation needs.
	TML&W P14	Top management promotes workers' participation in identifying and evaluating ergonomic risks, investigating incidents, and determining corrective actions.
	TML&W P16	Top management promotes the means and invites workers to report incidents, hazards, risks, and opportunities freely and confidently.
	TML&W P17	Workers report risks and hazards freely and confidently.

These items were used to develop a digital form in the Jotform® platform (https://www.jotform.com/) to facilitate its application and data processing.

5.3 Phase III: Instrument Application

A total of 286 invitations were sent electronically, but only 34 experts responded to the evaluation instrument. The experts have at least five years of experience in one of the areas of knowledge (Ergonomics, Occupational Health and Safety, Management Systems, and Logistics). 76.4% are men, and 23.6% are women. They are from Mexico (64.71%), South America (32.31%), and Cuba (2.94%). Of these, 64.70% belong to the private sector and the rest to the academic area.

5.4 Phase IV: Descriptive analysis

The values of the descriptive measures obtained from the experts' responses are shown in Table 4.

Table 4. Medians, Quartiles, and Interquartile Ranges of the dimensions of top management leadership and employee participation

Dimensions	Code / Item	Median[a]	Quartiles[b]			IQR
			25	50	75	
Leadership and commitment	TML&WP1**	4.50	3.6	4.50	5.00	1.40
	TML&WP2**	4.48	3.6	4.48	5.00	1.40
	TML&WP 3	4.27	3.29	4.27	4.92	1.63
	TML&WP15*	4.04	3.20	4.04	4.72	1.52
Ergonomics Policy	TML&WP4**	4.37	3.42	4.37	5.00	1.58
	TML&WP5**	4.41	3.45	4.41	5.00	1.55
Organization roles, responsibilities, and authorities	TML&WP6*	4.04	3.24	4.04	4.75	1.51
	TML&WP7	4.22	3.35	4.22	4.85	1.50
Consultation and participation of workers	TML&WP8	4.15	3.28	4.15	4.78	1.50
	TML&WP9	4.31	3.5	4.31	4.90	1.40
	TML&WP10*	4.08	3.06	4.08	4.79	1.73
	TML&WP11*	4.00	2.89	4.00	4.74	1.85
	TML&WP12	4.16	3.24	4.16	4.84	1.60
	TML&WP13*	4.08	3.25	4.08	4.73	1.48
	TML&WP14	4.28	3.17	4.28	4.96	1.79
	TML&WP16**	4.41	3.64	4.41	5.00	1.36
	TML&WP17	4.32	3.50	4.32	4.93	1.43

Note:
* Top management leadership practices and worker participation of lesser consensus.
** Top management leadership practices and worker participation of highest consensus.
[a] Median for pooled data,
[b] Quartiles with pooled data.
IQR: Interquartile range.

From the highest medians and smallest interquartile ranges for each practice, it is determined that the experts have high agreement that the best practices of top management leadership and employee participation in SC for EM are:

1. Top management should take full responsibility for injury prevention, health impairment, accountability, and the provision of safe and healthy activities and workplaces.
2. Top management should establish the ergonomics policy and objectives, support the formation of the health and safety committee, and ensure the availability of the necessary resources.
3. Top management should implement and maintain a documented, communicated, and relevant ergonomics policy committed to complying with legal and other relevant requirements and eliminating or reducing ergonomic hazards.
4. The ergonomics policy is kept available (documented), communicated, and relevant.
5. Top management should promote the means and invite workers to report incidents, hazards, risks, and opportunities freely and confidently.

For all TML&WPPs, the ratings of more than half of the experts agree that organizations should implement and evaluate the level of EM considering these practices. These practices evaluate the level of EM and play a crucial role in assessing the level of leadership and worker participation within the SC, enabling each member to contribute to the balance and performance of the SC and its partners.

Defining the best TML&WPPs in the SC related to EM is essential since their compliance can prevent illnesses due to dysergonomic factors and improve the SC's overall efficiency and productivity by implementing ergonomics projects or programs in conjunction with benefits for SC members. In addition, it is feasible to evaluate the SC's EM level through compliance with the TML&WPPs.

6. CONCLUSIONS

In conclusion, it is essential to evaluate the ergonomic aspects inherent to the working conditions using an adequate ergonomics program in the absence of an EMS that offers an evaluation of good practices and EM requirements in the SC (Rodríguez-Gámez et al., 2023). Considering these considerations and the literature, top management leadership and worker participation practices (TML&WPPs) are recognized as fundamental elements for the design of the EMS (Rodríguez-Gámez et al., 2023). They are also considered critical factors that significantly influence EM, as both elements contribute significantly to the success of ergonomic programs and can positively impact employee health, safety, and productivity. So, it is expected that TML&WPPs will also be present in the SC links for ergonomics management. The overall efficiency of the SC can be improved by complying with them and implementing ergonomics projects or programs that benefit the members of the SC. In addition, it is feasible to evaluate the SC's level of EM through compliance with them. The objective was met since the main TML&WPPs recommended by the experts were determined, in which the leadership and commitment of top management in establishing the ergonomics policy and objectives aimed at compliance with legal requirements, injury prevention, health care, as well as the provision of safe and healthy activities and workplaces, stand out. In addition, top management leadership must support the formation of the health and safety committee and ensure the availability of the necessary resources for implementing ergonomics programs and promote consultation and participation of workers to contribute to the effectiveness of the EM.

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ANALYSIS OF THE CAUSAL RELATIONSHIP BETWEEN THE NEW CONSTRUCTS OF COMPETITIVENESS AND OCCUPATIONAL HEALTH.

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Resumen: En el actual contexto de globalización y competitividad, las organizaciones se enfrentan a crecientes presiones para mejorar su productividad y eficiencia. Este estudio analiza la relación entre los constructos de competitividad y la salud ocupacional, a través de un análisis exhaustivo de 48 estaciones de trabajo en la industria manufacturera y maquiladora de exportación en la zona noreste de Sonora. Se diseñó y validó un instrumento para la recopilación de datos que evaluó tanto la importancia de los constructos de competitividad como las variables operativas y de salud ocupacional, incluyendo tiempo de ciclo, tiempo estándar, nivel de riesgo ergonómico (RULA), incidencias laborales, avisos de atención médica inicial (ST7), calificación de probable enfermedad de trabajo (ST9) y días de incapacidad.

El análisis reveló que la mejora continua de la calidad es el constructo de competitividad más valorado por las empresas, asociado a una mejor gestión de los tiempos operativos, lo que sugiere una relación positiva entre este constructo y la eficiencia organizacional. No obstante, el estudio también encontró que los mayores niveles de riesgo ergonómico están correlacionados con un aumento en las incidencias de salud ocupacional y una mayor duración de las incapacidades laborales. Estos hallazgos subrayan la importancia de abordar los riesgos ergonómicos para proteger la salud de los trabajadores y garantizar la sostenibilidad de la productividad a largo plazo.

La investigación también evidenció que, aunque las empresas priorizan la calidad y la eficiencia, a menudo subestiman la integración de prácticas ergonómicas en sus estrategias de competitividad. Esto puede resultar en una desconexión entre las metas de competitividad y las condiciones de trabajo, aumentando el riesgo de accidentes y enfermedades laborales. Las correlaciones positivas entre altos niveles de riesgo RULA y los indicadores de salud ocupacional adversos refuerzan la necesidad de adoptar un enfoque holístico que integre la ergonomía en la cultura organizacional, asegurando que la búsqueda de eficiencia no se realice a costa del bienestar de los trabajadores.

La principal contribución de este estudio al campo de la ergonomía radica en demostrar que la competitividad empresarial no solo depende de la mejora continua de la calidad y la eficiencia, sino también de la implementación de prácticas ergonómicas efectivas. Al minimizar los riesgos laborales y promover la salud ocupacional, las empresas no solo protegen a sus trabajadores, sino que también fortalecen su capacidad competitiva en un mercado global cada vez más exigente.

La investigación subraya que la integración de la ergonomía en las estrategias de competitividad es esencial para asegurar un entorno laboral productivo y saludable. Este enfoque no solo mejora la satisfacción y el rendimiento de los empleados, sino que también contribuye al desarrollo empresarial sostenible, alineando la eficiencia operativa con el respeto a la integridad de los trabajadores.

Palabras clave: Competitividad, nuevos constructos, salud ocupacional.

Relevancia para la ergonomía: La investigación propuesta realiza una contribución significativa al campo de la ergonomía al demostrar la importancia de equilibrar las demandas de competitividad con el bienestar de los trabajadores. Este estudio resalta la necesidad crítica de integrar prácticas ergonómicas efectivas que no solo minimicen los riesgos laborales, sino que también promuevan la salud ocupacional.

Al hacerlo, se potencia la sostenibilidad y la eficiencia organizacional, estableciendo un vínculo claro entre el cuidado de los trabajadores y el éxito empresarial a largo plazo.

Abstract: In the current context of globalization and competitiveness, organizations face increasing pressures to improve their productivity and efficiency. This study analyzes the relationship between competitiveness constructs and occupational health through a comprehensive analysis of 48 workstations in the manufacturing and export maquiladora industry in the northeastern region of Sonora. A data collection instrument was designed and validated, evaluating both the importance of competitiveness constructs and operational and occupational health variables, including cycle time, standard time, ergonomic risk level (RULA), workplace incidents, initial medical attention notifications (ST7), probable work-related illness ratings (ST9), and days of incapacity.

The analysis revealed that continuous quality improvement is the most valued competitiveness construct by companies, associated with better management of operational times, suggesting a positive relationship between this construct and organizational efficiency. However, the study also found that higher levels of ergonomic risk are correlated with an increase in occupational health incidents and longer durations of work-related incapacities. These findings underscore the importance of addressing ergonomic risks to protect workers' health and ensure long-term productivity sustainability.

The research also demonstrated that while companies prioritize quality and efficiency, they often underestimate the integration of ergonomic practices into their competitiveness strategies. This can lead to a disconnect between competitiveness goals and working conditions, increasing the risk of workplace accidents and illnesses. The positive correlations between high RULA risk levels and adverse occupational health indicators reinforce the need to adopt a holistic approach that integrates ergonomics into organizational culture, ensuring that the pursuit of efficiency does not come at the expense of workers' well-being.

The primary contribution of this study to the field of ergonomics lies in demonstrating that business competitiveness depends not only on continuous quality improvement and efficiency but also on the effective implementation of ergonomic practices. By minimizing workplace risks and promoting occupational health, companies not only protect their workers but also strengthen their competitive capacity in an increasingly demanding global market.

The research emphasizes that integrating ergonomics into competitiveness strategies is essential to ensure a productive and healthy work environment. This approach not only enhances employee satisfaction and performance but also contributes to sustainable business development, aligning operational efficiency with respect for workers' integrity.

Keywords. Competitiveness, new constructs, occupational health.

Relevance to Ergonomics: The proposed research makes a significant contribution to the field of ergonomics by demonstrating the importance of balancing competitiveness demands with workers' well-being. This study highlights the critical need to integrate effective ergonomic practices that not only minimize workplace risks but also promote occupational health. By doing so, organizational sustainability and efficiency are enhanced, establishing a clear link between caring for workers and long-term business success.

1. INTRODUCTION

In the contemporary context of globalization and intensified competitiveness, organizations face increasing pressure to optimize their productivity and operational efficiency. This imperative has led to the development of advanced constructs of competitiveness, designed to maximize organizational performance, but which, in turn, present significant challenges for the workforce (Batt & Appelbaum, 2013; Porter, 1998). The relationship between these emerging constructs and occupational health has become central to the field of ergonomics, a discipline that strives to balance efficiency at work with the preservation of the integral well-being of workers (Dul & Neumann, 2009; Wilkinson & Wood, 2012).

The advent of disruptive technologies and accelerated digital transformation have reconfigured competitive parameters, introducing constructs that prioritize efficiency and productivity, often without adequate recognition of the impact on the operator's quality of life (Schwab, 2017; Brynjolfsson & McAfee, 2014). This imbalance raises the need for research that explores the causal interactions between these constructs and working conditions, highlighting the importance of an ergonomic approach that promotes occupational health (Van Loon & Brusman, 2014).

Research on the interrelationship between competitiveness and occupational health is crucial for the creation of work environments that support both organizational efficiency and worker well-being (Karasek & Theorell, 1990; Siegrist, 1996). A thorough understanding of how modern constructs of competitiveness influence occupational health can guide the implementation of balanced practices, mitigating the risks associated with intensifying work demands (Ganster & Rosen, 2013).

The current techno-social environment, characterized by rapid adoption of emerging technologies, is redefining production methods and altering labor market dynamics (Autor, Levy, & Murnane, 2003; Brynjolfsson & Hitt, 2000). The integration of these technologies into organizational processes offers substantial opportunities to enhance competitiveness; however, it also elevates the physical and mental demands on workers (Westerman, Bonnet, & McAfee, 2014; Acemoglu & Restrepo, 2018). This duality underscores the need to investigate the impact of competitiveness on occupational health, especially in a context where the pursuit of efficiency may conflict with healthy working conditions (Scully-Russ, 2005).

The intensification of work demands, driven by the quest for greater productivity and efficiency, can lead to working conditions that increase the risk of occupational health problems such as stress, musculoskeletal injuries and burnout (Aronsson & Gustafsson, 2005; Demerouti, Bakker, Nachreiner, & Schaufeli, 2001). The impact of these problems transcends the individual sphere, also affecting the overall productivity of organizations and the sustainability of economies (Bongers, Ijmker, van den Heuvel, & Blatter, 2006). Addressing these issues from a scientific perspective is essential to develop strategies that harmonize competitiveness with occupational health (Clarke & Cooper, 2004).

2. OBJECTIVES

General objective: To establish a procedure to explore the causal relationship between the new competitiveness construct Productivity-Efficiency, the demands on the labor force and the impact it generates on the occupational health of the worker.

Specific objectives:

1. To analyze the main theoretical currents and methodological approaches related to the causal relationships between the constructs of competitiveness, workforce demands and their impact on occupational health.
2. To develop a procedure that explores the causal relationship between the new competitiveness construct Productivity-Efficiency, the demands on the workforce and the impact it generates on the occupational health of the worker.
3. Validate the designed procedure through its practical application.

3. METHODOLOGY

The research on the causal relationship between the constructs of competitiveness - productivity - efficiency, the demands on the workforce, and the impact on the occupational health of the worker will be approached through a methodology structured in four main phases: literature review, instrument development, data collection and analysis, and validation of the proposed procedure.

In the first phase, an exhaustive review of the existing literature on the aforementioned constructs and their relationship with occupational health will be carried out. This analysis aims to identify the main theoretical currents and methodological approaches used to study these relationships, thus providing a solid theoretical basis for the development of the proposed procedure.

The second phase will consist of the development of appropriate measurement instruments to capture data on competitiveness, productivity, efficiency, labor demands and their impact on occupational health. These instruments will include questionnaires, ergonomic assessment scales and structured interview guides. The design of these instruments will follow psychometric principles to ensure their validity and reliability, and pilot tests will be conducted to fine-tune and optimize the tools prior to implementation. Preliminary validation of the instruments will be carried out through a pilot study with a small sample, using internal consistency analysis, such as Cronbach's alpha.

Once the instruments have been validated, the third phase will focus on data collection and analysis in selected work environments. The sample will include workers from various sectors exposed to different levels of work demands and competitiveness. Data will be collected through surveys, interviews and direct observations in the workplace, using digital formats to facilitate analysis.

Finally, the fourth phase will consist of the validation of the designed procedure, applying it in a real environment to evaluate its effectiveness and applicability. Initially, the procedure will be implemented in a controlled environment or in a pilot sample to evaluate its functionality and effectiveness in identifying causal relationships. The results obtained will be analyzed using statistical methods to test the robustness of the identified causal relationships, and adjustments will be made to the procedure and instruments if necessary. Validation will be completed by assessing the external validity of the procedure through its replicability in different work contexts and the consistency of the results. In addition, predictive validity will be tested by monitoring workers over time to observe the effects of work demands on their occupational health.

4. RESULTS

So far, 48 studies have been conducted to analyze how workforce demands and their impact on occupational health are correlated with the new constructs of competitiveness. For this purpose, a two-part data collection instrument was designed and validated. The first part includes a semi-structured survey that assesses the importance of competitiveness constructs within companies. The second part focuses on the collection of operational and occupational health data, including cycle time (Tc Min), standard time (Te Min), RULA risk level, initial medical attention notice and rating of probable occupational accident (ST7), medical attention notice and rating of probable occupational disease (ST9), recorded incidences and average days of incapacity, framed by the Mexican Social Security Institute. Table 1 shows the design of the information collection instrument.

The instrument showed high internal consistency, with a Cronbach's alpha coefficient of 0.803, which guarantees its reliability for application in different business environments.

The analysis of the complete data confirms that the competitiveness construct of greatest importance for the companies is continuous quality improvement, with predominantly high scores. However, it was also observed that, in some contexts, other constructs such as innovation and operational improvement receive high ratings. Collaborative work, on the other hand, continues to be the construct with the lowest overall rating, although it presents variability depending on the specific context of the company.

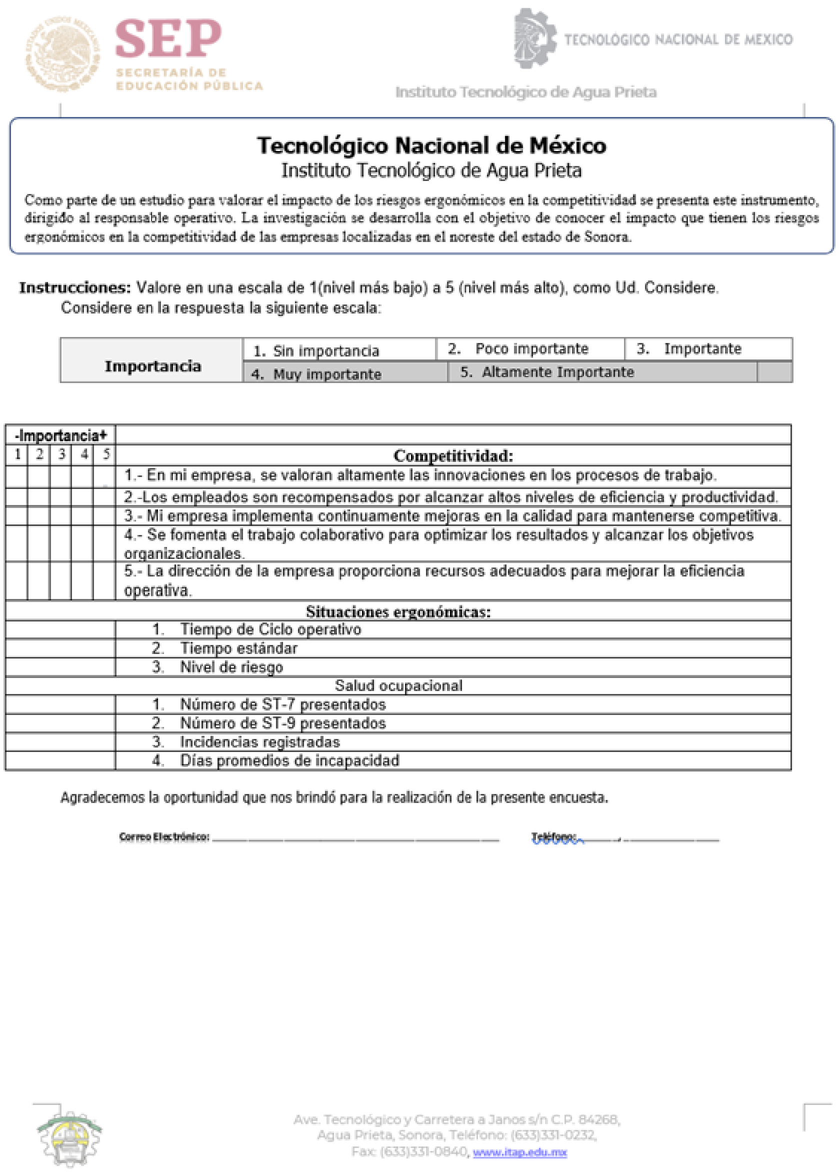
The correlations between the different operational and occupational health variables and the continuous quality improvement construct show that the higher the cycle time and standard time, the more important these variables are for the companies that value quality. However, when analyzing variables related to occupational health, such as the RULA risk level, it is observed that the higher the risk recorded at the workstation, the lower the importance assigned to the competitiveness construct. This finding suggests a possible disconnect between competitiveness strategies and safety measures in certain business contexts.

In addition, detailed analysis of the relationships between RULA risk and occupational health indicators revealed significant patterns: It was observed that the higher the levels of RULA risk (levels 6 and 7), there is a tendency to higher ST7 values, indicating that work environments with higher ergonomic risks are more likely to generate incidents requiring immediate medical attention. This underscores the importance of ergonomic interventions to mitigate these risks.

Similarly, as RULA risk levels increase, an increase in ST9 values is observed, especially at higher risk levels (RULA 7). This suggests that higher ergonomic risks are not only associated with acute incidents, but also with the occurrence of occupational diseases, probably related to prolonged and repetitive working conditions.

The analysis showed that higher risk levels (RULA 6 and 7) are associated with a higher number of reported incidences. This pattern suggests that as ergonomic risk increases, so does the frequency of adverse events in the workplace, reinforcing the need for preventive strategies in these settings

Table1: Information collection instrument



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Como parte de un estudio para valorar el impacto de los riesgos ergonómicos en la competitividad se presenta este instrumento, dirigido al responsable operativo. La investigación se desarrolla con el objetivo de conocer el impacto que tienen los riesgos ergonómicos en la competitividad de las empresas localizadas en el noreste del estado de Sonora.

Instrucciones: Valore en una escala de 1(nivel más bajo) a 5 (nivel más alto), como Ud. Considere.
Considere en la respuesta la siguiente escala:

Importancia	1. Sin importancia	2. Poco importante	3. Importante
	4. Muy importante	5. Altamente Importante	

-Importancia+					
1	2	3	4	5	**Competitividad:**
					1.- En mi empresa, se valoran altamente las innovaciones en los procesos de trabajo.
					2.-Los empleados son recompensados por alcanzar altos niveles de eficiencia y productividad.
					3.- Mi empresa implementa continuamente mejoras en la calidad para mantenerse competitiva.
					4.- Se fomenta el trabajo colaborativo para optimizar los resultados y alcanzar los objetivos organizacionales.
					5.- La dirección de la empresa proporciona recursos adecuados para mejorar la eficiencia operativa.
Situaciones ergonómicas:					
					1. Tiempo de Ciclo operativo
					2. Tiempo estándar
					3. Nivel de riesgo
Salud ocupacional					
					1. Número de ST-7 presentados
					2. Número de ST-9 presentados
					3. Incidencias registradas
					4. Días promedios de incapacidad

Agradecemos la oportunidad que nos brindó para la realización de la presente encuesta.

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Finally, it was shown that higher ergonomic risks are associated with longer incapacities. In particular, at the highest risk levels (RULA 6 and 7), incapacities of up to 31 days were recorded, indicating a greater severity of occupational injuries or illnesses in environments with high levels of ergonomic risk.

The results of this study have important implications for ergonomic practice and business competitiveness. Competitiveness constructs, particularly those related to continuous quality improvement, are intrinsically linked to occupational health. While companies prioritize efficiency and quality, findings suggest that these goals may be in conflict with workers' health if ergonomic risks are not adequately managed. The positive relationship between high levels of RULA risk and adverse occupational health indicators (ST7, ST9, incidences and disabilities) underscores the need to integrate ergonomic strategies into competitive models to ensure not only productivity, but also the long-term well-being of the workforce.

This study reinforces the idea that the sustainability of business competitiveness depends largely on the ability of organizations to balance operational efficiency with the health and safety of their employees, proposing a preventive approach that integrates ergonomics into the corporate culture.

5. DISCUSSION

The results of this study provide a valuable perspective on the relationship between the constructs of competitiveness and occupational health, revealing the complex dynamics between organizational efficiency and workers' well-being. This research is framed in a context where globalization and the constant search for productivity improvements demand a critical analysis of business strategies, especially when considering the implications for the ergonomic health of the workforce.

Continuous quality improvement, identified as the competitiveness construct most valued by the companies in our study, reflects a trend well documented in the literature. Previous studies, such as those by Batt and Appelbaum (2013) and Porter (1998), have highlighted the importance of quality in global competitiveness, noting that firms that manage to maintain high quality standards tend to be more successful in highly competitive markets. However, our finding that the higher the ergonomic risk (as measured by RULA), the lower the importance assigned to this construct suggests a dissonance between the pursuit of quality and safety and health practices in some contexts. This is consistent with Dul and Neumann (2009), who argue that companies often prioritize productivity over well-being, which can lead to increased occupational risks when working conditions are not adequately managed.

Our results also revealed a clear correlation between RULA risk levels and occupational health indicators, such as ST7, ST9, incidences and incapacities. These findings are consistent with the specialized literature, which has shown that elevated ergonomic risks are associated with an increased likelihood of occupational accidents and diseases. For example, Ganster and Rosen (2013) and Bongers et al. (2006) have documented how intensified work demands, without corresponding attention to ergonomic conditions, can result in a significant increase in occupational health problems, including musculoskeletal disorders and occupational stress.

The high frequency of prolonged disability observed at higher levels of RULA is of particular concern. Siegrist (1996) and Karasek and Theorell (1990) have already warned about the negative consequences of work environments that do not adequately consider ergonomic demands. These studies highlight that continuous exposure to adverse working conditions not only increases the risk of accidents, but also contributes to a decrease in the worker's quality of life, which can lead to prolonged incapacity and, therefore, to a reduction in organizational productivity.

The results of our study also highlight the need for an integrated approach that balances competitiveness with occupational health and safety. While the literature emphasizes the importance of continuous improvement and efficiency as pillars of competitiveness (Schwab, 2017; Brynjolfsson & McAfee, 2014), our findings suggest that these goals should not be achieved at the expense of worker well-being. Van Loon and Brusman (2014) propose that competitive strategies should incorporate ergonomic practices as part of the organizational culture, which not only improves employees' quality of life, but also contributes to long-term sustainable productivity.

This study provides additional evidence for the argument that integrating ergonomics into competitive strategies is not only beneficial for workers, but also essential for organizational sustainability. Wilkinson and Wood (2012) argue that companies that adopt integrated ergonomic practices are better able to adapt to changing market demands without compromising the health of their workforce.

In summary, this study confirms the importance of considering ergonomic risks when designing competitive strategies in companies. Our results underscore the need to balance the pursuit of efficiency and quality with the implementation of ergonomic practices that mitigate occupational health risks. Integrating these aspects not only protects workers, but can also improve long-term competitiveness by reducing disability rates and increasing productivity. These findings have important implications for ergonomic practice and business competitiveness management. Companies should adopt a holistic approach that prioritizes both quality and productivity and the health and safety of workers, ensuring a work environment that is competitive and, at the same time, safe and healthy.

6. CONCLUSIONS

In the current context of globalization and competitiveness, organizations face increasing demands to improve their productivity and efficiency. This study has investigated the relationship between the constructs of competitiveness and occupational health, analyzing data from 48 workstations in the manufacturing and maquiladora export industry in the northeastern part of the state of Sonora. The results have revealed valuable information that underscores the importance of balancing the demands of competitiveness with the well-being of workers.

Companies that prioritize continuous quality improvement tend to have better management of operating cycle time and standard time, suggesting a positive relationship between these factors and competitiveness. This indicates that implementing continuous quality improvements not only optimizes production processes, but also boosts operational efficiency, which is crucial for maintaining a competitive advantage in the global marketplace. This finding is aligned with the existing literature, which highlights the importance of quality as a fundamental pillar for competitiveness in a globalized environment.

However, the study also reveals a worrying relationship between higher levels of ergonomic risk and an increase in occupational health incidences, as well as in the duration of incapacities. The results show that as ergonomic risk increases, as measured by the RULA method, the likelihood of workers suffering accidents or developing occupational diseases increases, leading to longer incapacities. This pattern highlights the need for companies to not only focus on continuous improvement of quality and efficiency, but also to integrate effective ergonomic practices into their competitive strategies. Inadequate ergonomic risk management can compromise both the health of workers and the long-term sustainability of business operations.

The study reaffirms the importance of considering occupational health as an essential component of business competitiveness. The results suggest that a holistic approach that integrates ergonomics into continuous improvement strategies not only protects workers, but also maximizes operational efficiency and organizational sustainability. This approach is crucial to developing a work environment that is simultaneously productive and healthy, ensuring that companies can compete effectively in the global marketplace without sacrificing the well-being of their employees.

Sufficient arguments are presented to establish that in order for organizations to thrive in today's competitive global environment, it is imperative that they adopt an integrated approach that balances continuous quality improvement with rigorous ergonomic risk management. In doing so, they not only improve employee satisfaction and performance, but also ensure sustainable business development that respects the integrity of workers and strengthens long-term competitiveness.

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LITERACY PROMOTION AND THEIR EFFECT ON TECHNOLOGY STRESSORS, AND BURNOUT IN ENGLISH LANGUAGE COLLEGE STUDENTS

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Resumen: La tecnología ha puesto la educación y el aprendizaje al alcance de todos. Los estudiantes pueden beneficiarse del uso de la tecnología porque proporciona un aprendizaje experimental e interactivo. Sin embargo, existen preocupaciones sobre las consecuencias del uso de la tecnología que pueden afectar al bienestar de los estudiantes. El estrés tecnológico es una consecuencia negativa del uso de la tecnología, que engloba los factores de estrés relacionados con la tecnología y la tensión psicológica. Los estudiantes pueden experimentar cinco tipos de factores estresantes al utilizar la tecnología: complejidad tecnológica, inseguridad tecnológica, invasión, sobrecarga e incertidumbre. Los estudios empíricos han relacionado los cinco factores de estrés tecnológico con la tensión, medida por variables como el miedo, la ansiedad, la insatisfacción laboral y el agotamiento. Promover la literacidad, promueve una cultura de colaboración en el lugar de trabajo al animar a los estudiantes a asesorarse sobre el uso de la tecnología. La investigación sugiere que compartir conocimientos con los usuarios de tecnología reduce las reacciones negativas hacia la tecnología y el burnout. En esta investigación, se propone un modelo conceptual para investigar el efecto de la promoción de la literacidad en los estresores tecnológicos y el efecto de los estresores tecnológicos en el burnout entre los estudiantes universitarios de inglés. Se han establecido cinco hipótesis para examinar el efecto de los estresores tecnológicos en el burnout y otras cinco hipótesis para examinar el efecto de los estresores tecnológicos en la promoción de la alfabetización. Para probar las hipótesis, se aplicó una encuesta en línea a 578 estudiantes universitarios de Inglés de tres universidades de la ciudad de Hermosillo, Sonora. La encuesta comprende de tres partes: la evaluación de la promoción de la literacidad, la evaluación de cinco estresores tecnológicos y la versión de Maslach del cuestionario de burnout estudiantil. Se elaboró un análisis del modelo de ecuaciones estructurales para determinar en qué medida los datos de la muestra apoyaban el modelo teórico propuesto. De acuerdo con el modelo hipotetizado, el fomento de la alfabetización se relacionó significativa y negativamente con los cinco estresores tecnológicos: H6: complejidad tecnológica (β=-0,45, p<0,001), H7: inseguridad tecnológica (β =-0,27, p<0,001), H8: invasión tecnológica (β =-0,56, p<0,001), H9: sobrecarga tecnológica (β =-0,23, p<0,001), y H10: incertidumbre tecnológica (β =-0,32, p<0,001). En cuanto a las hipótesis H1 a H5: La complejidad tecnológica se relacionó positivamente con el burnout (β =0,65, p<0,001), H2: La inseguridad tecnológica se relacionó positivamente con el burnout (β =0,38, p<0,001), H3: La invasión tecnológica se relacionó positivamente con el burnout (β =0,53, p<0,001), H4: La sobrecarga tecnológica se relacionó positivamente con el burnout (β =0,39, p<0,001), y H5: La incertidumbre tecnológica se relacionó positivamente con el burnout (β =0,23, p<0,001). Los resultados apoyan el modelo propuesto que postula la promoción de la literacidad como un factor crítico en la reducción de los factores estresantes debidos a la tecnología, disminuyendo el burnout entre los estudiantes. Este estudio identifica que la promoción de la literacidad podría mitigar los efectos de los estresores tecnológicos y el burnout. Todos los estresores tecnológicos tuvieron un impacto negativo en la promoción de la literacidad, lo que puede explicarse por la variedad de tecnologías que se implantaron en un corto periodo de tiempo, lo que pudo crear incertidumbre y estrés en los estudiantes de Inglés de todas las instituciones encuestadas

Palabras clave: Estresores tecnológicos, burnout, literacidad, modelos de ecuaciones estructurales.

Relevancia para la ergonomía:

Esta investigación contribuye al campo de la ergonomía en varios aspectos: El fomento de la literacidad mejora la capacidad de los estudiantes para procesar, comprender y gestionar la información, lo que constituye un aspecto fundamental de la ergonomía cognitiva. Por otra parte, mejorar la literacidad permite a los estudiantes navegar por las plataformas digitales con mayor eficacia, reduciendo la carga cognitiva y minimizando los errores. Esto, a su vez, reduce los factores de estrés tecnológico, lo que mejora la salud mental y el rendimiento académico. Al mejorar las capacidades de uso de tecnología, los estudiantes están mejor preparados para hacer frente a las exigencias de la educación moderna. Esto reduce la probabilidad de experimentar frustración, confusión y ansiedad asociadas al uso de herramientas y recursos digitales. La ergonomía puede asistirse de estos hallazgos para diseñar tecnologías e interfaces educativas más fáciles de usar que se adapten a los niveles de literacidad de los estudiantes, minimizando así el estrés y mejorando la experiencia del usuario. El burnout es un problema crítico que afecta

al bienestar de los estudiantes y a su éxito académico. La promoción de la literacidad puede mitigar el burnout dotando a los estudiantes de las habilidades necesarias para gestionar eficazmente su carga de trabajo académico y reducir los retos que plantea la tecnología. Los hallazgos de esta investigación pueden servir de base para diseñar entornos de aprendizaje ergonómicos que favorezcan los aspectos físicos y cognitivos del bienestar de los estudiantes. De esta manera, pueden integrarse programas de promoción de literacidad en los planes de estudio para garantizar que los estudiantes no sólo dominen sus asignaturas, sino que también cuenten con las habilidades necesarias para manejar los componentes digitales de su educación. Los espacios de estudio diseñados ergonómicamente teniendo en cuenta el uso de la tecnología pueden favorecer aún más el desarrollo de la literacidad y reducir la fatiga física y mental. Comprender la relación entre la literacidad, los factores estresantes de la tecnología y el burnout permite establecer un enfoque holístico de la salud y la ergonomía de los estudiantes. Las intervenciones pueden diseñarse para abordar las exigencias tanto físicas como cognitivas de los estudiantes, promoviendo el bienestar general. Esto puede conducir al desarrollo de estrategias ergonómicas integrales que incluyan la promoción de la literacidad como componente clave de los servicios de apoyo a los estudiantes. Adicionalmente, las instituciones educativas pueden poner en marcha iniciativas de literacidad específicas, e intervenciones ergonómicas basadas en pruebas, asegurándose de que abordan eficazmente las necesidades específicas de los estudiantes en un entorno de aprendizaje digital. Al abordar la ergonomía cognitiva, reducir los factores estresantes de la tecnología y mitigar el agotamiento, las instituciones educativas pueden crear entornos de aprendizaje más favorables y eficaces. Este enfoque holístico no sólo mejora el rendimiento académico de los estudiantes, sino que también contribuye a su salud mental y física en general, en consonancia con los objetivos de la ergonomía.

Abstract:

Technology has made education and learning accessible to everyone. Students may benefit from the use of technology because it provides experiential and interactive learning. However, there are concerns about unintended negative consequences that can impact student well-being. Technology stress is a negative consequence of using technology, it encompasses technology-related stressors and psychological strain. Students may experience five types of stressors when using technology, including technology-complexity, technology-insecurity, invasion, overload, and uncertainty. Empirical studies have linked all five technology-stressors to strain, measured by variables such as fear, anxiety, job dissatisfaction, and burnout. Promoting literacy fosters a collaborative workplace culture by encouraging employees to advice about using technology for work. Research suggests that sharing technical knowledge with end users reduces negative feelings toward technology and burnout. In this research, a conceptual model is proposed to investigate the effect of literacy promotion on technology-stressors and the effect of technology-stressors on burnout among English college students. Five hypotheses have been established to examine the effect of technology stressors in burnout and other five hypothesis have been established to examine the effect of technology stressors in the literacy promotion. To test the hypotheses, an online survey was completed by 578 English language college students from three universities in the city of Hermosillo, Sonora. The survey comprised three items: the assessment of literacy promotion, the assessment of five technology stressors and Maslach's version of the student burnout questionnaire. A structural equation model analysis was developed to determine how sample data support proposed theoretical model. According to hypothesized model, literacy promotion was significantly and negatively related to the five techno-stressors: H6: technology-complexity (β=-0.45, p<0.001), H7: technology-insecurity (β=-0.27, p<0.001), H8: technology-invasion (β=-0.56, p<0.001), H9: technology-overload (β=-0.23, p<0.001), and H10: technology-uncertainty (β=-0.32, p<0.001). Regarding to hypothesis H1 to H5: Techno-complexity was positively related to burnout (β=0.65, p<0.001), H2: Techno-insecurity was positively related to burnout (β=0.38, p<0.001), H3: Techno-invasion was positively related to burnout (β=0.53, p<0.001), H4: Techno-overload was positively related to burnout (β=0.39, p<0.001), and H5: Techno-uncertainty was positively related to burnout (β=0.23, p<0.001). The findings support the theoretical framework that posits literacy as a critical factor in reducing both direct and technology-mediated stressors, ultimately decreasing burnout among students. This study identifies that promoting literacy could mitigate the effects of technology stressors and burnout. All the techno-stressors had a negative impact on literacy promotion, which can be explained by the variety of technology that was implemented in a short period of time, which created uncertainty and stress for students at all the institutions surveyed.

Keywords: Technology stressors, burnout, literacy, structural equation model.

Relevance to Ergonomics:

This research offers significant contributions to the field of ergonomics in several ways: Literacy promotion enhances students' ability to process, understand, and manage information, which is a fundamental aspect of cognitive ergonomics. Improved literacy skills enable students to navigate digital platforms more effectively, reducing cognitive load and minimizing errors. This, in turn, reduces technology stressors, leading to better mental health and academic performance. By improving literacy skills, students are better equipped to handle the technological demands of modern education. This reduces the likelihood of experiencing frustration, confusion, and anxiety associated with the use of digital tools and resources. Ergonomics can leverage these findings to design more user-friendly educational technologies and interfaces that align with students' literacy levels, thereby minimizing stress and enhancing user experience. Burnout is a critical issue that affects students' well-being and academic success. Literacy promotion can mitigate burnout by empowering students with the skills needed to efficiently manage their academic workload and reduce the perceived challenges posed by technology. Ergonomics can apply these insights to develop interventions and support systems that focus on literacy as a preventative measure against burnout. The findings can inform the design of ergonomic learning environments that support both physical and cognitive aspects of student well-being. For instance, literacy programs can be integrated into curricula to ensure that students are not only proficient in their subjects but also equipped with the necessary skills to handle the digital components of their education. Ergonomically designed study spaces that consider lighting, seating, and technology use can further support literacy development and reduce physical and mental fatigue. Understanding the relationship between literacy, technology stressors, and burnout allows for a holistic approach to student health and ergonomics. Interventions can be designed to address both the physical and cognitive demands placed on students, promoting overall well-being. This can lead to the development of comprehensive ergonomic strategies that include literacy promotion as a key component of student support services. The research findings can guide the development of policies and programs aimed at promoting literacy and reducing stress and burnout among students. Educational institutions can implement targeted literacy initiatives and ergonomic interventions that are evidence-based, ensuring that they effectively address the specific needs of students in a digital learning environment. Incorporating literacy promotion into ergonomic practices offers a multifaceted approach to enhancing student well-being and academic success. By addressing cognitive ergonomics, reducing technology stressors, and mitigating burnout, educational institutions can create more supportive and effective learning environments. This holistic approach not only improves students' academic performance but also contributes to their overall mental and physical health, aligning with the broader goals of ergonomics.

1. INTRODUCTION

Technology has made education and learning accessible to everyone, regardless of race, gender, financial status, or physical limitations. According Yssel et al. (2014), technology is becoming increasingly prevalent in higher education classrooms around the world. Students may benefit from the use of technology because it provides experiential and interactive learning, encourages individualized learning, and makes learning enjoyable Herold (2016). However, there are concerns about unintended negative consequences that can impact student well-being(Al-Fudail & Mellar, 2008). Technology stress is a negative consequence of using technology(Tarafdar et al., 2019). Technology stress encompasses technology-related stressors and psychological strain (Ayyagari et al., 2011). Additionally, Burnout, defined as a syndrome of emotional exhaustion, depersonalization, and decreased personal accomplishment (Hederich-Martínez, 2016) can cause psychological distress such as anxiety, depression, frustration, hostility, or fear. Previous research has shown that burnout can lead to lower commitment, higher turnover, absenteeism, lower productivity, low morale, and less human consideration (Cordes y Dougherty, 1993). In recent years, the number of studies on burnout has increased, and the study of burnout has been extended to almost all occupations and even to non-occupational samples such as students (Chang et al., 2000; Fimian et al., 1989). Besides, stress is a complex process that includes stressors, strains, consequences, and coping mechanisms (Hargrove et al.,2013). Early research on stress and technology focused on the experiences of managers and employees (King & Sethi, 1998). Recent research suggests that technology-induced stress, is called techno-stress (Tarafdar et al., 2011). Tarafdar et al. (2019) emphasizes the importance of identifying and investigating the negative effects of techno-stress and recognizing ways to mitigate them. Research suggests ways to mitigate the negative effects of technology stress on end-users (Srivastava et al., 2015). Promoting literacy fosters a collaborative workplace culture by encouraging employees to share knowledge, skills, and advice about using technology for work (Ragu-Nathan et al., 2008). As a result, end users become more knowledgeable about using technology for work and are better able to overcome the challenges that come with it.

Students may experience five types of stressors when using technology, including technology-complexity, technology-insecurity, invasion, overload, and uncertainty. Empirical studies have linked all five technology-stressors to strain, measured by variables such as fear, anxiety, job dissatisfaction, and burnout (Brooks & Califf, 2017; Salanova et al., 2000). Research suggests that sharing technical knowledge with end users reduces negative feelings toward technology and burnout(Doll & Torkzadeh, 1989; Ragu-Nathan et al., 2008). In this research, a conceptual model is proposed to investigate the effect of literacy promotion on technology-stressors and the effect of technology-stressors on burnout, according to figure 1:

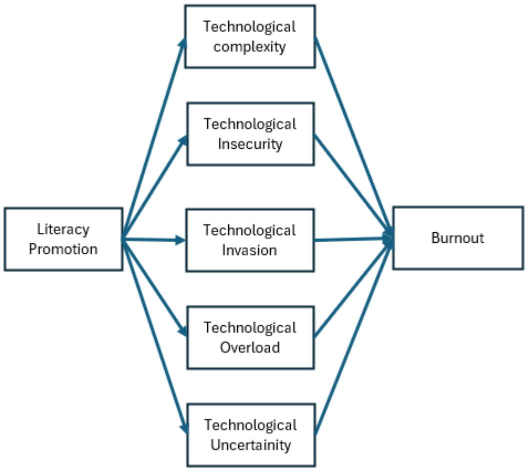

Figure 1 Proposed conceptual model

The conceptual model is proposed to empirically explore the effect of five technology stressors on burnout. In addition, the direct effect of literacy promotion on technology stressors and burnout is examined. We argue that when students are exposed to technology stressors such stressors cause strain in the form of burnout. Based on these considerations, we hypothesize the following:

H1-5: The five technology-stressors (technology-complexity, technology-insecurity, technology-invasion, technology-overload, and technology-uncertainty) are positively associated with burnout among college English students. Besides, collaboration and sharing of technology-related knowledge (Literacy promotion) among students can reduce the negative effects of the technology stressors and prevent burnout. Therefore, we hypothesize:

H6-10: Students experience five technology stressors: complexity, insecurity, invasion, overload, and uncertainty, all of which have a negative impact on literacy promotion.

The sample data collection considered 578 English language college students.

2. OBJETIVES

The purpose of this study is to analyze the effect of literacy promotion on technology stressors and the effect of technology stressors on burnout in college students through a structural equation model.

3. METHODOLOGY

The following sections present the methodology employed to validate the research hypotheses depicted in Figure 1.

3.1 Participants

To test the hypotheses, an online survey was completed by 578 English language college students from three universities in the city of Hermosillo, Sonora. Participants in the study were required to be full students at the time of study. The response rate was 100%. A convenience sampling method was employed to select the sample.

3.2 Survey design

The survey used to obtain the data was based on the survey developed by Califf & Brooks (2020) comprising three items: the assessment of literacy promotion, the assessment of five technology stressors and a short burnout questionnaire, which was replaced by Maslach's version of the student burnout questionnaire. Additionally, some sociodemographic items were integrated to this questionnaire: age, gender, and body mass index.

3.2 Survey administration

The survey used to obtain the data was based on the survey developed by (Califf & Brooks, 2020) comprising three items: the assessment of literacy promotion, the assessment of five technology stressors and a short burnout questionnaire, which was replaced by Maslach's version of the student burnout questionnaire. Additionally, some sociodemographic items were integrated to this questionnaire: age, gender, and body mass index. To assess literacy promotion and technology stressors, a five-point Likert scale was used according to Table 1. Burnout was evaluated with a six-point scale according to Table 2.

Table 1 Literacy promotion and Technology stressors survey scale

1	2	3	4	5
Never	Rarely	Often	Frequently	Always

Table 2 Maslach's survey scale

1	2	3	4	5	6
Never	Rarely	Sometimes	Often	Frequently	Always

3.3 Data capture and screening

A database was constructed in Microsoft Excel, with the columns representing the observed variables and each row representing an answer. To screen the data, the estimated standard deviation and variables with standard deviation lower than 0.5 were discarded.

3.4 Structural equation model analysis

A structural equation model analysis was developed to determine how sample data support proposed theoretical model. The model comprised seven latent variables that interrelates them through ten research hypotheses as illustrated in figure 1. The model was tested using IBM *SPSS* Amos (Analysis of Moment Structures) V.

26.They were examined the output for model fit indices: Chi-square (χ^2), to assess whether the model significantly differs from the observed data (non-significant χ^2 indicates good fit); Comparative Fit Index (CFI), values above 0.90 indicate acceptable fit, and values above 0.95 indicate good fit; Root Mean Square Error of Approximation (RMSEA), Values less than 0.06 indicate good fit, and values up to 0.08 indicate acceptable fit; and Standardized Root Mean Square Residual (SRMR), Values less than 0.08 indicate good fit.

4 RESULTS

4.1 Structural equation model analysis

The application of Structural Equation Modeling (SEM) using AMOS SPSS to investigate the effects of literacy promotion on technology stressors and burnout among English college students yielded significant and insightful results. This result and discussion section interprets the findings in the context of the research hypotheses and theoretical framework.

4.2 Model fit

Model fit indices in AMOS SPSS are used to assess how well the proposed structural equation model (SEM) fits the observed data. These indices provide various statistical measures to evaluate the adequacy of the model and help determine whether the hypothesized relationships between variables are supported by the data. Model fit indices indicate how well the model captures the patterns and relationships present in the data. A good fit suggests that the model accurately represents the underlying structure of the data, while a poor fit indicates that the model may need modification. Model Fit Indices as recommended by Thompson (2004) are:

Chi-Square (χ^2): The purpose of this index is to test the null hypothesis that the model fits the data perfectly, in other words, test the difference between the predicted and the observed relationships (correlations/covariances). A non-significant χ^2 ($p > 0.05$) indicates a good fit. However, it is sensitive to sample size, often leading to rejection of models even with good fit in large samples. Results indicate that $\chi^2 = 150.35$, $p < 0.001$

Comparative Fit Index (CFI): It compares the fit of the hypothesized model to an independent baseline model. It assesses the fit of the proposed model relative to the independence model, which assumes that there are not relationships in the data. Values range from 0 to 1, with values above 0.90 indicating acceptable fit and values above 0.95 indicating good fit. The CFI was 0.95, then the data support the model.

Tucker-Lewis Index (TLI): Its purpose is to adjusts the CFI for model complexity. Its values range from 0 to 1, with values above 0.90 indicating acceptable fit and values above 0.95 indicating good fit. TLI was 0.94 in this study.

Root Mean Square Error of Approximation (RMSEA): Measures the discrepancy per degree of freedom in the model. It is the average of the residuals between the observed correlation/covariance from the sample and the expected model estimated from the population. Values less than 0.06 indicate good fit, values up to 0.08 indicate acceptable fit, and values above 0.10 indicate poor fit. RMSEA also provides a confidence interval for more nuanced interpretation. RMSEA was 0.05 which indicates a good fit, according to (Loehlin & Beaujean, 2004).

Standardized Root Mean Square Residual (SRMR): it represents the standardized difference between observed and predicted correlations. Values less than 0.08 are generally considered good fit. SRMR was 0.03.

Goodness-of-Fit Index (GFI) and Adjusted Goodness-of-Fit Index (AGFI). This index measures the proportion of variance accounted for by the model. Values range from 0 to 1, with values above 0.90 indicating good fit. AGFI adjusts GFI for model complexity. GFI was 0.95.

These indices suggest that the model adequately represents the relationships among literacy promotion, technology stressors, and burnout. The high values of CFI and TLI, coupled with low RMSEA and SRMR, confirm the robustness and reliability of the SEM model.

4.3 Direct effects

Direct effects are the coefficients that describe the direct influence of an independent variable (predictor) on a dependent variable (outcome). They refer to the relationships between variables that are represented by single-headed arrows in the path diagram. Specifically, a direct effect quantifies the immediate impact one variable has on another without considering any mediating variables that might also influence this relationship. In the path diagram, direct effects are depicted as single-headed arrows pointing from the predictor variable to the outcome variable.

The magnitude and sign of the direct effect indicate the strength and direction of the relationship. A positive direct effect means that as the predictor variable increases, the outcome variable also increases, and vice versa for a negative direct effect.

Direct effect of literacy Promotion on Technology Stressors: The standardized path coefficient was -0.45 ($p < 0.001$), indicating a significant negative relationship. This suggests that increased literacy promotion reduces technology stressors among students. Improved literacy skills likely empower students to handle technological demands more effectively, reducing their stress levels.

Direct effect of literacy Promotion on Burnout: The standardized path coefficient was -0.30 ($p < 0.001$), indicating a significant negative relationship. This suggests that literacy promotion directly reduces burnout levels. Enhanced literacy skills may enable students to manage their academic workload more efficiently, decreasing feelings of exhaustion and disengagement.

Direct effect of technology Stressors on Burnout: The standardized path coefficient was 0.60 ($p < 0.001$), indicating a significant positive relationship. This finding confirms that higher levels of technology stressors are associated with increased burnout. This aligns with existing literature that links technological challenges and pressures with higher burnout rates.

4.3.1 Indirect effects

Indirect effects quantify the impact of an independent variable on a dependent variable through one or more mediating variables. Indirect effects refer to the influence of one variable on another that occurs through one or more intervening (mediating) variables. These effects capture the pathways where an independent variable affects a dependent variable indirectly via one or more mediators. In a path diagram, indirect effects involve a series of single-headed arrows connecting the independent variable to the mediating variable(s) and then to the dependent variable. Indirect effects are computed by multiplying the path coefficients along the indirect pathway.

Indirect effect of literacy promotion on technology stressors and burnout was -0.27 ($p < 0.001$). This significant indirect pathway indicates that part of the effect of literacy promotion on burnout is mediated through its impact on technology stressors. In other words, literacy promotion reduces burnout not only directly but also indirectly by alleviating technology stressors.

4.3.2 Hypothesis testing

According to hypothesized model, literacy promotion was significantly and negatively related to the five techno-stressors: H6: technology-complexity (β=-0.45, p<0.001), H7: technology-insecurity (β=-0.27, p<0.001), H8: technology-invasion (β=-0.56, p<0.001), H9: technology-overload (β=-0.23, p<0.001), and H10: technology-uncertainty (β=-0.32, p<0.001). Regarding to hypothesis H1 to H5: Techno-complexity was positively related to burnout (β=0.65, p<0.001), H2: Techno-insecurity was positively related to burnout (β=0.38, p<0.001), H3: Techno-invasion was positively related to burnout (β=0.53, p<0.001), H4: Techno-overload was positively related to burnout (β=0.39, p<0.001), and H5: Techno-uncertainty was positively related to burnout (β=0.23, p<0.001).

According to the above hypothesis test table, each hypothesis has a t-value value greater than 1.96 for significance level of 5%. Thus, the data support defined hypothesis (Table 2).

Table 2 Hypothesis test results

Hypothesis	Statement	t-value Alpha= 5%	Result
H1	Technology-complexity has a positive effect on burnout	5.23	The data support the hypothesis
H2	Technology-insecurity has a positive effect on burnout	7.23	The data support the hypothesis
H3	Technology-invasion has a positive effect on burnout	8.37	The data support the hypothesis

H4	Technology-overload has a positive effect on burnout	12.37	The data support the hypothesis
H5	Technology-uncertainty has a positive effect on burnout	8.45	The data support the hypothesis
H6	Technology-complexity has a negative effect on burnout	7.23	The data support the hypothesis
H7	Technology-insecurity has a negative effect on burnout	2.45	The data support the hypothesis
H8	Technology-invasion has a negative effect on burnout	3.38	The data support the hypothesis
H9	Technology-overload has a negative effect on burnout	4.63	The data support the hypothesis
H10	Technology-uncertainty has a negative effect on burnout	6.23	The data support the hypothesis

4.3.3 Model research results

Table 3 shows the path coefficients of the SEM, which demonstrate a strong relationship between the model variables and in all cases are significantly.

Table 3 Results of path coefficients

Independent variable	Dependent variable	Path Coefficient	SE	p-value
Literacy facilitation	Technology-complexity	-0.45	0.018	0.00025
Literacy facilitation	Technology-insecurity	-0.27	0.035	0.00004
Literacy facilitation	Technology-invasion	-0.56	0.008	0.00018
Literacy facilitation	Technology-overload	-0.23	0.005	0.00015
Literacy facilitation	Technology-uncertainty	-0.32	0.007	0.00027
Technology complexity	Burnout	0.65	0.008	0.00071
Technology insecurity	Burnout	0.38	0.001	0.00082
Technology invasion	Burnout	0.53	0.001	0.00078
Technology overload	Burnout	0.39	0.001	0.00081
Technology uncertainty	Burnout	0.23	0.002	0.00018

The findings support the theoretical framework that posits literacy as a critical factor in reducing both direct and technology-mediated stressors, ultimately decreasing burnout among students. Literacy promotion appears to equip students with the necessary skills to manage technological demands more effectively, thereby reducing their overall stress levels and preventing burnout. The results have important practical implications for educational institutions: Integrating literacy promotion programs into the curriculum can help students develop skills to manage digital and academic challenges more effectively. Besides, offering targeted support services to enhance literacy can mitigate technology-related stress and reduce burnout. Additionally, educational institutions should consider ergonomic principles when designing and implementing technological tools to ensure they align with students' literacy levels and reduce cognitive overload. The study's cross-sectional design limits the ability to establish causality. Longitudinal studies are recommended to explore the causal relationships over time. The reliance on self-reported measures may introduce response biases. Future research could incorporate objective measures of literacy skills and stress levels. The findings may not be generalizable to non-English-speaking students or those in different educational contexts. Replicating the study in diverse settings would enhance the generalizability of the results. This study demonstrates the critical role of literacy promotion in reducing technology stressors and burnout among English college students. The SEM analysis using AMOS SPSS provided robust evidence supporting the hypothesized relationships. By prioritizing literacy initiatives, educational institutions can create a supportive academic environment that promotes student well-being and academic success. Future research should continue to explore these relationships, incorporating longitudinal designs and diverse populations to further validate and expand upon these findings.

5. CONCLUSIONS

This study identifies several sources of technology stress among English college students and the impact of these stressors on burnout. In addition, the study identifies that promoting literacy could mitigate the effects of technology stressors and burnout. All the techno-stressors had a negative impact on literacy promotion, which can be explained by the variety of technology that was implemented in a short period of time, which created uncertainty and stress for students at all the institutions surveyed. No other studies were found regarding to English college students, other similar studies in teachers, found a strong relationship between technology stressors and burnout. We hope that this research will encourage administrators to reconsider the role of technology in the classroom, as it may have unintended negative consequences for end-users when many changes are promoted in a short period of time.

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.

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EVALUATION OF THE WORKLOAD IN THE MIDDLE MANAGEMENT OF AN AUTOMOTIVE COMPANY

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Resumen. La globalización ha traído consigo cambios importantes en los centros de trabajo. En este sentido, a nivel nacional e internacional han prestado atención a los riesgos laborales intangibles que repercuten en la salud y rendimiento laboral. Entre ellos destaca el exceso de carga laboral que experimentan los trabajadores. Por ello, este estudio analiza dicho factor de riesgo en mandos medios con el objetivo de identificar los aspectos que incrementan el riesgo. La Guía de Referencia III propuesta por la NOM-035-STPS-2018 se utilizó para la recolección de datos. La metodología se conforma de tres etapas: realizar trabajo de campo, la depuración de la base de datos y el análisis estadístico descriptivo. Los resultados reportan 88% de los supervisores con nivel de riesgo elevado. Esto se atribuye a realizar tareas de manera simultánea, alta responsabilidad y la necesidad de tomar decisiones rápidamente. En conclusión, la carga laboral representa un factor de riesgo psicosocial que necesita atenderse a la brevedad. Se requiere diseñar e implementar estrategias que fomenten un equilibrio entre las exigencias laborales y las capacidades del trabajador. Así como brindarle los recursos necesarios para facilitar la toma decisiones y su quehacer diario.

Palabras clave: Carga de Trabajo, Mandos Medios, NOM-035-STPS-2018.

Relevancia para la ergonomía: Este estudio a través de la NOM-035-STPS-2018 permite conocer el nivel de riesgo psicosocial (derivado de la carga laboral) al que están expuestos específicamente los mandos medios en una empresa manufacturera de ciudad Juárez. Con ello, facilita la identificación de aquellos aspectos que repercuten en la salud y bienestar de los trabajadores. Es así como las organizaciones podrán establecer políticas y estrategias que permitan minimizar el riesgo y las repercusiones que puede llegar a propiciar el exceso de carga laboral en la salud de los supervisores.

Abstract. Globalization has brought with it important changes in the workplace. In this sense, at a national and international level, they have paid attention to the intangible occupational risks that impact health and work performance. Among them, the excessive workload experienced by workers stands out. Therefore, this study analyzes this risk factor in middle managers to identify the aspects that increase the risk. Reference Guide III proposed by NOM-035-STPS-2018 was used for data collection. The methodology comprises three stages: fieldwork, database filtering, and descriptive statistical analysis. The results report that 88% of supervisors have a high-risk level. This is attributed to performing tasks simultaneously, high responsibility, and the need to make decisions quickly. In conclusion, workload represents a psychosocial risk factor that needs to be addressed as soon as possible. It is necessary to design and implement strategies that promote a balance between work demands and the worker's capabilities. As well as providing them with the resources needed to facilitate decision-making and their daily work.

Keywords: Workload, Middle Management, NOM-035-STPS-2018.

Relevance for ergonomics: This study through NOM-035-STPS-2018 allows us to know the level of psychosocial risk (derived from the workload) to which middle managers are specifically exposed in a manufacturing company in Ciudad Juárez. This facilitates the identification of those aspects that have an impact on the health and well-being of workers. This is how organizations will be able to establish policies and strategies that minimize the risk and the repercussions that the excessive workload can have on the health of supervisors.

1. INTRODUCTION

Workplaces have undergone considerable changes as a result of globalization and the implementation of technological advances. In this sense, international organizations show interest in identifying, evaluating, and addressing the working conditions inherent to work that bring about these changes and that have an impact on the health and performance of the worker (Joint ILO-WHO Committee, 1984). This is how in 2012 the International Labor Organization [ILO] launched the program Solve, which recognizes that the worker is not only exposed to physical risks but also that there are intangible risk factors. These are related to the type of organization, working day, work environment, and interpersonal relationships, among others. In addition, it underlines the need to guarantee favorable working environments through the balance between the worker and his or her work to be carried out (International Labour Organization [ILO], 2012).

In this context, Mexico launched a draft standard on psychosocial risk factors in 2016. Thus, on October 23, 2018, NOM-035-STPS-2018 was published in the Official Gazette of the Federation, whose objective is to identify, analyze, and prevent these risk factors, as well as to promote a favorable work environment. This regulation states that psychosocial risk factors promote anxiety, sleep problems, and stress. These include poor working conditions, excessive workloads, lack of control over work, type and duration of the working day, interference in the work-family relationship, and negative interpersonal relationships (Ministry of Labor and Social Welfare [STPS], 2019). This regulation applies to all workplaces located within Mexican territory. It addresses five categories: 1. Physical conditions, 2. Demands of the task, 3. Organization of working time, 4. Leadership and labor relations and 5. Organizational environment. Domains are derived from them. For this study, only the items corresponding to the Workload domain (contemplated in the category Demands of the task) were used.

This risk factor has shown a considerable increase in workers in various sectors. For example, in education where workload has been shown to significantly impact emotional exhaustion and job performance (Jomuad et al., 2021; Ujir et al., 2020). Studies in health professionals have shown a relationship between workload and the level of elevated risk in terms of psychosocial risk factors. Specifically in workers who must fulfill multiple tasks (Astale et al., 2023; Larsson et al., 2022). While, in the manufacturing industry, exposure to high workloads stands out because, on the one hand, they receive orders from management and on the other, they are responsible for the results of their area. This leads to an atmosphere of tension (Armenta-Hernández et al., 2018; Gutiérrez Hernández, 2021; Gutiérrez-Hernández et al., 2020; Macias-Velasquez et al., 2019). Although these workers have greater control over the work by sometimes being able to decide the order of the activities to be carried out, they regularly attend to tasks simultaneously.

The authors highlight the importance of analyzing the workload considering the characteristics of the task, the employer, the physical conditions, the mental and psychological load, and the type of organization, to mention a few. In other words, it is considered a multidisciplinary construct (Ding et al., 2020). On the contrary, the authors state that it is possible to approach it through a single dimension (Calderón

De la Cruz et al., 2018; Gil-Monte, 2016). One of the most widely used instruments to assess workload is the Battery of the Psychosocial Research Unit of Organizational Behavior [UNIPSICO]. This has been shown to satisfactorily meet the reliability and validity of the construct, especially in Spanish speakers (Bambula & Gómez, 2016; Calderón De la Cruz et al., 2018; Llorca-Rubio et al., 2022; Merino Soto et al., 2021). Similarly, NOM-035 addresses it as a one-dimensional construct through 15 items (Ministry of Labor and Social Welfare [STPS], 2019).

Based on the above the manufacturing industry is a pillar in the country's economy with 73% of formal jobs with 5171 plants in Mexico. Of these, 321 are located in Ciudad Juárez, representing 65% of the state total (Monthly statistical information, 2024). In addition to presenting increases in turnover and absenteeism from work during January – June 2024. Companies dedicated to sewing are the ones with the highest turnover percentage (Maquiladora Association, A.C. Index Juárez, 2024). The purpose of this study was to analyze the workload to which middle managers of a company dedicated to automotive seat covers located in Ciudad Juárez, Chihuahua, are exposed.

2. METHODOLOGY

The study was assumed as a mixed research proposal since its purpose is to identify the level of psychosocial risk derived from the workload to which the supervisors of an automotive manufacturing company in Ciudad Juárez are exposed. The methodology consists of three stages.

Stage 1. Fieldwork

First, both the informed consent and the instrument were sent electronically and answered voluntarily and anonymously. The sample is made up of 100% of the middle managers of the first shift. The protocol for this research was approved by the Doctoral Senate of the Division of Graduate Studies and Research in conjunction with the Committee on Ethics and Prevention of Conflicts of Interest of the TecNM-Ciudad Juárez on February 18, 2019. The research was carried out during the period February-June.

Instruments

Reference Guide III proposed by NOM-035-STPS-2018 was used for data collection. This instrument is made up of five general categories, from which 10 domains are derived and these at the same time in 25 dimensions, with a total of 72 items (Ministry of Labor and Social Welfare [STPS], 2019). For this study, the 15 items corresponding to the workload domain were used. This domain through six dimensions considers a variety of workloads or work demands, as well as the pace of work. The items are Likert type with a five-point scale, where: Never = 0, Rarely = 1, Sometimes = 2, Almost always = 3, and Always = 4. Table 1 shows the structure of the domain, the description of the items, and the cut-off points to determine the level of risk.

Table 1. Items of NOM-035, the Workload domain.

Dimension	# item	Description
Quantitative Loads	6	Because of the amount of work I have, I have to stay in addition to my shift
	12	My job requires me to attend to several issues at the same time
Accelerated work rates	7	Because of the amount of work I have, I need to work non-stop
	8	I believe that it is necessary to maintain an accelerated pace of work
Mental load	9	My job requires me to be very focused
	10	My job requires me to memorize a lot of information
	11	In my job I have to make difficult decisions very quickly
Emotional psychological burdens	65	I see very angry staff
	66	My job requires me to attend to people with different qualities (physical, and health, among others).
	67	To do my job I must take actions without getting carried away by my feelings
	68	My job requires me to deal with aggressive situations (yelling, discrimination, humiliation, among others)
Highly responsible loads	13	In my work I am responsible for things of great value
	14	I answer to my boss for the results of my entire area of work
Contradictory or inconsistent burdens	15	At work they give me contradictory orders
	16	I consider that in my work I am asked to do unnecessary things
Cut-off points		
Very High		$Cworkload \geq 37$
High		$27 \leq Cworkload < 37$
Medium		$21 \leq Cworkload < 27$
Low		$15 \leq Cworkload < 21$
Null/ Zero		$Cworkload < 15$

Source: Own elaboration

Stage 2. Database Debugging

The database was created in IBM SPSS Statistics® Software version 26. First, the responses of the 15 items were scored according to the five-point Likert scale proposed by NOM-035-STPS-2018. Once created, this database was analyzed to identify both outliers and missing values. For the analyses to be correct, it is necessary to ensure the debugging of outliers and the replacement of the missing values utilizing the median (since they are ordinal data) (IBM Corporation, United States, 2019). Subsequently, the median and quartiles were calculated to analyze the behavior of the responses.

Stage 3. Statistical analysis

Once the responses have been graded according to the Likert scale, they are summed up to determine the level of risk derived from the workload according to the established cut-off points. In addition, this level was analyzed by department. In addition, the analysis by dimension was carried out to know if any dimension contributes to a high psychosocial risk.

3. RESULTS

Stage 1 Results. Fieldwork

The research was carried out during the period from March to June 2019. The instrument was answered by 100% of the personnel who occupied the supervisor position during the first shift. A total of 60 supervisors participated (50.5% were men and 49.5% were women) whose age was between 30 and 50 years.

Stage 2 Results. Database Debugging

The database was cleaned in IBM SPSS Statistics® version 26 software. No outliers or missing values were found. Then, the behavior of the items that make up the analyzed domain was analyzed. Table 2 shows the mean, median, and interquartile range of each item. Among the results, it is observed that supervisors report high demands for concentration, are responsible for things of great value, are required to attend to several matters at the same time, and answer for the results of the area with an average higher than 3 and median of 3 and 4. In other words, they must always or almost always do so during their working day. On the other hand, according to the interquartile range, the responses to these situations present a broad consensus when obtaining the smallest values.

Table 2. Item behavior

Item	Stocking	Median	RI
Because of the amount of work I have, I have to stay in addition to my shift	2.3167	2.0000	1.00
Because of the amount of work I have, I need to work non-stop	1.9167	2.0000	2.00
I believe that it is necessary to maintain an accelerated pace of work	2.3500	2.0000	1.00
My job requires me to be very focused	3.4333	4.0000	1.00
My job requires me to memorize a lot of information	2.8000	3.0000	1.00
In my work I have to make difficult decisions very quickly	2.7333	3.0000	2.00
My job requires me to attend to several issues at the same time	3.0333	3.0000	2.00
In my work, I am responsible for things of great value	3.5167	4.0000	1.00
I answer to my boss for the results of my entire area of work	3.1000	3.0000	1.75
At work, they give me contradictory orders	1.3000	1.0000	1.00
I consider that in my work I am asked to do unnecessary things	1.4000	1.0000	1.00
I serve very angry customers or users	1.4912	2.0000	1.00
My job requires me to care for people who are very much in need of help or who are sick	1.7193	2.0000	1.00
To do my job I must show feelings different from my own	2.5614	3.0000	2.00
My work requires addressing situations of violence	1.0351	1.0000	2.00

Stage 3 Results. Statistical analysis

In this stage, the level of risk to which supervisors are exposed was analyzed under the points proposed by Nom-035. Figure 1 shows that 88% of supervisors have a high level of psychosocial risk due to workload. Additionally, the results were analyzed according to the department to which they belong. Table 3 shows that the production department has the highest number of supervisors with a very high-risk level, followed by materials. Additionally, it is striking how they are concentrated in high-risk levels and that none presents a zero-risk level.

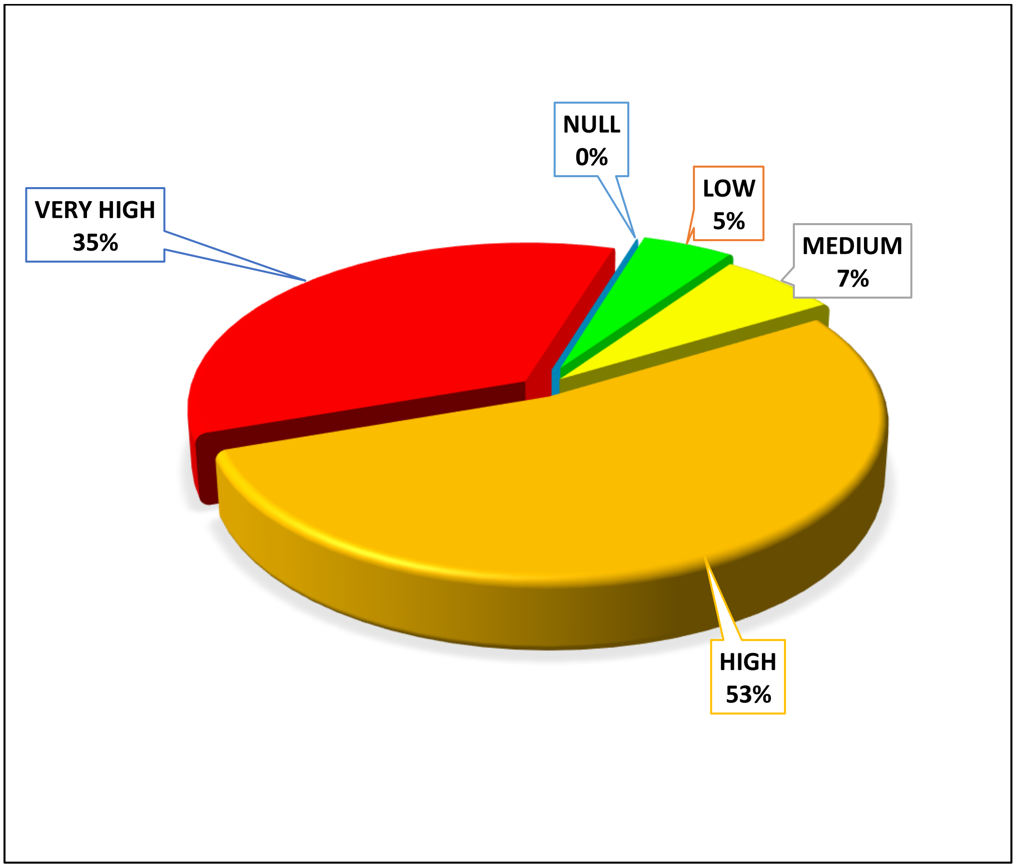

Figure 1. Level of Psychosocial Risk corresponding to the Workload

Table 3. Risk Level by Department

	Level of Psychosocial Risk				
Department	Null	Low	Middle	High	Very high
Finance	0	0	0	5	0
Production	0	2	0	9	6
Engineering	0	0	1	3	3
Releases	0	0	0	3	2
Quality	0	0	0	4	3
Materials	0	0	2	6	5
Continuous improvement	0	1	1	0	1
Human resources	0	0	0	2	1
Total	0	3	4	32	21

Based on the previous results, it was decided to analyze the responses for each of the six dimensions analyzed in the workload domain. Figure 2 shows the distribution of responses in percentage points for each dimension. For example, the dimension corresponding to high responsibility burdens with 57.5% is always. That is, they are always in charge of things of great value and must answer for the results of their area of work. Another dimension worth analyzing is related to mental load, since the percentages show that to carry out their work they must almost always or always be very concentrated, memorize a lot of information, and make difficult decisions quickly. It is also observed that most of them sometimes responded to questions related to quantitative burdens and the need to maintain an accelerated pace of work.

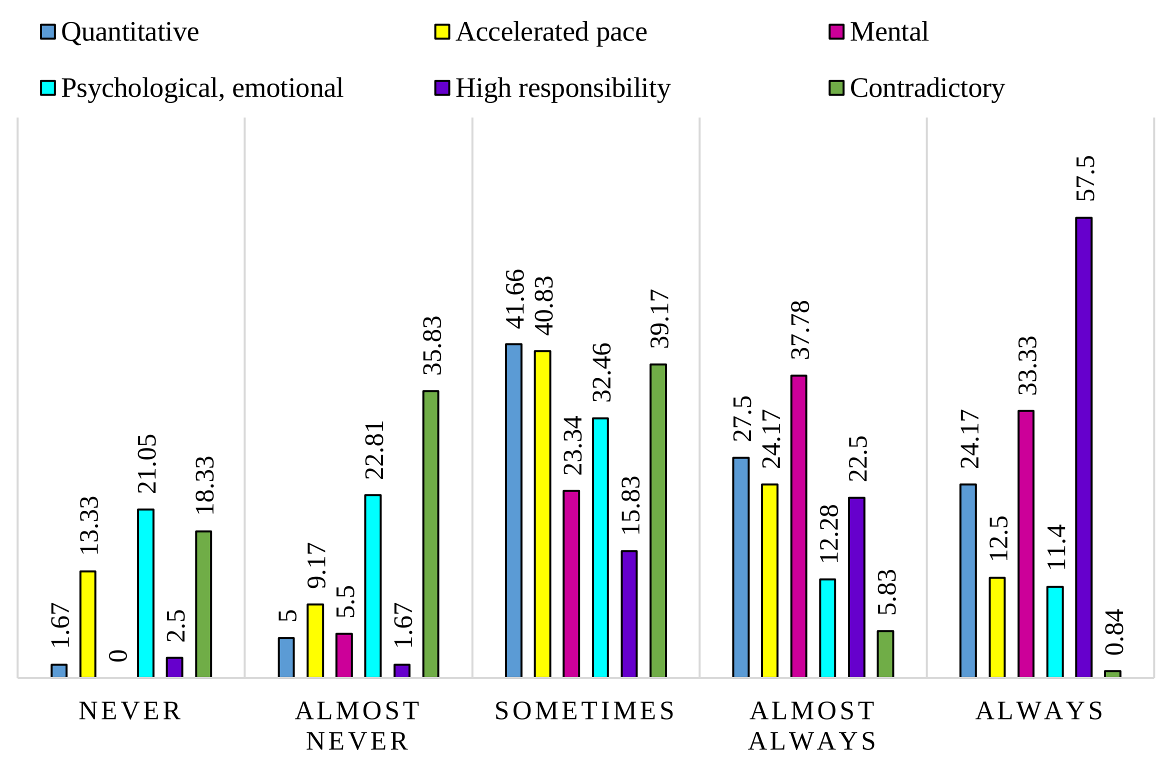

Figure 2. Percentage of responses by dimension

4. CONCLUSIONS

This study met the proposed objective by obtaining the level of psychosocial risk derived from the workload to which middle managers of a manufacturing company are exposed. The results report that a considerable percentage of middle managers (88%) have high levels of risk. The analysis by department reveals that production, materials, and engineering have the highest number of supervisors with very high-risk levels. In addition, the graphs show that the dimensions related to high responsibilities and mental load lead to these high levels.

Despite the interest shown by organizations at the national and international levels, much remains to be done. It is essential to have the necessary instruments and processes to identify these risk factors, and to subsequently design strategies that promote healthy work environments, in which the balance between the demands and physical and mental characteristics of the worker predominates. To be in constant training and to make use of technical and scientific advances that facilitate the work and decision-making of middle and upper management.

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PROPOSAL FOR A COMPUTER SUPPORT FOR ADMINISTRATIVE ASSISTANTS OF THE TECNOLÓGICO DE ESTUDIOS SUPERIORES DE VALLE DE BRAVO

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RESUMEN: Este proyecto tiene como objetivo diseñar e implementar un soporte de computadora ergonómico para auxiliares administrativos, con el fin de mejorar la comodidad y reducir los problemas de salud asociados con el uso prolongado de computadoras portátiles. El soporte será diseñado para ser ajustable, estable y fácil de usar, permitiendo a las personas mantener una postura correcta y reducir la fatiga visual y musculoesquelética.

Se considerarán materiales sostenibles y se buscará una estética atractiva y moderna, que se integre bien con el entorno laboral. Así mismo, busca contribuir a la creación de un ambiente laboral más saludable, confortable y productivo, mejorando la calidad de vida de los usuarios y reduciendo los costos asociados con problemas de salud.

Por lo tanto, se busca identificar y abordar las necesidades específicas de los auxiliares administrativos, proporcionando una solución práctica y eficaz para optimizar su espacio de trabajo y mejorar su bienestar. Se espera que el soporte de computadora ergonómico tenga un impacto positivo significativo en la salud, la productividad y la satisfacción de los usuarios.

PALABRAS CLAVE: Ergonomía, soporte, administrativo, salud, seguridad.

APORTACIÓN A LA ERGONOMÍA:

1. Ajustabilidad

Altura y Ángulo: El soporte debe permitir ajustar la altura y el ángulo de la pantalla para que el usuario pueda mantener una postura neutral, con los ojos al nivel de la parte superior de la pantalla.

Versatilidad: Debe adaptarse a diferentes tipos de computadoras (portátiles, monitores, etc.) y permitir múltiples posiciones.

2. Estabilidad y Seguridad

Materiales Robustos: Utilizar materiales de calidad que aseguren que el soporte sea estable y duradero.

Diseño Antideslizante: Incorporar características que eviten que la computadora se deslice, como superficies antideslizantes o almohadillas de goma.

3. Facilidad de Uso
Montaje Sencillo: El soporte debe ser fácil de montar y desmontar, preferiblemente sin necesidad de herramientas complejas.
Portabilidad: Si es posible, el soporte debería ser ligero y fácil de transportar para su uso en diferentes lugares.
4. Ergonomía Visual
Distancia Adecuada: El soporte debe permitir ajustar la pantalla a una distancia adecuada para evitar la fatiga ocular.
5. Postura y Salud
promoción de Buena Postura: Asegurar que el soporte ayude a mantener una postura correcta, con el cuerpo alineado y evitando tensiones en cuello, hombros y espalda.
6. Estética y Diseño
Atractivo Visual: Un diseño atractivo que se integre bien con el entorno de trabajo puede mejorar la satisfacción del usuario
Personalización: Ofrecer opciones de personalización en color, materiales y estilo para adaptarse a las preferencias personales.
7. Sostenibilidad
Materiales Ecológicos: Utilizar materiales sostenibles y reciclables para reducir el impacto ambiental.
Durabilidad: Diseñar para la durabilidad y el uso a largo plazo, reduciendo la necesidad de reemplazos frecuentes.

ABSTRACT: This project aims to design and implement an ergonomic computer stand for administrative assistants, in order to improve comfort and reduce health problems associated with prolonged use of laptops. The stand will be designed to be adjustable, stable and easy to use, allowing people to maintain a correct posture and reduce visual and musculoskeletal fatigue.

Sustainable materials will be considered and an attractive and modern aesthetic will be sought, which integrates well with the work environment. Likewise, it seeks to contribute to the creation of a healthier, more comfortable and productive work environment, improving the quality of life of users and reducing costs associated with health problems.

Therefore, it seeks to identify and address the specific needs of administrative assistants, providing a practical and effective solution to optimize their workspace and improve their well-being. The ergonomic computer stand is expected to have a significant positive impact on the health, productivity and satisfaction of users.

Keywords: ergonomics, support, administrative, health, safety.

CONTRIBUTION TO ERGONOMICS

1. Adjustability
Height and Angle: The stand should allow for adjusting the height and angle of the screen so that the user can maintain a neutral posture, with the eyes at the level of the top of the screen.
Versatility: It should adapt to different types of computers (laptops, monitors, etc.)

and allow for multiple positions.
2. Stability and Safety
Robust Materials: Use quality materials that ensure the stand is stable and durable.
Non-Slip Design: Incorporate features that prevent the computer from sliding, such as non-slip surfaces or rubber pads.
3. Ease of Use
Simple Assembly: The stand should be easy to assemble and disassemble, preferably without the need for complex tools.
Portability: If possible, the stand should be lightweight and easy to transport for use in different locations.
4. Visual Ergonomics
Adequate Distance: The stand should allow the screen to be adjusted to an appropriate distance to avoid eye fatigue.
5. Posture and Health
Promoting Good Posture: Ensure that the stand helps maintain a correct posture, with the body aligned and avoiding tension in the neck, shoulders and back.
6. Aesthetics and Design
Visual Appeal: An attractive design that integrates well with the work environment can improve user satisfaction.
Customization: Offer customization options in color, materials and style to suit personal preferences.
7. Sustainability
Eco-Friendly Materials: Use sustainable and recyclable materials to reduce environmental impact.
Durability: Design for durability and long-term use, reducing the need for frequent replacements.

1. INTRODUCTION

This project focuses on a laptop computer stand, which is designed to provide greater comfort and functionality by addressing the specific needs of administrative staff. Through this stand, a practical and efficient solution is offered to optimize the workspace, allowing the user to have more freedom of movement, with a healthy posture during working hours in front of the laptop.

GENERAL OBJECTIVE

Conduct a comprehensive diagnosis to identify ergonomic problems present in work environments with laptops, in order to develop and implement effective solutions using appropriate ergonomic supports to improve the health and well-being of users.

SPECIFIC OBJECTIVES

1. Implement measures to improve users' screen visualization ergonomically, reducing the need to adopt postures harmful to health, through the use of adjustable

stands that promote proper ergonomics and contribute to users' well-being and productivity.

2. Through the implementation of a computer stand, facilitate the ergonomic adjustment of the monitor, allowing for uniform light distribution and avoiding glare, in order to improve visual comfort and reduce eye fatigue for users throughout the workday.

DELIMITATION

Various data will be obtained by conducting a study on the use of a laptop computer stand in the administrative work centers of the Technological Institute of Higher Studies of Valle de Bravo.

3. METHODOLOGY

User needs research and analysis: understand the needs and requirements of users. · Ergonomic risk assessment: identify potential risks associated with computer use. · Conceptual design: generate design ideas for the computer stand that address the needs. · Prototypes: develop prototypes of the computer stand for testing. · Evaluation and adjustments: test the prototypes with users to evaluate comfort, usability, and effectiveness. · Development and production: once the design has been refined, proceed with large-scale development and production. · Evaluation: conduct follow-up after implementation to gather and provide feedback.

4. RESULTS

Based on the established objectives for implementing ergonomic measures and using appropriate computer stands, the following results are expected:

Improvement in visual comfort and prevention of eye problems: By implementing ergonomic adjustments in the workstation, such as the use of computer stands that allow optimal viewing, it is expected to reduce visual fatigue and prevent possible eye problems related to prolonged exposure to screens.

Increase in user well-being and productivity: By reducing physical and visual fatigue through the optimization of posture and lighting, users are expected to experience a higher level of comfort in their work environment, which can translate into an increase in productivity and the quality of work performed.

Reduction in musculoskeletal discomfort: The implementation of ergonomic measures, such as the use of adjustable computer stands, can contribute to improving users' posture and reducing musculoskeletal discomfort associated with inadequate postures, which in turn can promote a healthier and more comfortable work environment.

5. CONCLUSION

In this project of creating a computer stand, we were helped to understand how important it is for human beings to create a more comfortable environment and cause the least possible harm to the environment, while taking into account the economy in terms of product cost.

We implemented this computer stand so that users can have a better way to work, study, or develop better techniques to make work less burdensome, taking into account the worker's health and allowing them to easily develop their skills.

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CLASSIFICATION AND FACTORS OF HUMAN ERROR IN THE CREATION OF MANUFACTURING DRAWINGS AND MATERIALS LISTS.

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Resumen: En cualquier tipo de proceso siempre existe la posibilidad de errores durante su desarrollo. La tarea analizada en este caso es una de las tareas del proceso de diseño de herramientas para el soldado de componentes en tablillas electrónicas que consiste en generar planos y listas de materiales de los diseños realizados. En esta actividad se reportan frecuentemente casos donde errores como información errónea o incompleta ocasiona diversos atrasos, cuellos de botella, retrabajo, desperdicios que representan costos e ineficiencia. El objetivo de este trabajo es utilizar técnicas para analizar la confiabilidad humana y proponer recomendaciones concretas para reducir la posibilidad de errores humanos. El estudio se llevó a cabo con herramientas de ergonomía cognitiva como el Análisis Jerárquico de Tareas (HTA) y después con el método de Enfoque Sistemático de Reducción y Predicción de Errores Humanos (Systematic Human Error Reduction and Prediction Approach SHERPA). Se utilizó una muestra por conveniencia de ocho miembros del equipo de diseño en una empresa de manufactura de herramientas para procesos de soldado de componentes en tablillas electrónicas en Ciudad Juárez, Chihuahua, México. El HTA se desglosó en la tarea principal y subtareas que la integran obteniendo información detallada de la actividad de cada una de ellas, procediendo después con la clasificación y asociación de modos de error en cada una el método SHERPA determinando las consecuencias asociadas a cada modo de error. La tarea 4 sobre generar planos y listas de materiales de diseño, resultó ser la tarea más extensa en el proceso con 17 subtareas y estas subtareas con actividades que demandan altos niveles de atención, son repetitivas y se ejecutan con urgencia por lo que es vulnerable a errores. Clasificando y asociando los modos de error de cada subtarea con las taxonomías de SHERPA, se identificaron consecuencias, posibilidades y criticidad de estos modos de error. Un total de 26 errores humanos, de los cuales 25 fueron de acción (96.15%) y 1 de selección (3.84%). Las taxonomías identificadas con mayor presencia fueron “actividad omitida” con 13, seguido de “actividad incompleta” con 9, “actividad demasiado corta o larga” 1, “poca o mucha cantidad de actividades” 1 y “selección incorrecta” 1. La criticidad y probabilidad, en conjunto definen un nivel de riesgo de ocurrencia del error, el nivel encontrado en las subtareas analizadas fue alto en 18 de ellas (69.23%) y mediano en 8 de ellas (30.77%). La repetibilidad de las actividades en cada proyecto tomando en cuenta que se realizan de 2 a 3 diarios por diseñador, hace que sea una tarea extensa y vulnerable a errores por condiciones, por lo que es recomendable realizar cambios en esta actividad.

Palabras Clave: Error humano, Análisis Jerárquico de Tareas, SHERPA.

Relevancia para la ergonomía: Esta investigación contribuye al análisis de tareas propias del diseño para la manufactura utilizando herramientas de Ergonomía Cognitiva, ya que el análisis del error humano es escaso en procesos de diseño. En este caso, se estudió la tarea de realizar planos de piezas o elementos diseñados y listas de materiales para cada proyecto en el departamento de diseño de una empresa local y los errores humanos que se presentan durante la realización de la actividad en el proceso de diseño. Esta tarea es una de las más frecuentemente realizada en los procesos de diseño para manufactura y las características de la tarea y las condiciones presentes en las industrias fomentan situaciones en las que el error humano es frecuente. Debido a una extensa realización de actividades y a un proceso largo en algunas subtareas, el individuo se ve afectado al tener que mantener altos niveles de atención, que influyen en el procesamiento de información y la memoria, estos sistemas cognitivos se van degradando, propiciando errores de acción, omisiones y dando como resultado el error humano con efectos como frustración, esfuerzo y carga mental en el ser humano. En aquellos cuya criticidad es alta, así como la alta probabilidad de ocurrencia propicia desperdicios, defectos y mala calidad en el subproducto y producto final generando altos costos en la compañía.

Abstract: In any process, there is always the possibility of errors during its development. The task analyzed in this case is one of the tasks of the tool design process for the soldering of components on electronic boards, which consists of generating drawings and bills of materials of the designs made. In this activity, cases are frequently reported where errors such as erroneous or incomplete information cause delays, bottlenecks, rework, and waste that represent costs and inefficiency. The objective of this work is to use techniques to analyze human reliability and propose concrete recommendations to reduce the possibility of human errors. The study was carried out with cognitive ergonomics tools such as Hierarchical Task Analysis (HTA) and then with the Systematic Human Error Reduction and Prediction Approach (SHERPA) method. A convenience sample of eight design team members was used in a tooling manufacturing company for electronic board component soldering processes in Ciudad Juarez, Chihuahua, Mexico. The HTA was broken down into the main task and subtasks that integrate it, obtaining detailed information of the activity of each one of them, proceeding later with the classification and association of error modes in each one using the SHERPA method, determining the consequences associated with each error mode. Task 4 generating drawings and designing BOMs, turned out to be the most extensive task in the process with 17 subtasks and these subtasks with activities that demand high levels of attention, are repetitive, and are executed with urgency so it is vulnerable to errors. By classifying and associating the error modes of each subtask with the SHERPA taxonomies, the consequences, possibilities, and criticality of these error modes were identified. A total of 26 human errors, of which 25 were action errors (96.15%) and 1 selection error (3.84%). The taxonomies identified with the highest presence were “omitted activity” with 13, followed by “incomplete activity” with 9, “activity too short or long” with 1, “too few or too many activities” with 1, and “incorrect selection” 1. The criticality and probability, together define a level of risk of occurrence of the error, the level found in the subtasks analyzed was high in 18 of them (69.23%) and medium in 8 of them (30.77%). The repeatability of the activities in each project, taking into account that 2 to 3 are performed daily by the designer, makes it an extensive task and vulnerable to errors due to conditions, so it is advisable to make changes to this activity.

Keywords: Human error, Hierarchical Task Analysis, SHERPA.

Relevance to Ergonomics: This investigation contributes to the analysis of tasks within design for manufacturing by utilizing Cognitive Ergonomics tools, as the study of human error in design processes is scarce. In this case, the task of creating drawings for designed parts or components and preparing material lists for each project was studied within the design department of a local company, along with the human errors that occur during the execution of these activities in the design process. This task is one of the most frequently performed in design for manufacturing processes, and the characteristics of the task, along with the conditions present in industries, create situations where human error is common. Due to the extensive nature of the activities and the prolonged process involved in some subtasks, individuals are affected by having to maintain high levels of attention, which influences information processing and memory. These cognitive systems degrade over time, leading to action errors, and omissions, and resulting in human error with effects such as frustration, effort, and mental workload. In cases where the criticality is high and the probability of occurrence is also high, this leads to waste, defects, and poor quality in the subproduct and final product, generating high costs for the company.

1.- INTRODUCTION

A work team of the design department of a manufacturing company in Ciudad Juarez Chihuahua Mexico is made up of engineers specialized in mechanical design and manufacturing for the development of support tools to process electronic boards through various assembly and soldering processes. In this company, in the internal process control records shown in Figure 1, it is observed that the frequency of errors where the information is erroneous, incomplete, or not updated in the manufacturing drawings is the highest in the elaboration of the parts designed by the engineers of the department. The consequences generated by these errors or omissions of information range from bottlenecks in the flow of the manufacturing process, rework of parts, time extension, and loss of materials, among others, which results in considerable costs and economic losses for the company that can amount to several thousand U.S. dollars. In addition, the performance of the task under adverse and stressful conditions (Salas-Arias et al., 2018) propitiates in employees high levels of mental load due to attention, frustration, and mental and physical effort due to the limited time required to execute it. It is defined that human error is the incorrect or inappropriate execution of an action, particularly the failure to perform an activity (Chamby, 2018). The study of human error and the reliability of their actions is a complex subject, in which it is convenient to keep in mind that the individual's actions are always due to and from a diverse number of variables that involve personal, organizational, situational and/or environmental issues, which usually make it impossible to definitively determine the causes (Báez et al., 2013). To study human error there are data collection techniques that are used to collect concrete information about the activities performed in complex systems, and task analysis methods describe and represent them. Among the best-known and most widely used task analysis methods is Hierarchical Task Analysis (HTA) (Phipps et al., 2011) (Annett & Duncan, 1967). Navas de Maya et al., (2022) mention that this analysis has the peculiarity of presenting the tasks in a strict hierarchical structure, the main objectives (tasks) are represented at the top, while the secondary objectives (subtasks) are presented at the bottom. Thus, the HTA process is simplistic, it involves collecting data about the task or system under analysis through multiple techniques such as observation, experience, questionnaires, interviews, or documentation review among others, and then uses the data to decompose and describe the objectives and sub-objectives involved, (Stanton et al., 2005). Generally, any human factors analysis requires some form of task analysis, whether it is usability evaluation, error identification, or performance evaluation (Stanton et al., 2005; Stanton, 2006). The task description provided by these task analysis methods is often used as a basis for other analysis methods such as Systematic Human Error Prediction and Analysis SHERPA (Ghasemi et al., 2013) (American Nuclear Society. Human Factors Division. et al., 1986). This technique by taxonomies is used to qualitatively and quantitatively evaluate human reliability and develop concrete recommendations to reduce the probability of human errors, especially in terms of procedures, personnel training, and equipment design (Torres-Medina, 2020).

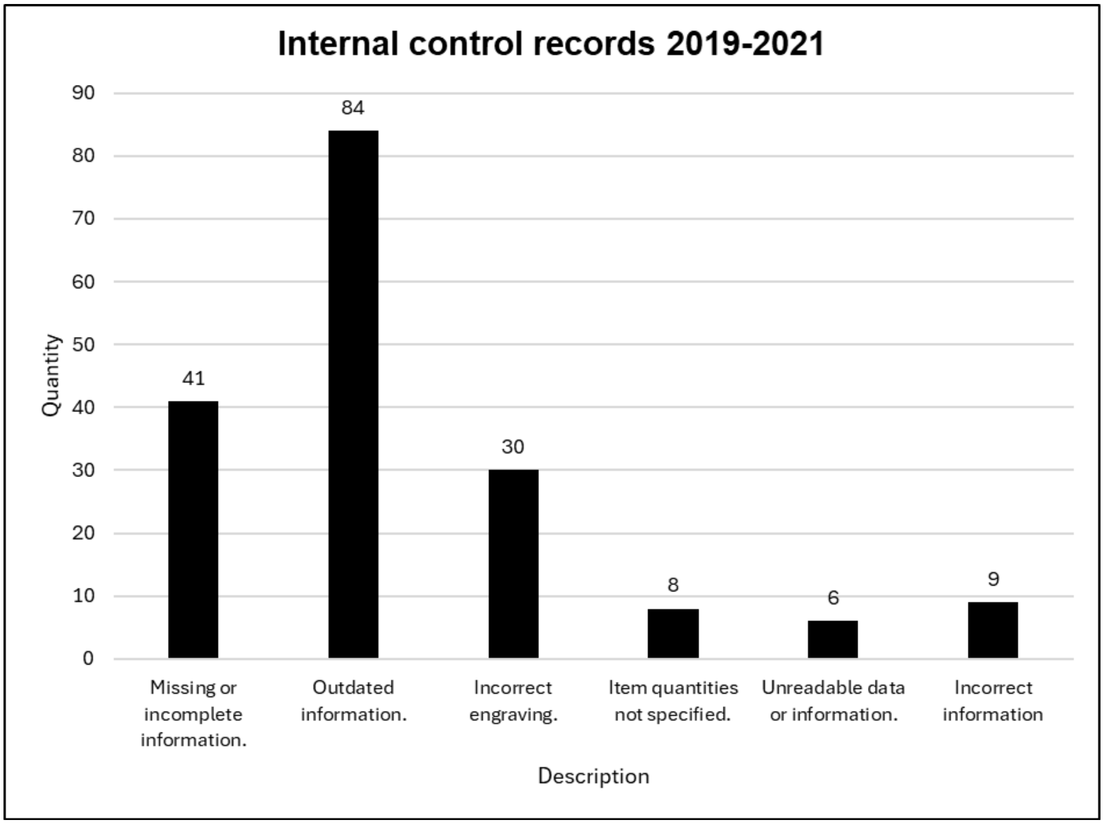


Figure 1. Records of Internal Control errors for the years 2019-2021

2. OBJECTIVES

To use techniques to analyze human reliability through data collection with the HTA and to qualitatively and quantitatively evaluate human reliability to classify and predict human errors using the SHERPA method and thereby propose concrete recommendations to reduce the probability of human errors.

3. DELIMITATION

This study seeks particularly to analyze human errors in the task of “Making drawings of parts and bills of materials” of the design department of a company in Cd. Juarez Chihuahua Mexico, dedicated to designing and manufacturing various tools for manufacturing processes of electronic boards of the local industry, proposes recommendations.

4. METHODOLOGY

This descriptive study seeks to analyze and classify the types of human error in the design process. The study will be carried out in two steps as shown in Figure 1, in the first step (HTA, Hierarchical Task Analysis) is hierarchical task analysis to break down the operations of the process of making drawings of parts and bills of materials, and the second step will consist of developing the SHERPA (Systematic Human Error Reduction and Prediction Approach) method, to qualitatively and quantitatively assess the reliability and where the taxonomies established to the type of error associated with specific operations within the task will be identified.

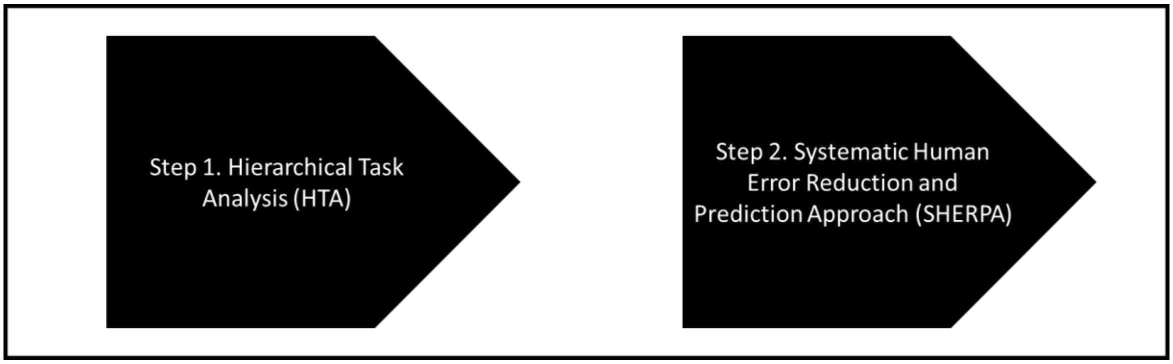


Figure 1. Steps in the methodology.

1.1 Hierarchical Task Analysis (HTA).

According to the methodology proposed by Stanton (2005), HTA is carried out by making a diagram showing a breakdown of hierarchical terms by objects, sub-objects, operations, and plans as shown in Figure 2.

1.2 Systematic Human Error Reduction and Prevention Analysis (SHERPA) Method

In this stage, the methodology proposed by Stanton 2005 will be developed. Thus, once the hierarchical task analysis has been performed, the task will be classified from the lower level of the hierarchical task analysis to the higher one, and the error modes will be classified according to the SHERPA taxonomy shown in Figure 3. He/she should then determine and describe the consequences associated with each error mode; furthermore, he/she should determine the recovery from the identified error. Also, once these steps are completed, you should determine the probability of occurrence of the error, its criticality, and how to remedy it through redesign, equipment modification, personnel training, changes to procedures, or changes in organizational culture and policies.

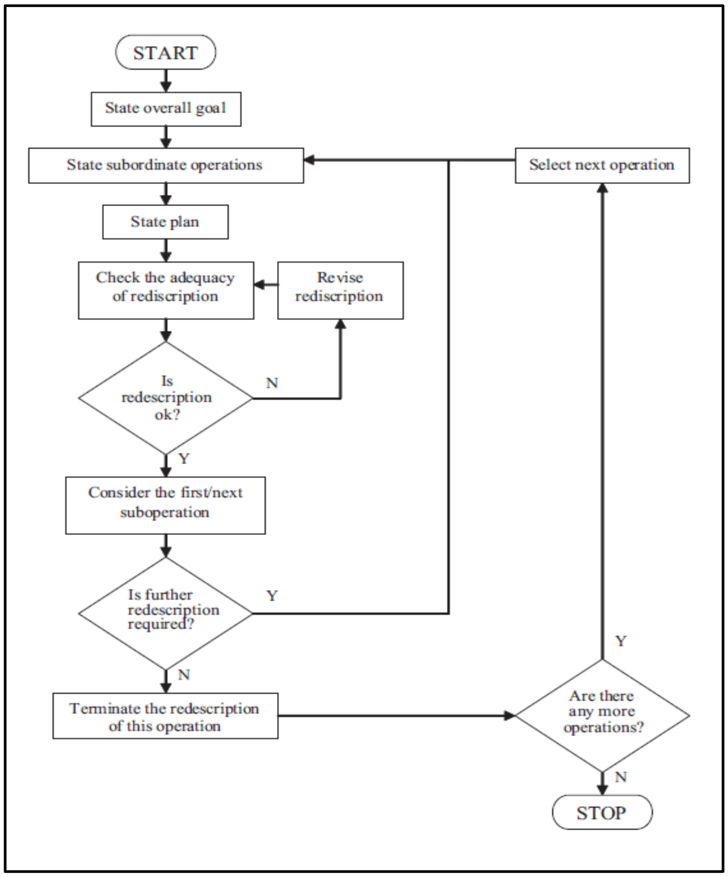
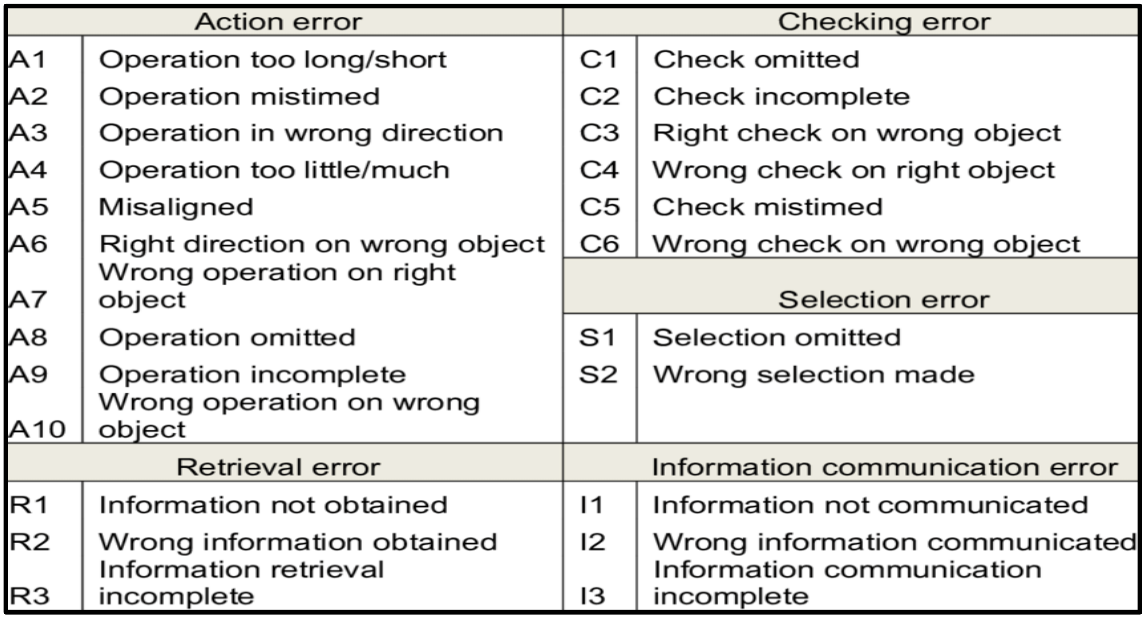


Figure 2. Hierarchical Task Analysis (HTA) Methodology



	Action error		Checking error
A1	Operation too long/short	C1	Check omitted
A2	Operation mistimed	C2	Check incomplete
A3	Operation in wrong direction	C3	Right check on wrong object
A4	Operation too little/much	C4	Wrong check on right object
A5	Misaligned	C5	Check mistimed
A6	Right direction on wrong object	C6	Wrong check on wrong object
A7	Wrong operation on right object		Selection error
A8	Operation omitted	S1	Selection omitted
A9	Operation incomplete	S2	Wrong selection made
A10	Wrong operation on wrong object		
	Retrieval error		Information communication error
R1	Information not obtained	I1	Information not communicated
R2	Wrong information obtained	I2	Wrong information communicated
R3	Information retrieval incomplete	I3	Information communication incomplete

Figure 3. Taxonomic error mode.

5. RESULTS

The results of this study were organized into the steps mentioned above and are shown below.

Step One. By collecting data through interviews with personnel directly and indirectly involved in the process and a thorough review of the activities, a hierarchical task analysis was developed with the main tasks or activities, as well as subtasks included in each of the main tasks of the design process as shown in Figure 4.

Task 4, the subject of this study and described as 'creating part drawings and material lists,' was broken down into 17 subtasks that comprise the main task in a sequential plan format, as shown in Figure 5

Step Two. Applying the SHERPA method to task 4, the classification of subtasks was carried out according to the taxonomies of the method (Figure 6), identifying error modes and finding between 1 and 4 error modes related to the method in each subtask. A total of 26 human errors were identified, of which 25 were action errors (96.15%) and 1 was a selection error (3.84%). The most frequently identified taxonomies were "omitted activity" with 13 occurrences, followed by "incomplete activity" with 9, "activity too short or too long" with 1, "too few or too many activities" with 1, and "incorrect selection" with 1. The criticality and probability, together, define a level of risk of error occurrence; the level found in the analyzed subtasks was high in 18 (69.23%) of them and medium in 8 (30.77%). Recovery strategies mainly involve the use of the individual's attentional resources, which include verification and observation activities.

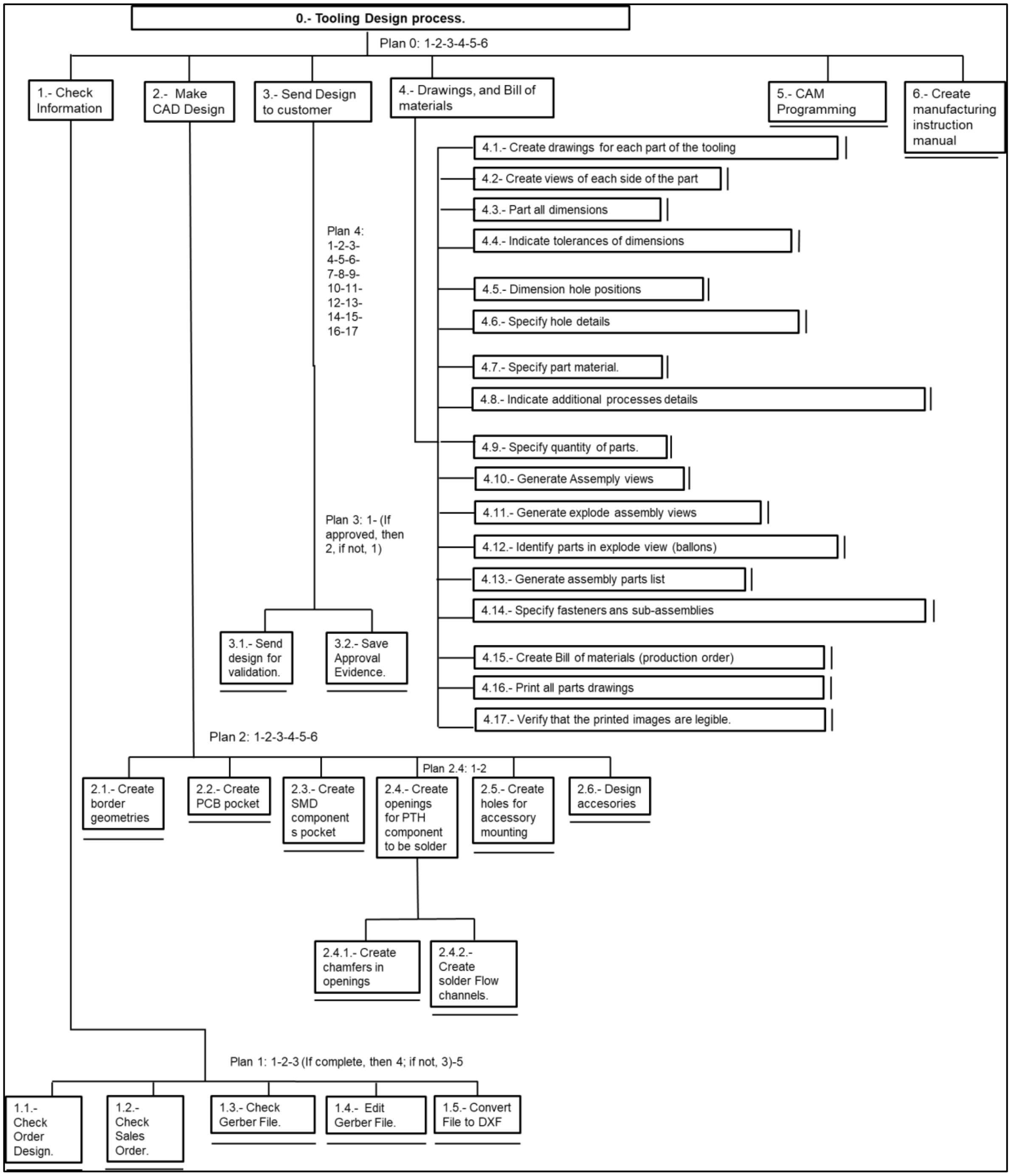


Figure 4. Hierarchical task analysis of the overall process.

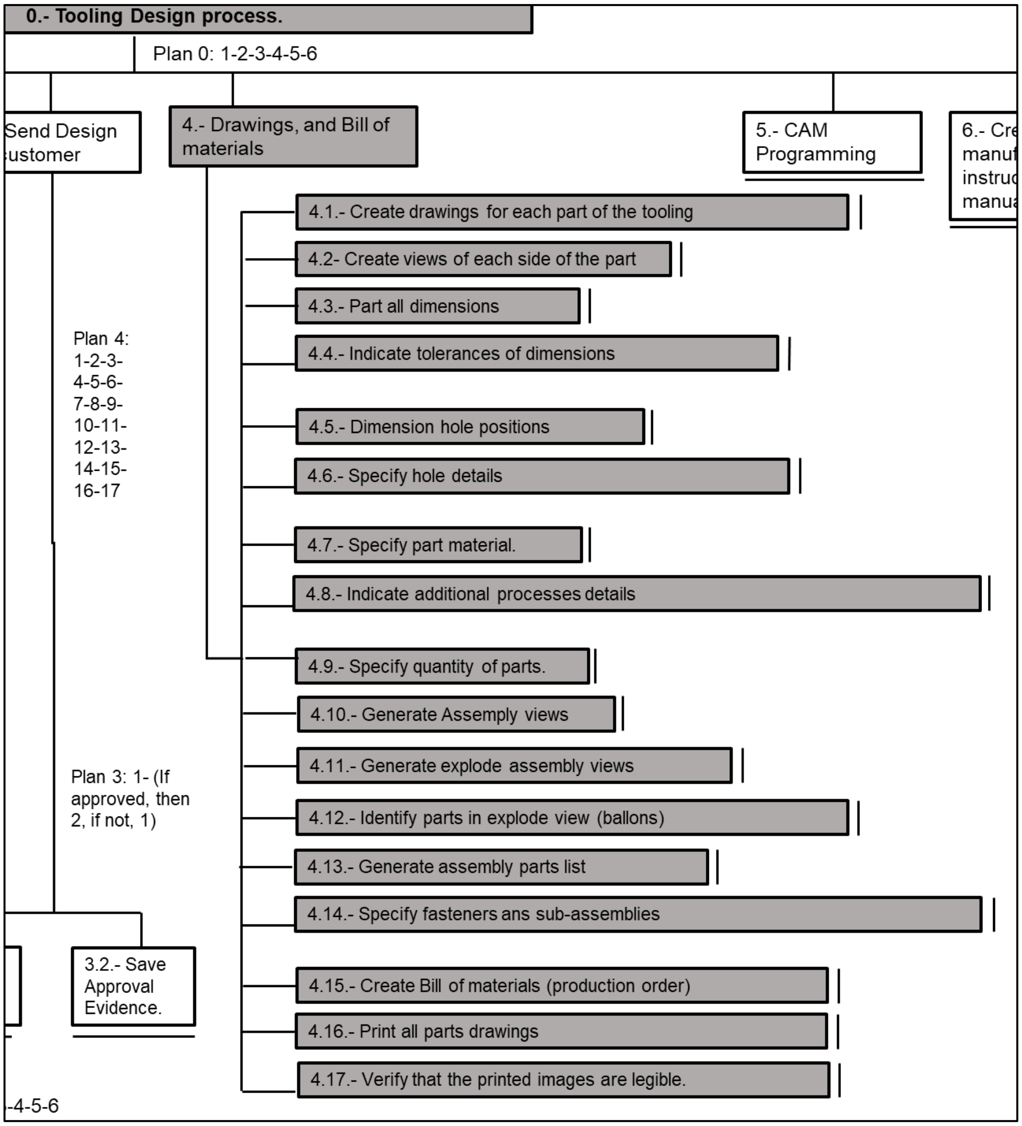


Figure 5. Detailed breakdown of Task 4

SHERPA output for task No.4.- Make part drawings and bill of materials.							
Step of Task	**Error Mode**	**Error Description.**	**Consecuences**	**Recovery**	**P**	**C**	**Recovery Startegy**
4.1.- Create drawings of each element of tooling	A1	Operation too long/short	Missing drawings	Task 4.1	H	_	Verify that the drawings of each part are available
	A4	Operation too little/much	Missing drawings and then they do not manufacture the part	Task 4.1	H	_	Verify that the drawings of each part are available
	A8	Operation omitted	Not manufacture the part	Task 4.1	H	_	Verify that the drawings of each part are available
	A9	Operation incomplete Wrong operation on wrong	Not manufacture the part	Task 4.1	H	_	Verify that the drawings of each part are available
4.2.- Create principal views of each part of tooling	A8	Operation omitted	No details of the parts are visible on the drawings.	Task 4.2	H	!	Verify that all views are present
	A9	Operation incomplete Wrong operation on wrong	No details of the parts are visible on the drawings.	Task 4.2	H	!	Verify that all views are present
4.3.- All dimensions of each part	A9	Operation incomplete Wrong operation on wrong	Part dimensions are missing and the part cannot be manufactured.	Task 4.3	H	_	Make sure all dimensions are present
	S2	Wrong selection made	The part is incorrectly dimensioned and poorly made.	Task 4.3	H	!	Verify that the dimension is correct.
4.4.- Indicate dimension tolerances.	A8	Operation omitted	The part is out of a functional size.	Task 4.4	H	!	Indicate tolerance on all dimension.
4.5.- Dimension Hole Positions	A8	Operation omitted	Drilling operation cannot be carried out	Task 4.5	H	!	Place the corresponding dimension
	A9	Operation incomplete Wrong operation on wrong	Drilling operation cannot be carried out	Task 4.5	H	_	Make sure all dimensions are present
4.6.- Specify Hole Characteristics	A8	Operation omitted	Incorrect drilling	Task 4.6	H	_	Make sure all dimensions are present
	A9	Operation incomplete Wrong operation on wrong	The hole is not functional	Task 4.6	H	!	Verify that the information is complete
4.7.- Specify Part Material	A5	Misaligned	Manufacture of the part with the wrong material	Task 4.7	H	!	Verify that the information is present and correct.
	A8	Operation omitted	Manufacture of the part with the wrong material	Task 4.7	H	!	Verify that the information is correct.
4.8.- Indicate Additional Processes if Applicable (Conventional Machining, Heat Treatment, Anodizing, Polishing, etc.)	A8	Operation omitted	Missing critical information to complete the part process	Task 4.8	H	!	Verify that it is indicated whether or not the part requires additional processing.
4.9.-Specify Quantity of Parts	A8	Operation omitted	Missing parts to complete the product	Task 4.9	M	_	Verify that the quantity of parts is indicated and is correct.
4.10.-Generate Assembly Views	A8	Operation omitted	Assembly details are not shown and features are omitted.	Task 4.10	M	_	Verify that the assembly view is present.
.11.- Generate Exploded Assembly View	A8	Actividad omitida	Assembly details are not visible and steps are omitted.	Task 4.11	M	_	Verify that the exploded view is present
4.12.-Identify Parts in the Exploded View (Balloons)	A8	Operation omitted	Items will not be fully identified	Task 4.12	M	_	Verify that the parts are identified in the explosion view
4.13.- Generate Assembly Parts List	A8	Operation omitted	That not all parts and quantities are contemplated and that it affects planning	Task 4.13	M	_	Verify that the assembly list is present for correct planning.
4.14.-Specify Fasteners and Sub-assemblies (Bolts, Pins, Nuts, Line Accessories, etc.)	A9	Operation incomplete Wrong operation on wrong	Wrong parts are placed	Task 4.14	H	_	Verify that the correct accessories are indicated.
4.15.- Create Bill of Materials (Production Order)	A9	Operation incomplete Wrong operation on wrong	Missing accessories to finish the product	Task 4.15	M	_	Verify that the bill of materials is complete and correct.
4.16.-Print All Part Drawings	A9	Operation incomplete Wrong operation on wrong	Missing drawings and parts are not made	Task 4.16	H	!	Verify that all drawings for product fabrication are in place.
4.17.- Verify that the Printed Images are Legible and Appropriately Sized	A8	Operation omitted	Measurements, details and characteristics of the parts are not legible.	Task 4.17	M	!	Verify that all drawings are legible and understandable.
	A9	Operation incomplete Wrong operation on wrong	Missing information and omission of important details	Task 4.17	M	!	Verify that all drawings are legible and understandable

Figure 6. SHERPA application in task 4.

6. CONCLUSIONS

The development of the hierarchical task analysis contributed to detail in a specific way the tasks and subtasks required and included in the process, achieving a clear and precise map of all the activities involved in the design process. In addition to this, the hierarchical task analysis contributed essential information for the development of the SHERPA method for the identification and classification of human error, detecting areas of opportunity in which standardization of elements and tools that contribute to the reduction of activities will be proposed, in addition to this, error recovery strategies in a systematic way to avoid affecting subsequent stages and process flows.

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CLASSIFICATION AND FACTORS OF HUMAN ERROR IN THE CREATION OF MANUFACTURING DRAWINGS AND MATERIALS LISTS.

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Resumen: En cualquier tipo de proceso siempre existe la posibilidad de errores durante su desarrollo. La tarea analizada en este caso es una de las tareas del proceso de diseño de herramientas para el soldado de componentes en tablillas electrónicas que consiste en generar planos y listas de materiales de los diseños realizados. En esta actividad se reportan frecuentemente casos donde errores como información errónea o incompleta ocasiona diversos atrasos, cuellos de botella, retrabajo, desperdicios que representan costos e ineficiencia. El objetivo de este trabajo es utilizar técnicas para analizar la confiabilidad humana y proponer recomendaciones concretas para reducir la posibilidad de errores humanos. El estudio se llevó a cabo con herramientas de ergonomía cognitiva como el Análisis Jerárquico de Tareas (HTA) y después con el método de Enfoque Sistemático de Reducción y Predicción de Errores Humanos (Systematic Human Error Reduction and Prediction Approach SHERPA). Se utilizó una muestra por conveniencia de ocho miembros del equipo de diseño en una empresa de manufactura de herramientas para procesos de soldado de componentes en tablillas electrónicas en Ciudad Juárez, Chihuahua, México. El HTA se desglosó en la tarea principal y subtareas que la integran obteniendo información detallada de la actividad de cada una de ellas, procediendo después con la clasificación y asociación de modos de error en cada una el método SHERPA determinando las consecuencias asociadas a cada modo de error. La tarea 4 sobre generar planos y listas de materiales de diseño, resultó ser la tarea más extensa en el proceso con 17 subtareas y estas subtareas con actividades que demandan altos niveles de atención, son repetitivas y se ejecutan con urgencia por lo que es vulnerable a errores. Clasificando y asociando los modos de error de cada subtarea con las taxonomías de SHERPA, se identificaron consecuencias, posibilidades y criticidad de estos modos de error. Un total de 26 errores humanos, de los cuales 25 fueron de acción (96.15%) y 1 de selección (3.84%). Las taxonomías identificadas con mayor presencia fueron "actividad omitida" con 13, seguido de "actividad incompleta" con 9, "actividad demasiado corta o larga" 1, "poca o mucha cantidad de actividades" 1 y "selección incorrecta" 1. La criticidad y probabilidad, en conjunto definen un nivel de riesgo de ocurrencia del error, el nivel encontrado en las subtareas analizadas fue alto en 18 de ellas (69.23%) y mediano en 8 de ellas (30.77%). La repetibilidad de las actividades en cada proyecto tomando en cuenta que se realizan de 2 a 3 diarios por diseñador, hace que sea una tarea extensa y vulnerable a errores por condiciones, por lo que es recomendable realizar cambios en esta actividad.

Palabras Clave: Error humano, Análisis Jerárquico de Tareas, SHERPA.

Relevancia para la ergonomía: Esta investigación contribuye al análisis de tareas propias del diseño para la manufactura utilizando herramientas de Ergonomía Cognitiva, ya que el análisis del error humano es escaso en procesos de diseño. En este caso, se estudió la tarea de realizar planos de piezas o elementos diseñados y listas de materiales para cada proyecto en el departamento de diseño de una empresa local y los errores humanos que se presentan durante la realización de la actividad en el proceso de diseño. Esta tarea es una de las más frecuentemente realizada en los procesos de diseño para manufactura y las características de la tarea y las condiciones presentes en las industrias fomentan situaciones en las que el error humano es frecuente. Debido a una extensa realización de actividades y a un proceso largo en algunas subtareas, el individuo se ve afectado al tener que mantener altos niveles de atención, que influyen en el procesamiento de información y la memoria, estos sistemas cognitivos se van degradando, propiciando errores de acción, omisiones y dando como resultado el error humano con efectos como frustración, esfuerzo y carga mental en el ser humano. En aquellos cuya criticidad es alta, así como la alta probabilidad de ocurrencia propicia desperdicios, defectos y mala calidad en el subproducto y producto final generando altos costos en la compañía.

Abstract: In any process, there is always the possibility of errors during its development. The task analyzed in this case is one of the tasks of the tool design process for the soldering of components on electronic boards, which consists of generating drawings and bills of materials of the designs made. In this activity, cases are frequently reported where errors such as erroneous or incomplete information cause delays, bottlenecks, rework, and waste that represent costs and inefficiency. The objective of this work is to use techniques to analyze human reliability and propose concrete recommendations to reduce the possibility of human errors. The study was carried out with cognitive ergonomics tools such as Hierarchical Task Analysis (HTA) and then with the Systematic Human Error Reduction and Prediction Approach (SHERPA) method. A convenience sample of eight design team members was used in a tooling manufacturing company for electronic board component soldering processes in Ciudad Juarez, Chihuahua, Mexico. The HTA was broken down into the main task and subtasks that integrate it, obtaining detailed information of the activity of each one of them, proceeding later with the classification and association of error modes in each one using the SHERPA method, determining the consequences associated with each error mode. Task 4 generating drawings and designing BOMs, turned out to be the most extensive task in the process with 17 subtasks and these subtasks with activities that demand high levels of attention, are repetitive, and are executed with urgency so it is vulnerable to errors. By classifying and associating the error modes of each subtask with the SHERPA taxonomies, the consequences, possibilities, and criticality of these error modes were identified. A total of 26 human errors, of which 25 were action errors (96.15%) and 1 selection error (3.84%). The taxonomies identified with the highest presence were “omitted activity” with 13, followed by “incomplete activity” with 9, “activity too short or long” with 1, “too few or too many activities” with 1, and “incorrect selection” 1. The criticality and probability, together define a level of risk of occurrence of the error, the level found in the subtasks analyzed was high in 18 of them (69.23%) and medium in 8 of them (30.77%). The repeatability of the activities in each project, taking into account that 2 to 3 are performed daily by the designer, makes it an extensive task and vulnerable to errors due to conditions, so it is advisable to make changes to this activity.

Keywords: Human error, Hierarchical Task Analysis, SHERPA.

Relevance to Ergonomics: This investigation contributes to the analysis of tasks within design for manufacturing by utilizing Cognitive Ergonomics tools, as the study of human error in design processes is scarce. In this case, the task of creating drawings for designed parts or components and preparing material lists for each project was studied within the design department of a local company, along with the human errors that occur during the execution of these activities in the design process. This task is one of the most frequently performed in design for manufacturing processes, and the characteristics of the task, along with the conditions present in industries, create situations where human error is common. Due to the extensive nature of the activities and the prolonged process involved in some subtasks, individuals are affected by having to maintain high levels of attention, which influences information processing and memory. These cognitive systems degrade over time, leading to action errors, and omissions, and resulting in human error with effects such as frustration, effort, and mental workload. In cases where the criticality is high and the probability of occurrence is also high, this leads to waste, defects, and poor quality in the subproduct and final product, generating high costs for the company.

1.- INTRODUCTION

A work team of the design department of a manufacturing company in Ciudad Juarez Chihuahua Mexico is made up of engineers specialized in mechanical design and manufacturing for the development of support tools to process electronic boards through various assembly and soldering processes. In this company, in the internal process control records shown in Figure 1, it is observed that the frequency of errors where the information is erroneous, incomplete, or not updated in the manufacturing drawings is the highest in the elaboration of the parts designed by the engineers of the department. The consequences generated by these errors or omissions of information range from bottlenecks in the flow of the manufacturing process, rework of parts, time extension, and loss of materials, among others, which results in considerable costs and economic losses for the company that can amount to several thousand U.S. dollars. In addition, the performance of the task under adverse and stressful conditions (Salas-Arias et al., 2018) propitiates in employees high levels of mental load due to attention, frustration, and mental and physical effort due to the limited time required to execute it. It is defined that human error is the incorrect or inappropriate execution of an action, particularly the failure to perform an activity (Chamby, 2018). The study of human error and the reliability of their actions is a complex subject, in which it is convenient to keep in mind that the individual's actions are always due to and from a diverse number of variables that involve personal, organizational, situational and/or environmental issues, which usually make it impossible to definitively determine the causes (Báez et al., 2013). To study human error there are data collection techniques that are used to collect concrete information about the activities performed in complex systems, and task analysis methods describe and represent them. Among the best-known and most widely used task analysis methods is Hierarchical Task Analysis (HTA) (Phipps et al., 2011) (Annett & Duncan, 1967). Navas de Maya et al., (2022) mention that this analysis has the peculiarity of presenting the tasks in a strict hierarchical structure, the main objectives (tasks) are represented at the top, while the secondary objectives (subtasks) are presented at the bottom. Thus, the HTA process is simplistic, it involves collecting data about the task or system under analysis through multiple techniques such as observation, experience, questionnaires, interviews, or documentation review among others, and then uses the data to decompose and describe the objectives and sub-objectives involved, (Stanton et al., 2005). Generally, any human factors analysis requires some form of task analysis, whether it is usability evaluation, error identification, or performance evaluation (Stanton et al., 2005; Stanton, 2006). The task description provided by these task analysis methods is often used as a basis for other analysis methods such as Systematic Human Error Prediction and Analysis SHERPA (Ghasemi et al., 2013) (American Nuclear Society. Human Factors Division. et al., 1986). This technique by taxonomies is used to qualitatively and quantitatively evaluate human reliability and develop concrete recommendations to reduce the probability of human errors, especially in terms of procedures, personnel training, and equipment design (Torres-Medina, 2020).

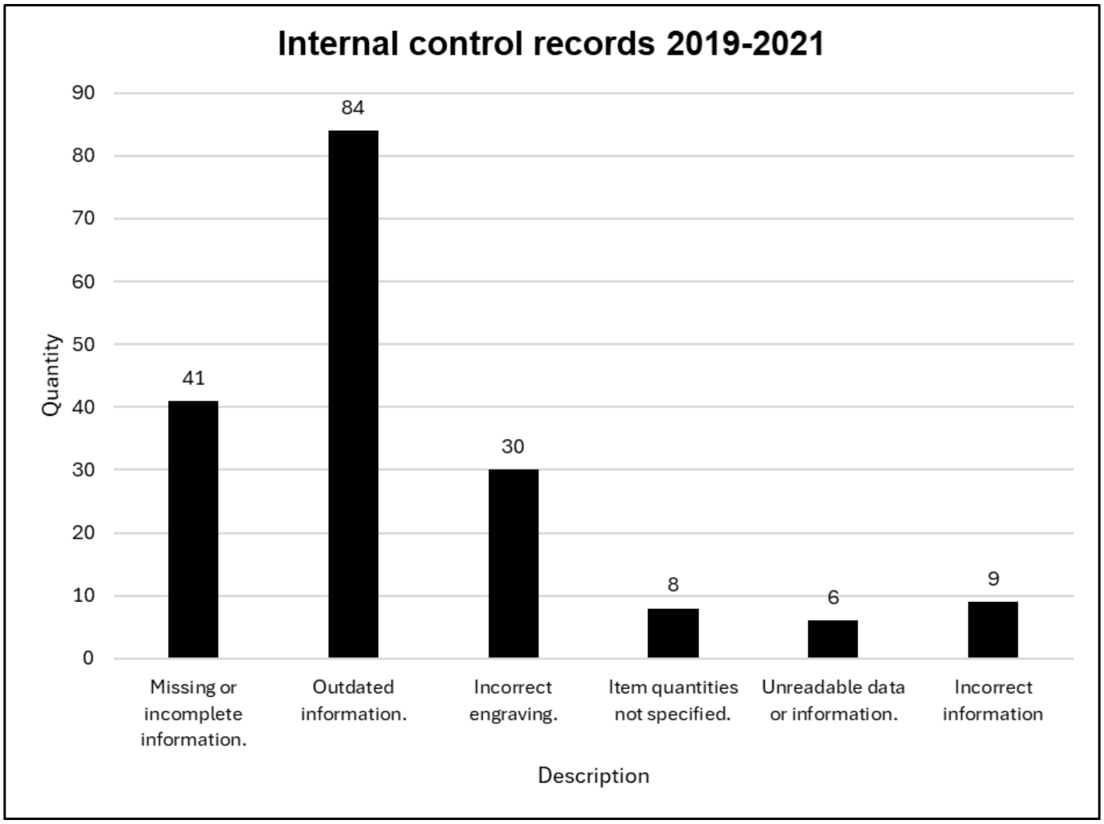


Figure 1. Records of Internal Control errors for the years 2019-2021

2. OBJECTIVES

To use techniques to analyze human reliability through data collection with the HTA and to qualitatively and quantitatively evaluate human reliability to classify and predict human errors using the SHERPA method and thereby propose concrete recommendations to reduce the probability of human errors.

3. DELIMITATION

This study seeks particularly to analyze human errors in the task of “Making drawings of parts and bills of materials” of the design department of a company in Cd. Juarez Chihuahua Mexico, dedicated to designing and manufacturing various tools for manufacturing processes of electronic boards of the local industry, proposes recommendations.

4. METHODOLOGY

This descriptive study seeks to analyze and classify the types of human error in the design process. The study will be carried out in two steps as shown in Figure 1, in the first step (HTA, Hierarchical Task Analysis) is hierarchical task analysis to break down the operations of the process of making drawings of parts and bills of materials, and the second step will consist of developing the SHERPA (Systematic Human Error Reduction and Prediction Approach) method, to qualitatively and quantitatively assess the reliability and where the taxonomies established to the type of error associated with specific operations within the task will be identified.

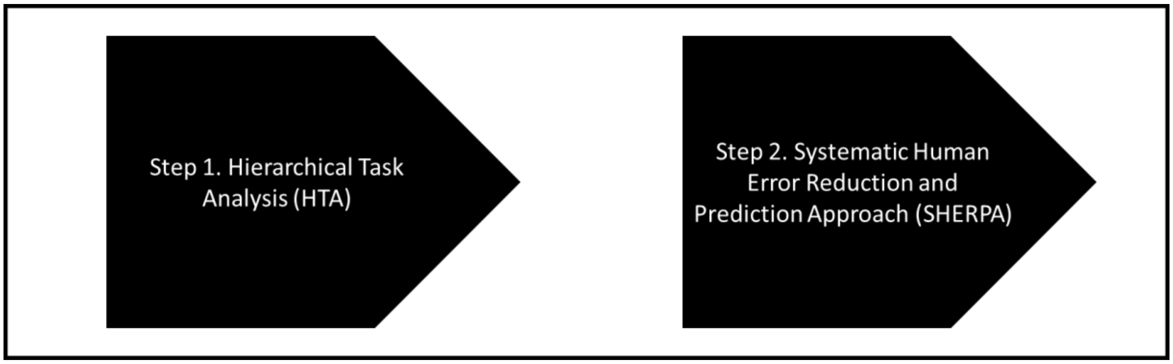


Figure 1. Steps in the methodology.

1.1 Hierarchical Task Analysis (HTA).

According to the methodology proposed by Stanton (2005), HTA is carried out by making a diagram showing a breakdown of hierarchical terms by objects, sub-objects, operations, and plans as shown in Figure 2.

1.2 Systematic Human Error Reduction and Prevention Analysis (SHERPA) Method

In this stage, the methodology proposed by Stanton 2005 will be developed. Thus, once the hierarchical task analysis has been performed, the task will be classified from the lower level of the hierarchical task analysis to the higher one, and the error modes will be classified according to the SHERPA taxonomy shown in Figure 3. He/she should then determine and describe the consequences associated with each error mode; furthermore, he/she should determine the recovery from the identified error. Also, once these steps are completed, you should determine the probability of occurrence of the error, its criticality, and how to remedy it through redesign, equipment modification, personnel training, changes to procedures, or changes in organizational culture and policies.

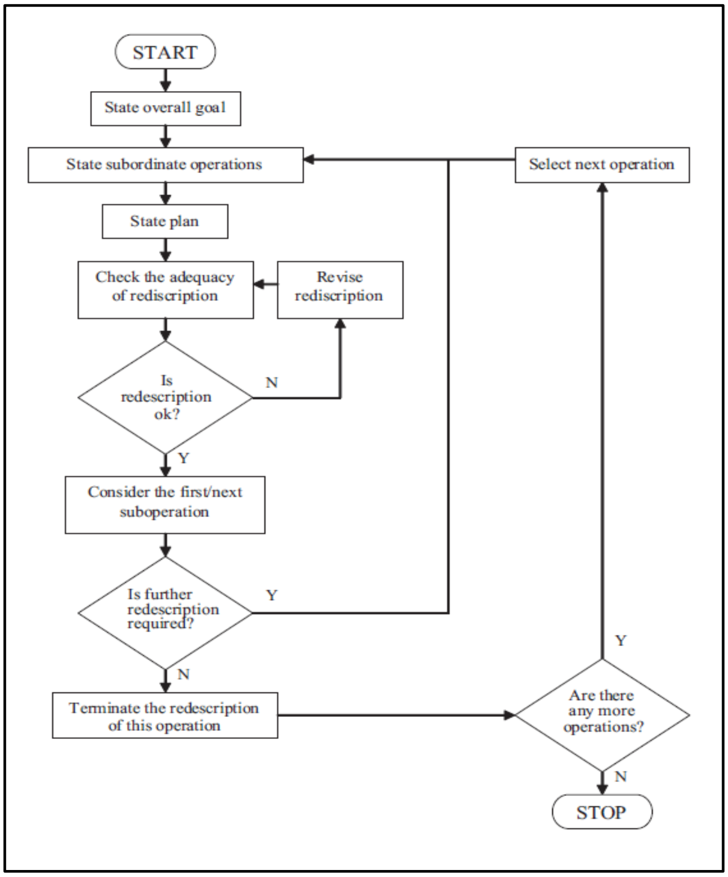
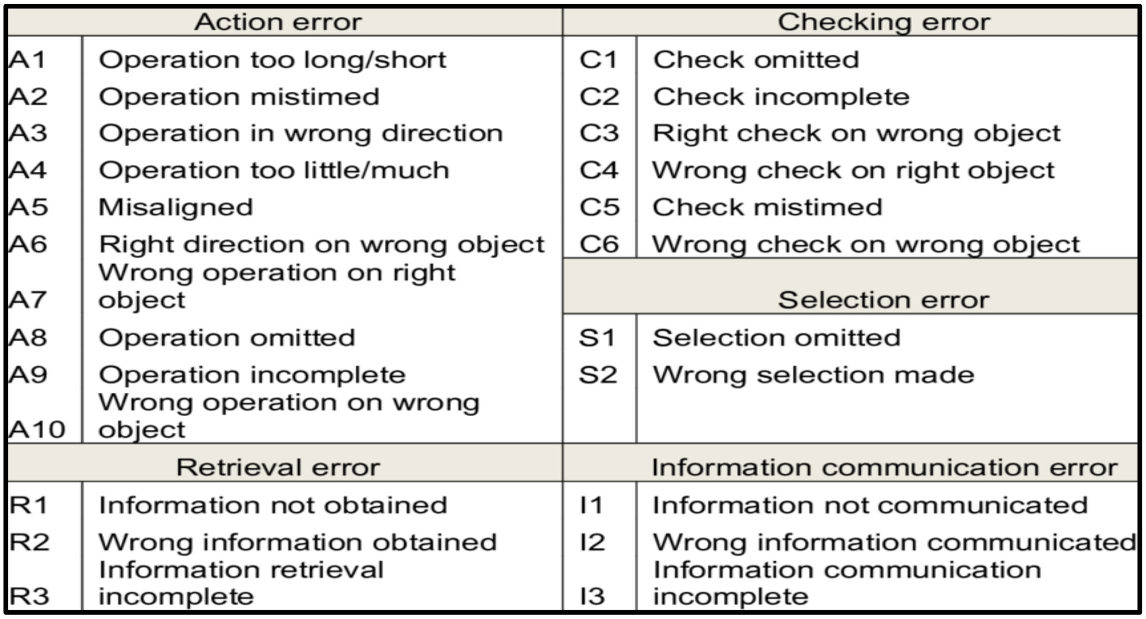


Figure 2. Hierarchical Task Analysis (HTA) Methodology



Action error		Checking error	
A1	Operation too long/short	C1	Check omitted
A2	Operation mistimed	C2	Check incomplete
A3	Operation in wrong direction	C3	Right check on wrong object
A4	Operation too little/much	C4	Wrong check on right object
A5	Misaligned	C5	Check mistimed
A6	Right direction on wrong object	C6	Wrong check on wrong object
A7	Wrong operation on right object	Selection error	
A8	Operation omitted	S1	Selection omitted
A9	Operation incomplete	S2	Wrong selection made
A10	Wrong operation on wrong object		
Retrieval error		Information communication error	
R1	Information not obtained	I1	Information not communicated
R2	Wrong information obtained	I2	Wrong information communicated
R3	Information retrieval incomplete	I3	Information communication incomplete

Figure 3. Taxonomic error mode.

5. RESULTS

The results of this study were organized into the steps mentioned above and are shown below.

Step One. By collecting data through interviews with personnel directly and indirectly involved in the process and a thorough review of the activities, a hierarchical task analysis was developed with the main tasks or activities, as well as subtasks included in each of the main tasks of the design process as shown in Figure 4.

Task 4, the subject of this study and described as 'creating part drawings and material lists,' was broken down into 17 subtasks that comprise the main task in a sequential plan format, as shown in Figure 5.

Step Two. Applying the SHERPA method to task 4, the classification of subtasks was carried out according to the taxonomies of the method (Figure 6), identifying error modes and finding between 1 and 4 error modes related to the method in each subtask. A total of 26 human errors were identified, of which 25 were action errors (96.15%) and 1 was a selection error (3.84%). The most frequently identified taxonomies were "omitted activity" with 13 occurrences, followed by "incomplete activity" with 9, "activity too short or too long" with 1, "too few or too many activities" with 1, and "incorrect selection" with 1. The criticality and probability, together, define a level of risk of error occurrence; the level found in the analyzed subtasks was high in 18 (69.23%) of them and medium in 8 (30.77%). Recovery strategies mainly involve the use of the individual's attentional resources, which include verification and observation activities.

6. CONCLUSIONS

The development of the hierarchical task analysis contributed to detail in a specific way the tasks and subtasks required and included in the process, achieving a clear and precise map of all the activities involved in the design process. In addition to this, the hierarchical task analysis contributed essential information for the development of the SHERPA method for the identification and classification of human error, detecting areas of opportunity in which standardization of elements and tools that contribute to the reduction of activities will be proposed, in addition to this, error recovery strategies in a systematic way to avoid affecting subsequent stages and process flows.

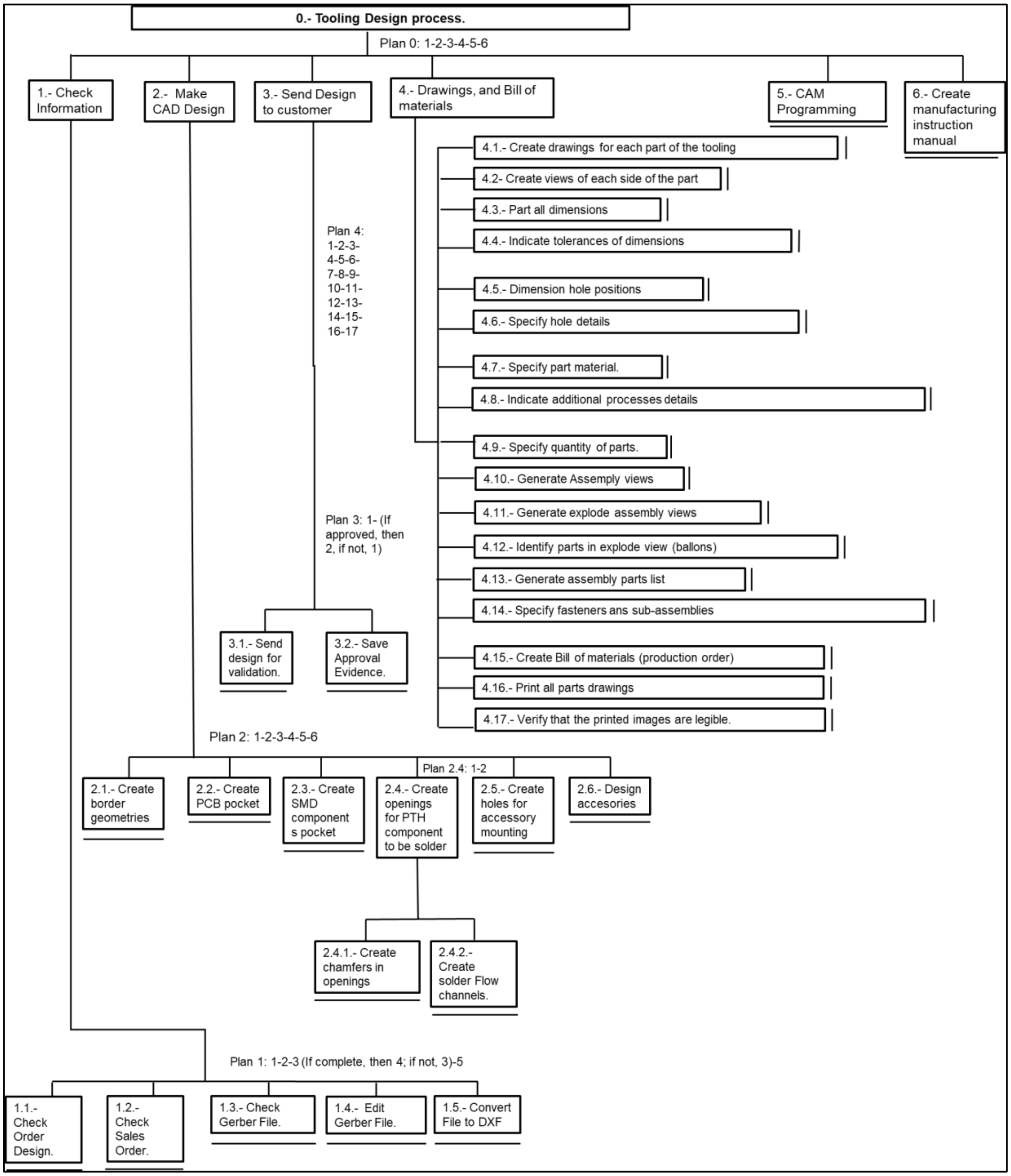


Figure 4. Hierarchical task analysis of the overall process.

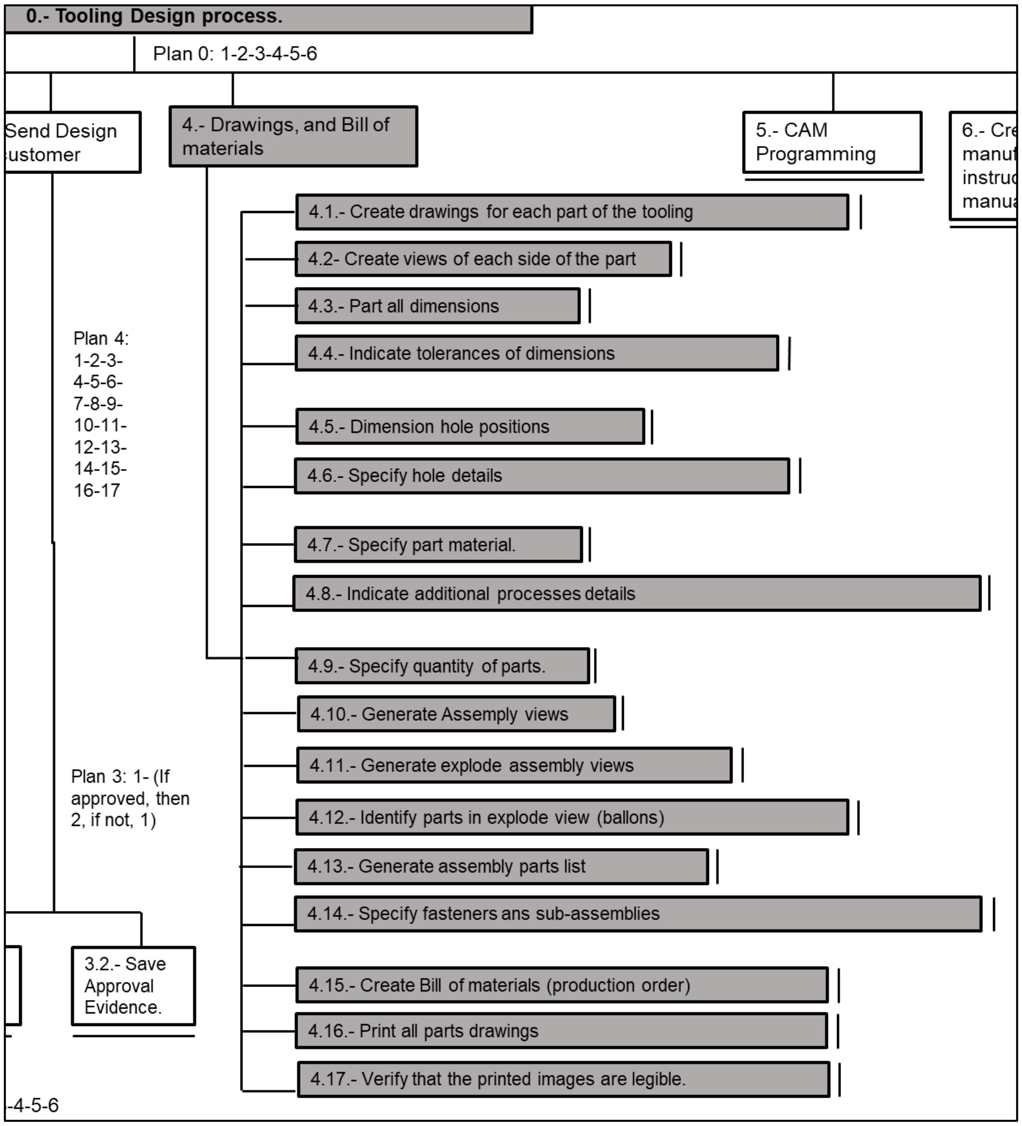


Figure 5. Detailed breakdown of Task 4

SHERPA output for task No.4.- Make part drawings and bill of materials.							
Step of Task	**Error Mode**	**Error Description.**	**Consecuences**	**Recovery**	**P**	**C**	**Recovery Startegy**
4.1.- Create drawings of each element of tooling	A1	Operation too long/short	Missing drawings	Task 4.1	H	_	Verify that the drawings of each part are available
	A4	Operation too little/much	Missing drawings and then they do not manufacture the part	Task 4.1	H	_	Verify that the drawings of each part are available
	A8	Operation omitted	Not manufacture the part	Task 4.1	H	_	Verify that the drawings of each part are available
	A9	Operation incomplete Wrong operation on wrong	Not manufacture the part	Task 4.1	H	_	Verify that the drawings of each part are available
4.2.- Create principal views of each part of tooling	A8	Operation omitted	No details of the parts are visible on the drawings.	Task 4.2	H	!	Verify that all views are present
	A9	Operation incomplete Wrong operation on wrong	No details of the parts are visible on the drawings.	Task 4.2	H	!	Verify that all views are present
4.3.- All dimensions of each part	A9	Operation incomplete Wrong operation on wrong	Part dimensions are missing and the part cannot be manufactured.	Task 4.3	H	_	Make sure all dimensions are present
	S2	Wrong selection made	The part is incorrectly dimensioned and poorly made.	Task 4.3	H	!	Verify that the dimension is correct.
4.4.- Indicate dimension tolerances.	A8	Operation omitted	The part is out of a functional size.	Task 4.4	H	!	Indicate tolerance on all dimension.
4.5.- Dimension Hole Positions	A8	Operation omitted	Drilling operation cannot be carried out	Task 4.5	H	!	Place the corresponding dimension
	A9	Operation incomplete Wrong operation on wrong	Drilling operation cannot be carried out	Task 4.5	H	_	Make sure all dimensions are present
4.6.- Specify Hole Characteristics	A8	Operation omitted	Incorrect drilling	Task 4.6	H	_	Make sure all dimensions are present
	A9	Operation incomplete Wrong operation on wrong	The hole is not functional	Task 4.6	H	!	Verify that the information is complete
4.7.- Specify Part Material	A5	Misaligned	Manufacture of the part with the wrong material	Task 4.7	H	!	Verify that the information is present and correct.
	A8	Operation omitted	Manufacture of the part with the wrong material	Task 4.7	H	!	Verify that the information is correct.
4.8.- Indicate Additional Processes if Applicable (Conventional Machining, Heat Treatment, Anodizing, Polishing, etc.)	A8	Operation omitted	Missing critical information to complete the part process	Task 4.8	H	!	Verify that it is indicated whether or not the part requires additional processing.
4.9.-Specify Quantity of Parts	A8	Operation omitted	Missing parts to complete the product	Task 4.9	M	_	Verify that the quantity of parts is indicated and is correct.
4.10.-Generate Assembly Views	A8	Operation omitted	Assembly details are not shown and features are omitted.	Task 4.10	M	_	Verify that the assembly view is present.
.11.- Generate Exploded Assembly View	A8	Actividad omitida	Assembly details are not visible and steps are omitted.	Task 4.11	M	_	Verify that the exploded view is present
4.12.-Identify Parts in the Exploded View (Balloons)	A8	Operation omitted	Items will not be fully identified	Task 4.12	M	_	Verify that the parts are identified in the explosion view
4.13.- Generate Assembly Parts List	A8	Operation omitted	That not all parts and quantities are contemplated and that it affects planning	Task 4.13	M	_	Verify that the assembly list is present for correct planning.
4.14.-Specify Fasteners and Sub-assemblies (Bolts, Pins, Nuts, Line Accessories, etc.)	A9	Operation incomplete Wrong operation on wrong	Wrong parts are placed	Task 4.14	H	_	Verify that the correct accessories are indicated.
4.15.- Create Bill of Materials (Production Order)	A9	Operation incomplete Wrong operation on wrong	Missing accessories to finish the product	Task 4.15	M	_	Verify that the bill of materials is complete and correct.
4.16.-Print All Part Drawings	A9	Operation incomplete Wrong operation on wrong	Missing drawings and parts are not made	Task 4.16	H	!	Verify that all drawings for product fabrication are in place.
4.17.- Verify that the Printed Images are Legible and Appropriately Sized	A8	Operation omitted	Measurements, details and characteristics of the parts are not legible.	Task 4.17	M	!	Verify that all drawings are legible and understandable.
	A9	Operation incomplete Wrong operation on wrong	Missing information and omission of important details	Task 4.17	M	!	Verify that all drawings are legible and understandable

Figure 6. SHERPA application in task 4.

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POSITION RISK EVALUATION WITH THE RULA METHOD IN TECNM/ITCJ STUDENTS IN THE LIBRARY AREA

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Resumen: En México, los estudiantes de nivel superior pasan gran parte de su tiempo en instituciones educativas, debido a la diversidad de horarios y la realización de actividades extracurriculares. Un espacio común donde los estudiantes aprovechan sus horas libres para realizar tareas, proyectos y estudiar es la biblioteca. Sin embargo, se ha observado que muchos adoptan posturas inadecuadas durante estas actividades, lo que podría llevar al desarrollo de lesiones musculoesqueléticas. Dada la importancia de la salud postural en ambientes educativos, se llevó a cabo un estudio ergonómico en la biblioteca del Tecnológico Nacional de México/Instituto Tecnológico de Ciudad Juárez (TecNM/ITCJ), con el objetivo de evaluar si las posturas adoptadas por los estudiantes podrían ser perjudiciales para su salud. Para este análisis, se empleó el método RULA (Rapid Upper Limb Assessment), una herramienta reconocida para la evaluación del riesgo de trastornos musculoesqueléticos relacionados con la postura. (Vásquez, 2015) El estudio se centró en la observación detallada de las posturas adoptadas por los estudiantes durante su estancia en la biblioteca, así como en el tiempo que pasan en este espacio y la adecuación del mobiliario disponible. Se busca determinar si las condiciones actuales podrían contribuir al desarrollo de lesiones, y si es necesario realizar modificaciones en el mobiliario o en las prácticas de uso de este espacio para promover un entorno más ergonómico y saludable. Villar M. F. (2011).

Palabras clave: Método RULA, Lesiones Musculoesqueléticas, Posturas inadecuadas

Relevancia para la ergonomía: este estudio destaca la importancia de la ergonomía en entornos educativos, particularmente en las bibliotecas universitarias. Aplicando el método RULA para evaluar las posturas de los estudiantes de la biblioteca del TecNM/ITCJ y la probabilidad de desarrollar lesiones musculoesqueléticas por posturas o mobiliario inadecuados.

Abstract: In Mexico, higher education students spend a significant portion of their time in educational institutions due to the variety of schedules and extracurricular activities.

A common space where students utilize their free time to work on assignments, projects, and study is the library. However, it has been observed that many adopt improper postures during these activities, which could lead to the development of musculoskeletal injuries. Given the importance of postural health in educational environments, an ergonomic study was conducted at the library of the TecNM/ITCJ to assess if the postures adopted by students could be harmful. The RULA (Rapid Upper Limb Assessment) method, a recognized tool for evaluating the risk of posture-related musculoskeletal disorders, was employed for this analysis. Vásquez D.C. (2015) The study focused on a detailed observation of the postures adopted by students during their time in the library, as well as the amount of time they spend in this space and the suitability of the available furniture. The goal is to determine whether the current conditions could contribute to the development of injuries and whether modifications to the furniture or usage practices are necessary to promote a more ergonomic and healthier environment. Villar M. F. (2011).

Keywords. RULA Method, Musculoskeletal Injuries, Improper Postures

Relevance to Ergonomics: This study highlights the importance of ergonomics in educational environments, particularly in university libraries. By applying the RULA method to evaluate the postures of students in the TecNM/ITCJ library and the probability of developing musculoskeletal injuries due to inadequate postures or inadequate furniture.

1. INTRODUCTION

Musculoskeletal disorders appear very frequently due to occupational diseases. The most common is the one that develops in the back, as well as in the upper extremities Gómez et al., 2020. Musculoskeletal disorders in the United States account for approximately 70 million doctor visits annually. The costs caused by these diseases between lost wages and lost productivity are estimated to be between $45 and 54 billion dollars annually. In biomechanics studies, it has been shown that psychosocial stress contributes to an increase in spinal loading; Therefore, there is a relationship between lumbar disorders, work pace, monotonous work, stress at work, as well as job satisfaction, National Research Council and Institute of Medicine (2001).

One of the understudied areas in the evaluation of postures to prevent musculoskeletal disorders is in schools with the posture of students. With the objective of understanding and improving ergonomic conditions in academic environments, this study focuses on the application of the RULA method to evaluate sedentary postures in students of the TecNM/ITCJ. The research was carried out in the library, a crucial space for academic development, with a representative sample of 30 individuals: 15 computer users and 15 people who write by hand. The use of the RULA method provides a comprehensive view of how sedentary postures affect the health and well-being of students, identifying potential areas for improvement and facilitating the implementation of preventive measures. This study not only provides a current assessment of conditions, but also lays the groundwork for future initiatives to promote healthier and ergonomically appropriate environments within educational institutions.

2. OBJECTIVE

Determine whether the postures adopted by students during their study activities could lead to musculoskeletal injuries.

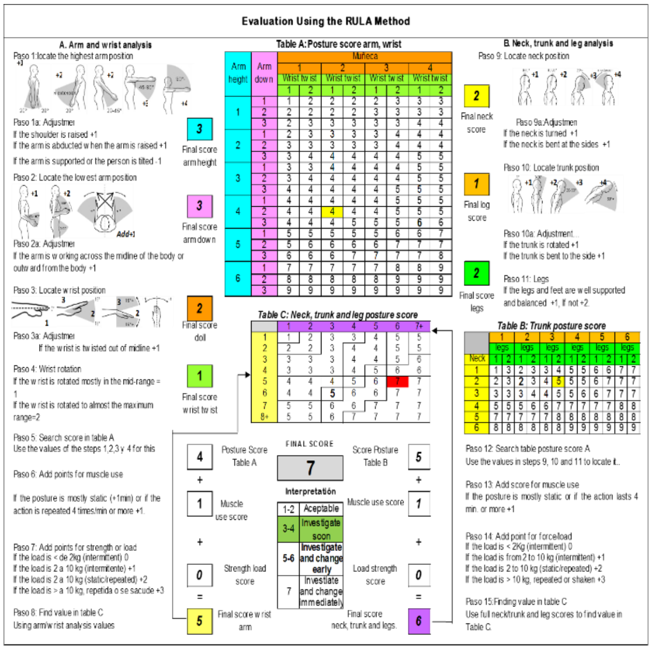
3. METHODOLOGY

The RULA method (short for Rapid Upper Limb Assessment) is a quick assessment tool used to analyze and improve posture and movement in the workplace, particularly those postures associated with repetitive activities, where repeated or prolonged use can affect the upper body. This method is employed in the field of ergonomics to determine the risk of musculoskeletal injuries and to recommend ergonomic adjustments to improve working conditions. International E.A (2024). The RULA method evaluates body postures in two groups, first group A evaluates the upper limbs (arm, forearm and wrists), then group B evaluates the legs, trunk and neck. To carry out the analysis, the tables associated with the method are used, assigning a score to each area. García M.G. (2018).

An ergonomic evaluation was carried out using the RULA (Rapid Upper Limb Assessment) method to analyze the postures of students in the library of the TecNM/ITCJ. The sample consisted of 30 students, divided into two groups: one made up of 15 students who worked in the traditional way with manuscripts and the other of 15 students who used laptops. The evaluations were conducted on different days and times to capture a variety of conditions. In addition, an online survey was administered to collect information about library users' experiences and their daily study time. See fig. 1.

4. RESULTS OF THE RULA METHOD

A sample of 30 students was selected, divided into two groups: 15 who used laptops and 15 who studied using traditional methods. The results of the study are presented in the following tables and graphs. See fig. 2.



Evaluation Using the RULA Method

A. Arm and wrist analysis

Paso 1:locate the highest arm position

Paso 1a: Adjustmer
If the shoulder is raised +1
If the arm is abducted w hen the arm is raised +1
If the arm is supported or the person is tilted -1

3 Final score arm height

Paso 2: Locate the low est arm position

3 Final score arm dow n

Paso 2a: Adjustmer
If the arm is w orking across the midline of the body or outw ard from the body +1

Paso 3: Locate w rist position

2 Final score doll

Paso 3a: Adjustmer
If the w rist is tw isted out of midline +1

Paso 4: Wrist rotation
If the w rist is rotated mostly in the mid-range = 1
If the w rist is rotated to almost the maximum range=2

1 Final score w rist tw ist

Paso 5: Search score in table A
Use the values of the steps 1,2,3 y 4 for this

Paso 6: Add points for muscle use

If the posture is mostly static (+1min) or if the action is repeated 4 times/min or more +1.

Paso 7: Add points for strength or load
If the load is < de 2kg (intermittent) 0
If the load is 2 a 10 kg (intermitente) +1
If the load is 2 a 10 kg (static/repeated) +2
If the load is > a 10 kg, repetida o se sacude +3

Paso 8: Find value in table C
Using arm/w rist analysis values

Table A: Posture score arm, wrist

Arm height	Arm down	Muñeca							
		1		2		3		4	
		Wrist tw ist		Wrist tw ist		Wrist tw ist		Wrist tw ist	
		1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Table C: Neck, trunk and leg posture score

	1	2	3	4	5	6	7+
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8+	5	5	6	7	7	7	7

4 Posture Score Table A
+
1 Muscle use score
+
0 Strength load score
=
5 Final score w rist arm

FINAL SCORE

7

Interpretación

1-2	Aceptable
3-4	Investigate soon
5-6	**Investigate and change early**
7	Investiate and change immediately

Score Posture Table B **5**
+
Muscle use score **1**
+
Load strength score **0**
=
Final score neck, trunk and legs. **6**

B. Neck, trunk and leg analysis

Paso 9: Locate neck position

2 Final neck score

Paso 9a:Adjustmen
If the neck is turned +1
If the neck is bent at the sides +1

Paso 10: Locate trunk position

1 Final log score

Paso 10a: Adjustment...
If the trunk is rotated +1
If the trunk is bent to the side +1

2 Final score legs

Paso 11: Legs
If the legs and feet are w ell supported and balanced +1, If not +2.

Table B: Trunk posture score

	1		2		3		4		5		6	
	legs		legs		legs		legs		legs		legs	
Neck	1	2	1	2	1	2	1	2	1	2	1	2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	9	9	9	9	9	9

Paso 12: Search table posture score A
Use the values in steps 9, 10 and 11 to locate it..

Paso 13: Add score for muscle use
If the posture is mostly static or if the action lasts 4 min. or more +1

Paso 14: Add point for force/load
If the load is < 2Kg (intermittent) 0
If the load is from 2 to 10 kg (intermittent) +1
If the load is 2 to 10 kg (static/repeated) +2
If the load is > 10 kg, repeated or shaken +3

Paso 15:Finding value in table C
Use full neck/trunk and leg scores to find value in Table C.

Figure 1. Method Evaluation RULA

Figure 2. Student posture in the library

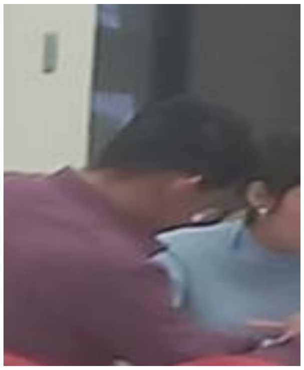


Figure 3. Student posture in the library

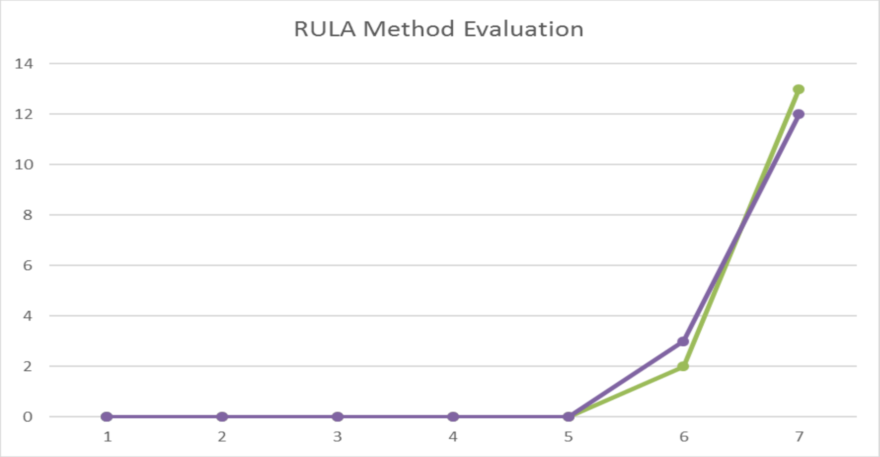


Figure 4. Results of Method RULA

The following tables show the results of table 1 and 2 where it is shown that in the evaluation using books (traditional method) 13 people fell into the risk 7 and 2 people in risk 2. Similarly, in the evaluation using computer 12 students fell into risk 7 and 3 in risk 6.

The table1 and 2 show that there are not differences in the postures of students when studying with books or with laptops with similar risks.

Table 1. Evaluation Using Books

EVALUATION RULA MANUSCRIPT		
EVALUATED	RISK 7	RISK 6
15	13	2

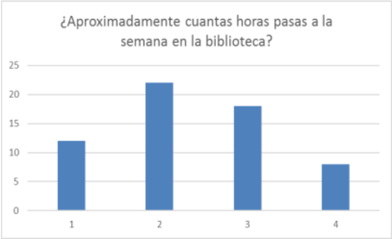
Table 2. Evaluation Using Computer

RULA Method evaluation using computer.		
EVALUATED	RISK 7	RISK 6
15	12	3

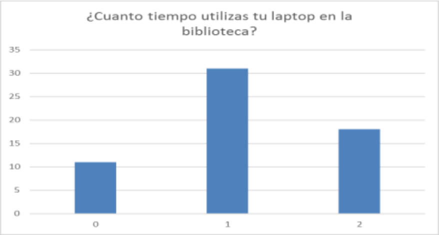
Also, a survey was also conducted to analyze whether students feel musculoskeletal discomfort due to the study position or furniture.

1. Do you use the school library?

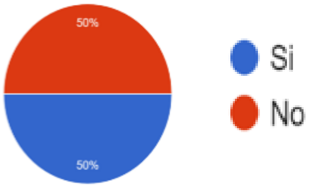
2. Approximately how many hours a week do you spend in the library?



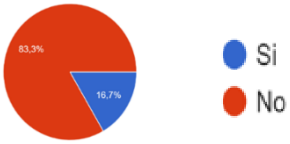
3. Do you use your laptop when you are in the library?



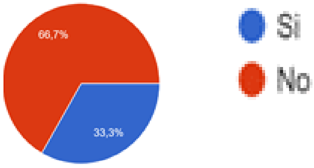
4. Is there a space to rest hands and forearms?



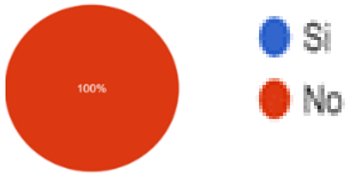
5. When you use your laptop, do you use a mouse?



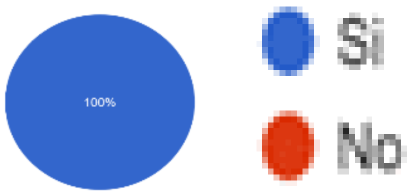
6. Does the mouse design adapt to the curve of your hand?



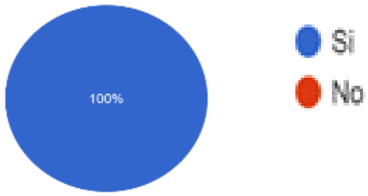
7. Does the force required to operate the keys cause you to strain?



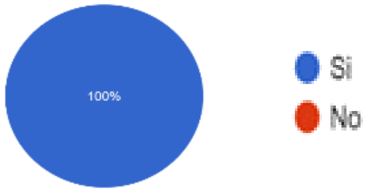
8. Does your keyboard include all letters and signs?



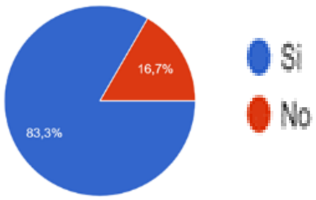
9. Is the height of the library tables suitable for your height?



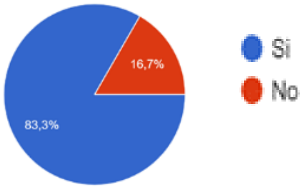
10. Does the chair fit your height?



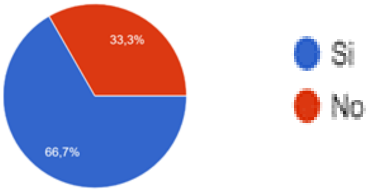
11. Does the library chair allow for a stable back position?



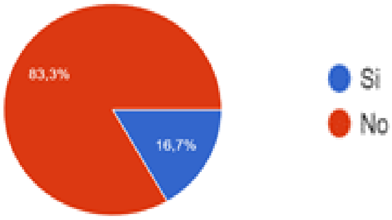
12. Do you find the design of the chair adequate and comfortable?



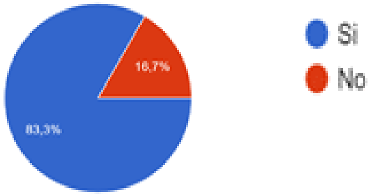
13. Can you rest your back correctly on the backrest?



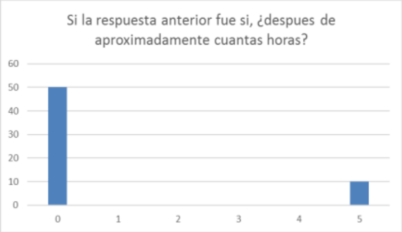
14. Would it be more comfortable for you if the chairs had footrests?



15.Do you experience any lumbar pain (back, neck, lower back, wrist) after certain hours of study?



16. If yes, after approximately how many hours?



5. CONCLUSIONS

The analysis of the results revealed that the postures adopted by students while studying in the library present a high risk, with scores of 6 and 7 on the RULA scale, most of which were grade 7. This indicates a significant risk of developing musculoskeletal injuries, necessitating immediate intervention. However, students reported not experiencing discomfort, which could be attributed to the fact that they spend few hours per week in the library. According to the survey, discomfort begins to appear after several time of study.

The study also highlighted that there is not a significant difference in risk between students who use laptops and those who work by hand; both groups showed similar risk factors, with a predominance of risk level 7 for those using notebooks and pencils.

In conclusion; some students are agreed that they suffer pain in the wrist, lower back and neck when they spend hours studying (question 16), they agreed that the design of the chairs is adequate and comfortable but they suggest they would be better off with footrests.

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USABILITY ANALYSIS FOR THE DESIGN OF A GLOVE FOR MEASURING FORCES IN THE PALM REGION AND FINGERS

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Resumen: Este estudio evalúa la usabilidad del guante Evo Pinch, un dispositivo inalámbrico con sensores de detección de fuerza (FSR) diseñado para medir la fuerza de los dedos, comparándolo con un prototipo rediseñado. Los dinamómetros tradicionales, aunque efectivos, son a menudo voluminosos y difíciles de usar. El guante Evo Pinch ofrece una alternativa más compacta, pero su usabilidad no había sido evaluada sistemáticamente. Cinco participantes de la Universidad Autónoma de Ciudad Juárez probaron ambos guantes a través de una serie de tareas. El guante Evo Pinch original obtuvo un 55% en usabilidad, indicando un nivel "regular". En contraste, el prototipo rediseñado alcanzó un 76%, clasificado como "muy bueno". El rediseño redujo significativamente el tiempo necesario para colocar el guante, de 2 minutos a 43 segundos, y mejoró la satisfacción del usuario. Estos resultados destacan la importancia del diseño iterativo y las pruebas centradas en el usuario en el desarrollo de dispositivos ergonómicos, demostrando que las pruebas de usabilidad pueden llevar a mejoras sustanciales en la eficiencia y la experiencia del usuario. Esta investigación subraya la necesidad de evaluaciones continuas de usabilidad para optimizar el diseño y la funcionalidad de dispositivos utilizados en la investigación ergonómica y de factores humanos.

Palabras clave: Usabilidad, Análisis, Evaluación, Diseño

Relevancia para la ergonomía: Relevancia para la ergonomía: este estudio enfatiza la importancia de utilizar herramientas de análisis de usabilidad en el diseño de equipos de medición, destacando la necesidad de mejorar la facilidad de uso y la eficiencia en la captura de datos. El rediseño del guante Evo Pinch muestra cómo los comentarios de los usuarios pueden mejorar significativamente la funcionalidad y la experiencia del usuario, que son fundamentales para el éxito en aplicaciones del mundo real.

Abstract: This study evaluates the usability of the Evo Pinch glove, a wireless device equipped with Force-Sensing Resistors (FSRs) designed to measure finger strength. Its performance was compared to that of a redesigned prototype. Although traditional dynamometers are effective, they tend to be bulky and difficult to handle. In contrast, the Evo Pinch glove offers a more compact alternative, but its usability had not been systematically evaluated until now. Five students from the Autonomous University of Ciudad Juárez tested both gloves in a series of tasks. The original Evo Pinch glove received a usability score of 55%, indicating a "fair" level. On the other hand, the redesigned prototype achieved a score of 76%, classified as "very good." The redesign significantly reduced the time required to put on the glove, from 2 minutes to 43 seconds, and improved user satisfaction. These results highlight the importance of iterative design and user-centered testing in the development of ergonomic devices, demonstrating that usability testing can lead to substantial improvements in both efficiency and user experience. This research underscores the need for continuous usability assessments to optimize the design and functionality of devices used in ergonomic and human factors research.

Keywords: Usability, Analysis, Evaluation, Design.

Relevance to Ergonomics: This study emphasizes the importance of using usability analysis tools in the design of measurement equipment, highlighting the need to enhance ease of use and efficiency in data capture. The redesign of the Evo Pinch glove shows how user feedback can significantly improve functionality and user experience, which are critical for success in real-world applications.

1. INTRODUTION

Usability is defined as the degree of effectiveness, efficiency, and satisfaction with which a product meets user needs in a specific environment, enabling them to achieve their objectives (Huelves Zarco, Aguayo González, Lama Ruiz, & Soltero Sánchez, 2009). Its specific goal is to identify the key functions and features that allow the product to satisfy user needs. Usability analysis is a method that provides information about the interaction between the user and the product through the observation of activities.

The measurement of hand and finger strength is typically carried out using dynamometers, which occupy a considerable portion of the hand's size. In recent years, more streamlined dynamometers in the form of gloves have been developed, allowing for the measurement of finger strength. The introduction of these new measurement tools enables ergonomic evaluations. However, their efficiency has not been systematically tested or analyzed, offering a significant opportunity to improve the design of these devices through usability analysis.

One of the available devices is the wireless Evo Pinch glove, an essential tool for collecting and analyzing data under real working conditions in research and human factors applications, as well as in industrial, engineering, and ergonomic studies. The Evo Pinch system includes force-sensing resistors that allow for the measurement of force in the phalanges.

Before conducting the usability analysis, it is necessary to determine the interaction between the user and the product by selecting the tasks to be observed. Therefore, the objective of this study is to perform a usability analysis of the Evo Pinch glove, determine its usability level, and compare it with a prototype glove, meeting the following specific objectives: a. Determine the usability level of the Evo Pinch glove. b. Design the glove. c. Perform a usability analysis of the new device and compare it with the current one.

This study consists of three stages. First, a usability analysis of the current glove is conducted to identify areas for improvement. Second, the glove is redesigned, proposing improvements to increase its usability and measurement capacity. Finally, the usability levels of the current glove and the new device are compared (see Figure 1).

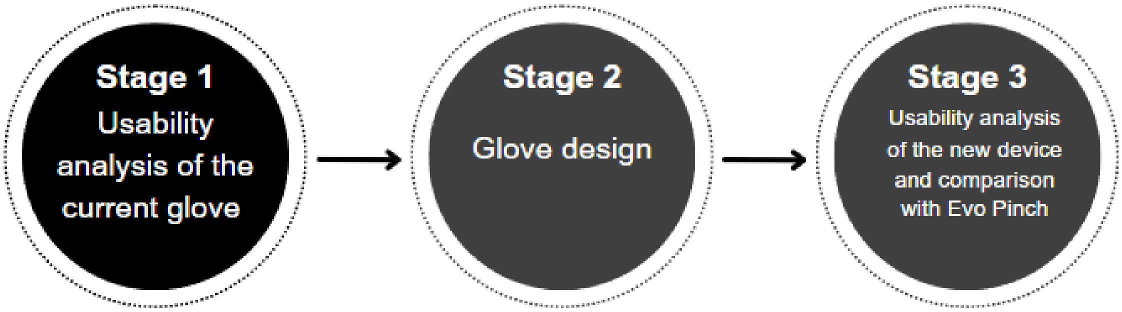

Figure 1. Diagram of the stages of usability analysis.

2. MATERIALS

A usability analysis was conducted based on the selection of activities and tasks with which the user would interact with the product. In this study, the wireless Evo Pinch glove was used, an essential device for collecting and analyzing data under real working conditions, applicable to research tests, human factors studies, as well as industrial, engineering, and ergonomic applications. The Evo Pinch system includes Force Sensing Resistors (FSRs), which, although not load cells or strain measurement devices, have similar properties and provide a reliable alternative. The FSR sensors included in the kit are thin, flexible, discreet, and cause minimal interference with the action and performance of the device and the task.

3. Methodology

According to Steanton and Baber (2006), it is recommended to conduct a usability test at the end of the design process, that is, when the product is fully completed and ready to be evaluated. This is because, to obtain valuable and accurate information about the product's usability, it is essential for users to interact with the product in its final form. This interaction allows for the identification of issues and areas for improvement that may not have been apparent in earlier stages of design. Additionally, another significant proposal, published by Hassan *and Ortega* (2009) in the "APEI Usability Report," introduces the concept of a "user test," which consists of the following: a general diagram of the usability methodology is presented to guide the process.

3.1 Product Description

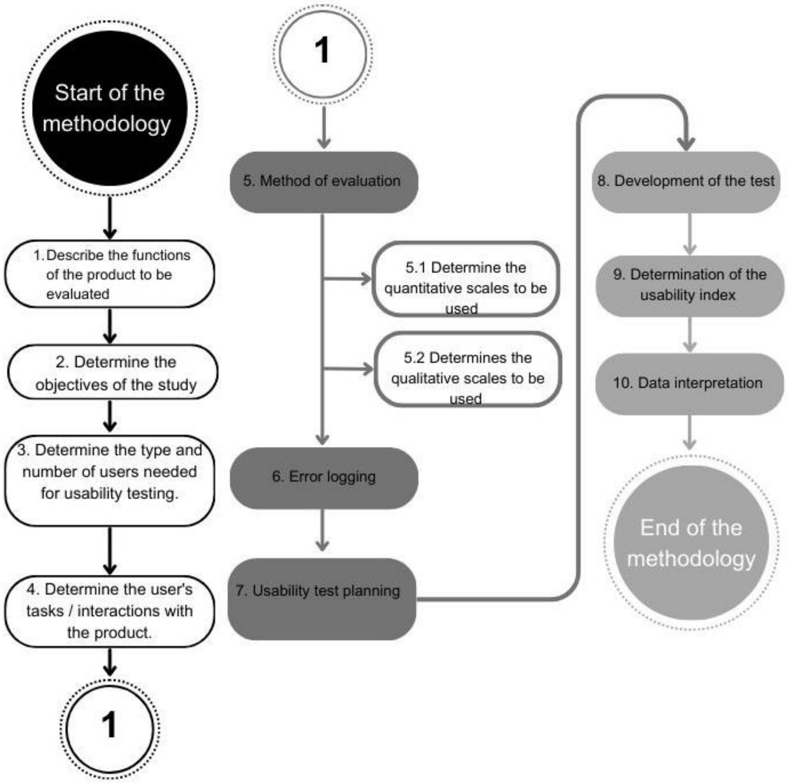

Figure 2. Methodology diagram (Hernandez & Hernandez, 2013)

The wireless EVO Pinch is an essential device for collecting and analyzing data under real working conditions, intended for applications in research testing, human factors, as well as industrial, engineering, and ergonomic contexts. The EVO Pinch

system includes Force Sensing Resistors (FSRs), which, while not load cells or strain measurement devices, possess similar properties and provide a reliable alternative. The FSR sensors included in the kit are thin, flexible, discreet, and cause minimal interference with the device's action and performance during tasks.
The FSR sensors offer the following features:

- They provide accurate measurements for a variety of testing applications.
- They allow for the combination of instrumentation devices to measure force, angle, and acceleration.
- Each sensor is independently calibrated to facilitate easy updates or replacements (except for accelerometers and FSR sensors, which are not calibrated).

3.2 Determination of study Objectives

General Objective: Identify areas of opportunity for improving the glove.

Specific Objectives:
a) Determine the application capacity of the glove.
b) Analyze the disadvantages in the glove's application.
c) Identify specific areas for improvement.

3.3 Determination of Users

The sample will be incidental and composed of volunteer participants from the student community of the Autonomous University of Ciudad Juárez. Each candidate will be informed about the study's process to ensure they understand the importance of their participation in the project, as well as the implications and benefits involved.

3.4 Number of Users

Usability tests must be conducted with volunteer users; otherwise, these tests cannot be carried out. Therefore, it is important to determine the appropriate number of participants (sample size). According to the usability methodology (2014), a maximum of 15 participants is suggested to detect 100% of usability issues.

3.5 Determine user/product tasks/interactions

The tasks and activities that the user will perform with the product are defined as follows:
a) Putting on the glove and its components.
b) Time spent on placing the components.
c) Adjustment of the FSR sensors.

3.6 Evaluation Method

The Likert scale is one of the most commonly used methods, as it allows for the rating of items or variables by linking a number to a linguistic expression. Typically, scales with 3, 5, or 7 divisions are used, as shown in Table 1.

Table 1. Likert Scale.

Rating	Expression
1	Good
2	Fair
3	Poor

3.6 Selection of tasks to be evaluated

Table 2. Tasks to be evaluate

Rating	Expression
1	Never
2	Only once in a while
3	Sometimes
4	Often
5	Always

Tasks to be evaluated	
Quantitative	Qualitative
1. Placing a screw	1. Task accessibility
2. Using a mouse	2. Glove comfort
3. Using cutting pliers	3. General satisfaction

3.6 Data Capture Format

Table 3. Tasks to be evaluated

Data Capture Format			
Qualitative Variables			
Column 9	Column 10	Column 11	Column 12
Error Type	Rating / Unit of Measurement	Interval	Score
1. Glove placement		0 = Critical 5 = Major |10 = Minor	
2. Number of errors during the test		< 1 Good = 10 2 Fair = 5 > 3 Poor = 0	
Sum of error scores (SES)			

To calculate, the following formula was used:

$$UI\left(\begin{matrix}\overline{15+10+5}\\(3+3+2).10\end{matrix}\right).100 = UI \qquad (1)$$

3.8 Usability level

Table 4. Usability level

Value obtained	Usability Level
76% to 100%	Very Good
51% to 75%	Good
26% to 50%	Fair
0% to 25%	Poor

4. RESULTS

The study involved 10 students, with an average age of 21.5 years. The results showed that, according to the calculated percentages, the average usability of the EVO Pinch glove among the 10 participants was 59% (see Table 5), which indicates a usability level classified as "fair" according to Table 4. Additionally, the results for the redesigned glove, with an average usability of 77% among the same 10 participants (see Table 6), indicate that the redesigned glove exhibits a usability level classified as "very good." These findings highlight the significant improvements in user experience achieved through the redesign.

Table 5. Results obtained for the usability level for both current and new glove design

Participant	Current design	New design
1	38%	75%
2	63%	75%
3	69%	75%
4	69%	81%
5	56%	81%
6	38%	81%
7	69%	69%
8	38%	75%
9	50%	69%
10	50%	75%
Average	55%	76%

5. CONCLUSION

In this research, quantitative and qualitative data were collected to determine the usability level, evaluating various tasks and obtaining both individual sample percentages and overall averages. The tests were conducted in two stages: first, a usability analysis of the current glove was performed, which showed a usability level of 55%, classifying it as "fair." Subsequently, the new glove design was evaluated, achieving a usability level of 76%, considered "very good". A significant optimization in the application of the glove was observed, as well as a reduction in the time required to put it on, which decreased from an average of 2 minutes with the original glove to 43 seconds with the redesigned glove.

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ERGONOMIC EVALUATION OF THE WORKPLACE IN A DISTRIBUTION COMPANY IN CIUDAD OBREGON, SONORA

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Resumen: La Ergonomía es una disciplina que contribuye a la calidad de vida de las personas, a través del estudio y comprensión de interacciones entre humanos, el medio que los rodea y la profesión. El presente estudio consistió en la evaluación de posturas de trabajadores del área de almacén de un sitio de trabajo localizado en Ciudad Obregón para la disminución de factores de riesgo asociados a la presentación de Trastornos musculo esqueléticos y cumplir con la Normatividad vigente. Como resultados fueron evaluadas 7 tareas mediante los métodos RULA y MAC, de las cuales 3 presentan nivel de riesgo alto en postura y 2 en relación a sobre esfuerzo. En conclusión, el detectar los niveles de riesgo permitió la generación propuestas de mejora que permitirá la reducción del nivel de riesgo y con ello mejorar la calidad de vida del trabajador.

Palabras clave: Ergonomía, factores, riesgo y TME

Relevancia para la ergonomía: Mejora de la calidad de vida en trabajadores en un sitio de trabajo mediante el empleo de métodos de análisis ergonómicos.

Abstract: Ergonomics is a discipline that contributes to the quality of life of people, through the study and understanding of interactions between humans, the environment that surrounds them and the profession. The present study consisted of the evaluation of postures of workers in the warehouse area of a work site located in Ciudad Obregón to reduce risk factors associated with the presentation of musculoskeletal disorders and comply with current regulations. As results, 7 tasks were evaluated using the RULA and MAC methods, of which 3 presented a high risk level in posture and 2 in relation to overexertion. In conclusion, detecting risk levels allowed the generation of improvement proposals that will reduce the risk level and thereby improve the worker's quality of life.

Keywords: Ergonomic, factors, risk and MSD.

Relevance to Ergonomics: Improving the quality of life of workers in a workplace through the use of ergonomic analysis methods

1. INTRODUCTION

According to the National Institute of Statistics and Geography (INEGI, 2023), the production of soft drinks and other non-alcoholic beverages has been increasing, presenting values ranging from 4,700 hours in 2018 to over 7,000 hours in 2023. In the same figure There is a decline during 2020, perhaps caused by the COVID 19 pandemic. According to INEGI (2023), one of the companies that produces and distributes large quantities of soft drinks is Coca Cola, which has a presence in countries on different continents as shown in the figure. 1.

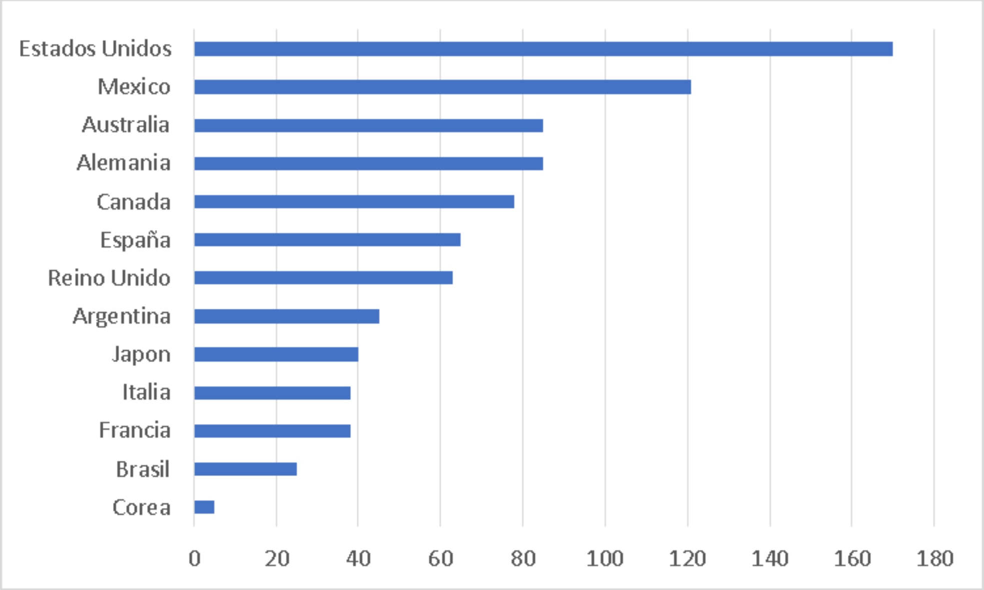


Figure 1. Beverage production by country.

Note. Average soft drink consumption behavior in different countries.
Source: INEGI (2023).

The previous figure shows the soft drink consuming countries, in which it is observed that the United States is the country in which the inhabitants consume the most soft drink, and it is also observed that Mexico is in second position with the value 120, which indicates that also in one of the countries where the consumption of soft drinks is reflected in its market. In the early 1980s, Coca-Cola was the largest buyer of sucrose in the United States, absorbing 10% of the country's consumption. Furthermore, the United States constitutes the main market for carbonated drinks in the world with a consumption of almost 180 liters/inhabitant, in second place is Mexico with 120 liters/inhabitant, however one of the least consuming countries is China with less than 20 liters. /inhabitant.(Peláez, 1996).

The Coca-Cola group has different Distribution Centers (CEDIS) throughout the country, however, for the purposes of the study it will focus on one in particular located in the town of Cajeme, in Sonora. The process followed in said CEDIS is the following:

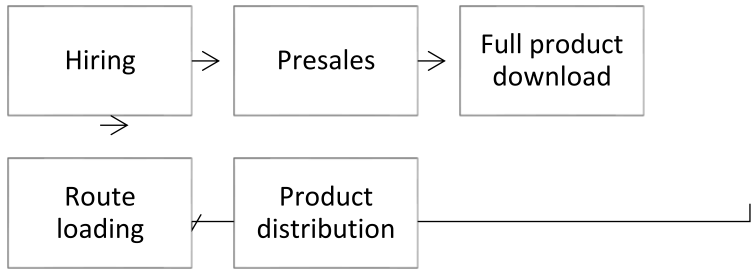
Tickets	**Process**	**Exit**
Production order Lift		Product distribution in the market

Figure 2. CEDIS process in Cajeme.

Note: Description of the CEDIS Obregón process.

In the table previously shown, you can analyze the first-level process of Coca Cola in Ciudad Obregón, which describes the necessary inputs to carry out the process being handled, and each of the main activities and activities is also described. As an output, the final result is obtained, which is the delivery of the product to each of its clients. Something to highlight is the importance expressed in aspects of safety and ergonomics, which is why it is regularly carrying out projects and audits aimed at improving the aspects related to this.

In accordance with the Federal Labor Law (Supreme Court of Justice of the Nation, 2012), every workplace must have measures to safeguard the safety of workers. As part of the project, an important point in the research is that the Permanent Disabilities Assessment table contains the affected part, device or system of the body; the sequel of the accident or work-related illness, and the percentage of disability that is applicable for each type of illness, that is, it is established that the Workplace Illnesses and Valuation of Permanent Disabilities tables are the subject of research and study.

When taking a tour of the CEDIS facilities, images of three operators were captured while carrying out their work, at the same time that the personnel in charge were interviewed in order to carry out a quick evaluation through the application of the questionnaire by (Kuorinka, Jonsson, Kilbom, Vinterberg, Biering-Sorensen, Andersson & Jorgensen, 1987). The results of this diagnostic assessment are shown below.

Figure 3. Postures subjected to rapid evaluation through Kuorinka's list
Note: Photographs taken of warehouse workers prior to the interview

The results of the interview showed that of the 11 employees: 1 has pain in the neck, 1 in the shoulder, 2 in the lower back and in the wrist. Given this situation, the following question arises:

What actions, from an ergonomic point of view, should be implemented in the process under study to reduce ergonomic risk factors and/or the presence of work-related illnesses?

2. OBJECTIVE

Ergonomically evaluate the man-machine system of the beverage distribution company to reduce risk factors associated with the presentation of MSDs and occupational diseases, and comply with current regulations.

3. METHODOLOGY

The subject under study includes the workers in the warehouse area of the company under study. The method to use is the one proposed by Ávila, G. et al. (2014) whose procedure is described below.

Analyze the current situation: In addition to the identification of ergonomic risks in the workplace and the result of the application of the Kuorinka checklist disclosed in the Introduction, the records of incidents, accidents, visits to medical services were reviewed, in addition to the results of interviews with workers.

Define the problem: Once the current situation was analyzed, a discussion was held with the coordinator and area head to together define the problem expressed so far as: What actions, from an ergonomic point of view, should be implemented in the process under study to reduce ergonomic risk factors and/or the presence of work-related illnesses?

Characterize tasks through observation: Part of the information collection was the visual analysis of the activities carried out in the warehouse, based on the identification of the people involved, the equipment and tools they use. For this phase, photographs were taken during the exercise of the work.

Evaluate method and posture in jobs: Once photographic evidence of each job is obtained, the ergonomic evaluation will be carried out through the use of the ergonomic methods RULA (McAtamney L, Nigel Corlett E. (1993) and MAC (Health and Safety Executive, 2003) both selected for their focus on postures and/or manual handling of materials. The results were captured in a table using a color code indicating areas of opportunity.

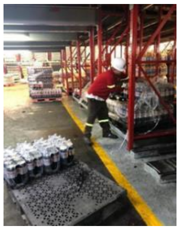
Generate improvement actions: Once the evaluations, their corresponding level of risk and the areas of opportunity detected have been obtained, improvement actions will be generated in the workplace and/or warehouse to eliminate risk factors associated with the presentation of MSDs and occupational diseases.

Verify the impact of the improvement: Here a comparative table of the affected aspects and the evidence of the change.

4. RESULTS

As results of the study, the visual analysis of the activities carried out in the warehouse can be seen, based on the identification of the people involved, the equipment and tools they use. For this phase, photographs were taken during the exercise of the work. The information was recorded in a table like the one shown below.

Table 1. Format for task characterization.

Task	**Task description**	**Data**	**Information additional**
	Pack packaged product in quantities of 3 soft drinks and arrange for stowage. Use of plastic for plastering.	No. Employee: 246793 Hours per shift: 8 Frequency: 4 times per shift	Plastic is used to Emplayar, the product that is placed on the pallets and that will be placed in the different areas of the warehouse, depending on the corresponding area.
	Arrange product by label in the space assigned by product. Use of pallets , cardboard .	No. Employee: 268332 Hours per shift: 8 Frequency: 3 times per shift	Pallets and cardboard are used to accommodate product by areas and corresponding labels.
	Arrange pallets with packed products at heights. Use of product packages to accommodate.	No. Employee: 238332 Hours per shift: 8 Frequency: 2 times per shift	The activity is carried out by 2 workers, passing the product to each other to accommodate it in the area corresponding to the type of product.
	Accommodate product on pallets, use cardboard and plaster	No. Employee: Hours per shift: 8 Frequency: 3 times per shift	Pallets, cardboard and plastic are used to accommodate product that will be loaded onto routes
	Transfer product to repackaging area	No. Employee: Hours per shift: 8 Frequency: 3 times per shift	The product that needs to be put in new packaging is transported
	Cleaning in work areas	No. Employee: Hours per shift: 8 Frequency: 1 time per shift	Cleaning of the different areas of the warehouse is carried out

	Repackage product in new packaging	No. Employee: Hours per shift: 8 Frequency: 10 times per shift	The products that need it are repackaged in new packaging.

The table record includes the number assigned to the task, the reference image, the description of the task, data of relevance prior to the evaluation (average age, number of employees, hours per shift, frequency) and additional information derived from observation of the workplace or posture.

Once the photographic evidence of each workplace was obtained, the ergonomic evaluation was carried out through the use of the ergonomic methods selected in relation to the findings, these being focused on postures and/or manual handling of materials. The results are captured in a table using a color code indicating the areas of opportunity as shown in the following format.

Table 2. Concentration of evaluations in the position and/or workplace.

Activity	Neck	Shoulders	Back	Arms and elbows	Dolls	Hands	Legs	Postures static	Punctuation
Task 1	1	3	3	3	2	2	2	3	6
Task 2	2	2	3	2	2	2	1	4	7
Task 3	1	2	4	4	2	2	1	5	7
Task 4	2	2	3	2	2	2	1	5	7
Task 5	1	3	1	2	2	2	1	1	5
Task 6	2	2	2	3	2	2	1	2	6
Task 7	1	2	1	5	2	2	1	1	6
								High	🟥
								Moderate	🟨
								Low	🟩

In the previous table, in addition to the record of the total score and risk level, the ratings were obtained for each of the aspects considered by the posture evaluation method (a) and Manual Materials Handling (b) indicating by color. Red if the rating is High, Yellow if it is moderate and Green if it is Low, thereby attempting to visualize where the focus should be for improvement.

In the same way as the posture evaluation was done, the manual handling of the load was evaluated, resulting in the following.

Table 3. Results of the evaluation of manual load handling

Activity	Weight	Horizontal Distance	Initial height	Distance get up	Frequency	Turn angle	Grip	Distance to charge	Punctuation
Task 1	0	0	0	0	4	1	2	1	8
Task 2	6	3	0	0	3	0	1	3	16
Task 3	6	6	1	1	2	0	1	0	17
Task 4	6	3	0	0	3	1	0	0	12
Task 5	0	3	3	3	3	0	1	3	16
Task 6	0	3	0	0	1	1	1	1	7
Task 7	0	3	0	0	10	0	1	3	17
								High	🟥
								Moderate	🟨
								Low	🟩

With respect to manual handling of loads, 2 activities appear with moderate risk and the rest with low risk, with the final inspection being the one with the highest score and the one on which they should focus.

Improvement and impact actions

Once the evaluations, their corresponding level of risk and the areas of opportunity detected have been obtained, improvement actions will be generated in the workplace and/or warehouse to eliminate risk factors associated with the presentation of MSDs and occupational diseases.

For this purpose, a digital investigation was carried out, with the aim of searching and finding a tool that would help improve the postures carried out by the warehouse workers since in the evaluation carried out and shown previously it was necessary to make an improvement to avoid musculoskeletal damage with the passage of time. time. In order to counteract the level of risk detected, a series of actions listed below are proposed: 1) Operator does not lift product from the floor; 2) Plaster platforms at waist height; 3) Use a glove for a better grip on the plaster; 4) Use electric skates to transport smaller and larger quantity products; 5) Do not handle very heavy loads

Once the improvement actions were implemented, the next step was the recording of the impact of these measures on the indicators proposed at the beginning of the project. The result of this can be seen in the following table.

Table 4.Improvement if the proposed

Method	Task	Current status	Proposed status	Goal
RULA	1	6	4	< 4
	2	7	5	< 4
	3	7	5	< 4
	4	7	5	< 4
	5	5	3	< 4
	6	6	3	< 4
	7	6	3	< 4
MAC	1	4	2	< 4
	2	12	8	0-4
	3	12	8	0-4
	4	15	12	0-4
	5	7	5	0-4
	6	7	5	0-4
	7	8	5	0-4

The table shown above shows the improvement if the proposed recommendations are met, always seeking a safe area and work so that the risks of musculoskeletal injuries are reduced.

5. DISCUSSION/CONCLUSIONS

The objective of this project to ergonomically evaluate the man-machine system of the beverage distribution company to reduce risk factors associated with the presentation of MSDs and occupational diseases and comply with current regulations was fully met.

The formats used were a key piece to obtain information on the status of the aforementioned, in turn conducting questionnaires to the workers to know how they felt personally and physically, helped the project to know what the form and care was. Corresponding measures that had to be taken.

By carrying out this work, the efficiency of the forklifts, tools and work equipment can be corroborated, as well as the health and well-being of the warehouse workers. Additionally, throughout the project, the participation of those involved and the importance of the area for the completion of this work.

Among the results obtained in relation to postures, 4 tasks were identified with risk level 7, two at level 6 and 1 without serious risk. With respect to lifting loads, only 1 of the 7 tasks was found without risk, so the proposed improvement actions focus on the remaining six tasks.

Recommendations

- Replicate the same research with the rest of the areas.
- Follow up on improvement actions.
- Keep the record of incidents and/or accidents updated.

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ERGONOMIC VALIDATION OF BOOK HANDLING IN LIBRARY WITH CRITICAL CONDITIONS

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Resumen. Este artículo se aplicó en una biblioteca de una Institución Educativa en el almacenamiento, manejo manual y traslado de libros como algunas de las actividades realizadas por hombres y mujeres del área administrativa.

Iniciamos con una valoración apegada a las Normas Mexicanas de la Secretaría del Trabajo y Previsión Social de las cuales obtuvimos una valoración rápida y una específica o de Plan ergonómico según nos marca la Norma de manejo de cargas.

Se evaluó el manejo de libros como una actividad critica por ello se utilizaron las metodologías de normas mexicanas NOM 036 STPS, iniciando con una estimación simple posteriormente se utilizaron las estimaciones específicas empleando los métodos ergonómicos NIOSH, WERA, QEC, ARTOOL y Liberty Mutual entre otros, así como las recomendaciones de la OIT.

Se propuso capacitación de NOM 036 con sus estimaciones simples y los métodos ergonómicos estimados ARTOOL y WERA.

Desafortunadamente se detectó una compañera con lesiones previas, por lo que debe manejar carga por debajo de los 2 kilogramos.

Palabras clave: Valoración especifica, Plan ergonómico, NIOSH

Relevancia para la ergonomía: Las estimaciones rápidas de la Norma de manejo de material permiten un previo análisis para identificar cuando aplicar las valoraciones especificas dadas por los métodos ergonómicos de valoración de riesgo ergonómico para que nuestros compañeros trabajen más confortablemente en sus áreas de trabajo.

Abstract. This article was applied in a library of an Educational Institution in the storage, manual handling and transfer of books as some of the activities carried out by men and women in the administrative area.

We started with an assessment in accordance with the Mexican Standards of the Ministry of Labor and Social Welfare, from which we obtained a quick assessment and a specific one or ergonomic plan according to the Load Handling Standard.

The handling of books was valued as a critical activity, so the methodologies of Mexican standards NOM 036 STPS were used, starting with a simple estimate, specific estimates were then used using the ergonomic methods NIOSH, WERA, QEC, ARTOOL and Liberty Mutual among others, as well as the ILO recommendations.

NOM 036 training was proposed with its simple estimates and the estimated ergonomic methods ARTOOL and WERA.

Unfortunately, a colleague with previous injuries was detected, so she must handle a load under 2 kilograms.

Keywords. Specific assessment, Ergonomic plan, NIOSH.

Relevance to Ergonomics: The quick estimates of the Material Handling Standard allow a prior analysis to identify when to apply the specific assessments given by the ergonomic methods of ergonomic risk assessment so that our colleagues work more comfortably in their work areas.

1. INTRODUCTION

Women and men from the administrative area of an Educational Institution carry out activities of storage, manual handling and transfer of books in a library.

The library has two shifts, the analyzed shift is the second from 2 to 9 pm, since heat and lighting conditions are critical in that shift.

The ergonomic risk was assessed in accordance with the Mexican Standards of the Ministry of Labor and Social Welfare, from which we obtained a quick assessment, a specific one and an ergonomic plan as set out in the Load Handling Standard.

The handling of books was evaluated as a critical activity, the methodologies of Mexican standards NOM 036 STPS were used, starting with a simple estimate, specific estimates were then used using the ergonomic methods NIOSH, WERA, QEC, ARTOOL and Liberty Mutual among others, as well as the ILO recommendations.

NOM 036 training was proposed with its simple estimates and the estimated ergonomic methods ARTOOL and WERA.

2. OBJECTIVES

Ergonomically validate the handling and transport of books when storing on shelves of a library, applying Mexican Standards, ergonomic methodologies, ILO recommendations to prevent and correct the unsafe conditions and acts to which our co-workers are exposed.

3. METHODOLOGY

1. Official Mexican standards of the Ministry of Labor and Social Welfare (STPS) on verification of risk factors, as well as NOM 036 STPS (risk estimation Appendix A).

2.Ergonomic methods NIOSH (The National Institute for Occupational Safety and Health), WERA (workplace ergonomic risks assesment), QEC (quick exposure check), ARTOOL y Liberty Mutual Charts for assessing physical risk factors.

3. ILO (International Labour Organization) checklist.

4. Anthropometry of people directly involved in management study

5. Handling of loads with auxiliary equipment measured with dynamometers, scales for weighing books, temperature and lighting measurement and observation of surface conditions of the movement of carts.

4. RESULTS

4.1 Mexican Standards

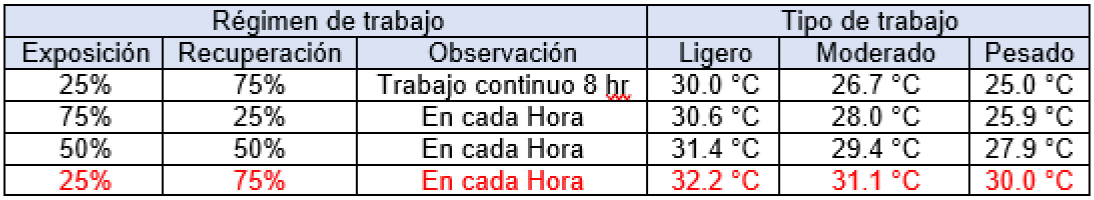
NOM-011-STPS-2001. (DOF, 2001) The measurements with sound level meters did not exceed 85 db, the noise in the library is controlled within what is allowed by the standard.

NOM 015 STPS-2001. (DOF, 2002) Co-workers were working without refrigeration in the middle of summer, with temperatures and humidity not suitable for working conditions that met the requirements of the standard, even the temperature values in the evening exceeded the values shown in Table 1. shows temperature taken on different days between 7 and 8 pm, as shown in the images in Figure 1, taken from different points inside the library where the classmates carry the books, for their respective storage.

Figure 1. Temperature and humidity inside the library on different days

NOM 019 STPS (Constitution, integration, organization and operation of safety and hygiene commissions) (DOF, 2011). It is required that the functioning of the safety and hygiene commissions support the management of optimal working conditions to work comfortably, so we confirm that the committees should support more in their operation.

Table 1. Values extracted from NOM 015 STPS

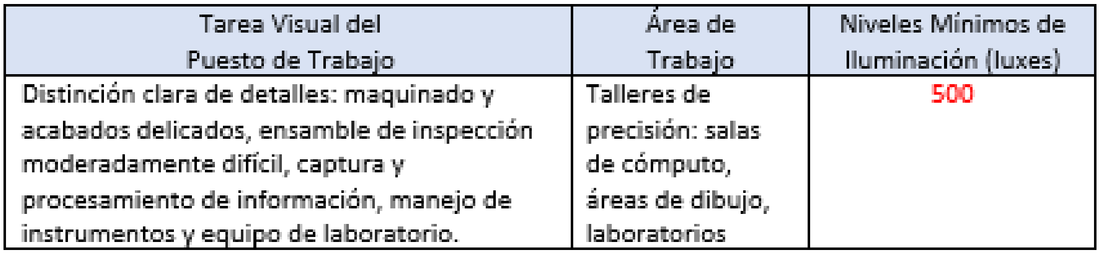


Régimen de trabajo			Tipo de trabajo		
Exposición	Recuperación	Observación	Ligero	Moderado	Pesado
25%	75%	Trabajo continuo 8 hr	30.0 °C	26.7 °C	25.0 °C
75%	25%	En cada Hora	30.6 °C	28.0 °C	25.9 °C
50%	50%	En cada Hora	31.4 °C	29.4 °C	27.9 °C
25%	75%	En cada Hora	32.2 °C	31.1 °C	30.0 °C

NOM 025 STPS. (DOF, 2008) The requirement of 500 lux by the standard is not met, as shown in table 2, in none of the readings taken was the expected value reached, on average the values were 78.98 lux. Figure 2. They can perceive some of the readings obtained in the measurements taken

Figure 2. Lighting inside the library with artificial light only

Table 2. Values extracted from NOM 025 STPS



Tarea Visual del Puesto de Trabajo	Área de Trabajo	Niveles Mínimos de Iluminación (luxes)
Distinción clara de detalles: maquinado y acabados delicados, ensamble de inspección moderadamente difícil, captura y procesamiento de información, manejo de instrumentos y equipo de laboratorio.	Talleres de precisión: salas de cómputo, áreas de dibujo, laboratorios	500

NOM 036 STPS (DOF, 2022). Figures 3 and Tables 3 show manual load handling, where corrective actions are required. It is recommended to examine the task in greater detail, apply a specific assessment, or implement control measures through an ergonomics program for manual handling of loads

Figure 3. Manual lifting and carrying of cargo

Table 3. Results when applying NOM-036-1-STPS-2018.

Factor de Riesgo	Levanta		Transporta	
Peso y Carga/Frecuencia	🟩	0	🟩	0
Distancia horizontal	🟨	3	🟨	3
Región vertical	🟥	3		
Torsión y flexión del Torso	🟥	2	🟩	0
Restricciones de postura	🟨	1	🟨	1
Acoplamiento mano-carga	🟨	1	🟨	1
Superficie de trabajo	🟩	0	🟩	0
Otros factores ambientales	🟥	2	🟥	2
Distancia de transporte			🟥	3
Obstáculo de ruta			🟩	0
Comunica, coordina y control				
Puntuación:	🟨	12	🟨	10
Nivel de Riesgo:	🟨	Medio	🟨	Medio

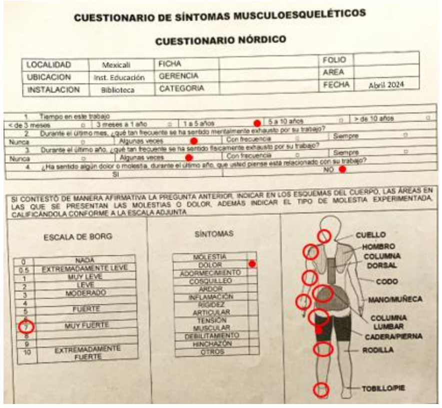
Figures 4 and Tables 4 show application of the standard in load thrust with 4-wheel auxiliary equipment, where short-term corrective actions are required. The task should be examined in greater detail, by applying a specific assessment, or by implementing control measures through an Ergonomics Program for manual load handling.

Figure 4. Load thrust with 4-wheel auxiliary equipment

Table 4. Estimation of the level of risk of activities that involve pushing loads with the use of auxiliary equipment

Factor de Riesgo	Equipo Mediano	
	Color	Valor
Tipo de equipo y Peso de la carga	🟦	0
Postura	🟦	0
Acoplamiento mano-carga	🟦	0
Patrón de trabajo		0
Distancia por viaje	🟥	3
Condición del equipo auxiliar	🟨	2
Superficie de trabajo	🟨	1
Obstáculo a lo largo de la ruta	🟨	2
Otros factores	🟥	2
Puntuación		10
Nivel de Riesgo	🟨	Medio

When applying the Nordico Kuorinka questionnaire, an out-of-institution injury was detected in a female colleague, it was necessary to review. Figure 5 shows the areas where the operative feels discomfort



CUESTIONARIO DE SÍNTOMAS MUSCULOESQUELÉTICOS

CUESTIONARIO NÓRDICO

LOCALIDAD	Mexicali	FICHA		FOLIO	
UBICACION	Inst. Educación	GERENCIA		AREA	
INSTALACION	Biblioteca	CATEGORIA		FECHA	Abril 2024

1 Tiempo en este trabajo
< de 3 meses ☐ | 3 meses a 1 año ☐ | 1 a 5 años ● | 5 a 10 años ☐ | > de 10 años ☐
2 Durante el último mes, ¿qué tan frecuente se ha sentido mentalmente exhausto por su trabajo?
Nunca ☐ | Algunas veces ● | Con frecuencia ☐ | Siempre ☐
3 Durante el último año, ¿qué tan frecuente se ha sentido físicamente exhausto por su trabajo?
Nunca ☐ | Algunas veces ● | Con frecuencia ☐ | Siempre ☐
4 ¿Ha sentido algún dolor o molestia, durante el último año, que usted piense está relacionado con su trabajo?
SI | NO ●

SI CONTESTÓ DE MANERA AFIRMATIVA LA PREGUNTA ANTERIOR, INDICAR EN LOS ESQUEMAS DEL CUERPO, LAS ÁREAS EN LAS QUE SE PRESENTAN LAS MOLESTIAS O DOLOR, ADEMÁS INDICAR EL TIPO DE MOLESTIA EXPERIMENTADA, CALIFICÁNDOLA CONFORME A LA ESCALA ADJUNTA

ESCALA DE BORG

0	NADA
0.5	EXTREMADAMENTE LEVE
1	MUY LEVE
2	LEVE
3	MODERADO
4	
5	FUERTE
6	
[✓ 7]	MUY FUERTE
8	
9	
10	EXTREMADAMENTE FUERTE

SÍNTOMAS

MOLESTIA	
DOLOR	●
ADORMECIMIENTO	
COSQUILLEO	
ARDOR	
INFLAMACIÓN	
RIGIDEZ ARTICULAR	
TENSIÓN MUSCULAR	
DEBILITAMIENTO	
HINCHAZÓN	
OTROS	

Figure 5. Areas of the body where administrator discomfort occurs

NOM 06 STPS (Handling and storage of materials-occupational health and safety conditions) (DOF, 2014).

In point 8.1, Environmental conditions, you must be sure to consider, Point f you can see the high temperature that is not taken care of because you do not have adequate air conditioning in summer time

In point 9.4, for the storage of materials, the safety conditions must be complied with (Prevent them from being blocked by the lighting)

In point 10, it specifies surveillance of the health of workers

4.2 Ergonomic methods

They are used as specific evaluations to evaluate the physical risk factors in the handling of loads, required by NOM 036 STPS.

NIOSH (The National Institute for Occupational Safety and Health),(INSST) (Diego-Mas,2015) For IL 0.61 as shown in table 5, the partner will not have a problem. For IL 2.64 you may have ailments or injuries in the partner. QEC (quick exposure check), Table 6 shows the levels are high at risk even very high for the man handling that load.

Table 5. Displays the data obtained when applying NIOSH.

Variable	Valor		Coeficiente	Resultado	
	Mujer	Hombre		Mujer	Hombre
Carga (Kg)	2	6	HM	0.49	0.49
H (cm)	61	61	VM	0.71	0.71
V (cm)	173	173	DM	0.887	0.887
D (cm)	66.32	66.32	AM	0.71	0.71
A (grados)	90	90	FM	0.65	0.45
F (Lev/min)	2	4	CM	1	1
Agarre	BUENO	BUENO	LPR	3.27	2.267
			IL	0.611	2.64
			Riesgo	limitado	Incremento moderado

Table 6. Assessment when applying the QEC method

Nivel Riesgo por manejo de carga							
Segmento corporal	Mujer		Hombre		Carga trabajo	Mujer	Hombre
	%	Nivel	%	Nivel		Nivel	Nivel
Cuello	88.8	Muy Alto	88.8	Muy Alto	Conduce	Bajo	Bajo
Espalda	69.5	Alto	82.6	Alto	Vibra	Bajo	Bajo
Hombro/Brazo	64.2	Alto	75	Muy Alto	Ritmo	Bajo	Bajo
Muñeca/Mano	73.9	Alto	73.9	Alto	Estrés	Bajo	Bajo

Table 7. WERA (workplace ergonomic risks assesment), ARTOOL

Factores de riesgo ergonómico	ARTOOL		WERA	
	Mujer	Hombre	Mujer	Hombre
Cuello	66.6%	66.6%	66.6%	66.6%
Espalda	66.6%	66.6%	66.6%	66.6%
Brazo	66.6%	66.6%	50.0%	50.0%
Mano/dedo/muñeca	33.3%	33.3%	33.3%	33.3%
Pierna/Tobillo			50.0%	50.0%
Fuerza	33.3%	33.3%	66.6%	83.3%
Nivel de Riesgo	50% Bajo (Consciente)	50% Bajo (Consciente)	50% Bajo (Aceptable)	56% Medio (Cambios)

In the neck, back, and arm, a high ergonomic risk level was detected in the WERA and ARTOOL methods, shown in Table 7.

Liberty Mutual Tables (INSST), when transporting books with 4-wheel auxiliary equipment, it is feasible to do so with the equipment as shown in table 8.

It can be carried out by 90% of women without any significant risk considered safe process, for men it is considered acceptable task

Table 8. Maximum Acceptable Thrust Forces for Women (Kg), values taken from Liberty Mutual Tables

Fuerzas iniciales		(30.5 metros) Un empuje cada				Fuerzas Sostenidas		(30.5 metros) Un empuje cada			
		Minutos						Minutos			
Altura	Porcentaje	1	2	5	**30**	Altura	Porcentaje	1	2	5	30
135	90	12	13	14	15	135	90	5	6	6	6
	75	15	16	17	19		75	7	8	9	9
	50	18	19	21	22		50	10	11	12	12
	25	20	22	24	26		25	13	14	15	15
	10	23	25	27	29		10	15	17	17	18

Figure 6 shows the heaviest books transported, the load was divided into low, medium and high to carry out the study. 2 kilograms is the maximum a woman carries because she is damaged in the back by accident and the man carries 6.4 kg.

Figure 6. Books and their maximum weight carried by staff

Table 9 shows that 90 percent of women can handle up to 12 kg in 30-minute periods without any significant risk, and for men the load of 6.4 kg is acceptable

Table 9. Maximum acceptable transport weight (Kg) values extracted from Liberty Mutual Tables

Fuerza Mujer		(8.5 metros) Un transporte cada					Fuerza Hombre		(8.5 metros) Un transporte cada				
		Minutos				Hr			Minutos				Hr
Altura	%	1	2	5	**30**	8	Altura	%	1	2	5	30	8
105	90	12	12	12	12	16	111	90	13	13	15	17	20
	75	14	14	14	14	19		75	18	18	20	23	27
	50	16	16	16	16	22		50	23	24	26	29	35
	25	18	18	19	19	25		25	29	29	32	36	43
	10	20	20	21	21	28		10	34	34	38	42	50

5. DISCUSSION/CONCLUSIONS

- The objective of ergonomically validating the handling and transport of books manually and with auxiliary transport equipment was met
- 6 rules of the Secretary of Labor were evaluated that allowed us to find feedback points to improve the comfort of our co-workers.
- The rapid assessments set out in the Load Handling Standard made it possible to assess the application made by the administrative staff in their work, hence the need to carry out specific assessment through ergonomic methods was detected.
- The ILO recommendations were selected by the managers themselves to facilitate their own adoption by appropriating their own proposals found in conjunction with the engineers
- Anthropometric and dynamometer measurements were taken into account when assessing the use of load handling equipment
- It was proposed to remove the carpet that is used on library surfaces, the use of auxiliary equipment without carpet has already been verified and the load necessary for pushing is only 25% of the force required in a sustained way
- Training in book storage is required to decrease the likelihood of ergonomic hazards

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EVALUATION OF THE PHYSICAL AND MENTAL WORK AT THE PRODUCTION UEB OF EPEP-CENTRO

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Resumen: La Ergonomía es una disciplina que estudia la interacción entre el hombre, la máquina el entorno, de ahí que su función principal sea la adaptación de los puestos de trabajo al hombre. La investigación se desarrolló en la UEB Producción de la Empresa de Perforación y Extracción de Petróleo del Centro y tiene como objetivo evaluar el trabajo físico y mental en puestos de trabajo. Se aplicó el método de la Prueba del Escalón para determinar Capacidad de Trabajo Física, el Método Tabular para Gasto Energético y el indicador Tiempo de Reacción para evaluar carga mental de trabajo. Los resultados mostraron que los trabajadores presentan una capacidad de trabajo física inferior al gasto energético y a su vez se evidencia fatiga mental en los mismos al culminar su jornada laboral. Por tanto, la organización debe implementar modificaciones en los puestos de trabajo para asegurar que los empleados cuenten con las competencias necesarias para desempeñarse de manera eficiente.

Palabras clave: capacidad, carga mental, gasto energético, trabajo físico.

Relevancia para la ergonomía: La mayoría de los puestos de trabajo en el contexto internacional poseen demandas físicas y cognitivas, por lo que es de vital importancia para el personal que atiende la seguridad y salud en el trabajo en las empresas conocer y dominar herramientas que permitan la evaluación de estos factores y permitan tomar decisiones para lograr una calidad de vida en el entorno laboral. En la presente investigación se aplican métodos que evalúan las demandas físicas que tiene un puesto de trabajo como la capacidad de trabajo físico y el gasto energético y por otra parte uno de los indicadores más empleados para valorar carga mental de trabajo como tiempo de reacción.

Abstract: Ergonomics is a discipline that studies the interaction between man, machine and environment, hence its main function is the adaptation of jobs to man. The research was developed in the UEB Production of the Center's Oil Drilling and Extraction Company and aims to evaluate the physical and mental work in the workstation. The Step Test method was applied to determine Physical Work Capacity, the Tabular Method for Energy Expenditure and the Reaction Time indicator for to determine mental workload. The results showed that workers have a physical work capacity lower than their energy expenditure and at the same time mental fatigue is evident in them at the end of their workday. Therefore, the organization must implement modifications to jobs to ensure that employees have the necessary skills to perform efficiently.

Keywords. capacity, mental load, energy expenditure, physical work.

Relevance to Ergonomics: Most jobs in the international context have physical and cognitive demands, so it is of vital importance for the personnel in charge of occupational health and safety in companies to know and master tools that allow the evaluation of these factors and allow making decisions to achieve a quality of life in the work environment. In the present investigation, methods are applied to evaluate the physical demands of a work position such as physical work capacity and energy expenditure, and on the other hand, one of the most used indicators to evaluate the mental workload is reaction time.

1. INTRODUCTION

Providing quality services, generating profits, protecting the environment, having healthy workers committed to the organizational objectives is a paradigm of the institutions. There are different disciplines that contribute to this in the world, one of them, is Ergonomics (González & Anyel, 2021).this is a science that studies the interaction between man and the work environment where there may be activities with physical and mental demands to improve the quality of life of people in labor issues fundamentally (Prieto et al., 2023).

Currently, occupational safety and health plays an important role in entities worldwide because it allows improving the performance of workers. This has been reflected on many occasions because employees have felt the concern of top management regarding the protection of their health and integrity (Diaz Lopez, 2020).

A problem present in organizations is that physical activity has been affected by a sedentary lifestyle which causes a low level of energy expenditure. Regarding the level of physical work and energy expenditure, metabolism is considered as the main biological indicator that continuously expresses and quantifies the amount of oxygen or metabolic cost of people. Thus, research on physical activity has several aspects depending on the work purpose (Urresta et al., 2021).

Due to the accelerated evolution of mankind, new forms of work organization were created. These changes caused an increase in the surveillance and control of the worker's performance, so that not only the elements related to the physical environment began to be analyzed, but also those related to mental workload (Acosta Prieto et al., 2023).

Cobiellas Carballo et al. (2020) and Gil Mejia (2019) emphasize that there is a close relationship between mental overwork and the appearance of diseases such as obesity, cardiovascular disorders, arterial hypertension, atherosclerosis, diabetes mellitus, dyslipidemia, digestive disorders, asthma, psychiatric disorders, cancer and the aforementioned stress. That is why it has been of utmost importance for different researchers to know the mental state of individuals.

The research was carried out at the Center's Oil Drilling and Extraction Company del Centro (EPEP-Centro), one of the most powerful oil industries in the nation's economy, which seeks not only to guarantee oil for the generation of electricity in the country, but also the welfare of its workforce.

The operation of the organization over time has been affected by musculoskeletal discomfort, concern and dissatisfaction due to the consequences of the physical and mental health of individuals. Therefore, the objective of the study is to evaluate the physical and mental work in the Production UEB, where the production and treatment of crude oil takes place, a key process for the proper functioning of the company and, therefore, for the fulfillment of its corporate purpose.

2. METHODOLOGY

The research presents a quantitative approach since it is based on the measurement of job characteristics, in this case both physical and mental. Its scope is descriptive because it defines the attributes of the group under study: operators A, B and C of crude oil collection and treatment.

The procedure used for the evaluation of physical and mental work is shown below.

2.1 Stage 1. Initial preparation

In this first stage, the need for the study is identified in the entity, and the evaluation site is characterized and chosen.

Step 1. Characterization of the company

To characterize the entity, a review of documents was used to learn about the general elements of its operation.

Step 2. Selecting the job to be evaluated

The parameters analyzed through direct observation are taken into account.

2.2 Stage 2. Application of the step test

According to García Dihigo (2017), the step test uses heart rate as the fundamental criterion. It integrates the variables of age, sex and body weight. This test needs very little laboratory equipment and its technique of use is very standardized, hence it has been considered for this research.

This is an indirect method for the determination of physical capacity by estimating the maximum oxygen consumption (VO2 max). The method is based on the application of three staggered physical loads on a bench at a specific rate of ascent and descent and with the control of heart rate (HR) as an indicator of effort (Moreno Vega, 2020).

2.3 Stage 3. Estimation of Energy Expenditure from tables of standard values

This method is applied because it does not require specific technology as well as being non-invasive, and provides quick and simple estimates for a wide range of activities.

When the metabolism is estimated through tables of standard values, it implies accepting predetermined values for different types of activity, effort, movement, and admitting that the population being studied at that moment is adjusted to that which served as the basis for the tables, and that the actions that generate energy expenditure are, in this case, the same as those expressed in the tables (Yanes García, 2022; Cáceres Tamayo and Echeverría Freire, 2023).

2.4 Step 4. Psychophysiological indicator Reaction Time to determine the presence of mental workload

The Reaction Time indicator was chosen because of its sensitivity to changes in cognitive functioning, such as attention, concentration and processing speed. In addition, the AMIS software is more accessible to users with different levels of technical expertise, due to its intuitive interface and easy navigation (Acosta, 2023).

Acosta Prieto et al. (2023) present a methodology to assess the mental workload of workers. For this purpose, the psychophysiological indicator Reaction Time to Sensory Stimuli is applied, where the user is subjected by the A.M.I.S. software to different reaction times: simple, simple redundant and complex, with which the results obtained before starting and at the end of the working day can be compared. If the behavior of the indicator is ascending, the presence of mental fatigue is inferred.

3. RESULTS

Operators A, B and C of crude oil collection and treatment who work in the crude oil processing plant were selected for the study. Their data are as follows:

Operator A. Age: 40 years old. Body weight: 82 kg. Height: 180cm

Operator B. Age: 49 years. Body weight:80 kg. Height:174cm. He suffers from hypertension

Operator C. Age: 37 years. Body weight: 75 kg. Height: 176cm.

Table 1 shows the results of the application of the step test to the workers under study.

Table 1. Results of the application of the step test

Operators	**FCmáx (puls/min)**	**FCref (puls/min)**	**FCsubmáx (puls/min)**	**VO_2máx (L/min)**	**CTFref (LO_2/min)**	**CTFref (J/JL)**
A	180	117	128	361	1,018	8 001 401,4
B	171	111,15	130	350	0,8925	7 015 050

C	183	118,95	125	364,5	1,028	8 080 158,6

For the estimation of the Energy Expenditure, the activities performed in the job were taken and the values of metabolism for each activity were determined as shown in Table 2 below.

Table 2. Results of the application of the step test

Act	Mb (W/m^2)	Mp (W/m^2)	MTT (W/m^2)	D (m)	T (s)	Mv (W/m^2/m/s)	Mcm (W/m^2)	Total (W/m^2)
1	44	0	55	200	540	110	40,74	139,74
2	44	25	85	0	1200	0	-	154
3	44	0	55	50	180	110	30,56	129,56
4	44	25	85	0	1500	0	-	154
5	44	0	55	100	360	110	30,56	129,56
6	44	25	55	0	1800	0	-	124
				Cycle	5580		GE (W/m2)	830,86

It is also known that the working day has a duration of 480 min, of which 45 min are taken as rest time and the rest is considered working time.

JL= 480 min = 28 800 s TT = 435 min = 26 100 s TD = 45 min = 2700 s

Standard= working time/cycle duration= 26100s/5580s=4 cycles/JL

Sc (m2) =1.74

GE (W or J/s) =1445.7

GE(J/JL) = 32268024

In all three cases, the physical work capacity (CTF) is less than the energy expenditure (GE), so none of the workers is fit for the job.

Table 3 shows the results of the mental workload assessment with the A.M.I.S. software application.

Table 3. Results of the reaction time evaluation

Workers	TRS (s)		TRSR (s)		TRC(s)	
	Before	After	Before	After	Before	After
Operator A	0,617	0,696	0,657	0,661	0,818	0,873
Operator B	0,597	0,644	0,694	0,723	0,834	0,888
Operator C	0,612	0,699	0,678	0,694	0,804	0,867

With the application of this tool, it was determined that the three workers who work in the crude oil collection and treatment station present mental fatigue at the end of their workday.

Therefore, the workers under study do not have the physical and mental capacities to perform their duties, which may have a negative impact on job performance and satisfaction. Because of this, the company should consider making changes to the jobs and ensure that employees are equipped with the necessary skills and knowledge to perform effectively.

4. DISCUSSION

According to the results found in this research on the presence of mental workload in the company's workers, it is in agreement with Sluiter et al. (2003), in reference to the negative consequences that mental workload has on the worker's health, such as a reduction in work motivation, emotional instability, anxiety, depressive states, low self-esteem, which are some of the causes of mental workload.

Sauter et al. (2012) states that the work activity should have an optimal level of performance according to the characteristics of the person performing it, but when the demand is excessive or too low then this leads to the emergence of psychotropic disorders associated with work.

It is a priority to highlight that most of the studies conducted to determine the presence of mental workload in workers have been carried out in hospital staff and in teaching and there is no evidence of having been conducted in industrial companies' staff, mainly operators, so it is not possible to compare specifically with other researches.

The components of energy expenditure can be determined by calorimetry, which can be direct or indirect. In addition to calorimetry, there are other methods to determine energy expenditure and energy requirement: predictive equations, bioelectrical impedance, doubly labeled water, bicarbonate dilution, heart rate recordings, the Quenouille equation. These techniques are relegated due to their complexity and cost (Redondo, 2015).

However, the tabular method for determining energy expenditure is the one that contains a greater and faster reference facility, since it contains a wide range of physical activities with their respective metabolic expenditure, which facilitates comparing energy expenditure between different types of exercises or tasks, providing clear and quantitative information that allows promoting the health of workers.

5. CONCLUSIONS

Ergonomics is a profoundly humanistic science, by propitiating the creation of conditions increasingly adequate to the physical, psychic and emotional requirements of people as social subjects, especially the workers who will always be more important than the objects or the productive processes in which they intervene.

The application of the step method and the tabular method showed that the energy expenditure is higher than the physical work capacities in the jobs of the crude oil collection and treatment operators. This difference can lead to ergonomic problems such as occupational diseases.

The measurement of the psychophysiological indicator Reaction Time to Sensory Stimuli showed that the three operators working at the workstation are mentally charged at the end of their working day, which can cause mental and emotional fatigue, work stress, professional burnout and even physical health problems.

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ERGONOMIC IMPROVEMENT PROPOSAL FOR THE SEALING STATION OF A WATER PURIFICATION PLANT

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Resumen El presente artículo tiene como objetivo principal investigar los efectos que las posturas y movimientos de la operación sellado de garrafones tienen sobre los trabajadores en una microempresa en Ciudad Juárez. Para ello, se utilizó el mapa del cuerpo de Marley y Kumar (1996) como referencia clave de las molestias musculoesqueléticas. Asimismo, se diseñará una propuesta de mejora ergonómica, fundamentada en un análisis de este paso en el proceso de purificación y comercialización de agua potable. Con ello implica el uso de principios antropométricos y herramientas audiovisuales como apoyo a la observación de los movimientos. El análisis de los movimientos realizados en la actualidad se llevará a cabo utilizando los métodos REBA y NIOSH, con el fin de evaluar tanto las posturas adoptadas como la manipulación manual de cargas. Esta evaluación permitirá determinar riesgo de las tareas, en consecuencia, identificar los puntos críticos que requieren rediseño en este proceso.

Finalmente, como resultado de la investigación, se propondrá el diseño de una estación de trabajo ergonómica y funcional. La propuesta se centrará en adaptar el entorno laboral a las capacidades y limitaciones de los trabajadores en la estación de sellado, priorizando su bienestar y seguridad.

Palabras clave: Purificadora de agua, REBA, NIOSH, Factores de Riesgo, Sellado.

Relevancia para la ergonomía: Este estudio ofrece un caso práctico de implementación de principios ergonómicos en un sector frecuentemente ignorado. La investigación demuestra cómo un análisis detallado de los movimientos, posturas, herramientas y lugar de trabajo contribuye a la salud y seguridad de los empleados. En otras palabras, este trabajo ofrece una mejora en las condiciones de trabajo y proporciona un marco importante para la aplicación de la ergonomía en microempresas, promoviendo un enfoque preventivo y proactivo en la gestión de factores de riesgo ocupacional.

Por último, este trabajo es un ejemplo de la diversidad de formas que puede tomar la ergonomía. Encaminarla a un área poco común abre paso a investigaciones más robustas y prácticas en el campo. Y al visibilizar y abordar estos problemas, se

potencia la conciencia sobre la ergonomía en sectores menos regulados y desatendidos.

Abstract: The primary aim of this article is to investigate the effects of postures and movements involved in the jugs sealing operation on workers in a microenterprise in Ciudad Juárez. The study uses Marley and Kumar's (1996) body map as a key reference for identifying musculoskeletal discomfort. Additionally, an ergonomic improvement proposal will be developed, based on an analysis of this step in the potable water purification and commercialization process. This will involve the use of anthropometric principles and audiovisual tools to support the observation of movements.

The current movements will be analyzed using the REBA and NIOSH methods to evaluate both the postures adopted and the manual handling of loads. This assessment will help determine the ergonomic risk of the tasks and, consequently, identify critical points that require transformation in this process.

Finally, the proposal for design of an ergonomic and functional workstation will be made. The proposal will focus on adapting the work environment to the capabilities and limitations of the workers at the sealing station, prioritizing their well-being and safety.

Keywords. Water Purification, REBA, NIOSH, Risk Factors, Sealing.

Relevance to Ergonomics: This study provides a practical case of implementing ergonomic principles in a frequently overlooked sector. The research demonstrates how a detailed analysis of movements, postures, tools, and the workplace contributes to the health and safety of employees. In other words, this work offers an improvement in working conditions and provides an important framework for applying ergonomics in micro-enterprises, promoting a preventive and proactive approach to managing occupational risk factors.

Finally, this work exemplifies the diverse ways ergonomics can be applied. By directing attention to a less common area, it paves the way for more robust and practical research in the field. By highlighting and addressing these issues, it raises awareness of ergonomics in less regulated and underserved sectors.

1. INTRODUCTION

1.1 Background

In Ciudad Juárez, it is common to see small businesses dedicated to the purification of drinking water in local neighborhoods. As micro-enterprises, they generally lack trained personnel to assess the layout of their work areas and the tasks to be performed. In this specific case, the water purification facility analyzed follows six steps for the purification and sale of drinking water: 1) External washing; 2) Internal washing; 3) Filling (where the dispensed water passes through purification filters before entering the jug); 4) Sealing; 5) Shipment; and 6) Sale of jugs to customers or at strategic points.

The nature of the movements and postures involved in the operation, which will be the focus of this article, has led to complaints of first-degree burns, sprains or wrist pain, fatigue, and lack of rest. However, there is no official record of these incidents and complaints.

1.2 Process Description

This work focuses on the sealing step, which does not have a dedicated workstation, as employees operate at ground level. However, it could be said that they have a designated area within the establishment. The sealing of jugs is an activity rotated among two young men and one adult woman. This activity is based on the following movements, which are performed in the order the individual deems appropriate. That is, the activities currently being performed are not standardized. Therefore, there is a need to establish a temporal standard based on observations of the movements and the captured frames. From this, it is determined that the key activities for sealing the water jugs are:

Preparing the materials: 1) Take the cap; 2) Assemble the cap; 3) Take the seal; and 4) Insert the seal.

Sealing: 1) Take the heat gun; 2) Use the heat gun; and 3) Release the heat gun.

Moving the jugs: 1) Take the jug; 2) Move the jug; and 3) Release the jug.

1.4 Problem Statement

1.4.1 Operational and Health Effects

Observing about two hours the way workers carry out this step in the process of purifying and selling purified water, various risk factors were observed in their activities and work area. To address them separately, the next table describing the effects of work design. And the next point explains the occupational risks associated with movements.

Table 1. Effects of Work Design

Health Effects	**Operational Effects**
Fatigue	High turnover rate
First-degree burns	Work-related accidents
Back problems	Low yield
Headaches	Worker complaints regarding their activities and/or work area
Muscle injuries	
Tension and inflammation in tendons and/or muscles	

1.4.2 Occupational Risk Factors

To provide a comprehensive view of the risks and effects associated with the activities performed at the carboy sealing station, an analysis of various occupational risk factors was conducted. The following table synthesizes the key findings related to energy exertion, repetitive efforts, stressful postures, mechanical stress, temperature extremes, and inadequate rest.

Table 2. Occupational Risk Factors at the Sealing Station

Category	**Body Areas Affected**	**Description**
Energy Exertion	Arms, forearms, shoulders, back, legs	Reach cover and seal: Upper limb exerts effort to support its weight and reach the lid.
		Move carboy: Body parts support the weight of the carboy.
Repeated Efforts	Arms, forearms, shoulders, hands (palmar zone), back, legs	Reach cover and seal: Left upper limb shows hyperextension, stretching muscles.
		Assembly cover and Insert seal: Vertical force on wrist; palm protects bones and muscles.
		Move carboy: Back, arms, and legs are involved, with knees, calves, and feet supporting movements.
Stressful Postures	Spine, neck, head, arms, shoulders, hands (palmar and dorsal area), wrists	Non-ergonomic handling of carboy.
		Activities involve curved posture and lack of neutral movements. Hand flexion and extension during cover insertion.
Mechanical Stress	Hands (palmar and dorsal zone)	Reach cover and seal: Hand conforms to lid diameter; fingers act as a clamp.
		Use heat gun: Restricted blood flow; index finger constantly presses trigger.
Temperature Extremes	Hands (palmar zone)	Use heat gun: Precision required to avoid first-degree burns.
Inadequate Rest and Recovery	All body	All activities involve highly repetitive movements.
		Speed of sealing task prevents recovery until task completion.

1.4.3 Survey Results

To confirm the risks and effects outlined above, a survey was conducted with each worker at the station to assess the discomfort they experience in their bodies. The survey format is authored by Marley and Kumar (1996). In addition to identifying the areas of the body experiencing pain, it is crucial to analyze the frequency and intensity of these discomforts. The following tables categorize the pains according to Marley and

Kumar's (1996) body scoring scale. The colors in the table indicate: 1) Green: pains that likely do not require treatment; 2) Yellow: those that likely need treatment; 3) Red: pains that require treatment and may have serious health implications; and 3) Gray: areas without severity.

The symbols used on the scoring sheets are as follows:

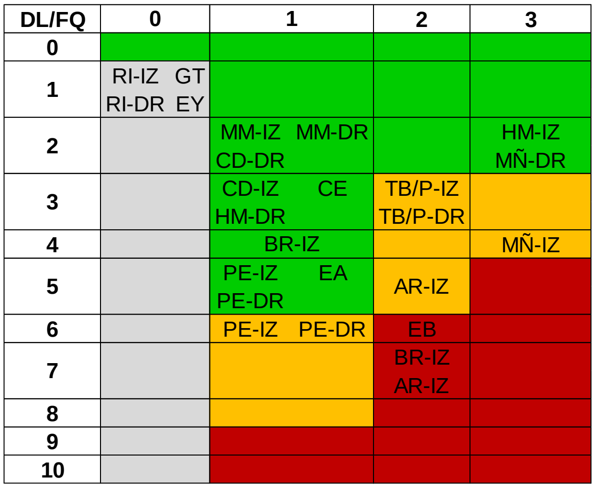
Body Part	Symbolism
Shoulder	HM
Arm	BR
Elbow	CD
Forearm	AR
Wrist	MÑ
Hand	MM
Leg	PE

Body Part	Symbolism
Knee	RI
Calf	PI
Ankle/Foot	TB/P
Back	EA
Neck	CE
Glutes	GT
Eyes	EY

Direction	Symbolism
Right	DR
Left	IZ

Figure 1. Symbolism.

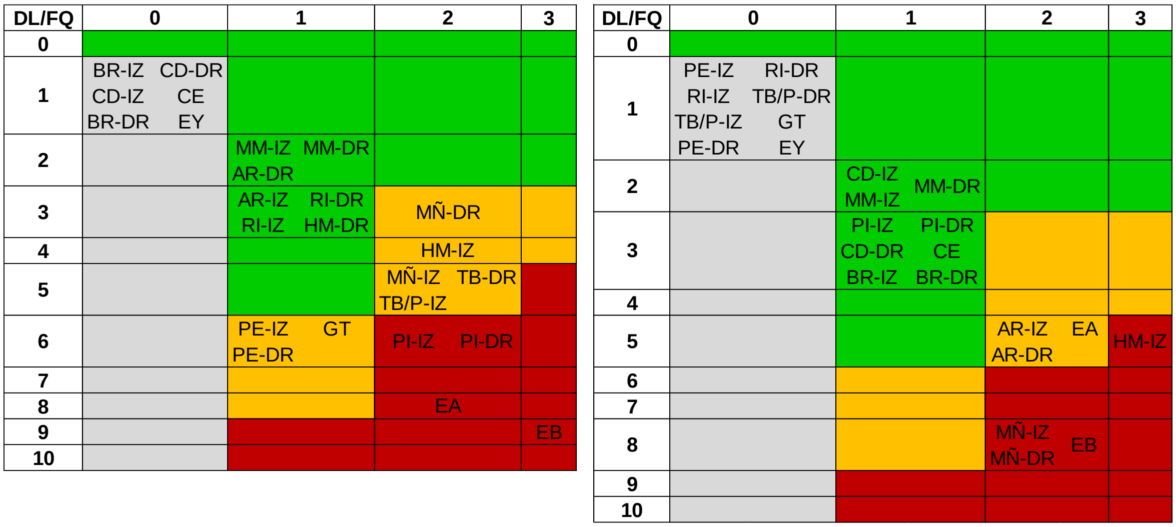
The results from the scoring sheets are:



DL/FQ	0	1	2	3
0	🟩	🟩	🟩	🟩
1	⬜ RI-IZ GT RI-DR EY	🟩	🟩	🟩
2	⬜	🟩 MM-IZ MM-DR CD-DR	🟩	🟩 HM-IZ MÑ-DR
3	⬜	🟩 CD-IZ CE HM-DR	🟨 TB/P-IZ TB/P-DR	🟨
4	⬜	🟩 BR-IZ	🟨	🟨 MÑ-IZ
5	⬜	🟩 PE-IZ EA PE-DR	🟨 AR-IZ	🟥
6	⬜	🟨 PE-IZ PE-DR	🟥 EB	🟥
7	⬜	🟨	🟥 BR-IZ AR-IZ	🟥
8	⬜	🟨	🟥	🟥
9	⬜	🟥	🟥	🟥
10	⬜	🟥	🟥	🟥

Figure 2. Survey Results: The level of discomfort risk in the employees' bodies (Women)

The areas with the most pain are in the left shoulder, forearms, wrists, hands, calves, upper and lower back. These specific areas are responsible for bearing weight or performing actions in stressful postures. Therefore, the pain levels reveal a direct correlation between the movements of the activities and physical discomfort. In other words, the effects mentioned in the previous point do influence the employee's health.



DL/FQ	0	1	2	3
0				
1	BR-IZ CD-DR CD-IZ CE BR-DR EY			
2		MM-IZ MM-DR AR-DR		
3		AR-IZ RI-DR RI-IZ HM-DR	MÑ-DR	
4			HM-IZ	
5			MÑ-IZ TB-DR TB/P-IZ	
6		PE-IZ GT PE-DR	PI-IZ PI-DR	
7				
8			EA	
9				EB
10				

DL/FQ	0	1	2	3
0				
1	PE-IZ RI-DR RI-IZ TB/P-DR TB/P-IZ GT PE-DR EY			
2		CD-IZ MM-DR MM-IZ		
3		PI-IZ PI-DR CD-DR CE BR-IZ BR-DR		
4				
5			AR-IZ EA AR-DR	HM-IZ
6				
7				
8			MÑ-IZ EB MÑ-DR	
9				
10				

Figure 3. Survey Results: The level of discomfort risk in the employees' bodies (Men)

2. OBJECTIVES

The objectives are to identify and determine musculoskeletal complaints among employees of the workstation. Determine the risks of the tasks by means ergonomic evaluation methods. Additionally, the aim is to propose improvements in worker well-being through the implementation of ergonomic and anthropometric principles to enhance productivity at the workstation. Furthermore, designs, methods, and strategies will be developed to propose a new design that may help reduce occupational risks. This includes the redesign and optimization of the work area to minimize injuries and improve worker efficiency while preserving their health and integrity. Ergonomic activities and methods specific to the sealing process will also be implemented to ensure its safe and efficient execution. Lastly, current occupational risks will be assessed, identifying their potential effects on both workers and the company.

3. METHODOLOGY

Initially, the water purification facility was identified as the focus for developing the research project. The subsequent stages were as follows: 1) observe the process; 2) select the object of study; 3) observe the sealing step for two hours; 4) define the problem based on employee feedback (including occupational risk factors, health effects, musculoskeletal discomfort, operational effects, and Marley and Kumar's questionnaires and tables (1996)); 5) identify areas for improvement; 6) research ergonomic and anthropometric principles; 7) study the movements using REBA and NIOSH methods; 8) analyze the study results; 9) design the improvement proposal; 10) review and refine the proposal; and 11) approve the improvement proposal.

3.1 Revision of Methods and Resources Used

For the analysis and development of the proposal, extensive research was conducted using various sources of information. The following is a chronological overview of the sources that contributed to the content of this article:

Surveys and Tables by Marley & Kumar (1996): These tools, developed by Marley and Kumar, facilitated the ergonomic assessment of the work environment relevant to the proposal. They were instrumental in identifying and quantifying employee discomforts and complaints associated with postures and movements in their tasks. The surveys collected data on employees' perceptions of physical load, pain, or discomfort in specific body areas. In essence, employees evaluated the frequency and severity of musculoskeletal complaints related to movements during the sealing of bottles. The tables complemented the surveys by providing a categorical and evaluative framework for assessing posture and movement risks in the workplace, thereby identifying the most critical postures and tasks affecting employee health.

Standard Time with MTM (Methods-Time Measurement): This tool was employed to measure task times in the sealing process. Key activities were broken down into basic movements (reaching, grasping, moving, etc.), which were recorded for subsequent evaluation. These movements were assigned a standard time and tolerance based on the book "Industrial Engineering: Methods, Standards, and Work Design" by Benjamin W. Niebel and Andris Freivalds (2009). It is important to note that the movements studied with this method were those temporally standardized in the current sealing process, alongside the proposed movements. Additionally, the use of these times allows for verification that the proposal not only improves the ergonomics of movements and the work area but also demonstrates the efficiency that the proposal brings to processing times.

REBA (Rapid Entire Body Assessment): This method was primarily used to evaluate ergonomic risk associated with awkward and forced postures during the activities discussed in this article. REBA allowed for the assessment of postures in body areas with higher discomfort indices, including the left shoulder, forearms, wrists, hands, calves, upper back, and lower back. As a versatile method, it was successfully applied to the subject of this study and proved particularly useful for repetitive movements, load handling, and uncomfortable positions. According to José Antonio D. (2015), REBA is a posture analysis method highly sensitive to tasks involving unexpected posture changes, typically due to the handling of unstable or unpredictable loads. The objective of REBA is to assess the level of worker exposure to risks arising from adopting inadequate postures.

NIOSH Manual Handling Lifting Method (National Institute for Occupational Safety and Health): This method is considered crucial in identifying the problem as well as developing improvement proposals. It was utilized to assess and enhance safety in lifting bottles per minute. This tool provided a systematic approach to evaluating the risks associated with lifting bottles, thus establishing limits on the recommended weight for lifting.

Ergonomic Solutions for Retailers: Prevention of Material Handling Injuries in the Grocery Sector (2014): This guide explains the importance of ergonomics in the workplace and how applying ergonomic principles can reduce musculoskeletal injuries, increase efficiency, and improve overall employee wellbeing. The guide provided valuable insights, including: 1) Space Organization: Understanding the arrangement of products and equipment to minimize unnecessary movements and uncomfortable positions; 2) Hand Tools: Recognizing the importance of lightweight and well-designed tools to reduce strain on hands and arms; 3) Manual Lifting Techniques: Emphasizing the need for proper training in safe lifting and handling techniques to reduce back strain and other bodily stress; 4) Task Rotation: Implementing task rotation to avoid prolonged repetitive activities that could lead to repetitive strain injuries; 5) Regular Breaks: Encouraging regular breaks to allow for muscle recovery and reduce fatigue; 6) Use of Mechanical Aids: Promoting the use of mechanical aids such as stackers, lifters, and conveyors to reduce manual handling; 7) Employee Awareness and Participation: Encouraging active employee involvement in identifying ergonomic issues and implementing solutions, given their firsthand knowledge of the physical effects of their tasks and work environment.

Percentiles: The use of percentiles was crucial for the ergonomic design of the workstation. By understanding the primary characteristics of employees who would be affected by the proposed improvements, specific percentiles were utilized. The measurements were based on the article "Anthropometric Dimensions of the Latin American Population: Mexico, Cuba, Colombia, Chile" by Rosalio A. C., Lilia R. P. L., and Elvia L. G. M. (2015).

OSHA Standard 1910.242 - Hand and Portable Powered Tools and Equipment: This standard emphasizes the importance of maintaining tools used by workers in safe conditions, raising awareness among employers about tool safety.

Books on Ergonomics and Tool Design: Various insights were extracted from references such as "Ergonomics in Action: A Practical Guide for the Workplace" (2015), "Kodak's Ergonomic Design for People at Work" (2004), and "Cumulative Trauma Disorders: A Manual for Musculoskeletal Diseases of the Upper Limbs" (1944). These books provided knowledge on tool design, including functional adequacy, user compatibility, fatigue reduction, and ease of use.

4. RESULTS

4.1 Rapid Entire Body Assessment Method

4.1.1 Current Method

The proposed method presents risk scores ranging from 2 to 15 points. The results by activity are as follows:

Activity 1: Put Material. For movements involving reaching for material (cover and seal), a total of 13 points is recorded, indicating an urgent and immediate action is required, with a very high risk. As for the movements of assembling the cover and inserting the seal, a score of 14 points is observed, representing a very high-risk level and necessitating urgent and immediate action.

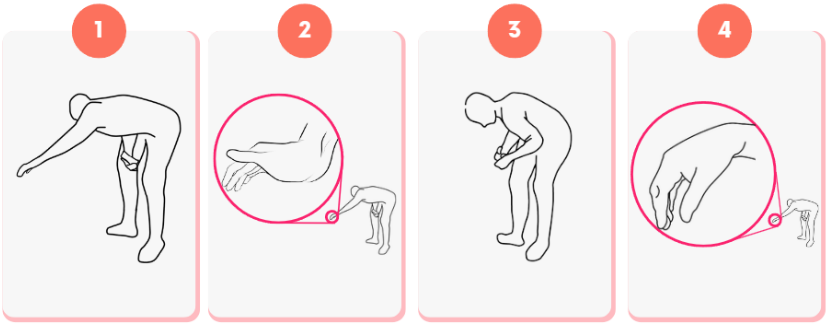


Figure 4. REBA's Results "Activity 1"

Activity 2: Sealing. The movements of using the heat gun and releasing it scored 13 risk points. On the other hand, picking up the tool scores 2 points, indicating a low risk that may require a potential change.

Figure 5. REBA's Results "Activity 2"

Activity 3: Moving Carboys. Grabbing and releasing the carboy involves a total of 15 points, indicating an extremely high-risk level, requiring immediate corrective action. Meanwhile, moving the carboy scores 7 points, representing a medium risk level with urgent and immediate corrective action needed.

Figure 6. REBA'S Results "Activity 3"

4.1.2 Proposed Method

It was determined that lifting the carboys poses no risk, as the operator only needs to press the power button once. Similarly, the movements involving "taking and inserting material" and "heat sealing" scored one point (no risk). This is because the worker has materials and tools within reach due to the ergonomic measures of the station, which are based on the percentiles of the Mexican population. Additionally, the neutral postures proposed for these movements contribute to these favorable results. Finally, the lifting within the process, although performed with correct postures, still presents an extremely high risk of 15 points according to the REBA method.

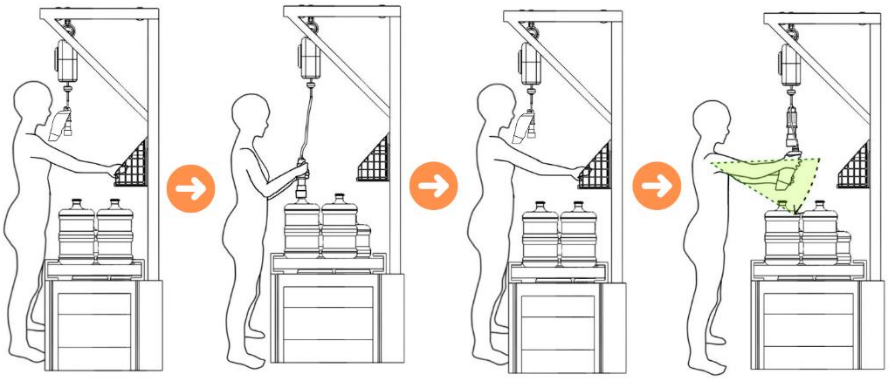


Figure 7. Sagittal View of the Proposed Method

Now then, the postures used for the proposal suggest the following general points for movement: 1) Maintain an upright posture at all times; 2) Raise the upper limbs to their natural extension or flexion; 3) When gripping the bottle's mouth, the wrist and shoulder should be aligned in the same direction; 4) Tools should be used exclusively in a vertical direction; and 5) Never bear the weight of the bottle yourself.

Regarding the characteristics of the postures for sealing the bottles, it is established that: 1) Weight should be evenly distributed between the feet, with legs kept shoulder-width apart; 2) The back must remain straight at all times; 3) If there is a need to bend forward, it should not exceed 20 degrees beyond the body’s centerline; 4) When bending, the shoulders should be relaxed and aligned; 5) The head should remain aligned with the spine; 6) The knees should be slightly bent, not fully extended; and 7) Step to the right after sealing each bottle to change your position and avoid muscle fatigue.

4.2 NIOSH Method for Evaluation of Manual Lifting

The current method for lifting loads resulted in a total risk score of 2.4 points with the current weight of the carboy. However, it is known in advance that the postures used are not appropriate for safely handling manual loads. In contrast, the proposed method yielded a total of 1.44 points, indicating a medium risk. After determining through the bisection method that the ideal weight would be approximately 5.3 kilograms, the decision was made to eliminate manual lifting of carboys.

4.3 Anthropometry in the Workspace

To ensure that postures proposed are adhered to, the workstation must be adapted to the anatomy of the employees. It is therefore considered that the station will be used by two biologically male individuals, young, of Mexican descent, with a work life rooted in physical labor from an early age. The third individual is a biologically female adult, also of Mexican descent, whose work life has not involved physical exertion until the past two years. Based on this information, the percentiles used for the design of the station reflect the following dimensions:

4.3.1 Horizontal Reaches

The current method does not include a station or designated areas specifically for handling tools and/or performing the activities involved in sealing a bottle. This prevents the visualization of vertical reaches within the current method.

In contrast, the proposed method provides vertical reaches for both tools and materials and products. It should be noted that visualizing these reaches in the sagittal plane would not accurately interpret them, as the versatility in the positioning of bottles, tools, and containers could obscure the intended reaches.

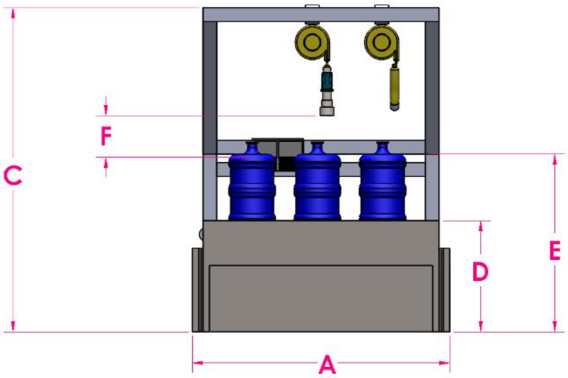


Figure 8. Horizontal Reaches of Ergonomic Design of Workstation

To understand the measurements of the workstation, the anthropometry of the workers must be considered. Since the aim of the improvement is to adapt the work to the worker, including the workstation, its dimensions must be tailored to their needs and limitations. Therefore, for the measurements, Mexican percentiles are considered based on sex, age range, and daily occupation. The following data is obtained:

Table 3. Anthropometry in the Workspace

Part	**A**	**B**	**C**	**D**	**E**	**F**
Description	Length	Width	Station Height	Table Height	Shelf Height	Distance between tool and container
Anthropometric Measurement	Twice the lateral reach (standing)	Front reach (standing)	Maximum reach	Height to the knee (standing)	Shoulder Height (standing)	E-(D + Jug Height)
Percentile	95%	95%	95%	70%	70%	-
Nationality	Mexican	Mexican	Mexican	Mexican	Mexican	-
Occupation	Worker	Worker	Worker	Worker	Worker	-
Sex	Women	Women	Women	Men	Men	-
Age	18 to 65	18 to 65	18 to 65	18 to 65	18 to 65	-
Measurement (cm)	150	74.1	202.6	62.69	168.7	56.01

4.3.2 Vertical Reaches

The current method lacks consistency in the positioning of its tools, materials, and equipment. This makes it difficult to map their locations within the workspace. In contrast, the proposed method yields the following diagram of horizontal reaches.

For this proposed method, it should be noted that the container and the bottles can move along the horizontal axis; that is, they are not fixed within the workstation. Since this is not a precision task, this does not pose a problem. On the contrary, it allows the operator to organize themselves comfortably without feeling pressured by the demand for bottles.

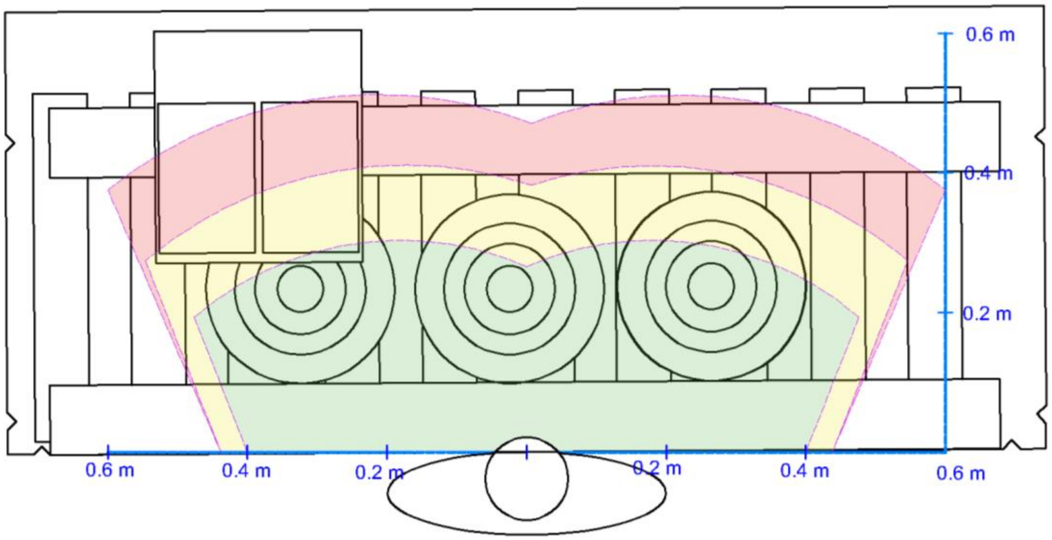


Figure 9. Vertical Reaches to Ergonomic Design of Workstation

4.3.3 Tool, Accessory tool and Container

Heat gun: This tool from the TRUPER brand allows the user to handle it like a pen. Its weight of 0.3 kg enables the hand to have mobility, and its shape ensures the hand maintains a neutral posture.

Figure 10. Heat gun

Tool stabilizer:

This tool accessory provides easy access to the heat gun and the press, enhancing the stability of the grip.

Press: It allows the user to assemble the cap with low force, ensuring the pressure is exerted on the carboy and not on the person’s extremities.

Figure 11. Press

The dimensions of this tool are also based on percentiles, just as with the entire workstation. These anthropometric dimensions are:

Table 4. Anthropometry in the tool

Description	Diameter of handle	Heigh of the handle
Anthropometric Measurement	Diameter of hand	Width of the hand
Percentile	95%	95%
Nationality	Mexican	Mexican
Occupation	Worker	Worker
Sex	Man	Man
Age	18 to 65	18 to 24
Measurement (cm)	5	10.3

Container: The container provides easiest access to the material used to seal the carboy, and it also allows visibility of the contents inside the container.

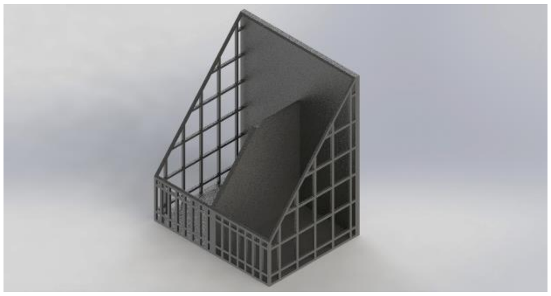


Figure 12. Container

Similarly, the container for the materials has dimensions based on the anthropometry of the workers, resulting in the following data:

Table 5. Anthropometry in the Container

Description	Container Length	Partition Width	Container Width
Anthropometric Measurement	Twice width of hand	Hand Width	Hand Length
Percentile	95%	95%	95%
Nationality	Mexican	Mexican	Mexican
Occupation	Worker	Worker	Worker
Sex	Man	Man	Man
Age	18 to 65	18 to 65	18 to 65
Measurement (cm)	20.6	10.3	18.5

4.4 Standard Times MTM (Methods-Time Measurement)

In terms of observation (i.e., without considering variability), the sealing process accounts for 1.2 minutes of processing time for 10 carboys, which equates to approximately 7.2 seconds per carboy. However, it should be noted that the activities are not standardized, making this time unreliable when analyzing operations. Nevertheless, standardizing the movements provides a closer approximation to the actual work behavior.

Based on this criterion, it was determined that processing a carboy with the current method takes 12.44 seconds, plus an additional 4% tolerance for fatigue, 2% for personal delays, 8% for method variability, and 1% for unexpected delays. This amounts to 1.866 seconds of tolerance, resulting in a total of 14.306 seconds.

The proposed improvement involves a processing time of 3.31 seconds, with 4% tolerance for fatigue, 1% for delays, 2% for method variability, and 2% for unexpected delays. Thus, the standard time for the proposed method amounts to 3.905 seconds per carboy, considering the tolerances.

Therefore, when comparing the standard times, it is evident that the proposed method reduces the processing time per carboy by 72.71%.

4.5 Improvement Proposal

The proposal primarily revolves around the redesign of the workstation, as illustrated in Figure 8. To operate the workstation, the worker is required to: 1) Elevate three carboys, each weighing 20 kilograms, to the workbench level using a lift; this bench is equipped with rollers to facilitate easy manipulation of the load; 2) Place a lid on each carboy and insert it using a press that is balanced and suspended by a retractable pulley system; 3) Apply a film over the carboy's opening, sourced from a material container that can freely move along its horizontal axis; and 4) Seal the carboy using a heat gun for one second; this tool is similarly balanced and suspended. Additionally, both the press and the heat gun are designed to move freely in all their axes, adhering to the workstation's dimensions. Similarly, the operating method includes having 6 units in the workstation: 3 on the elevator and 3 on the table.

It is also advised that the company performs sealing operations whenever there are six units in the workstation—three on the lift and three on the workbench—and rotates tasks per shift. Although indirectly, this practice is understood to reduce production time and the number of units per batch, contributing to a decrease in worker fatigue. Furthermore, the vertical use of the heat gun mitigates the risk of first-degree burns for the user.

Figure 11. Proposal: Sealing Station

5. CONCLUSIONS

The study focused on the sealing stage, where ergonomic deficiencies were identified. The movements and postures observed were inadequate from the outset, causing discomfort and ailments among employees, which suggested occupational risk factors.

These findings were supported by the Marley and Kumar (1996) tables, which indicated that the highest risk levels, in terms of both frequency and intensity of pain, were associated with the wrists and back.

The research employed ergonomic methods and anthropometric studies to formulate the improvement proposal, which included a detailed observation of the work process and the application of researched principles and methods. Key references for this proposal included: the *NIOSH lifting index*, *REBA* movement analysis, percentiles of the Mexican population (segregated by sex, age, and occupation), the *NIOSH Guide on Prevention of Material Handling Injuries in the Grocery Sector* (2014), *OSHA Standard 29 CFR 1910.242 - Hand and Portable Powered Tools and Equipment*, and the books *Ergonomics in Action: A Practical Guide for the Workplace* (2015), *Kodak's Ergonomic Design for People at Work* (2004), and *Cumulative Trauma Disorders: A Manual for Musculoskeletal Diseases of the Upper Limbs* (1944).

The proposal had successfully materialized in the design of the station, which is tailored to meet the workers' needs. This design enables them to perform movements with minimal risk, as it reduces physical load and stress.

Regarding efficiency, if the proposal is applicated, may significantly decrease production time and eliminates the need for harmful lifting activities. It also may reduce fatigue and enhances safety during the process. The ergonomic proposal would not only may improve working conditions but also can help mitigates health risks for employees and boosts their productivity at the sealing station.

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ERGONOMIC ANALYSIS FOR THE CASHIER'S CONTINUOUS IMPROVEMENT OF ALSUPER'S CD. CUAUHTÉMOC

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Resumen El principal objetivo de este proyecto es la evaluación ergonómica del sistema hombre-máquina que se presenta en las cajeras de una cadena de supermercados en Cd. Cuauhtémoc, Chih. La metodología utilizada para el análisis postural de los trabajadores fue ART TOOL, por otra parte se hicieron mediciones de factores ambientales como son el ruido, la luminosidad y la temperatura, además se realizaron encuestas a las trabajadoras enfocadas a su percepción del ambiente laboral, todo los anterior para analizar por una parte como el estar de pie por largos periodos de tiempo afecta tanto la salud del trabajador como su desempeño laboral y otros aspectos psicosociales involucrados.

Como resultados, en una muestra de diez cajeras repartidas de manera equitativa en las tres sucursales y los dos turnos, utilizando ART TOOL para el análisis ergonómico valores mínimos de 22 fueron obtenidos lo que implica que urgentemente se tienen que realizar cambios por el riesgo de lesiones musculoesqueléticas en las trabajadoras, con respecto a las mediciones ambientales, se determinó estas cumplen con la normatividad vigente. Por último en relación con la encuesta aplicada a las trabajadoras se concluye que la parte subjetiva relacionada con la apreciación de las cajeras tiene mucho que ver con su percepción del ambiente laboral.

Palabras clave: Análisis Ergonómico, ART TOOL. Mejoramiento Continuo, Lesiones Laborales

Relevancia para la ergonomía: Esta investigación ayuda a evaluar las condiciones ergonómicas y ambientales de un Sistema hombre-máquina, ayuda a ver las condiciones y mejoras que pueden ser aplicadas al puesto de trabajo de cajeras de supermercado, y constatar los hallazgos de estudios anteriores.

Abstract: The main objective of this project is the ergonomic evaluation of the man-machine system presented in the supermarket chain cashiers in Cd. Cuauhtémoc, Chih. The methodology used for the postural analysis of the workers was ART TOOL, on the other hand, measurements were made of environmental factors such as noise, luminosity, and temperature, in addition, surveys were carried out on the workers focused on their perception of the work environment, all of the above to analyze how standing for long periods affects both the worker's health and his work performance and others psychosocial aspects involved.

As a result, in a sample of ten cashiers distributed equally in the three branches and the two shifts, using ART TOOL for ergonomic analysis, minimum values of twenty-two were obtained, which implies that changes have to be urgently made due to the risk of musculoskeletal injuries in the workers, for environmental measurements, it was determined that these comply with current Mexican regulations. Finally, concerning the survey applied to the subjects, it is concluded that the subjective part related to the appreciation of the cashiers has a lot to do with their perception of the work environment.

Keywords. Ergonomics analysis, ART TOOL, Continuous Improvements, Work Injuries

Relevance to Ergonomics: This research helps to evaluate the ergonomic and environmental conditions of a human-machine system, helps to see the conditions and improvements that can be applied to the supermarket cashier's workplace and to verify the findings of previous studies.

1. INTRODUCTION

The main objective of this project is the ergonomic evaluation of the man-machine system presented in supermarket chain cashiers in Cuauhtémoc, Chih, using the ART TOOL methodology, to analyze how standing for long periods in front of a monitor or cash register affects both the employee's health and performance in their work.

The cashier's job in the Cuauhtémoc city Alsuper is one of the occupations in these workplaces that can cause the greatest risk when suffering from a musculoskeletal disorder. An adequate workstation ergonomic design, in conjunction with a good work organization, adequate environmental conditions, and the correct evaluation of the physical and mental load that cashiers must bear, are essential aspects that must be considered when implementing the necessary preventive measures to preserve the health and well-being of these workers. Among the factors related to the physical load in these positions, the high repetitiveness of movements and the pace of work that must sometimes be endured, the static posture, and the handling of loads that, although individually are not usually very large, can cumulatively become a problem if the manipulation is not carried out correctly. There is not adequate muscle recovery during the working day. It is not surprising, therefore, that workers who occupy this job often report suffering from muscle and joint discomfort and disorders (hands, wrists, arms, shoulders, and neck) and other types of disorders such as headaches, sleep disorders, or visual fatigue.

Ergonomics is the discipline that ensures that the workspace, tools, and work tasks match the employee's physiological, anatomical, and psychological characteristics to safeguard their well-being and mental and physical health (Kawarsky & Zhang, 2021). Relevant Ergonomic factors related to this job are:

- Body Posture: Prolonged posture in a static position can cause muscle fatigue and back problems. It's crucial to design workstations that allow cashiers to adjust their posture and alternate between standing and sitting.
- Repetitive Movements: Performing rapid movements repeatedly is a common action at checkout counters, even more so with the widespread use of scanners at checkouts. The problems that this risk factor can cause are aggravated if the work organization prevents or limits the job rotation or the establishment of adequate breaks for the muscle group recovery involved in the action, which can lead to disorders in the shoulders, arms, wrists, and hands directly related to this type of movement
- Reach and Access: Items should be located to be easily accessible to cashiers, without the need to reach too far or bend over repeatedly.
- Workspace: The workspace should be sufficient to allow comfortable movements and minimize collisions with other workers or customers (CENEA, 2024)

Continuous Improvement Strategies:

- Implementation of changes in the workstations design.
- Training of staff in ergonomic practices and proper use of equipment.
- Working conditions regular monitoring and employee feedback.
- Collaboration with ergonomics and occupational health experts to identify and address specific issues (CENEA, 2024).

There are several studies where ergonomic analysis of cashiers' work in supermarkets is carried out, identifying ergonomic risks and proposing measures to prevent and minimize these risks, however, in the organizations evaluated nobody knows about these studies. A compendium of these studies can be found in Algarni & Alkhaldi, 2021, their article is a literature review to describe previous studies and their findings among cashiers to discover the prevalence of Musculoskeletal diseases among them.

Following other studies and their findings will be mentioned, Silva, et al, 2024, used RULA to conclude high ergonomic risk in the product scanning task and REBA methodology to obtain high ergonomic risk in the replacement of paper rolls for the receipt machine at the checkout counter and based on these findings, they recommend the redesign of the workstations to alleviate the physical demands on cashiers. Roxo, et al, 2021 obtained a score of 6 using RULA based on a high prevalence of musculoskeletal pain in the neck, shoulders, wrist/hands, and lower and upper back in cashiers involved in the study. Fariza & Oktalia, 2021 using RULA and a Quick Exposure Checklist (QEC) using ErgoFellow software found that the operator's risk level worked in the medium risk classification with a final score of 5 and the exposure score of 60.49%, so concluded that Work posture recommendations for operators can be supported by redesigning tools on chairs and tables so that they are more comfortable to use and doing stretching every certain unit of time. Ceballos (2021) established critical variables to control using the RULA method and after redesigning the workplace to improve cashier's posture.

In this project, the results obtained using the Art Tool method show a high ergonomic risk, on the other hand, environmental measurements that were carried out comply with corresponding Mexican regulations, the general analysis, and based on the results of the respondents, the area could be improved by implementing rotating benches, these would reduce muscle pain in feet, poor circulation and torticollis.

2. OBJETIVE AND DELIMITATION

2.1 General Objective.

To perform a general ergonomic analysis of the human-machine system related to the activities of supermarket cashiers, to identify and evaluate possible musculoskeletal injuries related to working conditions, especially those related to standing for long periods.

2.2 Delimitation

Three of four Alsuper in Ciudad Cuauhtémoc were covered, thus being 75% of the total, there was a delimitation of information since the four Alsuper were not investigated, so there was less information since there was no access to the organization.

3. METHODOLOGY

1st. Carry out a detailed ergonomic analysis of the workplace using the Art Tool method, which is based on analyzing the postures of the staff, in this case, cashiers, when performing the task in their work area, where the characteristics of the workers, the workstation and the levels of ergonomic risk must be identified.

2nd. The environmental conditions of the workplace were evaluated and compared with the corresponding regulations.

3rd. A worker survey was carried out to assess the psychosocial aspects of the workplace and complement the ergonomic analysis.

4th. The corresponding proposals were made based on ergonomic principles and corresponding regulations.

4. RESULTS

The study was carried out on a total of ten cashiers (3 cashiers from Alsuper Allende, 3 cashiers from Alsuper Tres Culturas, and 4 cashiers from Alsuper Cinépolis), analyzing that the data coincided in each Alsuper. Figure 1 shows an example of the man-machine systems analyzed.

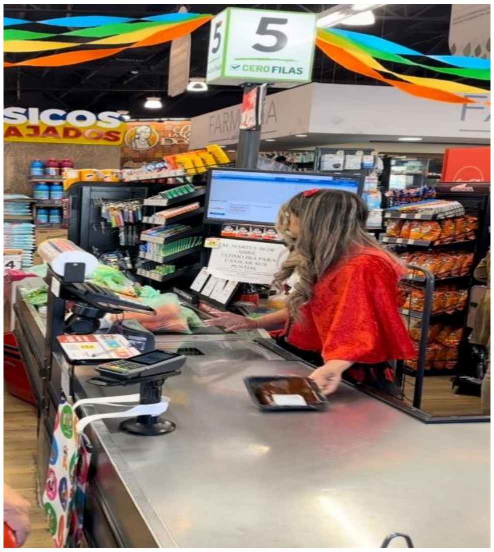
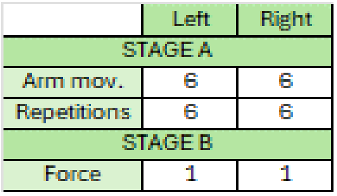


Figure 1. Man-machine system analyzed

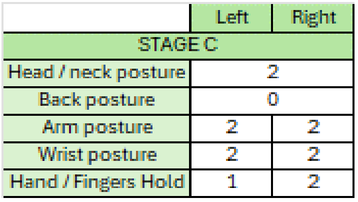
4.1 Ergonomic Analysis

The following tables show the data obtained using the Art Tool methodology, the first one is from the analysis of the Alsuper Allende cashiers, and based on the table of ranges of the method and the results of 31 and 32 it is concluded that it needs urgent research, as in the second table of the Alsuper three cultures cashiers with data 27 and 28, as well as in the third table of the Alsuper Cinépolis cashiers with results 22 and 23 since based on rank everyone is at the highest level, which tells us that postures are risky for cashiers.

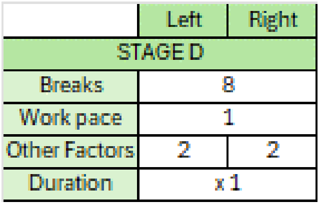
Table 1. Art tool results. ALSUPER ALLENDE



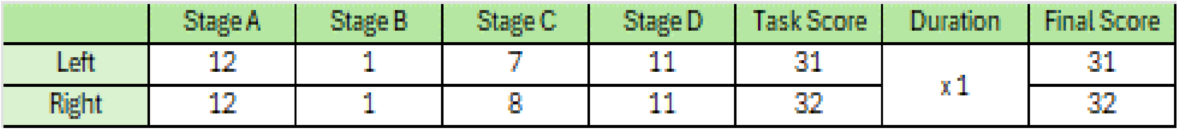
	Left	Right
STAGE A		
Arm mov.	6	6
Repetitions	6	6
STAGE B		
Force	1	1



	Left	Right
STAGE C		
Head / neck posture	2	
Back posture	0	
Arm posture	2	2
Wrist posture	2	2
Hand / Fingers Hold	1	2

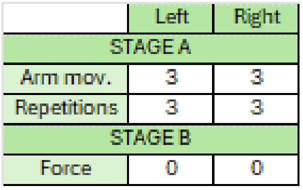


	Left	Right
STAGE D		
Breaks	8	
Work pace	1	
Other Factors	2	2
Duration	x 1	

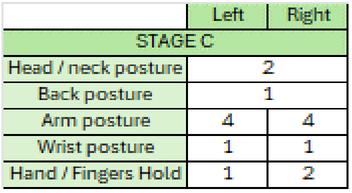


	Stage A	Stage B	Stage C	Stage D	Task Score	Duration	Final Score
Left	12	1	7	11	31	x 1	31
Right	12	1	8	11	32		32

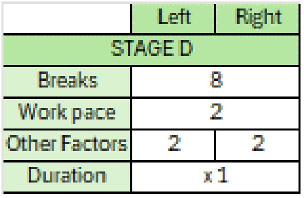
ALSUPER TRES CULTURALES



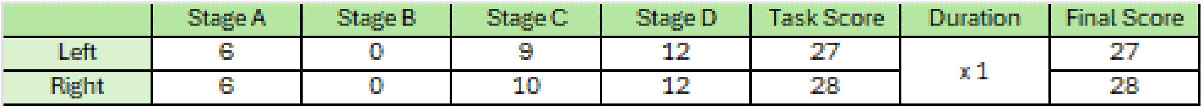
	Left	Right
STAGE A		
Arm mov.	3	3
Repetitions	3	3
STAGE B		
Force	0	0



	Left	Right
STAGE C		
Head / neck posture	2	
Back posture	1	
Arm posture	4	4
Wrist posture	1	1
Hand / Fingers Hold	1	2

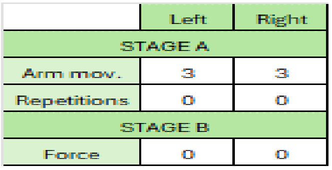


	Left	Right
STAGE D		
Breaks	8	
Work pace	2	
Other Factors	2	2
Duration	x 1	

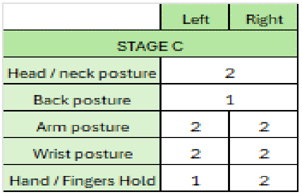


	Stage A	Stage B	Stage C	Stage D	Task Score	Duration	Final Score
Left	6	0	9	12	27	x 1	27
Right	6	0	10	12	28		28

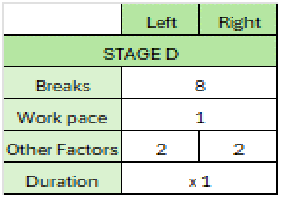
ALSUPER CINEPOLIS



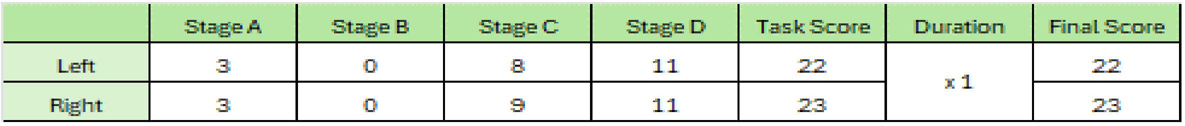
	Left	Right
STAGE A		
Arm mov.	3	3
Repetitions	0	0
STAGE B		
Force	0	0



	Left	Right
STAGE C		
Head / neck posture	2	
Back posture	1	
Arm posture	2	2
Wrist posture	2	2
Hand / Fingers Hold	1	2



	Left	Right
STAGE D		
Breaks	8	
Work pace	1	
Other Factors	2	2
Duration	x 1	



	Stage A	Stage B	Stage C	Stage D	Task Score	Duration	Final Score
Left	3	0	8	11	22	x 1	22
Right	3	0	9	11	23		23

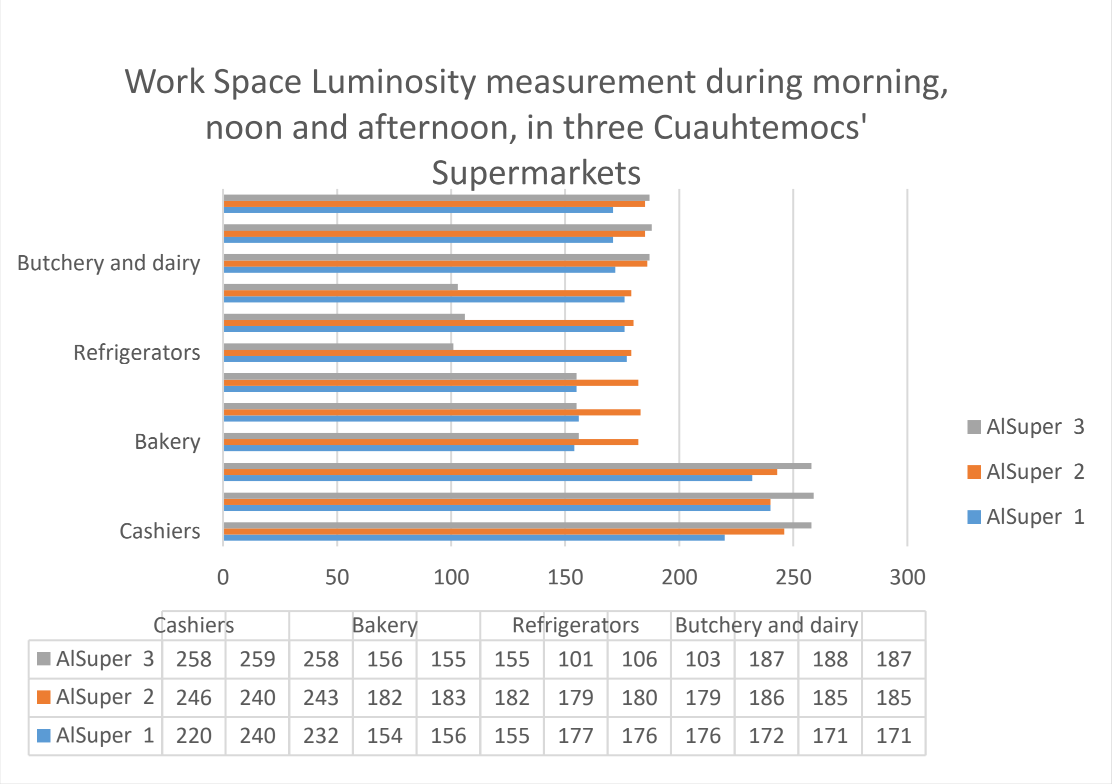
On the other hand, in the surveys related to the cashier's task, it was shown that the average weight carried in the Alsuper is 2 to 5 kilos and that both sides of the body are affected when carrying this weight.

In addition, tools such as the product code folder, scanner, and keypad are used to mark the products during the task.

On average the break is half an hour, but the schedules are very varied, it depends on each Alsuper but the workday does have a fixed duration of 7 hours.

4.2 Environmental Measurements

The following figures show the environmental measurements of the Alsuper's, which were carried out at different times of the day; concerning workspace luminosity (Figure 2) and based on the NOM -025 STPS-2008 (STPS, 2008) the measurement complies with the simple visual requirements that include visual inspection and pieces counting tasks that done by the cashiers. Other spaces in the organization comply with the interior requirements.



	Cashiers		Bakery			Refrigerators			Butchery and dairy			
AlSuper 3	258	259	258	156	155	155	101	106	103	187	188	187
AlSuper 2	246	240	243	182	183	182	179	180	179	186	185	185
AlSuper 1	220	240	232	154	156	155	177	176	176	172	171	171

Figure 2. Workspaces luminosity measurements

The Standard NOM-011-STPS-2001 (STPS, 2001), indicates that the noise in the workplace should not be more than 90 dB for more than 8 hours as can be seen in Figure 3 the maximum range is not reached at any time of day.

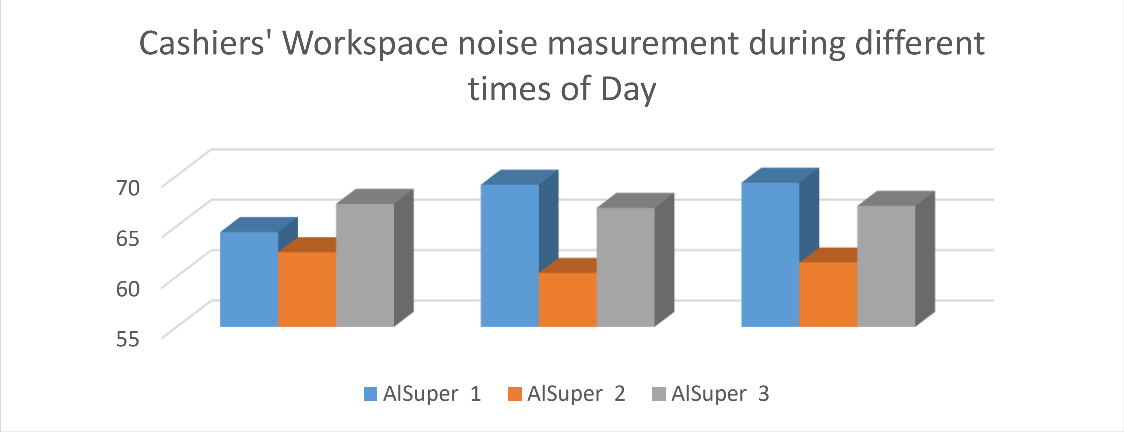


Figure 3. Noise measurements.

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4.3 Survey Results

A survey of 25 cashiers in different shifts and days was conducted, to analyze psychosocial risk factors. The working shifts are divided into 60% in the morning shift, which is the one in which there is more work, and 40% in the evening, thus completing a 7-hour workday.

The first question was related to How much time cashiers spend standing during the workday, results show that 48% spend 5 to 6 hours standing, 24% 6 to 7 hours, and 28% 8 hours or more (Figure 4), the latest is because overtime, or when there are too many clients or other cashiers do not come to work.

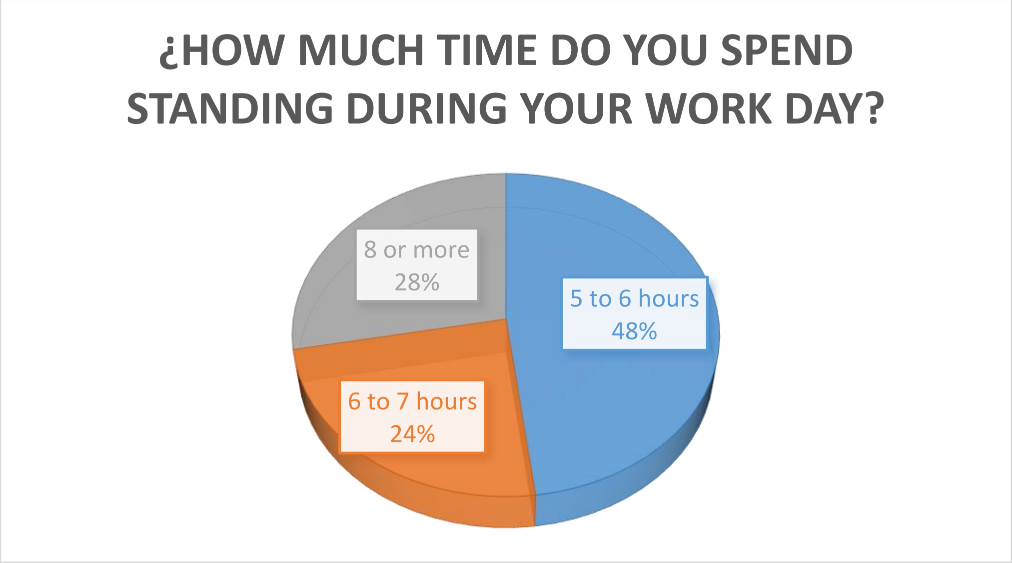

Figure 4. Results to question How much time do you spend standing during your workday?

Concerning Movements that cause pain during the working day the results were classified as standing 54% being the highest percentage, head turning 22%, arm movement 16% and wrist movement 8% (Figure 5) .

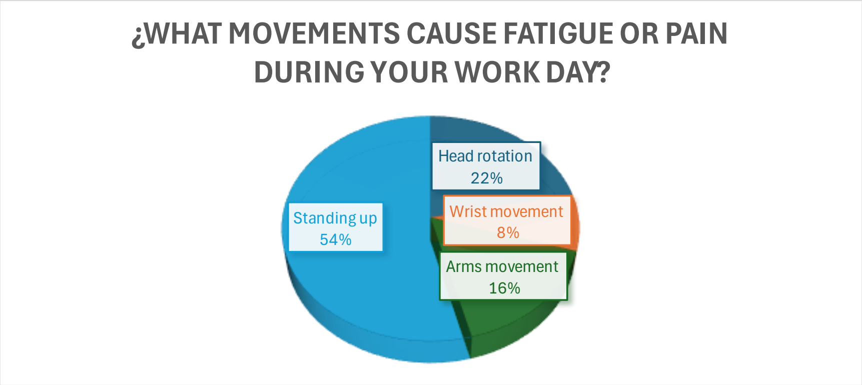

Figure 5. Results to question ¿What movements cause fatigue or pain during your workday?

All workers have a break during their working day, working 6:30 hours with a 30-minute break. In a 7-hour workday, 76% of respondents rest for 30 minutes, and 8% for 15 minutes, these breaks are considered because shifts are not continuous. Because all people think differently and have different personalities, it varies whether they are comfortable in a work environment, 44% are comfortable, 40% think it could be better, and 16% do not like the work environment, this could be due to disagreements between colleagues (Figure 6).

Figure 6. Results to question ¿Are you comfortable with the work environment?

Work dimensions are comfortable because being larger could be better or more suited to the worker, 52% of the cashiers consider workplace dimensions are fine, 44% say it could be better, and 4% do not consider them comfortable (Figure 7).

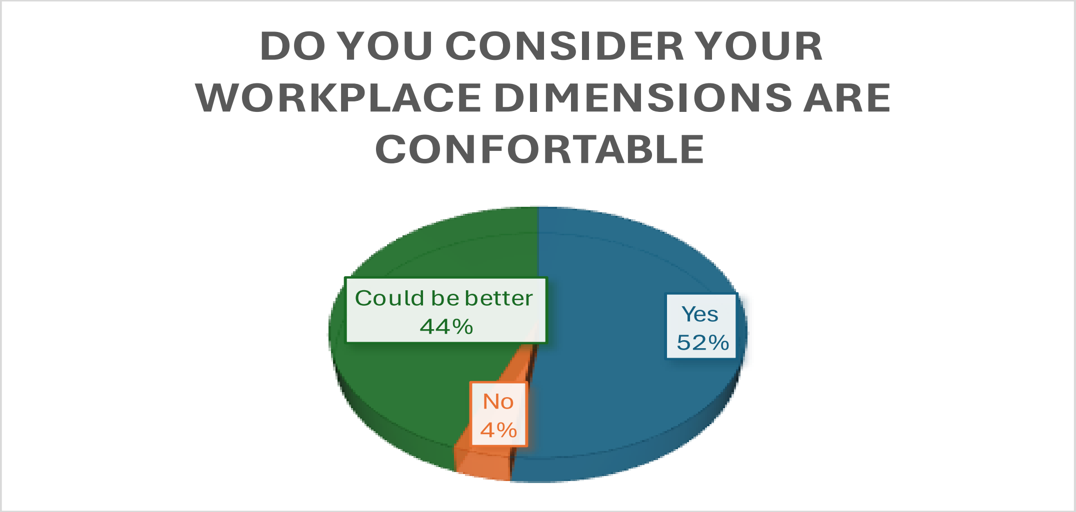

Figure 7. Results to question ¿Do you consider your workplace dimensions are comfortable?

Twenty cashiers consider that a rotating bench would be a nice addition to their workplace, even so, they do not know about ergonomics, this seems to be a solution to most of the ergonomics risks found during the analysis. Other recommendations were ergonomic mats and two screens one for them and another for the clients (Figure 8).

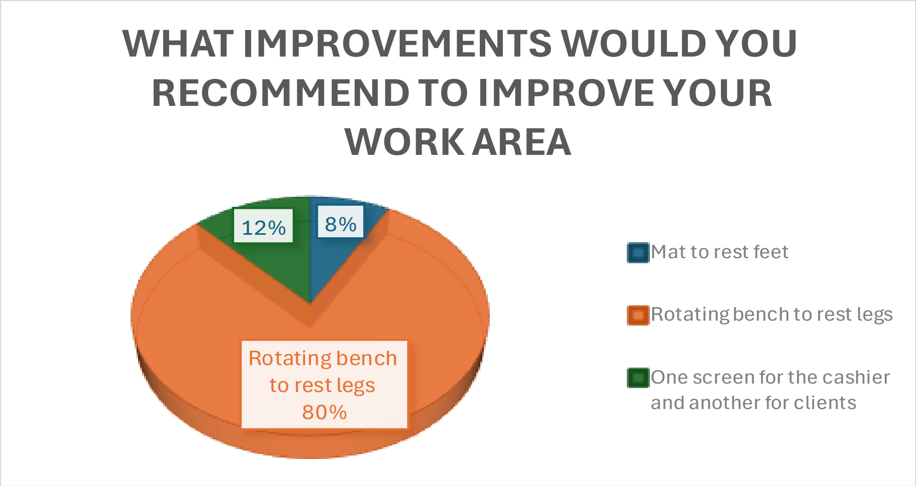

Figure 8. Results to question ¿What improvements would you recommend to improve your work area?

5. CONCLUSION

The research resulted in a high level of risk in the human-machine system because it does not have the ergonomic comforts adapted to the system, the surveys carried out showed that the system can have improvements, such as implementing rotating benches to reduce fatigue in the feet and avoid health problems, as well as installing screens for customers and operators, which will decrease the pain in the operator's neck. Environmental factors such as luminosity and noise comply with current Mexican laws. It is important to mention that the findings are congruent with previous research on the same type of workstations and workers.

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WERA ASSESSMENT IN INDUSTRY

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Resumen Es importante siempre estar evaluando las actividades y los puestos de trabajo de cualquier tipo de industria con la finalidad de detectar que cosa puede originar una enfermedad de trastorno musculoesquelético (TME). La importancia de realizar evaluaciones ergonómicas radica en mejorar tanto la eficiencia laboral como la salud y seguridad de los trabajadores. Al implementar evaluaciones ergonómicas, las empresas pueden identificar áreas problemáticas en sus procesos de producción que podrían estar causando fatiga, estrés o lesiones a los trabajadores. El presente estudio fue un diseño no experimental, ya que solo se observó en tiempo real la manera en cómo los trabajadores realizaban sus actividades y transversal ya que se observó el proceso en un único momento del tiempo, tal cual sucedieron las cosas. El alcance del trabajo fue descriptivo ya que se buscaron los valores del nivel de riesgo; alto, moderado o bajo de cada parte del cuerpo analizada. El presente estudio fue diseñado bajo el planteamiento metodológico del enfoque cuantitativo, ya que se centró en mediciones objetivas y análisis estadístico de las diversas posiciones del cuerpo, la cantidad de repeticiones, la duración del trabajo en horas y la fuerza al levantar cargas. Los datos numéricos recopilados de las diversas posiciones del cuerpo, la cantidad de repeticiones, la duración del trabajo y la fuerza al levantar cargas, fueron recopilados utilizando la evaluación ergonómica Workplace Ergonomic Risk Assessment (WERA). Se evaluaron a un total de 30 personas de 3 diferentes actividades; armado de abanico, ensamble de motor y empaque de una empresa industrial de la zona metropolitana de Monterrey, Nuevo León, siendo el hombro con la cantidad mayor de puntos de nivel de riesgo y obteniendo un nivel de riesgo moderado. Se propone utilizar polipasto automático, así como realizar pautas de descanso programadas

Palabras clave: Evaluación Ergonómica WERA, Trastornos Musculo esqueléticos, Procesos industriales.

Relevancia para la ergonomía: Este trabajo de investigación es relevante para la detección de enfermedades TME que pueden ocurrir al estar realizando actividades en los procesos industriales y así mismo es relevante porque permite conocer y utilizar una herramienta ergonómica.

Abstract: It is always important to evaluate the activities and jobs of any kind of industry in order to detect the cause of musculoskeletal Disorder Disease (MSD). The importance of made ergonomic evaluations is because the improving work efficiency and safety health in the workers. By implementing ergonomic assessments, companies can identify problem areas in their production processes that could be causing worker fatigue, stress, or injury. The present study was a non-experimental design, since only the way in which workers made their activities were observed in real time, and transversal since the process was observed at a single moment in time, just as things happened. The scope of the work was descriptive since the risk level values were sought; high, moderate or low of each body part analyzed. The present study was designed under the methodological approach of the quantitative approach, since it focused on objective measurements and statistical analysis of the various body positions, the number of repetitions, the works duration in hours and the strength when lifting loads. Numerical data collected from various body positions, number of repetitions, work duration and strength when lifting loads were collected using the Workplace Ergonomic Risk Assessment (WERA). A total of 30 people from 3 different activities were evaluated; fan assembly, motor assembly and packaging of an industrial company in the metropolitan area of Monterrey, Nuevo León, being the shoulder with the highest number of risk level points and obtaining a moderate risk level. It is proposed to use an automatic hoist, as well as to carry out programmed rest patterns.

Keywords. Ergonomic Assessment WERA, Musculoskeletal Disorders Disease, industrial process.

Relevance to Ergonomics: This research work is relevant for the TME detection diseases that can occur when someone is working or making their activities in the industrial processes and is also relevant because it allows us to know and use a ergonomic assessment tool.

1. INTRODUCTION

It is always important to be evaluating the activities and jobs of any type of industry in order to detect what may cause a musculoskeletal disorder (MSD). The importance of makes ergonomic assessments is because, it improving both work efficiency and the safety health workers. By implementing ergonomic assessments, companies can identify problematic areas in their production processes that could be causing fatigue, stress or injuries workers.

According to Sugiono, Efranto and Budiprasetya (2018) the MSDs are a major complaint from workers within industries. They comment that MSDs can be fatal if the cause is not thoroughly investigated and generally their effects do not appear immediately. They also comment that MSDs can be generated by several causes such as prolonged work time, overwork, inadequate and highly repetitive postures, among others.

On the other hand, Ozgur, Bulduk, Suren, and Ovali (2014) state that MSDs are one of the major public health problems that often result in work restrictions, work time losses, and consequently, low retirement age. They mention that work-related risk factors include physical demands with prolonged periods of sitting, body alignments, repetitive movements, vibrations, and noise.

Chavez, Zaldumbide, Aguirre and Nieto (2016) clarify that musculoskeletal injuries have a great economic impact, which highlights the socio-economic relevance of this problem and justifies the need to develop ergonomic evaluation methods that allow its prevention.

Madriz and Schulze (2010) mention that MSDs are increasing in the workplace because, an evaluation lack, there is also a prevention policies lack, responsibilities assignments, administrative organization of prevention (safety commissions), procedures lack, and audit systems lacks.

Health and safety issues in the workplace have become essential, nowadays they are a priority and these issues should not be abandoned by small companies, on contrary, ergonomic evaluation should be considered to design an industrial workstation in such a way that MSDs can be reduced (Mufti, Ikhsan and Putri, 2019). Likewise, they comment that repetitive work in particular can cause damage to the tendons, so it is important to do an ergonomic evaluation of the workplace to ensure that the work system is adequately designed to improve the safety and health of workers.

Li and Buckle comment that the identification of work-related MSD risks is of particular interest and there is therefore a strong interest in carrying out practical ergonomic assessments. They mention that it is important to develop a practical MSD risk exposure assessment tool.

Sugiono, Efranto, and Budiprasetya (2018) mention that the Workplace Ergonomic Risk Assessment (WERA) method is an ergonomic assessment method that can be used to identify the types of occupations with the highest risk of developing an MSD. They clarify that WERA provides a rapid method of screening work tasks to expose physical risk factors associated with work-related musculoskeletal problems. The WERA assessment consists of six physical risk factors including posture, repetition, force/force effort, vibration, contact stress, and task duration, as well as involves five main body parts: shoulders, wrists, back, neck, and legs.

Mufti, Ikhsan, and Putri (2019) say that WERA provides a good indication towards work-related MSDs and that experts and management agree that the WERA tool prototype is easy and quick to use.

Mohd, James, Aziz, and Abdul (2016) concluded in their research work that the WERA ergonomic assessment has excellent intra- and inter-rater reliability as an observation tool to identify work-related MSDs.

Smith and Johnson (2019) commented that they explored specific strategies to improve employee health and productivity through ergonomic practices in the work environment. They highlight the importance of designing workstations that minimize musculoskeletal injuries and promote overall well-being. And they discuss practical recommendations, such as adjusting desk heights, using ergonomic chairs, and encouraging movement throughout the workday to reduce sedentary behavior.

Lee and Davis (2020) examined how ergonomic interventions can impact the office worker's health. Their study showed that making ergonomic adjustments to furniture and workspace design can reduce back pain and other musculoskeletal problems, thereby improving quality of work life.

On the other hand, Brown and Wilson (2021) comment that they reviewed ergonomic practices in healthcare settings. They highlight the importance of ergonomic design in hospitals and clinics to ensure the comfort and safety of healthcare professionals and patients. They offered detailed guidelines on how to optimize the spaces design to reduce fatigue and the injury risks among medical staff.

Chen & Yang (2017) examined how ergonomics can contribute to improving safety performance in manufacturing industries. They highlight in their research the importance of designing ergonomic workstations to minimize workplace accidents and improve operational efficiency. They also discussed specific strategies for implementing effective ergonomic practices in industrial settings.

2. OBJETIVES

- Evaluate work stations using an ergonomic tool.
- Determine the risk level for the MSD development.

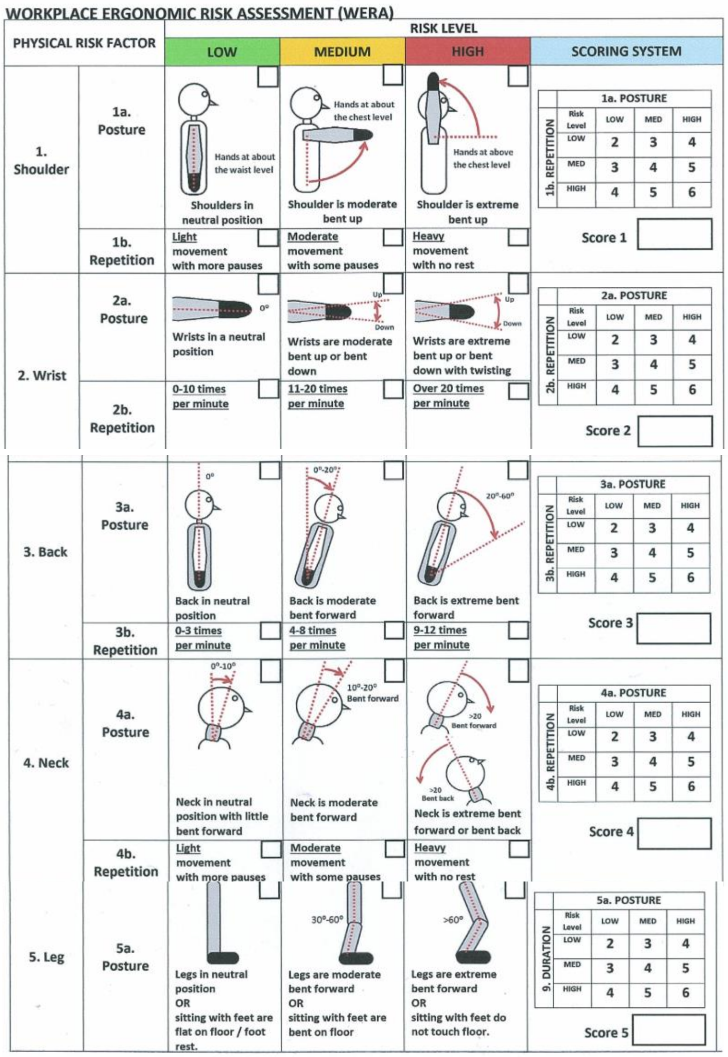
3. METHODOLOGY

The present study was a non-experimental design, since only the way in which workers made their activities was observed in real time and transversal since the process was observed at a single moment in time, as things happened. The scope of the work was descriptive since the risk level values were sought; high, moderate or low for each part of the body analyzed. The present study was designed under the methodological approach of the quantitative style, since it focused on objective measurements and statistical analysis of the various positions of the body, the number of repetitions, the duration of the work in hours and the strength when lifting loads.

3.1 WERE Ergonomic Tool.

The tool used for the activities evaluation was Workplace Ergonomic Risk Assessment (WERA) which is made up of 2 parts. Part A consists of five main areas of the body, including the shoulders, wrists, back, neck and legs. This section analyses two physical risk factors; posture and repetition, as can be seen in Figure 1.

An intersection is made between repetition and posture ranging from 2 points to 6 points for each part of the body, and then each number of points is added, as can be seen in Figure 2. With 3 levels of low, medium and high risk. And part B consists of four physical risk factors that include force, vibration, contact stress and task duration. With 3 levels of low, medium and high risk. This part was not considered in the present study.



WORKPLACE ERGONOMIC RISK ASSESSMENT (WERA)

PHYSICAL RISK FACTOR		RISK LEVEL			SCORING SYSTEM
		LOW	MEDIUM	HIGH	
1. Shoulder	1a. Posture	☐ Hands at about the waist level Shoulders in neutral position	☐ Hands at about the chest level Shoulder is moderate bent up	☐ Hands at above the chest level Shoulder is extreme bent up	1a. POSTURE / 1b. REPETITION
	1b. Repetition	Light movement with more pauses ☐	Moderate movement with some pauses ☐	Heavy movement with no rest ☐	Score 1 ☐
2. Wrist	2a. Posture	☐ 0° Wrists in a neutral position	☐ Up Down Wrists are moderate bent up or bent down	☐ Up Down Wrists are extreme bent up or bent down with twisting	2a. POSTURE / 2b. REPETITION
	2b. Repetition	0-10 times per minute ☐	11-20 times per minute ☐	Over 20 times per minute ☐	Score 2 ☐
3. Back	3a. Posture	☐ 0° Back in neutral position	☐ 0°-20° Back is moderate bent forward	☐ 20°-60° Back is extreme bent forward	3a. POSTURE / 3b. REPETITION
	3b. Repetition	0-3 times per minute ☐	4-8 times per minute ☐	9-12 times per minute ☐	Score 3 ☐
4. Neck	4a. Posture	☐ 0°-10° Neck in neutral position with little bent forward	☐ 10°-20° Bent forward Neck is moderate bent forward	☐ >20 Bent forward >20 Bent back Neck is extreme bent forward or bent back	4a. POSTURE / 4b. REPETITION
	4b. Repetition	Light movement with more pauses ☐	Moderate movement with some pauses ☐	Heavy movement with no rest ☐	Score 4 ☐
5. Leg	5a. Posture	☐ Legs in neutral position OR sitting with feet are flat on floor / foot rest.	☐ 30°-60° Legs are moderate bent forward OR sitting with feet are bent on floor	☐ >60° Legs are extreme bent forward OR sitting with feet do not touch floor.	5a. POSTURE / 9. DURATION Score 5 ☐

		1a. POSTURE		
	Risk Level	LOW	MED	HIGH
1b. REPETITION	LOW	2	3	4
	MED	3	4	5
	HIGH	4	5	6

Score 1 ☐

		2a. POSTURE		
	Risk Level	LOW	MED	HIGH
2b. REPETITION	LOW	2	3	4
	MED	3	4	5
	HIGH	4	5	6

Score 2 ☐

		3a. POSTURE		
	Risk Level	LOW	MED	HIGH
3b. REPETITION	LOW	2	3	4
	MED	3	4	5
	HIGH	4	5	6

Score 3 ☐

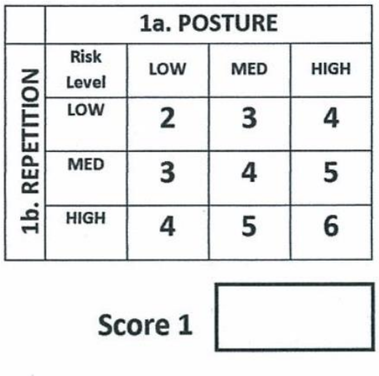
		4a. POSTURE		
	Risk Level	LOW	MED	HIGH
4b. REPETITION	LOW	2	3	4
	MED	3	4	5
	HIGH	4	5	6

Score 4 ☐

		5a. POSTURE		
	Risk Level	LOW	MED	HIGH
9. DURATION	LOW	2	3	4
	MED	3	4	5
	HIGH	4	5	6

Score 5 ☐

Figure 1. WERA Assessment.



		1a. POSTURE		
	Risk Level	LOW	MED	HIGH
1b. REPETITION	LOW	2	3	4
	MED	3	4	5
	HIGH	4	5	6

Score 1 ☐

Figure 2. Posture & Repetition Score

3.2 Evaluation Procedure.

First, the activities were observed within an industrial company in the metropolitan area of Monterrey City. Later, 3 activities were selected to be analyzed under repetition and posture criteria, highlighting the activities; fan assembly, motor assembly and packaging. See Figure 3. Then, a total of 30 people were evaluated using WERA. The evaluations were applied by ninth-semester industrial engineering students. They were previously trained in the use and application of WERA evaluation. Each body part was scored under the repetition and posture criteria. Then, the total number of each body part was added up to determine the risk level of each body part, classifying it as high, medium or low according to Figure 4.

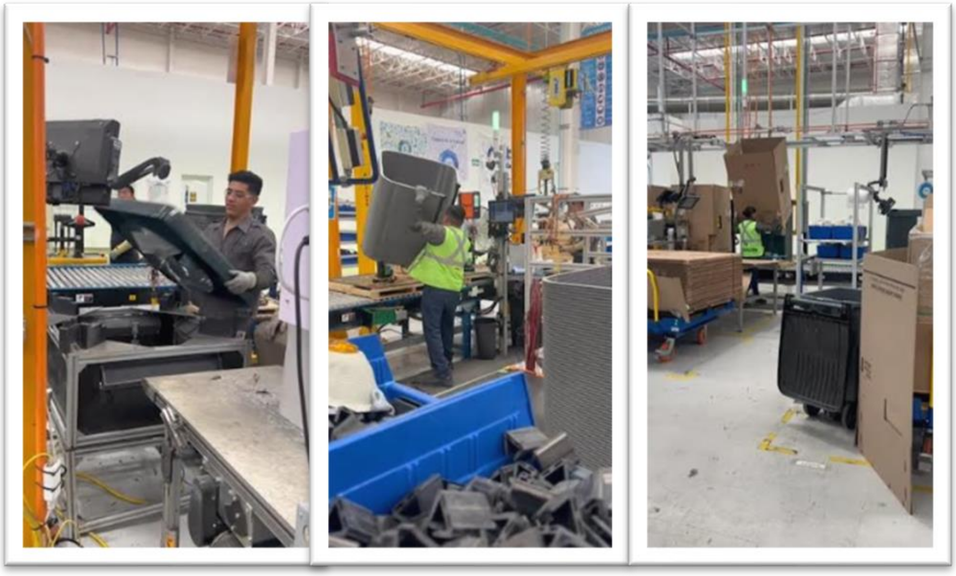
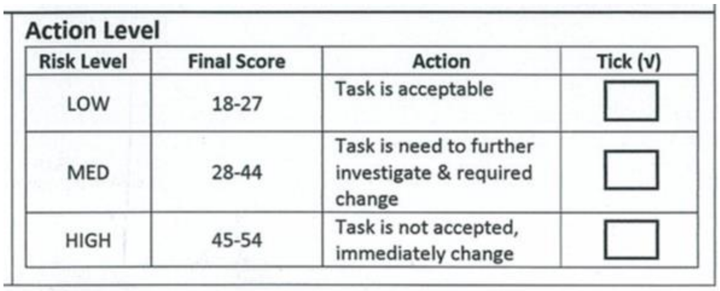


Figure 3. Activities: fan assembly, motor assembly and packaging.



Action Level

Risk Level	Final Score	Action	Tick (√)
LOW	18-27	Task is acceptable	☐
MED	28-44	Task is need to further investigate & required change	☐
HIGH	45-54	Task is not accepted, immediately change	☐

Figure 4. Activities: fan assembly, motor assembly and packaging.

4. RESULTS

The results applying WERA evaluation, it can be observed in Figure 5 that the body part that had the highest scores in relation to posture and repetition was the shoulder, a total of 570 points recorded, 140 points were in the shoulder area, which represented 25%. The back and feet are the second body part that had high scores, which represented 21%. The neck is in fourth position, it obtained results that represented 17%, and lastly the wrists with 16% of the total of 570 points recorded for all body parts.

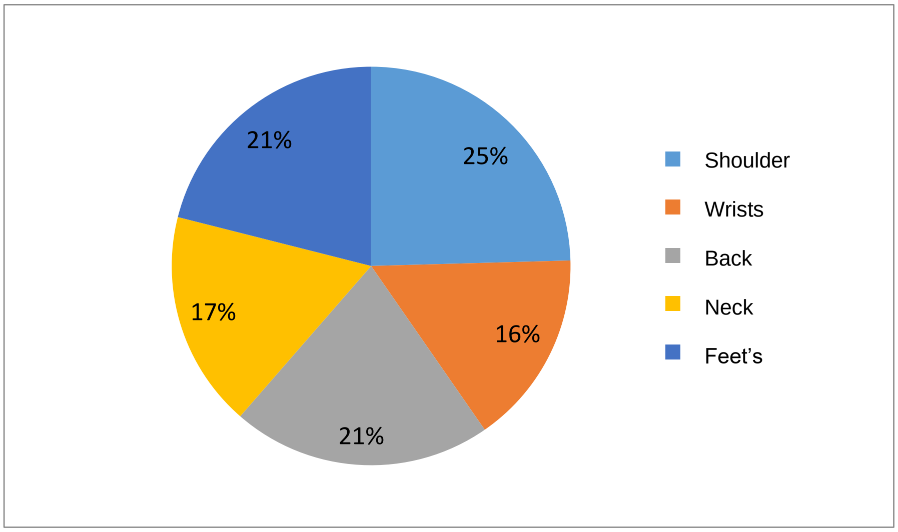


Figure 5. Body parts with the highest number of risk points (percentage)

In Figure 6 it can be observed that of the 30 people analyzed by WERA evaluation, there were 3 cases with a high risk level, which means that they had a result greater than or equal to 45 points, 24 cases with a moderate risk level, which is equivalent to having results between 28 and 44 points and only 3 cases with a low risk level, which means that they had results with less than 27 points.

The 3 activities analyzed and evaluated using WERA ergonomic tool, the fan assembly activity was the only activity that had a high risk level with 3 cases; the motor assembly and packaging activity did not have any cases with a high risk level, as can be seen in Figure 7.

In relation to the moderate risk level, the fan assembly activity presented 7 cases, motor assembly 10 cases and the packaging activity recorded 7 cases, as can be seen in Figure 8.

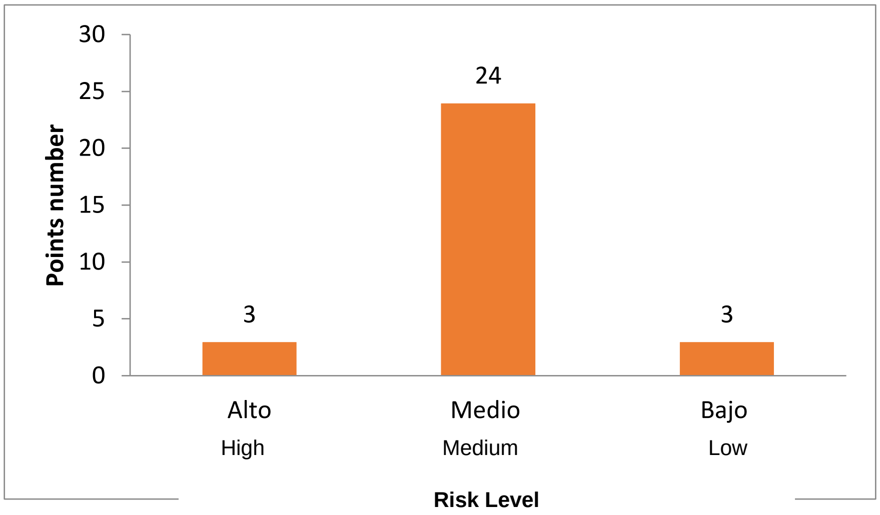


Figure 6. Ergonomic Risk Level.

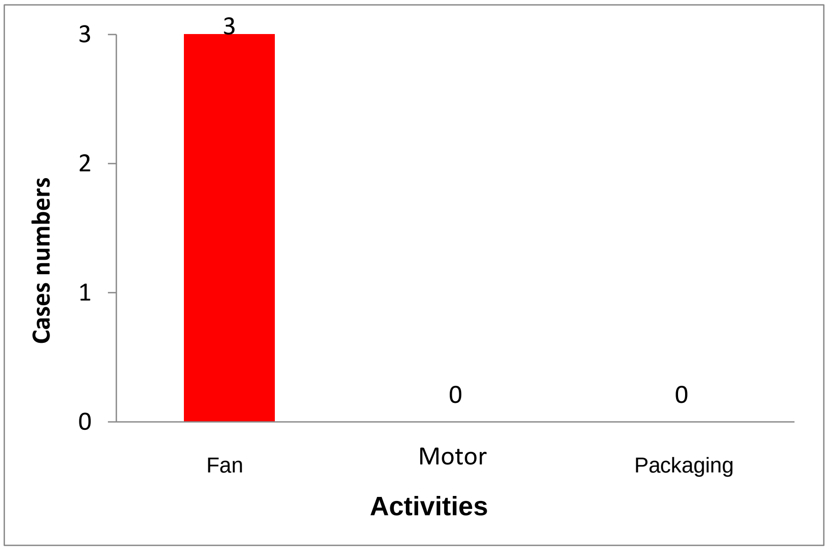


Figure 7. Ergonomic High Risk Level by Activity

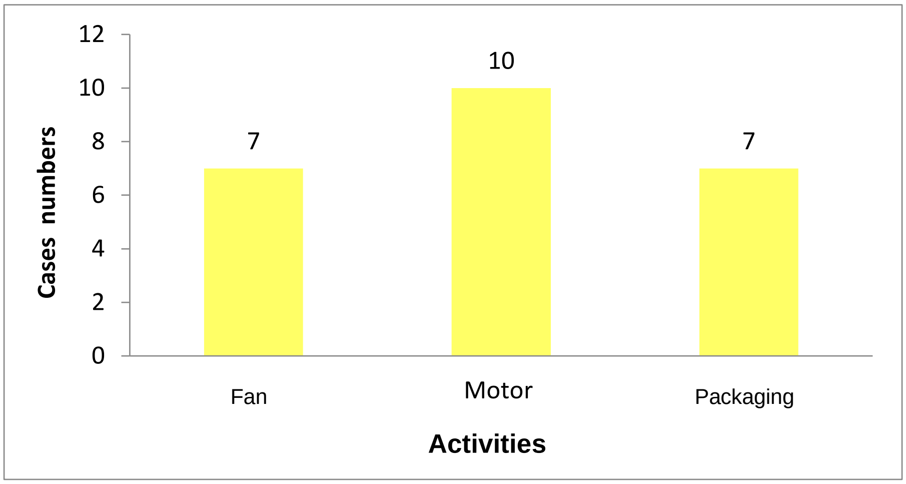


Figure 8. Ergonomic Medium Risk Level by Activity.

5. DISCUSSION / CONCLUSIONS

In the work research by Mufti, Ikhsan and Putri (2019) they mentioned that the use of WERA assessment is a good method to determine the physical risk exposure in relation to musculoskeletal disorders. In the present work research using the WERA assessment, the risk level could be determined based on the posture and repetition of the workers and we can conclude that in the activities carried out in the fan assembly area there is a risk of developing a shoulder MSD. In addition, it can be mentioned that the use of the WERA assessment was very useful, simple and practical. Likewise, Mufti, Ikhsan and Putri (2019) mention that through WERA it is possible to measure the physical risk factor related to a MSD.

One of the areas that caused high shoulder scores at the assessment, was that operators had to insert screws from one end to the other end, bending their back and extend their arms above their shoulders to be able to screw the part in. This was mainly due to insufficient space to move around. Therefore, a redesign of the workstation allowing the operator to move around the fan would benefit and improve shoulder postures and reduce the level risk.

This is consistent with Sugiono, Efranto and Budiprasetya (2018) research where they mention that a workstation redesign was also carried out, which in their case included adjusting the height, width and slope of the work table in order to reduce the shoulders and neck WERA score.

Finally, stop using the shoulders to lift the cover that covers the fan and instead use a hoist that can lift the cover using pressure and suction and move it to the next operation. This is also intended to reduce shoulder postures, postures that are performed above the shoulder, as can be seen in Figure 9, the suction hoist.

Figure 9. Suction Hoist.

References should be listed together at the end of the paper. References should be arranged in alphabetical order according to the last name of the author, or the last name of the first-named author for papers with more than one author. Refer to the examples shown below.

Making adjustments or modifications to the workplace, tools used, equipment and other relevant aspects, in order to improve working conditions, leads to a series of benefits, such as increased productivity, reduced costs associated with workplace injuries, greater employee satisfaction and well-being, and decreased staff turnover. In addition, by complying with appropriate ergonomic standards, companies can avoid fines for non-compliance regulations.

It is always important to be evaluating the activities and jobs of any type of industry in order to detect what can cause a musculoskeletal disorder (MSD). According to Sugiono, Efranto and Budiprasetya (2018) MSDs are a major complaint of workers within industries. They comment that MSDs can be fatal if the cause is not thoroughly investigated and generally their effects do not appear immediately.

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ERGONOMIC EVALUATION OF MOUSE EFFICIENCY: A COMPARATIVE STUDY OF SIX MODELS

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Resumen: Un aumento en la eficiencia se traduce en una reducción del tiempo de tarea, menor fatiga y, en última instancia, un incremento en la productividad. Este estudio tiene como objetivo evaluar la eficiencia de seis modelos de ratón mediante una prueba de clics en la que los usuarios deben seleccionar objetivos que aparecen aleatoriamente en un monitor durante un período de 30 segundos. La investigación se centra en analizar cómo el diseño de cada ratón afecta el rendimiento, la precisión y la comodidad del usuario. El objetivo es identificar el ratón que permita el mayor número de clics precisos mientras minimiza la fatiga y maximiza la comodidad. Los resultados proporcionarán una evaluación integral que considera tanto la eficiencia técnica como el impacto ergonómico en la experiencia del usuario.

Palabras clave: Ratón, género, precisión, efectividad,

Relevancia para la Ergonomía: Un diseño ergonómico facilita un agarre natural que optimiza tanto la velocidad como la precisión en los clics, lo cual es clave para lograr la eficiencia en las tareas. La ergonomía contribuye a reducir la fatiga y mejorar la precisión, permitiendo a los usuarios mantener un rendimiento constante durante la prueba sin experimentar incomodidad.

Abstract: Increased efficiency translates into reduced task time, less fatigue, and ultimately, increased productivity. This study aims to evaluate the efficiency of six mouse models through a click test in which users must select randomly appearing targets on a monitor over a 30-second period. The research focuses on analyzing how the design of each mouse affects user performance, accuracy, and comfort. The goal is to identify the mouse that allows for the highest number of precise clicks while minimizing fatigue and maximizing comfort. The results will provide a comprehensive evaluation that considers both technical efficiency and ergonomic impact on the user experience.

Keywords: Mouse, gender, precision, effectiveness

Relevance to Ergonomics: An ergonomic design facilitates a natural grip that optimizes both speed and accuracy in clicks, which is key to achieving task efficiency.

Ergonomics contributes to reducing fatigue and improving precision, allowing users to maintain consistent performance during the test without experiencing discomfort.

1. Introduction

In today's world, prolonged use of input devices, such as mice, is common in work and entertainment environments. However, factors such as the design and ergonomics of these devices can significantly affect user performance and health. A poorly designed mouse can generate fatigue, reduce task precision, and increase the risk of repetitive strain injuries.

Ergonomics, understood as the adaptation of the work environment and tools to user characteristics, plays a key role in optimizing performance and preventing physical discomfort. This study focuses on evaluating the efficiency of six mouse models, considering not only the number of clicks in a random target selection task but also the influence of ergonomic design on user precision, speed, and comfort.

The main objective is to determine which of the evaluated mouse models provides the best performance, thus identifying the most efficient device for prolonged use. This research aims to provide valuable information for device designers and users interested in improving their user experience and preventing problems derived from inadequate design.

2. Methodology

Participants

A sample of 70 participants was selected, consisting of 35 men and 35 women between 18 and 50 years of age, with computer-related occupations.

Materials

- Vernier caliper used to measure the dimensions of the user's dominant hand, considering length, as well as palm length and width.
- LENOVO ThinkPad computer used for conducting the tests, maintaining the same conditions for all samples.
- Mouse Accuracy - Mouse Accuracy and Pointer Click Training program
- KINOVEA used to import videos taken from two angles (lateral and superior) to obtain the angles that the user might make, whether flexion, extension, ulnar and radial deviations, always taking into account the worst posture.

Finally, 6 mice were used, chosen so that they all had different shapes, sizes, and grips. The descriptions of each mouse with the corresponding measurements are as follows:

1. Mouse 1: Logitech M170 Wireless Mouse / Nano USB receiver / Gray with black / PC / Laptop / Mac. Measurements: 9.7 x 6.1 x 3.5 cm.

2. Mouse 2: Wireless ergonomic optical mouse | MC-ERGONOMOUSEN. Measurements: 12.5 x 6.4 x 7.9 cm.
3. Mouse 3: Mini wireless mouse. Measurements: 8 x 5.5 x 3.2 cm.
4. Mouse 4: Wired vertical ergonomic mouse (MSE-012). Measurements: 10 x 7.2 x 8 cm.
5. Mouse 5: K-Snake BM600 rechargeable
6. Mouse STEREN USB Mouse COM-5265. Measurements: 12.3 x 6 x 3.9 cm.

1

2

3

4

5

6

Procedure

The participant is asked to click on each point that appears on the screen of the program (*Mouse Accuracy - Mouse Accuracy and Pointer Click Training*). This is performed under the same conditions with each of the mice. The tests have a duration of 30 seconds, with 52 targets at random locations. The targets have normal speed, medium size, are red in color, and a cross cursor is used.

Upon completion of the test, the program (*Mouse Accuracy - Mouse Accuracy and Pointer Click Training*) provides various user results, including:

- Efficiency
- Precision
- Total number of clicks
- Number of misses
- Clicks per second

3. RESULTS

Multivariate Tests, Effect of mouse

All multivariate tests (Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root) showed significant results ($p < 0.001$). This suggests that there are significant differences between the six mice in terms of efficiency.

Mice * Gender Interaction:

None of the multivariate tests were significant for the interaction between mice and gender ($p = 0.553$). This indicates that gender does not significantly influence the efficiency of the mice.

Ergonomic Implications of the Procedure and Initial Results

1. **Standardized Testing Environment**: The use of a consistent testing procedure across all mice models ensures that the differences observed are due to the mice themselves rather than variations in testing conditions. This standardization is crucial for ergonomic evaluations, as it allows for direct comparisons between different designs.
2. **Comprehensive Performance Metrics**: The variety of metrics collected (efficiency, precision, total clicks, misses, and clicks per second) provides a holistic view of mouse performance. This multi-faceted approach is essential in ergonomics, as it captures different aspects of user interaction that may impact comfort and productivity.
3. **Short-Duration, High-Intensity Task**: The 30-second test with 52 targets represents a high-intensity task. While this may not directly mirror prolonged use scenarios, it can reveal performance differences that might be amplified over extended periods, which is relevant for ergonomic considerations.
4. **Gender-Neutral Performance**: The lack of significant interaction between mouse type and gender suggests that the ergonomic benefits (or drawbacks) of different mouse designs are consistent across genders. This finding supports the development of universally ergonomic designs rather than gender-specific solutions.
5. **Efficiency Variations**: The significant differences in efficiency between mice underscore the importance of ergonomic design in input devices. These variations likely reflect differences in shape, size, and other design features that affect user interaction.
6. **Potential for Personalization**: While the study shows overall differences between mice, the lack of gender interaction suggests that individual preferences and physiological differences may play a more significant role than broad demographic categories in determining the most ergonomic mouse for a user.

These initial results and the testing procedure provide a solid foundation for a detailed ergonomic analysis of mouse designs. They highlight the complex interplay between device design and user performance, emphasizing the need for comprehensive ergonomic evaluations in the development and selection of computer mice.

Table 1. Multivariate test

Pruebas multivariante^{a}

Efecto		Valor	F	gl de hipótesis	gl de error	Sig.
Mouses	Traza de Pillai	.785	46.768^{b}	5.000	64.000	.000
	Lambda de Wilks	.215	46.768^{b}	5.000	64.000	.000
	Traza de Hotelling	3.654	46.768^{b}	5.000	64.000	.000
	Raíz mayor de Roy	3.654	46.768^{b}	5.000	64.000	.000
Mouses * Genero	Traza de Pillai	.059	.801^{b}	5.000	64.000	.553
	Lambda de Wilks	.941	.801^{b}	5.000	64.000	.553
	Traza de Hotelling	.063	.801^{b}	5.000	64.000	.553
	Raíz mayor de Roy	.063	.801^{b}	5.000	64.000	.553

Within-Subjects Effects Tests

Main effect of mice:

The analysis of variance showed that the differences between the mice are significant ($p < 0.001$), confirming that the mice vary in their efficiency.

Linear, quadratic, cubic, and higher-order contrasts were also significant, suggesting that the differences between the mice follow a complex pattern, beyond a simple linear trend.

Mice * Gender Interaction:

No significant effects were found in the interaction between mice and gender ($p = 0.660$), indicating that gender does not substantially modify the efficiency of the mice.

Ergonomic Implications of Within-Subjects Effects

1. **Complex Efficiency Patterns**: The significance of linear, quadratic, cubic, and higher-order contrasts reveals a complex relationship between mouse design and efficiency. This complexity has important ergonomic implications: a. *Non-linear improvements*: Ergonomic enhancements in mouse design may not lead to proportional improvements in efficiency. Some changes might have disproportionately large or small effects. b. *Multifaceted design considerations*: Designers need to consider multiple aspects of mouse design simultaneously, as improvements in one area might have unexpected effects on overall efficiency. c. *Personalization potential*: The complex efficiency patterns suggest that different users might find different designs optimal, supporting the case for personalized ergonomic solutions.

2. **Consistent Gender Performance**: The lack of significant interaction between mouse type and gender in both multivariate and within-subjects tests strengthens the conclusion that ergonomic benefits of mouse designs are generally consistent across genders. This has several implications: a. *Universal design approach*: Manufacturers can focus on creating universally ergonomic designs rather than gender-specific mice. b. *Workplace implementations*: Organizations can implement ergonomic mouse solutions without needing to consider gender as a factor, simplifying the process of improving workplace ergonomics. c. *Research focus*: Future ergonomic studies might benefit more from focusing on individual physiological differences or task-specific requirements rather than gender-based distinctions.
3. **Importance of Comprehensive Testing**: The complex patterns revealed by these tests underscore the need for thorough ergonomic evaluations of input devices: a. *Beyond simple metrics*: Evaluations should go beyond simple efficiency measures to capture the nuanced ways in which design affects performance. b. *Long-term studies*: While this study used short, intense tasks, the complex efficiency patterns suggest that long-term studies might reveal additional ergonomic insights. c. *Task-specific evaluations*: Different tasks might reveal different efficiency patterns, suggesting the need for task-specific ergonomic evaluations of mice.
4. **Implications for User Training and Adaptation**: The complex efficiency patterns suggest that users might need time to adapt to new mouse designs to fully realize ergonomic benefits: a. *Learning curves*: Organizations implementing new mouse designs should consider potential learning curves and provide adequate time and training for users to adapt. b. *User feedback*: Given the complex relationships between design and efficiency, gathering ongoing user feedback becomes crucial in assessing the long-term ergonomic benefits of different mouse designs.

These within-subjects effects results (Table 2) provide valuable insights for ergonomic design, workplace implementation, and future research directions in the field of computer input devices. They highlight the intricate nature of ergonomic design and the importance of comprehensive, nuanced approaches to improving user efficiency and comfort.

Table 2. Within-Subjects Effects Test

Medida: Porcentaje

Origen		Tipo III de suma de cuadrados	gl	Media cuadrática	F
Mouses	Esfericidad asumida	1.042	5	.208	55.339
	Greenhouse-Geisser	1.042	4.443	.234	55.339
	Huynh-Feldt	1.042	4.862	.214	55.339
	Límite inferior	1.042	1.000	1.042	55.339
Mouses * Genero	Esfericidad asumida	.012	5	.002	.652
	Greenhouse-Geisser	.012	4.443	.003	.652
	Huynh-Feldt	.012	4.862	.003	.652
	Límite inferior	.012	1.000	.012	.652
Error(Mouses)	Esfericidad asumida	1.280	340	.004	
	Greenhouse-Geisser	1.280	302.155	.004	
	Huynh-Feldt	1.280	330.649	.004	
	Límite inferior	1.280	68.000	.019	

Finally, Table 3 shows the polynomial within-subjects contrast test (linear, quadratic, cubic, 4th order, and 5th order), which helps identify patterns in the data across different conditions.

1. Main effect of Mice:
    - The linear contrast (F = 121.170, p < 0.001) is highly significant, suggesting a strong linear trend in performance across different mouse models.
    - The quadratic (F = 105.068, p < 0.001) and cubic (F = 15.115, p < 0.001) contrasts are also significant, indicating more complex patterns in the data.
    - The 5th order contrast (F = 5.798, p = 0.019) is significant, which could indicate more subtle differences between models.

b) Mice * Gender interaction:

- None of the contrasts are statistically significant (all p > 0.05), suggesting there is no significant interaction between gender and performance with different mouse models.

In conclusion, we can say that there are significant differences in performance between the different mouse models. Furthermore, the pattern of these differences is complex, involving linear, quadratic, and higher-order trends, and gender does not seem to significantly influence how participants perform with different mouse models.

The implications are that mouse designs significantly affect user performance, and the differences in performance between mouse models are consistent across genders. This interpretation provides a solid basis for understanding how different mouse models affect user performance, regardless of gender.

Pruebas de contrastes intra-sujetos

Medida: Porcentaje

Origen	Mouses	Tipo III de suma de cuadrados	gl	Media cuadrática	F	Sig.
Mouses	Lineal	.418	1	.418	121.170	.000
	Cuadrático	.547	1	.547	105.068	.000
	Cúbico	.044	1	.044	15.115	.000
	Orden 4	.007	1	.007	2.568	.114
	Orden 5	.025	1	.025	5.798	.019
Mouses * Genero	Lineal	.004	1	.004	1.070	.305
	Cuadrático	.001	1	.001	.237	.628
	Cúbico	7.407E-6	1	7.407E-6	.003	.960
	Orden 4	.007	1	.007	2.519	.117
	Orden 5	9.786E-5	1	9.786E-5	.022	.882
Error(Mouses)	Lineal	.235	68	.003		
	Cuadrático	.354	68	.005		
	Cúbico	.197	68	.003		
	Orden 4	.196	68	.003		
	Orden 5	.299	68	.004		

4. CONCLUSIONS

Based on the multivariate analysis and within-subject effects, significant differences in efficiency have been revealed among the various mouse models evaluated.

In particular, Mouse 6 stood out as the device with the best performance in terms of precision, surpassing Mouse 5 and Mouse 1 in this area. This differentiation suggests that the design and specific features of each mouse can notably influence its effectiveness and precision during use. Regarding the interaction between mice and gender, the results indicated that there is no significant influence of gender on the efficiency of the devices.

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EVALUATION OF THE IMPACT IN THE POSTURAL LOAD, AFTER AN EDUCATIVE INTERVENTION AND REDESIGN IN THE JOB POSITION OF A MEDICAL ASSISTANT IN THE H.G.Z #50 IMSS.

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Resumen: Determinar el puntaje total de la metodología Rapid Office Strain Assessment y del Cuestionario Nórdico Estandarizado de las asistentes médicas del Hospital General de Zona 50 del Instituto Mexicano del Seguro Social antes y después de la intervención educativa y de rediseño en su puesto de trabajo. Participaron 50 asistentes médicas. Se les realizó una evaluación inicial del puesto de trabajo por medio de la metodología Rapid Office Strain Assessment. y se les aplicó el Cuestionario Nórdico Estandarizado para evaluar las partes corporales afectadas por dolor o disconfort. Posterior se les realizó una intervención educativa y de rediseño en el puesto de trabajo de oficina y al mes y a los 3 meses se les realizó una nueva evaluación por medio de la metodología Rapid Office Strain Assessment y del Cuestionario Nórdico Estandarizado. En la evaluación Rapid Office Strain Assessment inicial, encontramos en total una media de 10 puntos (6 -10), (p: 0.0435). La evaluación al mes posterior a la intervención educativa y de rediseño encontramos en total una media de 9 puntos (4 -10), (p: 0.4862) y a los 3 meses fue una media total de 9 puntos (3-10), (p:0.4862). Respecto al total de los puntos dolorosos del Cuestionario Nórdico Estandarizado 7 días inicial encontramos en total una mediana de 2 (0-8), (p: 0.6838), al mes encontramos en total una mediana de 2 (0-9), (p: 0.04306) y a los 3 meses encontramos de total una mediana de 2 (0-9), (p: 0.1927). Posterior a nuestra intervención educativa y de rediseño del puesto de trabajo de las asistentes médicas estudiadas, hubo una mejoría en la carga postural a través de la determinación del riesgo de presentar trastornos musculoesqueléticos mediante la metodología Rapid Office Strain Assessment, destacando disminución estadísticamente significativa en el riesgo al analizarlo por áreas laborales. A través del cuestionario Nórdico, no encontramos diferencias antes y después de dicha intervención en las regiones corporales afectadas, pero hubo mejoría en la carga postural al analizar por áreas de trabajo.

Palabras clave: dolor musculoesquelético; modificación ergonómica; asistente médico; trabajo de oficina; intervención.

Aportación a la Ergonomía: es de nuestra relevancia, darle importancia a la capacitación Ergonómica, respecto a las máquinas y herramientas utilizadas en los puestos de trabajo, así como fomentar esta práctica basada en evidencia, dando pie a realizar más estudios e investigaciones que sustenten esta práctica. Además de crear conciencia de lo fundamental que es el diseño del puesto de trabajo de oficina por medio de maquinaria y herramienta ajustable de acuerdo con las necesidades de los trabajadores con el fin de prevenir los trastornos musculoesqueléticos.

Abstract: To determine the total score of the Rapid Office Strain Assessment methodology and the Nordic Standardized Questionnaire of the medical assistants of the General Hospital of Zone 50 of the Mexican Institute of Social Security before and after the educational intervention and redesign in their workplace. 50 medical assistants participated. An initial job evaluation was carried out using the Rapid Office Strain Assessment methodology. and the Nordic Standardized Questionnaire was applied to evaluate the body parts affected by pain or discomfort. Subsequently, an educational and redesign intervention was carried out in the office workplace and after one month and 3 months a new evaluation was carried out using the Rapid Office Strain Assessment methodology and the Nordic Standardized Questionnaire. In the initial Rapid Office Strain Assessment, we found a total of 10 points (6 -10), (p: 0.0435). The evaluation one month after the educational intervention and redesign found a total of 9 points (4 -10), (p: 0.4862) and at 3 months it was a total mean of 9 points (3-10), (p: 0.4862). Regarding the total of the painful points of the initial 7-day Nordic Standardized Questionnaire, we found a total median of 2 (0-8), (p: 0.6838), at one month we found a total median of 2 (0-9), (p: 0.04306) and at 3 months we found a total median of 2 (0-9), (p: 0.1927). After our educational intervention and redesign of the workplace of the medical assistants studied, there was an improvement in postural load through the determination of the risk of musculoskeletal disorders using the Rapid Office Strain Assessment methodology, highlighting a statistically significant decrease in risk when analyzed by work areas. Through the Nordic questionnaire, we did not find differences before and after this intervention in the affected body regions, but there was an improvement in postural load when analyzing by work areas.

Keywords: musculoskeletal pain; Ergonomic modification; Medical Assistant; Office worker; intervention.

Relevance to Ergonomics: it is of our relevance to give importance to Ergonomic training, regarding the machines and tools used in the workplace, as well as to promote this practice based on evidence, giving rise to more studies and research that support this practice. In addition to raising awareness of how fundamental the design of the office workplace is through adjustable machinery and tools according to the needs of workers to prevent musculoskeletal disorders.

1. INTRODUCTION

It is well-established that certain occupational activities, such as office work, can elevate the risk of musculoskeletal disorders. The Mexican Social Security Institute employs 33,000 medical assistants engaged in such activities, where this risk factor is evident, compounded by a lack of knowledge regarding office ergonomics and a deficiency of ergonomic studies in this field. The prevalence of musculoskeletal disorders among individuals who regularly use computers in an office setting (3-5 hours daily) ranges from 40% among students, 50% among new employees in their first year, to over 70% among office workers and students. Extrapolating this data to the IMSS population suggests a potential prevalence of between 13,200 workers in their first year of employment and 23,100 workers experiencing musculoskeletal disorders attributable to postural strain in their workplace.

The objective of this research is to minimize the risk of our medical assistants experiencing these disorders while educating them on the significance of ergonomics within their work environment. The workstation was evaluated utilizing the Rapid Office Strain Assessment (ROSA) methodology and the standardized Nordic questionnaire.

2. OBJETIVES

The primary objective is to compare the effects on postural load evaluated by ROSA and the Nordic questionnaire, both prior to and following an educational and redesign intervention in the medical assistant's workplace at H.G.Z, 50 of the I.M.S.S.

The specific objectives are as follows:

1. To ascertain the overall score of the Rapid Office Strain Assessment (ROSA) methodology for the medical assistants at H.G.Z. 50 of the I.M.S.S. prior to the educational and redesign intervention in their workplace.
2. To ascertain the total score of the Nordic questionnaire among medical assistants at H.G.Z. 50 of the I.M.S.S. prior to an educational and redesign intervention in their workplace.
3. To ascertain the overall score of the Rapid Office Strain Assessment (ROSA) methodology utilized by the medical assistants at H.G.Z. 50 of the I.M.S.S. for evaluating postural load one month and three months following the implementation of the educational and redesign intervention in their workplace.
4. To ascertain the overall score of the Nordic questionnaire among the medical assistants at H.G.Z. 50 of the I.M.S.S. one month and three months following the implementation of the educational and redesign intervention in their workplace.
5. To compare the results derived from the Rapid Office Strain Assessment (ROSA) methodology and the Nordic questionnaire administered to the medical assistants of H.G.Z. 50 of the I.M.S.S. before, one month after, and three months after the educational and redesign intervention to analyze the resulting impact.

The secondary objective is to assess medical assistants regarding office ergonomics to document their knowledge and its effects following the previously mentioned intervention.

3. METHODOLOGY

This is a quasi-experimental study conducted before and after the intervention. The study setting is the General Hospital of Zone Number 50 in San Luis Potosí, S. L. P. The study population comprises all medical assistants at the General Hospital of Zone Number 50 in San Luis Potosí, S. L. P., with a designated timeframe for the study spanning from April 2023 to July 2024.

3.1 Criteria for Selection:

Our inclusion criteria encompassed medical assistants employed at the General Hospital Zone Number 50 in San Luis Potosí, S. L. P. Specifically, we targeted operating medical assistants aged between 18 and 50 years who consented to participate and signed the informed consent form. The selection criteria required participants to have a prior diagnosis of hypothyroidism, pregnancy, rheumatoid arthritis, fibromyalgia, osteoarthritis, systemic lupus erythematosus, mixed connective tissue disease, or reactive arthritis. The elimination criteria included medical assistants who did not adequately complete the measurement instruments, those who chose to withdraw from the study and rescinded their informed consent, and individuals who were unavailable for the second measurement due to contractual obligations or vacation. The sampling technique employed was non-probabilistic sampling. To determine the sample size, we utilized a finite population approach, which included 50 medical assistants from the General Hospital Zone Number 50 in San Luis Potosí, S. L. P. Furthermore, we applied inferential statistics through hypothesis testing and utilized percentage parameters to analyze the variations within our study population.

3.2 Statistical Evaluation

Descriptive analysis: the normality of the variables was evaluated utilizing the Shapiro-Wilk test and QQ plot. Measures of central tendency and dispersion were employed. For continuous variables, means and standard deviations were calculated. Nominal variables were presented as frequencies and percentages. Frequency tables and graphs were also utilized to convey the results. Inferential analysis: the comparison between the study groups was conducted using the student’s t-test or its non-parametric equivalent.

3.3 Procedure.

Authorization to conduct the research protocol was sought via a letter from the General Hospital of Zone Number 50. The medical assistants were then convened to brief them on the protocol and their significant involvement, as well as the percentage of informed consent from the population that agreed to participate in the study. An initial evaluation of the medical assistants' work environment was conducted utilizing the R.O.S.A. methodology through a two-minute video recording of the medical assistant engaging in their tasks. Musculoskeletal symptoms were assessed using the standardized Nordic questionnaire at times that did not disrupt their work activities.

Immediately following the assessment, the assistants were convened before each shift to participate in a 30-minute educational intervention led by the principal investigator. This session was supported by audiovisual materials focusing on the topic of Ergonomics in the office. A knowledge assessment was conducted both at the beginning and at the conclusion of the intervention. Subsequently, visits to the workstations of the participating assistants were scheduled for a redesign intervention in their work areas, which involved reorganizing their work equipment based on the resources available at the Institute. An interval of approximately 4 to 12 weeks was allowed to elapse before conducting a new random evaluation of the workstation using the R.O.S.A. methodology and the Nordic Standardized Questionnaire. Once both sets of results were obtained, they were compared and compiled into Excel tables for analysis and interpretation of the findings.

4. RESULTS

4.1 Flowchart and Demographic Information

Between August and September 2023, 50 medical assistants were invited to participate in the study. Informed consent was obtained, and those who agreed had their information collected via a data collection sheet. The selection criteria were subsequently applied. All 50 assistants, who are operational staff at General Hospital Zone #50 of the I.M.S.S, met the inclusion criteria. However, 4 individuals exited the group—2 due to hypothyroidism and 2 due to fibromyalgia—resulting in 46 participants. Ultimately, after applying the elimination criteria, 8 participants withdrew from the study: 5 due to retirement, 2 due to reassignment, and 1 due to disability, leaving a total of 38 participants (see flowchart).

The total number of patients who completed the protocol was 38, among whom the normality analysis of the study variables was conducted using the Shapiro-Wilk test and QQ-plot. Variables with $p<0.05$ were analyzed using the ANOVA test, while those with $p>0.05$ were assessed with the Kruskal-Wallis's test.

Subsequently, a decision was made to categorize the study population for enhanced analysis based on the type of reported work area: 1) outpatient clinic (n=10), 2) emergency (n=9), 3) hospitalization (n=9), 4) temporary (n=3), and 5) management (n=7). The corresponding analysis was conducted, examining the variables of age, marital status, and body mass index as presented in Table 1.

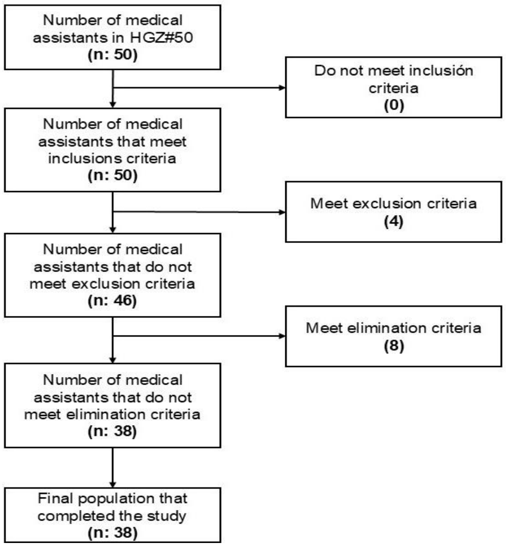

Figure 1. Flowchart depicting patient progression within the research protocol

Table 1. Overview of the Study *Participants.*

Variable	**CE (N=10)**	**UEM (N=9)**	**HOSPITAL (N=9)**	**EVENTUAL (N=3)**	**HEADQUARTERS (N=7)**	**TOTAL (N=38)**	**p-valo**
AGE							
Mean (SD)	42.0 (8.41)	40.7 (11.0)	39.2 (5.61)	32.3 (6.35)	44.0 (5.35)	40.6 (8.11)	0.3044**&**
Median [Min, Max]	43.5 [27.0, 55.0]	41.0 [24.0, 58.0]	41.0 [29.0, 45.0]	36.0 [25.0, 36.0]	42.0 [39.0, 52.0]	41.5 [24.0, 58.0]	
ECIV							
S	4 (40.0%)	4 (44.4%)	3 (33.3%)	1 (33.3%)	2 (28.6%)	14 (36.8%)	0.9038¥
C	**5 (50.0%)**	**3 (33.3%)**	**4 (44.4%)**	**2 (66.7%)**	**3 (42.9%)**	**17 (44.7%)**	
UL	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)	0 (0%)	1 (2.6%)	
V	0 (0%)	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)	1 (2.6%)	
D	1 (10.0%)	1 (11.1%)	1 (11.1%)	0 (0%)	2 (28.6%)	5(13.2%)	
IMC (Kg/m2)							
Mean (SD)	28.3 (4.4)	26.9 (3.22)	28.7 (4.03)	**29.7 (4.92)**	**30.7 (3.42)**	28.6 (3.92)	0.4441

*Abbreviation: NS = not significant, & = ANOVA, ¥ = Pearson Chi2 test. CE = outpatient clinic, UEM = emergency room, SD = standard deviation. *p < 0.05.*

In terms of work shift variables, a greater proportion of participants, specifically 52.6% (20/38), are engaged in the morning shift. This finding is statistically significant (p= 0.001) among the various work area groups. The distribution for other shifts is as follows: evening 36.8% (14/38), night 5.3% (2/38), and rotating 5.3% (2/38). This same distribution was noted in most other work areas (Table 2). Concerning work seniority, no significant differences were identified; however, a median of 8 years is noteworthy, with a broad range spanning from one year to 27 years of employment. Similarly, regarding weekly working hours, no significant differences were found, yet a median of 40 hours is prominent, with a range of 32 to 52 hours across all work area groups (Table 2).

Table 2. Overview of the Study Participants.

Variable	**CE (N=10)**	**UEM (N=9)**	**HOSPITAL (N=9)**	**EVENTUAL (N=3)**	**HEADQUARTERS (N=7)**	**TOTAL (N=38)**	**p-**
Work shift							
M	**6 (60.0%)**	**4 (44.4%)**	**5 (55.6%)**	1 (33.3%)	**4 (57.1%)**	**20 (52.6%)**	**0.001 ¥**
V	4 (40.0%)	3 (33.3%)	4 (44.4%)	0 (0%)	3 (42.9%)	14 (36.8%)	
N	0 (0%)	2 (22.2%)	0 (0%)	0 (0%)	0 (0%)	2 (5.3%)	
E	0 (0%)	0 (0%)	0 (0%)	2 (66.7%)	0 (0%)	2 (5.3%)	
Professional experience							
Median [Min, Max]	9.50 [4.00, 21.0]	8.00 [1.00, 27.0]	8.00 [4.00, 25.0]	2.00 [1.00, 3.00]	12.0 [6.00, 17.0]	8.00 [1.00, 27.0]	.109‡
Hours Worked Weekly							
Median [Min, Max]	40.0 [32.0, 50.0]	36.0 [32.0, 48.0]	40.0 [32.0, 48.0]	40.0 [32.0, 52.0]	40.0 [40.0, 40.0]	40.0 [32.0, 52.0]	.337‡

Abbreviations: NS = not significant, & = ANOVA, ¥ = Pearson Chi2 test, ‡ = Kruskal-Wallis's test, CE = outpatient clinic, UEM = emergency room, SD = standard deviation.

4.2 Outcomes of the Rapid Office Strain Assessment (ROSA) methodology

To address the primary objective of this study, the overall score of the Rapid Office Strain Assessment (ROSA) methodology was compared before and after the educational intervention and job redesign. Notably, in this initial assessment, the scores ranged from 6 to 10 points, revealing statistically significant differences among the groups of medical assistants across various work areas (p=0.043) during this first evaluation. The highest scores were recorded by the assistants in CE, hospitalization, and temporary positions (Table 3).

Table 3. Comparison of Rapid Office Strain Assessment (ROSA) prior to educational and redesign interventions in work area groups.

Variable	**CE (N=10)**	**UEM (N=9)**	**HOSPITAL (N=9)**	**EVENTUAL (N=3)**	**HEADQUARTERS (N=7)**	**TOTAL (N=38)**	**p-valor**
ROSA first							
Median [Min, Max]	10.0 [9.00, 10.0]	9.00 [7.00, 10.0]	10.0 [9.00, 10.0]	10.0 [9.00, 10.0]	8.00 [6.00, 10.0]	10.0 [6.00, 10.0]	**0.0435**

*Abbreviations: CE = outpatient clinic, UEM = emergency room, SD = standard deviation. *p < 0.05.*

Concerning the ROSA evaluation conducted one month following the educational intervention and job redesign, we noted significant differences among the work area groups (p=0.008). This finding underscores a reduction in the average score from the initial ROSA (10) to the ROSA at one month (9), with the total population's scores ranging from 4 to 10 points. The lowest score was recorded by the assistants in the management area. (Table 4)

Table 4. Comparison of Rapid Office Strain Assessment (ROSA) *one-month* post-educational intervention and redesign within the study groups.

Variable	**CE (N=10)**	**UEM (N=9)**	**HOSPITAL (N=9)**	**EVENTUAL (N=3)**	**HEADQUARTERS (N=7)**	**TOTAL (N=38)**	**p-valo**
ROSA 1 month							
Median [Min,Max]	9.50 [6.00, 10.0]	9.00 [8.00, 10.0]	9.00 [5.00, 10.0]	8.00 [5.00, 10.0]	5.00 [4.00, 8.00]	9.00 [4.00, 10.0]	**0.0082**

*Abbreviations: CE = outpatient clinic, UEM = emergency room, SD = standard deviation. *p < 0.05.*

Upon evaluating the ROSA score (3 months), we noted no significant differences; however, there was a general decline across all work area groups, exhibiting a broader range of 3 to 10 points, particularly within the management group, followed by hospital assistants and temporary workers. (Table 5).

Table 5. Comparison of the Rapid Office Strain Assessment (ROSA) at three months following the educational and redesign interventions in the workplace groups.

Variable	**CE (N=10)**	**UEM (N=9)**	**HOSPITAL (N=9)**	**EVENTUAL (N=3)**	**HEADQUARTERS (N=7)**	**TOTAL (N=38)**	**p-valo**
ROSA 3 month							
Median [Min, Max]	9.00 [6.00, 10.0]	9.00 [6.00, 10.0]	9.00 [5.00, 10.0]	8.00 [5.00, 9.00]	8.00 [3.00, 10.0]	9.00 [3.00, 10.0]	0 .4862

*Abbreviations: CE = outpatient clinic, UEM = emergency room, SD = standard deviation. *p < 0.05.*

Upon analyzing the results of the three ROSA assessments, we observed that the initial total mean was 10 points, indicating extreme risk, with a range of 6 to 10 points. Following the educational intervention and the redesign of the medical assistants' workplace, a month later, the total mean decreased to 9 points. Notably, there was a reduction in the minimum score, which fell from 6 points to 4 points, signifying that some assistants transitioned from very high risk to improvable risk. After three months, the total mean remained at 9 points; however, there was a more significant reduction in the minimum scores, resulting in a range of 3 to 10 points. This indicates that medical assistants sustained an improbable risk with a lower score in the ROSA methodology. When analyzing the work areas, we observed that in the CE sector, the initial average was 10 points (indicating extreme risk) with a range between 9 and 10 points. This median was maintained at one month and three months; however, the range decreased to between 6 and 10 points, indicating that some medical assistants in CE transitioned from extreme risk to very high risk. In the emergency department, the initial average was 9 points (extreme risk) with a range of 7 to 10 points. Although the average remained unchanged at one month and three months, the minimum scores decreased at three months, resulting in a range of 6 to 10 points. In the hospitalization sector, the initial average was 10 points (extreme risk) with a range of 9 to 10 points. At one month, the average declined to 9 points, with a range of 5 to 10 points, which remained consistent at three months. This indicates that some medical assistants moved from extreme risk to high risk. For occasional assistants, the initial average was also 10 points (extreme risk) with a range of 9 to 10 points. At one month and three months, the average decreased to 8 points, with a range of 4 to 8 points at one month and 5 to 9 points at three months. It was concluded that some medical assistants transitioned from extreme risk to improvable risk. Finally, the management area demonstrated a more favorable response to the educational intervention and job redesign, starting with an average of 10 points (extreme risk) and decreasing to 9 points after one month, followed by a further reduction to 8 points after three months. The initial minimum scores were 6, which decreased to 4 points after one month and further to 3 points after three months. This represented the most significant reduction in minimum scores, indicating that some assistants progressed from extreme risk to a level of risk that could be improved.

4.3 Outcomes of the Standardized Nordic Questionnaire

The following presents the findings from the Nordic questionnaire, which evaluates body parts experiencing issues (pain, discomfort, or aches) and obstacles to performing regular work (both at home and outside) due to these discomforts over the past 12 months and the last seven days. In our study, we opted to aggregate the affected body parts (neck, shoulder, elbow, wrist, dorsal region, lumbar region, one or both legs or hips, one or both knees, one or both feet), resulting in a total of 12 potentially affected areas (12 points), thereby creating a quantitative variable.

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Table 6. Comparison of the initial Nordic Standardized Questionnaire across the work area groups

Variable	**CE (N=10)**	**UEM (N=9)**	**HOSPITAL (N=9)**	**EVENTUAL (N=3)**	**HEADQUARTRS (N=7)**	**TOTAL (N=38)**	**p-valo**
NORDIC COMPONENTS IMPACTED INITIAL							
Median [Min, Max]	5.50 [1.00, 11.0]	5.00 [0, 6.00]	4.00 [2.00, 9.00]	4.00 [0, 4.00]	5.00 [3.00, 9.00]	4.50 [0, 11.0]	0.3022
NORDIC OFFSIDE-INITIAL							
Median [Min, Max]	3.00 [0, 8.00]	2.00 [0, 5.00]	1.00 [0, 6.00]	2.00 [0, 3.00]	2.00 [0, 7.00]	2.00 [0, 8.00]	0.4662
NORDIC 7 DAYS-ORIGIN							
Median [Min, Max]	1.50 [0, 7.00]	3.00 [0, 6.00]	1.00 [0, 7.00]	1.00 [0, 3.00]	2.00 [0, 8.00]	2.00 [0, 8.00]	0.6838

*Abbreviations: CE = outpatient clinic, UEM = emergency room, SD = standard deviation. *p < 0.05.*

Following our educational intervention and the redesign of the workstation for medical assistants, a second Nordic questionnaire was administered one-month post-intervention, followed by a third Nordic questionnaire three months after the intervention. We observed no statistically significant differences concerning the affected areas of the musculoskeletal system and their impairment over the last 12 months as indicated in each questionnaire. This may be attributed to the fact that the questionnaires administered one month and three months after the intervention still evaluated a timeframe that overlaps with the first questionnaire, resulting in no significant changes in the affected body regions among the work groups.

Each Nordic questionnaire evaluates musculoskeletal issues experienced in the past seven days, making it crucial to compare the results of the initial questionnaire with subsequent assessments following our educational intervention and job redesign for medical assistants.

In the Nordic questionnaire conducted one-month post-intervention, the musculoskeletal issues reported in the preceding seven days averaged 2 affected regions (2 points), with a range from 0 to 9. This assessment revealed statistically significant differences between the groups (p: 0.04306). In the Outpatient and Inpatient work groups, we observed an increase in the average number of affected regions compared to the initial evaluation (+2.5 and +2 affected regions, respectively). Conversely, we noted a significant decrease in the Emergency, Temporary, and Headquarters groups, with reductions in the averages of affected body parts (-1, -1, and -1, respectively). (Table 7).

Table 7. Comparison of the Standardized Nordic Questionnaire following the educational and redesign intervention in the office workplace after one month.

Variable	**CE (N=10)**	**UEM (N=9)**	**HOSPITAL (N=9)**	**EVENTUAL (N=3)**	**HEADQUARTERS (N=7)**	**TOTAL (N=38)**	**p-valo**
NORDIC COMPONENTS IMPACTED PER MONTH							
Median [Min, Max]	5.50 [2.00, 10.0]	4.00 [1.00, 9.00]	5.00 [0,8.00]	1.00 [0,4.00]	5.00 [2.00, 6.00]	4.50 [0, 10.0]	0.1234
NORDIC OFFSIDEL PER MONTH							
Median [Min, Max]	3.00 [0, 8.00]	1.00 [0, 4.00]	0 [0, 5.00]	0 [0, 1.00]	1.00 [0, 4.00]	1.00 [0,8.0]	0.1216
NORDIC 7 DAYS- PER MONTH							
Median [Min, Max]	4.00 [1.00, 9.00]	2.00 [0, 5.00]	3.00 [0, 6.00]	0 [0, 1.00]	1.00 [0, 5.00]	2.00 [0, 9.00]	**0.04306**

*Abbreviations: CE = outpatient clinic, UEM = emergency room, SD = standard deviation. *p < 0.05.*

Three months following our intervention focused on educational and workplace redesign, no statistically significant differences were observed among the work area groups in the standardized Nordic questionnaire. However, the improvement within the group of medical assistants in the Outpatient Clinic was remarkable, decreasing from an average of 4 points in the one-month evaluation to 2.5 points in the most recent assessment, while the other work area groups sustained their averages relative to the prior evaluation. (Table 8).

Table 8. Comparison of the Standardized Nordic Questionnaire following the educational and redesign intervention in the office workplace at the three-month

Variable	CE (N=10)	UEM (N=9)	HOSPITAL (N=9)	HEADQUARTERS (N=3)	JEFATURA (N=7)	TOTAL (N=38)	p-valo
NORDIC COMPONENTS IMPACTED-3 MONTHS							
Median [Min, Max]	4.00 [0, 9.00]	5.00 [0, 7.00]	4.00 [1.00, 8.00]	1.00 [0, 4.00]	3.00 [0, 8.00]	4.00 [0, 9.00]	0.5338
NORDIC OFFSIDE FOR A DURATIONS OF 3 MONTHS							
Median [Min, Max]	2.50 [0, 6.00]	3.00 [0, 4.00]	3.00 [0, 6.00]	0 [0, 1.00]	1.00 [0, 7.00]	1.50 [0, 7.00]	0.3901
NORDIC 7 DAYS TO 3 MONTHS							
Median [Min, Max]	2.50 [0, 9.00]	2.00 [0, 5.00]	3.00 [0, 6.00]	0 [0, 1.00]	1.00 [0, 7.00]	2.00 [0, 9.00]	0.1927

*Abbreviations: CE = outpatient clinic, UEM = emergency room, SD = standard deviation. *p < 0.05.*

In analyzing the work areas, particularly the section of the Nordic questionnaire addressing issues encountered in the past seven days, we conducted three evaluations. Among the outpatient assistants, we observed no improvement; rather, the score increased from 1.5 to 2.5 points over three months, with the highest range rising from 7 to 9 points. Conversely, in the emergency medical assistants, we noted an improvement in the average score, which decreased from 3 points to 2 points over the same period, alongside a reduction of one point in the highest range. For the hospitalization medical assistants, no improvement was evident, as the average score rose from 1 to 3 affected parts. The temporary medical assistants were the least affected group and demonstrated a positive response to the educational and redesign intervention, with an average score decreasing from 1 to 0 points. In the management area, the medical assistants exhibited minimal improvement, with the average score declining from 2 to 1 point; however, the maximum range of affected parts fluctuated from 8 to 5 and then to 7. Overall, the average number of affected parts remained stable, with the maximum range shifting from 8 to 9, and a minimum of 0 recorded across the three studies.

4.4 Outcomes of the evaluation of Ergonomics knowledge in the office environment.

Finally, we assessed the knowledge of the medical assistants both prior to and following our educational intervention, during which an evaluation of effective and ineffective ergonomic practices in the office environment was conducted. Prior to the intervention, we noted that only 13.2% (5) achieved an outstanding score, 44% (17) received a satisfactory score, and 42.1% obtained an unsatisfactory score. Our findings indicated that most medical assistants possessed limited knowledge concerning ergonomics in the office setting, with no statistically significant differences identified among the various work area groups. (Table 9).

Table 9. Assessment of Knowledge Regarding Office Workplace Ergonomics Prior to Training

	CE (N=10)	**URGENCIAS (N=9)**	**HOSPITAL (N=9)**	**HEADQUARTERS (N=3)**	**JEFATURA (N=7)**	**TOTAL (N=38)**	**p-valo**
CEI							
UNACCEPTABLE	3 (30.0%)	3 (33.3%)	**4 (44.4%)**	**3 (100%)**	3 (42.9%)	**16 (42.1%)**	0.664
SATISFYING	6 (60.0%)	4 (44.4%)	4 (44.4%)	0 (0%)	3 (42.9%)	17 (44.7%)	
OUTSTANDING	1 (10.0%)	2 (22.2%)	1 (11.1%)	0 (0%)	1 (14.3%)	5 (13.2%)	

*Abbreviations: CE = outpatient clinic, UEM = emergency room, SD = standard deviation. *p < 0.05, CEi= Initial ergonomics exam score.*

Following the training of the medical assistants, a subsequent evaluation was conducted, revealing that 89.5% (34) achieved an outstanding score, 10.5% (4) received a satisfactory score, and there were no instances of unsatisfactory performance. In terms of work area groups, it was noted that all outpatient medical assistants and temporary medical assistants attained an outstanding score. Furthermore, no statistically significant differences were observed among the work area groups (Table 10).

Table 10. Comparison of knowledge evaluation regarding office workplace ergonomics post-training, categorized by work area groups.

	CE (N=10)	**URGENCIAS (N=9)**	**HOSPITAL (N=9)**	**EVENTUAL (N=3)**	**HEADQUARTERS(N=7)**	**TOTAL (N=38)**	**p-valo**
CEF							
UNACCEPTABLE	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	NS
SATISFYING	0 (0%)	1 (11.1%)	2 (22.2%)	0 (0%)	1 (14.3%)	4 (10.5%)	
OUTSTANDING	10 (100%)	8 (88.9%)	7 (77.8%)	3 (100%)	6 (85.7%)	34 (89.5%)	

*Abbreviations: CE = outpatient clinic, UEM = emergency room, SD = standard deviation. *p < 0.05, CEF= final ergonomics exam score.*

5. DISCUSSION/CONCLUSIONS

5.1 Discussion

This study evaluated postural strain among office assistants utilizing the Nordic Parts Affected Questionnaire and assessed workplace ergonomics through the R.O.S.A. method. Robertson M et al. (2003) aimed to explore the impact of an intervention involving ergonomic training and modifications at office workstations. Their findings indicated that the training fostered a heightened awareness of risk factors associated with office work prior to participation. The results from the pre- and post-knowledge assessments demonstrated a significant 32% increase in overall understanding of office ergonomics ($t = 21.3$, $p < .01$). In our study, we discovered that prior to the educational intervention, only 13.2% achieved an outstanding score, 44% received a satisfactory score, and 42.1% were classified as unsatisfactory. However, following the training, 89.5% attained an outstanding score, 10.5% achieved a satisfactory score, and no unsatisfactory scores were recorded, indicating a substantial enhancement in knowledge of ergonomics within the office environment.

In the same study, the group that underwent an ergonomic redesign of the workstation and received training exhibited a significant reduction in general discomfort, particularly in the lower back, elbows, fingers, and legs, when compared to the control group (x2= 7.76, p<0.01). The authors conclude that an understanding of ergonomic principles related to office workstations and their redesign effectively mitigates musculoskeletal risks and discomfort associated with computer use. In our evaluation, discomfort was assessed using the Standardized Nordic Questionnaire at the onset of the intervention, one month later, and at three months. While no significant overall changes were observed, we did identify statistically significant differences between the groups (p: 0.04306). In the Emergency, Temporary, and Management work groups, there were reductions in the mean discomfort or pain reported in affected body parts (-1, -1, and -1, respectively).

Shariat et al. (2018) assessed the efficacy of exercise, ergonomic modifications, and a combination of both interventions on pain scores among office workers. Their findings indicated no significant differences (p>0.01) between the treatment groups (exercise and ergonomic redesign of the office workstation) after 2 and 4 months of intervention. However, all groups demonstrated significant improvement compared to the control group (no treatment) and their baseline scores, with the intervention exerting a significant effect (p <0.05) on discomfort scores related to neck, shoulder, and low back pain. In our study, while we did not evaluate the effectiveness of exercise, we assessed pain scores in office workers using the Nordic Questionnaire, administered at baseline, 1 month, and 3 months. The average sum of the parts affected by pain over the past 7 days was 2 points, remaining consistent throughout the study and deemed non-significant (p= 0.1927). Nevertheless, utilizing the ROSA method, we reported an average extreme risk of developing musculoskeletal disorders, with no significant changes observed during the study, irrespective of the interventions applied. We did, however, note a reduction in initial minimum scores from 6 points to 4 points after one month, which was statistically significant between work area groups (p= 0.0082). After 3 months, scores further decreased to 3 points, leading to the conclusion that some participants transitioned from extreme risk to very high risk, high risk, and even improvable categories, as per the risk classification of the ROSA methodology.

In the research conducted by Pereira M. et al. (2019), the immediate and long-term effects of workplace ergonomics and neck exercises administered by a physiotherapist were compared to ergonomics and health promotion through a one-month weekly seminar that addressed neck exercises and office ergonomics, specifically regarding days of absenteeism from work. Among office workers experiencing neck pain, those participating in the exercise program exhibited lower sickness absenteeism at the 12-month mark compared to those receiving health promotion information [0.7 days (SD 1.0) vs 1.4 days (SD 3.1); P=0.012], despite a short-term rise in sickness absenteeism post-intervention relative to baseline for the exercise group [1.2 days (SD 2.2) vs 0.6 days (SD 0.9); P<0.001]. The authors concluded that a workplace intervention integrating ergonomics and neck exercises contributes to a reduction in disability due to illness and enhances work productivity. In our study, we did not assess work absenteeism, which warrants consideration in future research; however, we did evaluate workplace ergonomics and pain across various body regions. Although we did not identify significant differences at one month and three months overall, we did observe statistical significance among work area groups (ROSA), with initial measurements showing a mean of 10 points (6-10, p: 0.0435), at one month a mean of 9 points (4-10, p: 0.0082, significant among work area groups), and at three months a mean of 9 points (3-10, p: 0.4862), indicating an extreme risk across the three evaluations. In the Nordic Standardized Questionnaire, the average sum of parts affected by pain over the past seven days was 2 points, remaining consistent throughout the study, yet it was statistically significant at one month among work groups (p: 0.04306). We concluded that, despite not observing a significant reduction in postural load, we noted minor changes that, with appropriate workplace redesign and extended monitoring beyond the three-month period, could yield more pronounced results.

Finally, Lee S. et al. (2021) conducted a comparison of pain intensity among office workers who underwent an ergonomic intervention. Their findings indicated that the neck region was the most significantly affected by pain, with improvements noted in neck symptoms, although modifications to the workstation proved insufficient. In terms of the shoulder, a reduction in symptom intensity was observed, as well as in the upper back, which was attributed to enhancements in thoracic spine positioning and increased support from the chair's backrest following the ergonomic intervention. Furthermore, they noted a slight increase in pain in the neck, shoulder, upper back, and wrist after 24 weeks, suggesting that this may have resulted from a lack of follow-up regarding the ergonomic adjustments made in the workplace. They recommended the implementation of periodic supervision of the work area, as the loss to follow-up was considerable: 19% after 12 weeks, 36% after 24 weeks, and 48% after 36 weeks. In our study, we did not assess pain intensity but rather the presence of pain or discomfort in affected body parts using the Standardized Nordic Questionnaire, both before and after an educational and redesign intervention. We found no significant changes overall, with an average of 2 affected parts initially, at one month, and at three months in the section concerning problems in the last 7 days. However, we did observe an increase in the range of affected points, which expanded from 0 to 8 affected parts at the outset (p: 0.6838) and from 0 to 9 affected parts at one month, remaining consistent at three months (p: 0.1927). This increase is suspected to have occurred due to insufficient follow-up in the control of ergonomics in the workplace for medical assistants, alongside a lack of awareness regarding discomforts associated with the work environment, as well as inadequate redesign in certain areas (such as the replacement of ergonomic chairs, adjustment of desks, and enhancement of computing equipment).

5.2 Conclusions

Following our educational intervention and the redesign of the workstation for the medical assistants under study, we observed an enhancement in postural load as assessed by the risk of musculoskeletal disorders using the ROSA methodology. The initial evaluation indicated an extreme risk for all medical assistants, which persisted in subsequent assessments; however, a statistically significant reduction in risk was noted when analyzed by work areas. The Nordic questionnaire revealed no differences in the affected body regions before and after the intervention, primarily due to the inability to implement a comprehensive workstation redesign owing to a lack of material resources at the time of the study. Additionally, an improvement in postural load was evident when analyzed by work areas.

We observed a notable enhancement in ergonomics knowledge among office personnel following our educational intervention, with assessments indicating satisfactory to outstanding performance, in contrast to the predominantly unsatisfactory results of the initial evaluation. It is important to note that for these improvements to be sustainable, ongoing training is essential. This motivates us to enhance workstations and uphold continuous training to achieve superior outcomes, ultimately broadening the scope of research into the optimization of office positions.

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