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Ergonomic evaluation of work sites in an aerospace maquiladora company

Evaluación ergonómica de sitios de trabajo en una empresa maquiladora de giro aeroespacial

RAMIREZ-CARDENAS, Ernesto†*, NARANJO-FLORES, Arnulfo, LOPEZ-ACOSTA, Mauricio and CORRAL-VELASQUEZ, Cristian Aarón

Instituto Tecnológico de Sonora

ID 1st Author: *Ernesto, Ramírez-Cárdenas* / **ORC ID:** 00-0002-5248-724X

ID 1st Co-author: *Arnulfo, Naranjo-Flores* / **ORC ID:** 0000-0002-5654-6091

ID 2nd Co-author: *Mauricio, López-Acosta* / **ORC ID:** 0000-0003-3728-9576, **Researcher ID Thomson:** X-4274-2019

ID 3rd Co-author: *Cristián Aarón, Corral-Velásquez* / **ORC ID:** 0009-0007-4477-0524

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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 practice of ergonomics in man-machine-environment systems is essential to eliminate risk factors associated with the presentation of musculoskeletal disorders (MSD), the reduction of occupational diseases and comply with current regulations, this being the objective of the present study. During the investigation, an exhaustive analysis of the different jobs was carried out and the ergonomic risk factors present in each of them were identified (inadequate postures, repetitive movements, excessive forces and unfavorable environmental conditions) and their level at through a specific evaluation method. Finally, specific intervention measures were proposed and applied to eliminate or reduce the level of risk. These measures included the redesign of work stations, the modification of equipment, tools, the implementation of active breaks and the training of staff in ergonomic practices. In conclusion, the results support the importance of incorporating ergonomics as an integral practice in work environments, in order to protect the health and well-being of workers, as well as improve the efficiency and productivity of organizations.

Ergonomic, Factors, Risk

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. La práctica de la ergonomía en los sistemas hombre-máquina-ambiente es fundamental para eliminar factores de riesgo asociados a la presentación de Trastornos musculo esqueléticos (TME), la disminución de enfermedades del tipo laboral y cumplir con la normatividad vigente siendo este el objetivo del presente estudio. Durante la investigación, se llevó a cabo un análisis exhaustivo de los diferentes puestos de trabajo y se identificaron los factores de riesgo ergonómicos presentes en cada uno de ellos (posturas inadecuadas, movimientos repetitivos, fuerzas excesivas y condiciones ambientales poco favorables) y su nivel a través de un método de evaluación específico. Para finalizar se propusieron y aplicaron medidas de intervención específicas para eliminar o reducir el nivel de riesgo. Estas medidas incluyeron el rediseño de estaciones de trabajo, la modificación de equipos, herramientas, la implementación de pausas activas y la capacitación del personal en prácticas ergonómicas. En conclusión, los resultados respaldan la importancia de incorporar la ergonomía como una práctica integral en los entornos laborales, con el fin de proteger la salud y el bienestar de los trabajadores, así como mejorar la eficiencia y productividad de las organizaciones

Ergonomía, Factores, Riesgo

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†Researcher contributing as first author.

Introduction

An accident at work, according to the Federal Labour Law (1970, pp 128), is any organic injury or functional disturbance, immediate or subsequent, death or disappearance resulting from a criminal act, produced suddenly in the course of or in connection with work, regardless of the place and time in which it is performed. Most accidents at work, according to the Mexican Institute of Social Security (IMSS), occur due to exposure to machinery, falls, overexertion and/or recklessness of workers (IMSS, 2023; Factorial, 2023).

The International Labour Organisation (ILO) notes that the cost of occupational accidents and diseases represents up to 4% of Gross Domestic Product (GDP) with a gradual increase in spending for IMSS from 2000 to 2017 in terms of subsidised days. These costs greatly affect the worker and the company (STPS, 2019).

In Sonora, statistics from the Mexican Institute of Social Security (□IMSS□, 2023) show that for the period 2021 occupational accidents increased by around 1500, and the average number of occupational diseases registered in the years 2020 and 2021 is 5 times higher than in previous years and the average number of incapacities amounts to 1571 cases (see Table 1).

Year	Employees	Accidents	Diseases	Disabilities
2015	561 756	15 784	749	1 472
2016	569 855	13 961	579	1 398
2017	587 633	14 848	679	1 581
2018	606 971	13 907	740	1 701
2019	618 880	13 511	586	1 739
2020	609 795	9 341	5 285	1 492
2021	620 718	10 854	3 042	1 611

Table 1 Occupational diseases and disabilities in Sonora
Source: IMSS Statistical Report (2023)

Among the most affected sectors is the aerospace industry, which is defined as all productive activity dedicated to the construction of aeroplanes, missiles, helicopters and satellites, as well as the equipment on which they depend (Carrincazeaux and Frigant 2007, pp.264).

Aerospace production in Mexico is concentrated in civil commercial aviation. Most exports are engines, airframes, landing gear, connecting systems, doors and other components.

Table 1 shows by State the number of factories dedicated to the production of aircraft parts.

State	Number of factories
Baja California	97
Sonora	58
Chihuahua	52
Querétaro	50
Nuevo León	33

Table 2 Number of aircraft parts manufacturing plants by State
Source: Aguilar (2020)

The company under study, located in Sonora, designs, manufactures and markets products for the automotive and aerospace sectors. During the last few months, it has been recording information related to occupational risks in three categories: Risks by month (figure 1), Risks by area (figure 2) and Risks by disease (figure 3).

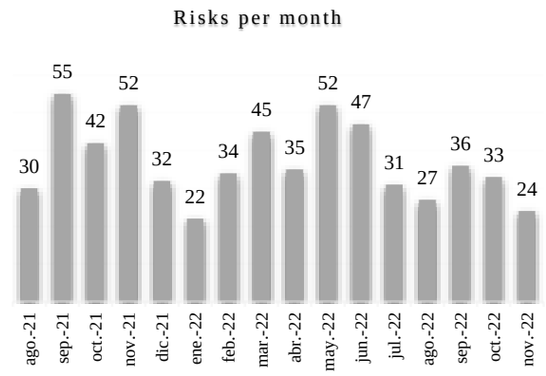

Figure 1 Risk register by month of consultation

Figure 1 shows the record of consultations related to occupational risks month by month, period August 2021- November 2022, averaging 37 per month with a cumulative total of almost 600.

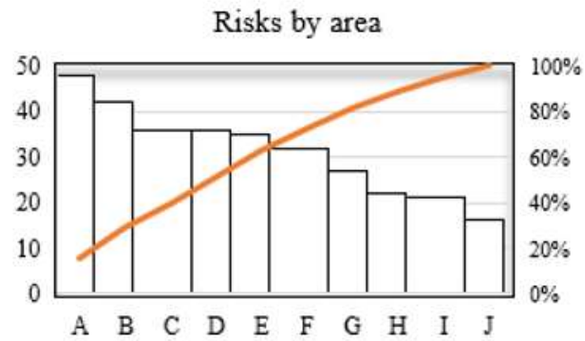

Figure 2 Risk register by work area

Figure 2 shows the accumulated risks by area, of which the first place and with the greatest opportunity for improvement is the process under study (A).

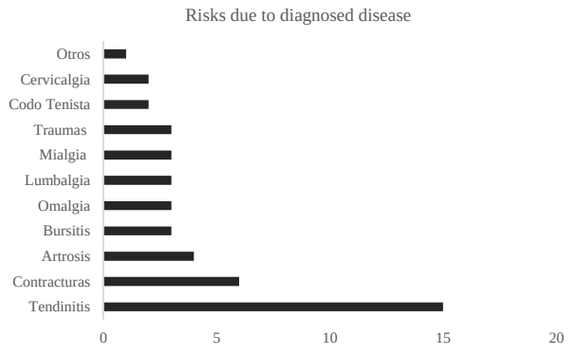

Figure 3 Number of probable risks in the process under study

Finally, Figure 3 shows the different work-related illnesses, where 15 people presented tendinitis, 6 contractures, 4 arthrosis and some others related to Musculoskeletal Disorders (MSD).

According to Llaneza (2009) MSDs are injuries or disorders of the muscles, nerves, tendons, joints, cartilage and upper and lower limbs, and injuries that occur in the neck, lower back, aggravated by exertion or prolonged exposure to physical factors such as repetition, force, vibration or awkward posture. Symptoms are muscle and/or joint pain, tingling, loss of strength and decreased sensation. Ergonomics is a helpful discipline to counteract this type of ailment.

Ergonomics is the scientific study of human work (Pheasant, 1991, p. 3), applying scientific principles, methods and data from a variety of disciplines (Kroemer, Kroemer & Kroemer-Elbert, 2001), to contribute to the design of all types of systems with three fundamental characteristics: (1) a systems approach, (2) it is design-driven and (3) it focuses on performance and well-being (Dul, et.al., 2012).

Ergonomic assessment of workplaces requires a broad and deep knowledge of the problems related to physical risk factors in order to understand the causes of their alterations, wear and tear and other adverse health effects (Avila, 2014).

On carrying out a tour of the company facilities under study, images were captured of two operators carrying out their work (figure 4), followed by an interview with the personnel in charge and a rapid assessment of the job was carried out using the "Rapid Upper Limb Assessment" (RULA) method based on the methodology suggested by Diego-Mas (2015), whose method focuses on the upper limbs when the activity presents excessive postural load (Mcatamney, 1993, pp.91-99).

Figure 4 Postures subject to rapid assessment

As can be seen in the figure above, the operators' postures are not very correct at first sight, which can lead to the presence of MSDs. The risk level obtained as a result of the RULA assessment was 7, making it necessary to study and modify the activity immediately.

In this context, added to the interest of the company under study to provide better working conditions and adhere to current regulations (remember that by the end of 2018 was approved in Mexico the NOM-036-STPS-2018 Ergonomic Risk Factors at Work-Identification, analysis, prevention and control where companies are required to generate actions or studies in Ergonomic matters) the following research 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 occupational diseases?

Objective

To ergonomically evaluate the man-machine-environment system of the maquiladora company in order to eliminate risk factors associated with the occurrence of MSDs and occupational diseases, and to comply with current regulations.

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Method

The object of study of this research is represented by the assembly line of components with the highest incidence of occupational hazards. The method used to answer the research question is the development of the ergonomic analysis through a lean approach (Womack, 2005) and thus implement the actions or proposals for improvement. The procedure is described below.

Characterise the current situation: This step starts with the identification of the person responsible for carrying out the process of defining the problem, who can be part of the business or an external agent. Following this, a process diagram was drawn up.

Define the problem: The problem was defined based on records of incidents, accidents, occupational diseases, visits to medical and/or disability services, as well as the result of interviews with workers to identify tasks or activities that they consider may contribute to MSDs.

Determine jobs to be evaluated: In order to determine the jobs to be assessed, the number of risk factors was considered with the aim of prioritising the activities with the highest degree of urgency.

Characterise tasks through observation: In this section it is necessary to describe the operator's activity, taking into account each relevant movement, to achieve this, video should be taken of at least 10 cycles of the operation or 30 minutes of it. The video should be taken with a camera and the whole body of the operator should be visible in the image in order to capture the image whose posture is considered to be the most risky. The information is recorded in a table that integrates: the number assigned to the task, the reference image, the description of the task, relevant data prior to the assessment (average age, number of employees, hours per shift, frequency) and additional information derived from the observation of the workplace or posture.

Assess method and posture at workstations: Once the characterisation of each workstation was obtained, the ergonomic assessment was carried out using the following steps:

1) Write data in the header such as name of the department, division, and name of the activity; 2) Description of force, posture and frequency; 3) Assign scores to: Neck, shoulders, back, arms-elbows, wrist, hand, legs, and static postures. The scores range from 0 to 20 points, where 0-5 is low (green colour), 10 moderate (yellow colour) and 15-20 high (red colour); 4) Add scores, the algebraic sum of the scores assigned to each limb will be used to determine if the level of risk, for this 0 to 40 is Low Risk, 41 to 85 is Moderate Risk and 85 to 100 is High Risk.

Assess lifting at workstations: The first step was to observe the working conditions, such as steps, slippery surfaces or hot and cold environments that affect the lifting task. Once the conditions were identified, scores were assigned according to: Object Weight, ranging from 0 to 30 points if the weight equals or exceeds 23. 1 kg; Horizontal Distance (HD), the distance between the worker and the object while holding it, ranges from 0 to 30 points when HD equals or exceeds 63.5 cm; Initial Height (IH), this factor is scored according to whether a worker must bend or raise the arm to grasp the object to be lifted; Lifting or Lowering Distance (LD/B), here it is scored in relation to the distance the object is lifted or lowered; Frequency, which is assigned according to the number of times the object is lifted every minute or hour; Angle of Trunk Twist, which is determined by the angle of contortion of the upper body while lifting, without the employee moving their feet; Quality of Grip, which is good when the object is shaped to grip and bad when it has sharp edges, slippery or hot objects, and; Carrying Distance, the distance the object is carried.

Generate improvement actions: In this section, a list of actions was obtained to reduce the ergonomic risk factors to which the personnel are exposed.

Results

The first step of the study consisted of appointing the supervisor of the area as the agent of change and/or in charge of improving the process, and then identifying the staff with the highest incidence of medical service according to the report of possible risks issued by the medical staff during the period January-December 2022.

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Based on this, it was determined that it is the component assembly area that has the highest incidence of risk (see figure 2) and whose assembly process and recorded incidents are shown in figure 5.

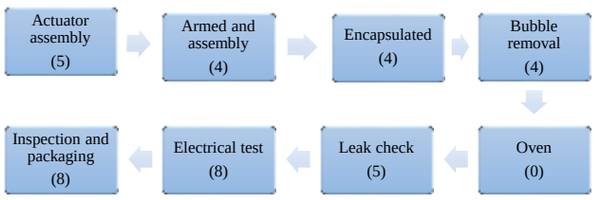

Figure 5 Process diagram of the area under study

The figure shows the activities of the assembly process under study and the number of cases of probable risks or incidents recorded for each activity, totalling 38. Due to the small difference in the number of cases per activity, it was decided to evaluate all the posts from the actuator to the packaging of the finished product.

As a prior step to the evaluation, each task was characterised by means of observation and data recording, in order to better understand the situation and in which the following stand out: identification of the posture by means of an image, a detailed description of the activities carried out by the operator, as well as relevant data and information (see table 3).

	Task	Task description
1	Actuator assembly  Age <45 No. Employees 2 Hours per shift 11 Frequency 450 /day	The operation consists of making small assemblies through pressing for which the operator operates a lever by means of a clamp-type gripper. Additional information It performs clamp-type gripping. There is no rotation in the task.
2	Actuator assembly  Age <45 No. Employees 2 Hours per shift 11 Frequency 450 /day	Wrap the relay with a metal shell and place two gaskets manually and then place it in an assembly press. Additional information There is torsion of the trunk and raised arm. There is no rotation in the task.
3	Encapsulation  Age <45 No. Employees 1 Hours per shift 11 Frequency 900 /day	Place epoxy resin in each piece according to a specified maximum level. Additional information Awkward postures, poor vision, elbows away from the body and elevated shoulders. No rotation in the task.
4	Bubble elimination  Age <45 No. Employees 1 Hours per shift 11 Frequency Not applicable	Eliminate, by means of a hot air gun, the possible bubbles present as a result of the resin placement. Additional information This task is performed for 10 minutes, in intervals longer than 2 minutes. Shoulder is elevated and arms suspended in the air without support. No rotation in the task
5	Oven  Age <45 No. Employees 1 Hours per shift 11 Frequency Not applicable	Place the pieces with resin in the ovens to be heated for 5 hours. Additional information Handling loads up to 19 lbs (8 kg), awkward posture during lifting. No rotation in the task.
6	leakage check  Age <45 No. Employees 2 Hours per shift 11 Frequency 450 /day	Verify that the product does not leak by injecting nitrogen. Additional information Raised arm during activity (very high table). No rotation in the task.
7	Electrical test  Age <45 No. Employees 1 Hours per shift 11 Frequency 450 /day	Check the correct operation of the product by electrical test according to specifications. Additional information Operator remains on her feet throughout the day. No rotation in the task
8	Inspection and packaging  Age <45 No. Employees 2 Hours per shift 11 Frequency 45 /day	This operation consists of packing 20 pieces per box and placing a label with the established format. Afterwards, it is verified that the pieces are not damaged, cables with resin and that there are no missing pieces. Additional information Handling of 8 to 11 kg loads in different locations. No rotation in the task.

Table 3 Characterisation of the tasks of the process under study

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As a result of the observation, the following were identified: pincer-type grip, torsion of the trunk, raised arm suspended without support, uncomfortable postures, poor vision, elbows separated from the body, raised shoulders, standing operators, no rotation in the task and in some cases in particular the handling of loads of up to 11 kg. Tables 4 and 5 present the results of the evaluation of workstations and lifting of loads.

Activity	Neck	Shoulders	Back	Arms and elbows	Doll	Hands	Legs	Static postures	Points
Actuator assembly	10	10	5	0	10	15	5	10	65
Armed and assembly	10	15	10	10	5	10	5	5	70
Encapsulated	10	15	10	5	5	5	10	5	65
Bubble removal	10	15	15	10	5	10	5	5	75
Oven	10	10	10	5	10	0	0	0	45
Leak check	10	15	10	10	5	5	5	5	65
Electrical test	10	10	15	10	5	10	10	15	85
Inspection and packaging	10	10	5	5	10	10	5	15	70

> 85 = High
40 a 84= Middle
<40= Low

Table 4 Job evaluation results

Activity	Weight	Horizontal distance	Initial height	Lifting distance	Frequency	Turning angle	Grip	Distance charge	Points
Actuator assembly	1	1	1	1	1	5	1	1	12
Armed and assembly	1	1	1	1	1	5	1	1	12
Encapsulated	10	1	1	10	1	5	1	1	30
Bubble removal	10	1	1	5	1	5	1	1	25
Oven	10	5	1	5	10	10	1	1	43
Leak check	10	1	1	1	5	5	1	5	29
Electrical test	10	5	1	1	10	20	1	1	49
Inspection and packaging	20	1	10	10	5	5	5	1	57

> 85 = High
40 a 84= Middle
<40= Low

Table 5 Results of the assessment of the lifting of loads

According to the results of the previous table in relation to the method and postures (section 1), the activity Final inspection is the one with the highest risk level, scoring 85 points, and therefore changes must be made urgently. The rest of the activities result in moderate risk, so they must attend to the extremity whose qualification has been marked in red, as is the case of shoulders, which appears in this condition in 4 of the 8 activities.

With regard to manual handling of loads, 3 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 that should be focused on.

Finally, there are some actions for improvement:

Implement intervention measures: Based on the results of the ergonomic assessments, implement specific intervention measures to eliminate or reduce the identified risk factors. These measures may include redesigning workstations, modifying equipment and tools, introducing active breaks, modifying the method and improving environmental conditions. The aim is to achieve a low risk rating (green).

– Establish an ergonomic team: Form a multidisciplinary team composed of professionals in ergonomics, occupational health and safety, human resources and workers. This team will be responsible for leading ergonomic activities and ensuring their effective implementation.

– Train staff: Provide ergonomics training and awareness to all employees. It is important to educate workers about the risks associated with MSDs, basic ergonomic principles and best practices to prevent work-related injuries.

– Conduct regular ergonomic assessments: Establish a regular programme of ergonomic assessments to proactively identify and address risk factors. These assessments can include analyses of postures, movements, forces and environmental conditions, as well as staff satisfaction and well-being surveys.

– Promote worker participation: Involve workers in the process of identifying risks and finding ergonomic solutions. Foster a participatory culture in which employees feel empowered to report problems and suggest improvements.

– Follow-up and evaluate results: Regularly monitor the results of implemented ergonomic measures. Evaluate the effectiveness of interventions in reducing risk factors and in the overall well-being of workers. Make continuous adjustments and improvements based on findings and feedback.

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– Keep up to date with current regulations: Maintain up-to-date knowledge of ergonomics standards and regulations. Ensuring compliance with relevant standards and legal requirements and making necessary adjustments in line with regulatory changes.

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Conclusions

In conclusion, according to the results, the objective of ergonomically evaluating the man-machine-environment system of the maquiladora company to eliminate risk factors associated with the presentation of MSDs and occupational diseases, and to comply with current regulations, was achieved. This study contributes to the achievement of a safe and healthy working environment for its employees, a better image and to avoid possible legal sanctions.

It is advisable to continue working on the ergonomic evaluation of all the different workstations for the timely identification of the risk factors present such as: inadequate postures, repetitive movements, excessive forces, vibrations and unfavourable environmental conditions. This will contribute to a better working environment and to the success of the organisation.

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