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Interdisciplinary Faculty of Economic and Administrative Sciences

RESEARCH

Ergonomic design of a sequencing workstation in an automotive manufacturing process

Diseño ergonómico de una estación de trabajo de secuenciado en un proceso de manufactura automotriz

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Abstract

Ergonomics has gained importance in modern industry as a key tool to optimize workplace well-being and productivity. This study presents an ergonomic redesign of a workstation in an automotive plant, aligned with the guidelines of the Mexican standard NOM-036-STPS-2018, related to the manual handling of loads. Analytical tools such as RULA, REBA, Sue Rodgers, and the NIOSH equation were used to identify critical postures and physical loads associated with material handling (fuel tanks), taking into account factors such as applied force, frequency, and task duration.

The project positively impacted the reduction of ergonomic risks and the prevention of musculoskeletal disorders (MSDs) among workers. The results highlighted the need to incorporate specific ergonomic aids and solutions for the workstation, which reduce or eliminate direct manual load handling. Furthermore, caloric expenditure studies and the RAPP Tool confirmed that the tasks can be performed within safe physical limits. The redesign of the work sequence not only ensures compliance with current regulations but also promotes a safer working environment, minimizing injury risk and enhancing operational efficiency.

Keywords: ergonomics, manufacturing, workstation design, manual material handling.

JEL Codes: J81, L62, M54, O14

Resumen

La ergonomía ha cobrado relevancia en la industria moderna como una herramienta clave para optimizar el bienestar laboral y la productividad. Se presenta un estudio enfocado en el rediseño ergonómico de una estación de trabajo en una planta automotriz, bajo los lineamientos de la norma mexicana NOM-036-STPS-2018, relativa al manejo manual de cargas. Se utilizaron herramientas de análisis como RULA, REBA, Sue Rodgers y la ecuación NIOSH para identificar posturas críticas y cargas físicas asociadas a la manipulación de material (tanques de combustible), considerando factores como fuerza

aplicada, frecuencia y duración de la actividad.

Se logró impactar positivamente en la reducción de riesgos ergonómicos, así como en la prevención de trastornos musculoesqueléticos (TME) entre los trabajadores. Los resultados evidenciaron la necesidad de incorporar soluciones y ayudas ergonómicas específicas para la estación de trabajo, las cuales reducen o eliminan la carga manual directa. Además, los estudios de gasto calórico y RAPP Tool confirmaron que las tareas pueden realizarse dentro de los márgenes de seguridad física permitidos. El rediseño de la secuencia de trabajo no impacta únicamente el cumplimiento de la normativa vigente, también promueve un ambiente de trabajo más seguro, minimizando el riesgo de lesiones e incrementando la eficiencia operativa.

Palabras Clave: ergonomía, manufactura, diseño de estaciones, manejo manual de cargas.

Códigos JEL: J81, L62, M54, O14

Introduction

Currently, organizations particularly those in industrial processes recognize the positive impact of ergonomics on productivity, occupational safety, increased job satisfaction, and cost reduction. As a result, the consideration of human factors provided by this branch of engineering has become essential in the design of production processes, contributing to the creation of healthier, more efficient, and more productive work environments for employees.

The study of ergonomics is not new; however, its recognition as a scientific discipline began in the 1940s (Torres & Rodríguez, 2021). During the same decade, Mexico established the Secretaría del Trabajo y Previsión Social (STPS), aimed at ensuring compliance with labor rights and improving workers' quality of life. Currently, there are 41 active Mexican Official Standards (NOMs) related to occupational health and safety, classified into five areas: safety, health, organization, specific, and product-related standards.

In 2018, the STPS issued NOM-036-1-STPS-2018, which outlines the requirements to identify, analyze, prevent, and control ergonomic risk factors in workplaces resulting from manual load handling, with the goal of preventing health impairments (Secretaría del Trabajo y Previsión Social, 2018). The publication of this regulation necessitated significant changes in many processes involving such activities. Although it was published in November 2018, full compliance was granted a grace period until March 31, 2024.

An assembly line, also known as a production line, is a manufacturing process in which a product is assembled sequentially through various workstations, each responsible for a specific task. At each station, components are added or operations are carried out until the semi-finished product moves to the next stage.

This research was conducted at a stamping and assembly automotive plant, where the final assembly processes include work sequences that require manual load handling, a situation common across many operations in the automotive industry (Bahramian et al., 2021).

The objective of the research is the ergonomic design of a sequencing workstation. This involves the integration of a secondary element into a variant of the main assembly in a pre-established sequence within the production flow, using ergonomic aids that allow personnel to handle and move the product safely and in accordance with ergonomic principles. The design also ensures compliance with Mexican regulations and the specific standards required by the automotive manufacturer, aiming to minimize the risk of musculoskeletal disorders (MSDs) and related injuries.

Theoretical Framework

2.1 Occupational risks

S According to data from the International Labour Organization (ILO, 2011a), approximately 160 million people worldwide suffer from non-life-threatening illnesses and injuries each year due to work-related activities. Technological advancements, social transformations, and economic changes have created new challenges and exacerbated existing ones, with a significant proportion related to musculoskeletal disorders (MSDs).

Nationally, statistics from the Mexican Social Security Institute (IMSS) show that in 2020, there were 4,315 cases of osteoarticular diseases in Mexico, accounting for 42.35% of all work-related health conditions. The primary cause of these cases was identified as inflammatory back conditions. Furthermore, a study conducted by the National Rehabilitation Institute (2014) on patients with musculoskeletal pain revealed that 11.5% of the 3,508 individuals surveyed performed manual labor as machine operators, mechanical artisans, or installation operators.

Hazardous working conditions such as lifting heavy objects, exposure to vibration, awkward postures, neck twisting, and high-repetition tasks cause musculoskeletal disorders. These injuries affect the musculoskeletal system and joints due to the high physical demands arising from inadequate workspace design or work methods (Jirapongsuwan et al., 2023). MSDs impact bones, muscles, joints, tendons, ligaments, nerves, and blood vessels.

2.2 Egronomics

Ergonomics is the discipline that analyzes work in relation to the environment and the people performing it. It is based on principles of human physical and psychological capabilities to adapt or design equipment, tools, and workspaces to reduce the risk of injuries and illnesses, improve efficiency, and enhance quality of life in the workplace (ILO, 2011b). Although its formal conception dates back to 1949 (Lehto & Landry, 2012), its relevance has steadily grown in industrial contexts.

2.3 Regulations for evaluating manual load risks

An occupational risk refers to the likelihood of a worker suffering harm to their health or physical integrity due to work activities. Such harm may include diseases, injuries, or conditions caused by work environment factors, chemical agents, physical hazards, or psychosocial elements. As industrialization progresses and technology becomes more embedded in production systems, positive contributions have emerged. However, this fast pace has also led to an increase in MSD-related illnesses. Handling materials, tools, and machinery has contributed to workplace accidents (Simsek & Turhan, 2023), negatively impacting process efficiency and resulting in worker absences (Safaeian et al., 2021).

In response, international regulations have been established, including ISO-11228-1 (2021) and HSE (Health and Safety Executive, 2020), which set guidelines for safe manual lifting, recommending maximum loads of 25 kg. Similarly, the U.S. National Institute for Occupational Safety and Health (NIOSH) sets the limit at 23 kg (2021).

In Mexico, NOM-036-STPS-2018 defines the necessary elements to identify, evaluate, anticipate, and manage ergonomic risks associated with manual load handling in workplaces. This standard applies to tasks involving loads of 3 kg or more that are handled more than once per day, setting the manual handling limit at 25 kg. Its implementation requires considering preventive measures such as applied force, vertical and horizontal transport distances, frequency of movements per minute, total task duration, and body postures during the activity (STPS, 2018).

Additionally, several methods are used to evaluate postural load: RULA (Rapid Upper Limb Assessment), it analyzes critical postures during assembly work. It evaluates Group A (arm, forearm, and wrists) and Group B (legs, trunk, and neck) on both the right and left sides (Diego-Mas, 2015a). REBA (Rapid Entire Body Assessment): Complementary to RULA, it analyzes the entire body, including the upper limbs, trunk, neck, and legs, and considers static muscle activity and force exerted (Diego-Mas, 2015b; Yazdanirad et al., 2018). NIOSH Lifting Equation: Assesses the risk of MSDs using seven task-specific parameters (Diego-Mas, 2015c; NIOSH, 2021). Sue Rodgers Method: Evaluates muscle effort levels, effort duration before rest, and activation frequency per minute, predicting muscular fatigue based on task duration and posture (Rodgers, 1988).

2.4 Caloric expenditure estimation

The American Medical Association (AMA) does not prescribe a single formula for estimating caloric expenditure but endorses scientifically validated methods for calculating Basal Energy Expenditure (BEE) and Total Energy Expenditure (TEE) (AMA, 2008). BEE represents the number of calories the body requires at complete rest to maintain vital functions such as breathing, heart rate, and body temperature. The Mifflin-St Jeor formula is one of the most accurate for BEE estimation (Mifflin et al., 1990). TEE is then calculated by multiplying BEE by a physical activity factor ranging from 1.2 (sedentary) to 1.9 (very active). Other influencing factors include body composition, physiological state, age, sex, and thermogenesis from food intake (AMA, 2008).

2.5 Related studies

In a study by López and Martínez (2019), workers on a home appliance assembly line in Spain performed manual lifting and transporting tasks. Pneumatic assist devices were implemented to lift components, work surface heights were adjusted, and a task rotation scheme was introduced. These interventions reduced the RULA risk score from 7 to 3, corresponding to a change from very high to low-moderate risk.

Martínez and González (2022) conducted a study on an automotive engine assembly line in Barcelona, Spain, where manual handling of components weighing up to 15 kg was performed. The NIOSH lifting index was reduced from 2.1 (high risk) to 0.85 (acceptable risk). This improvement was achieved through the introduction of mechanical lifting aids and the reorganization of tools and equipment within workstations to minimize workers' body twisting.

In the research by González and Herrera (2020), carried out in a motorcycle assembly plant in Colombia where engines and wheels were manually lifted, the assembly sequence and workstation layout were redesigned to reduce material handling and carrying distances. Additionally, height-adjustable work surfaces were introduced. These changes led to a reduction in lower back injury risk, minimized idle times, and significantly decreased the number of work-related disability cases due to lower back injuries.

Methodology

This study adopts a non-experimental approach. The research setting was observed in its natural environment without altering any variables (Fernández-Collado & Baptista-Lucio, 2014). The study was conducted over a six-month period, during which the production process operated under normal conditions. Observations were made across all three shifts in the final assembly area of an automotive stamping and assembly plant located in Hermosillo, Mexico. The sample included 80 observations/evaluations during this period. Operators included in the study were those assigned to the workstation under analysis, performing tasks that involve manual load handling and repetitive physical efforts. A design/redesign method is proposed for workstations where manual handling activities occur (e.g., lifting, moving, pushing, holding), taking into account dimensional, environmental, and regulatory aspects. The methodology consists of five phases, described below:

3.1 Preliminary analysis

This phase involves a technical review of the characteristics and conditions under which tasks are performed at the workstation. The automotive manufacturer adheres to two types of regulations: Mexican Official Standards (NOMs)and its own internal standards and evaluation methods.

The first step was to analyze applicable Mexican standards. The STPS provides a web-based tool to identify relevant NOMs based on specific process characteristics (STPS, 2025), which are categorized into safety, health, and organizational standards. Organizationally, and for each type of manufacturing process, it is essential to identify the occupational safety and risk standards that must be met. The outcome of this analysis is a list of applicable standards and regulations to be considered in the design or redesign of the workstation.

3.2 Initial design

3.2.1 Problem Identification and Risk Conditions: Based on a review of internal (NOM) and external standards, the specific risks and issues associated with the task are identified.

3.2.2 Ergonomic Risk Assessment: Ergonomic risk factors to which workers are exposed are identified in order to guide appropriate workstation design.

3.2.3 Workstation Design: Considerations include the dimensions of the work area, anthropometric data, internal company standards, and applicable regulations.

3.2.4 Design of Tools and Support Devices: Ergonomic aids for lifting and manual handling specific to the assembly sequence are designed. These tools are developed in accordance with the standards identified in Phase 1, with a focus on mitigating identified risks through the ergonomic support elements of the workstation.

3.3 Design validation

With the risks already identified, proposed redesigns of workstation layout and prototypes of ergonomic aids for manual handling and transport were developed and implemented.

A preliminary risk assessment was conducted using a checklist aligned with relevant NOMs and the automotive manufacturer's internal evaluation methods. Based on the assessment results, adjustments were made to both the work sequence and the physical layout of the station.

3.4 Implementation

This phase involved executing the redesign through detailed planning, including start and end times for each activity, workstation dimensions, environmental conditions, ergonomic aids, tools, and necessary process control softwareinstallations.

Upon completion, operators and supervisors were trained, trial production runs were conducted, and initial cycle times were calculated. Following this pilot phase, adjustments were made to station layout, work sequences, and ergonomic aids as needed.

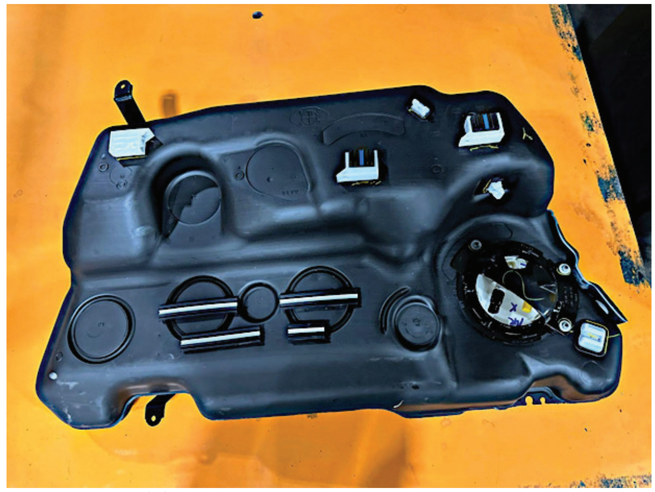
3.5 Continous improvement

Based on issues identified in the initial design whether related to physical layout, environmental conditions, or ergonomic aids as well as problems discovered in the work sequence, it will be evaluated whether it is necessary to repeat the design process from Phase 1. This would aim to address overlooked risks or improve existing conditions.

Results

The assembly line processes two types of automotive units, which share the same platform; however, the main assembly component fuel tanks has minor variations between the two vehicle types. Figure 1 shows one of the types of fuel tanks.

Figure 1. Type 1 fuel tank



Source: Own elaboration

4.1 Preliminary analysis

4.1.1. General standards and regulations

To comply with Mexican regulations, NOM-STPS-036 (2018) regarding the manual handling of materials was considered. In terms of safety conditions, the following Official Mexican Standards were met:

- NOM-004-STPS: Protection systems and safety devices on machinery and equipment used in the workplace (1999)
- NOM-006-STPS: Handling and storage of materials (2014)
- Similarly, for the health approach, the following standards were taken into account:
- NOM-011-STPS: Safety and hygiene conditions in workplaces where noise is generated (2001)
- NOM-024-STPS: Safety and hygiene conditions in workplaces where vibrations are generated (2001)
- NOM-025-STPS: Lighting conditions in the workplace (2008)

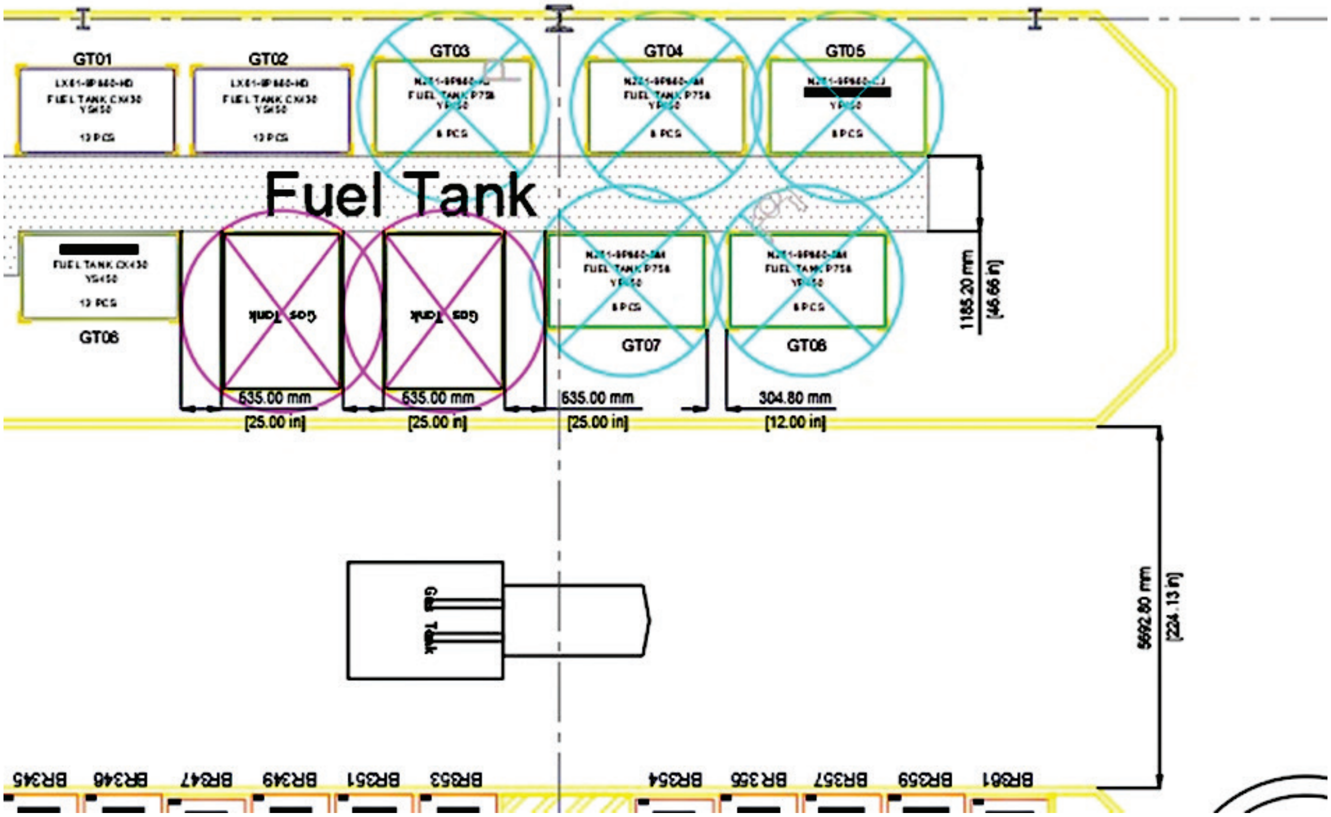
4.1.2. Internal standards

Internal directives and standards were also taken into consideration. These relate to the company's own workstation design principles, mainly concerning shelf design, aisle (traffic) dimensions, minimum space for handling and supplying materials, and general dimensions of work areas. The starting point was a verification of the characteristics of similar workstations within the assembly line, along with a meeting with final assembly management to receive design recommendations.

4.2 Initial design

The initial design of the station's physical layout was developed (Figure 2), considering appropriate dimensions for efficient handling of the supply area where sequenced material is located towards the assembly cell for the tank to the vehicle unit. The size of the material packaging was adjusted

Figure 2. Physical layout of the workstation



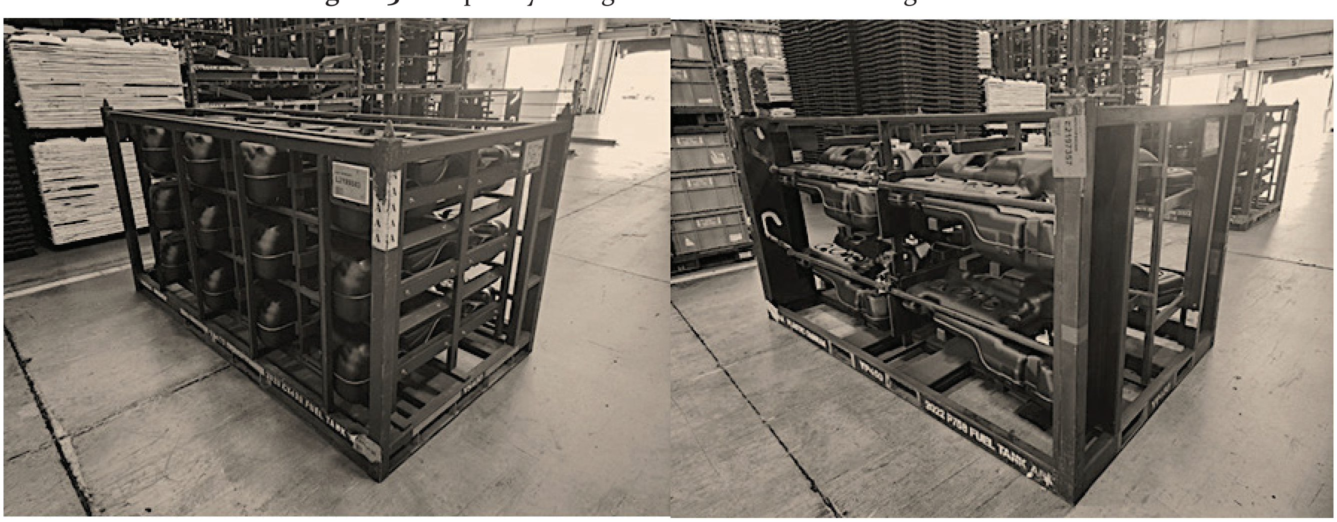
Source: Own elaboration

to facilitate operations and minimize the physical effort required from the operators.

Prototypes of two sequenced transport and temporary storage devices were designed and manufactured for the types of fuel tanks to be installed in the two automobile models processed on the assembly line (figure 3).

Finally, an ergonomic aid prototype was designed and built (Figure 4), specifically to efficiently transfer material from the storage racks to the location where the vehicle will be for installation. This aid completely eliminates the need for operators to carry the material during transfer, thereby reducing physical effort and minimizing potential risks associated with lifting or manual

Figure 3. Temporary storage rack for fuel tanks. Designs 1 and 2



Source: Own elaboration

handling. To ensure smooth and easy movement of this device across the work area, the ergonomic aid was equipped with bearings that move along rails installed between the aisles designated for material traffic.

Figure 4. Ergronomic aid

Source: Own elaboration

4.3 Design validation

During this phase, ergonomic evaluations of the workstation were carried out over a trial period. In addition, feedback and improvement suggestions were gathered from operators and supervisory personnel, considering that at this initial stage the workstation had not yet been permanently incorporated into the production line.

4.3.1 Postural risk assesment – Sue Rodgers Method

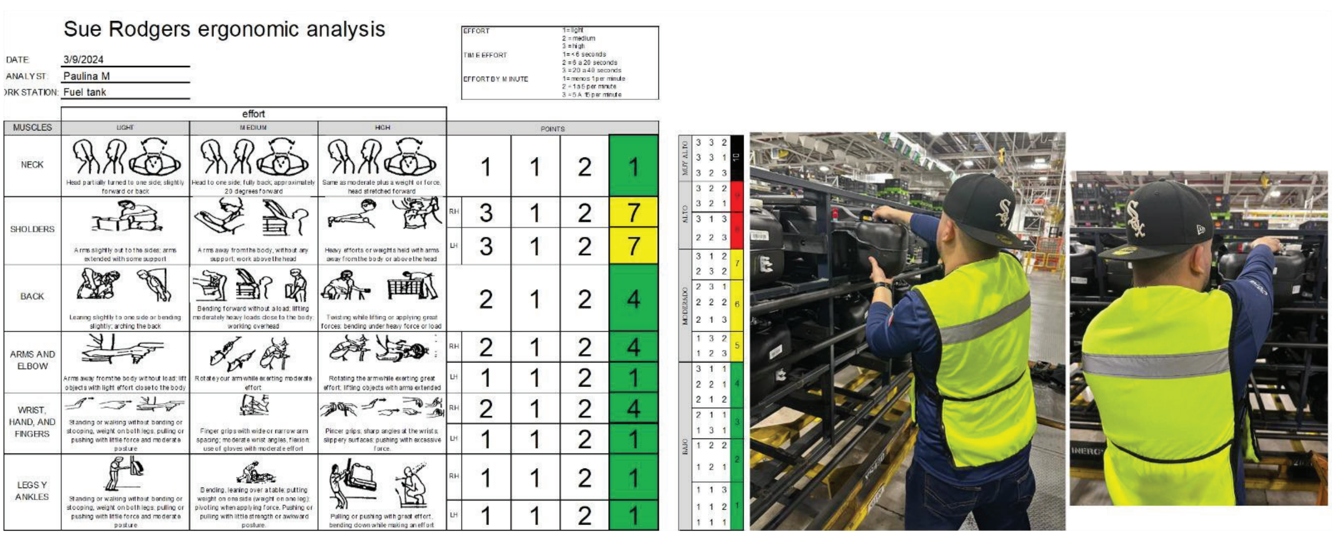
A detailed analysis was conducted using the Sue Rodgers ergonomic assessment method, which focused on evaluating the most demanding postures in the work sequence. Clearly, during the assembly sequence, the operator adopts various postures, among which the most hazardous were analyzed. The material handling process was precisely defined, taking into account both the posture required and the applied force. Based on this, it was determined that the sustained effort lasted less than 6 seconds, placing it within the recommended limits to prevent muscle fatigue.

However, it is important to note that the weight of the handled material (fuel tanks) ranges between 9 and 13 kilograms, which requires careful analysis of the physical load this represents for the workers involved in the task. The evaluation results are presented for the two products that will be processed at the workstation, along with images of the high-risk postures during the assembly sequence (Figures 5 and 6).

In the case of postural effort related to the handling of fuel tanks installed in model 1, it was found that the right shoulder is the most affected, with a score of 7, indicating significant strain. In addition, the arms and back showed sustained load with scores of 4, while wrists, hands, neck, and legs experienced lower levels of effort. The analysis highlights the importance of implementing breaks to reduce physical strain and prevent injuries.

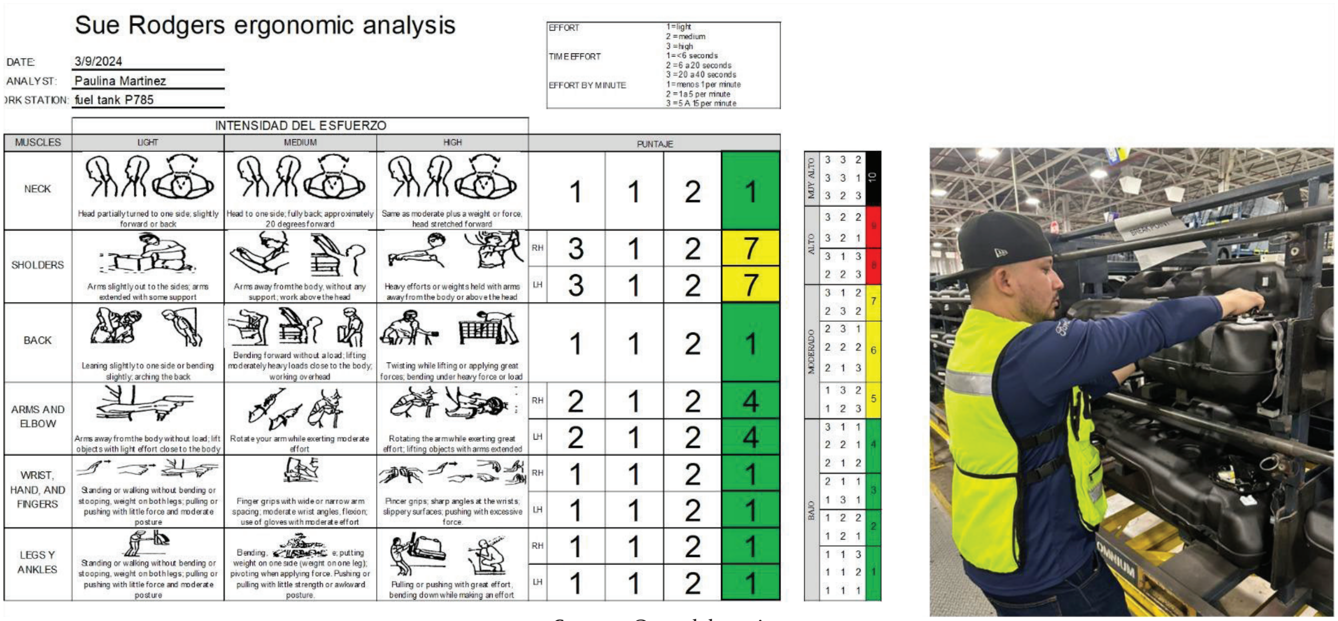
The ergonomic study of the sequenced tank rack identified the shoulders as the most affected area, with a score of 7, reflecting high and sustained

Figure 5. Sue Rodgers anaysis for fuel tank model 1



Source: Own elaboration

Figure 6. Sue Rodgers analysis for fuel tank model 2



Source: Own elaboration

effort due to a fixed posture with raised arms. The back, arms, and elbows showed moderate to high risk, with scores of 4 due to repetitive and continuous movements. In contrast, the wrists, hands, and fingers showed low effort with a score of 2, while legs and ankles experienced a moderate load with a score of 4 due to prolonged weight bearing. These results underscore the importance of adjusting posture and task duration to minimize ergonomic impact.

4.3.2 Caloric. expenditure

An Excel template was used to calculate caloric expenditure during the specific assembly sequence at the station, based on the method recommended by the American Medical Association (AMA). See Figure 7.

For the activity sequence in each cycle, arm movement was considered moderate, with displacements greater than 50 cm. Additionally, it was calculated that the operator walks approximately 8 meters per minute. The weight of the parts exceeds 5 kg. The task frequency (speed) was considered moderate. Finally, it was considered that material handling requires considerable effort when pushing or pulling with a force of 13 kg and a displacement of 1 meter per minute. Based on this data, the total metabolic expenditure for performing the task is 270.4 Kcal/hr, considering different activities such as arm movement (50 Kcal/hr), walking (16 Kcal/hr), task execution (52 Kcal/hr), and material handling (33.8 Kcal/hr).

It was determined that a male operator has the capacity to work up to 826 minutes, meaning a 420-minute work shift would not pose any problem. In the case of female operators, work capacity was calculated at 470 minutes, a value closer to the length of the work shift. Nonetheless, both fall within the permitted range, indicating that the activity can be carried out without issues during the workday (see Figure 8).

4.3.3 RAPP Tool

The RAPP (Risk Assessment of Pushing and Pulling) method (HSE, 2016) is used to analyze risks associated with manual pushing and pulling operations. It helps identify high-risk activities and evaluate the effectiveness of risk-reduction measures, particularly those involving full-body effort. With the inclusion of ergonomic aids (devices that improve operator comfort, safety, and efficiency during a task) for movement (Figure 4), RAPP results were obtained for the workstation (Figure 9).

The RAPP assessment results show that most of the factors analyzed such as load weight, posture, grip, transport distance, and equipment condition scored 0, indicating no significant risk. However, work pace scored a 3, suggesting a moderate risk level and indicating that adjustments are needed. Overall, the total score of 3 suggests that the ergonomic condition is acceptable, but it is advisable to review the work pace to optimize the operation.

Figure 7. Energy expenditure calculation at the workstation

AMAA PREDICTIVE METHOD			
DATE	12/11/2023	WORK STATION	Gasoline tanks
JOB DESCRIPTION			
Sequencing of gasoline tanks			
GENDER (M/F)	F	AGE	20
WORK TIME ANALYSIS (MIN):	420		
ANALYST:			

METABOLIC ENERGY EXPENDITURE		
A.- Arm Movements		
0	• If there is little arm/hand movement	
1	• If arm/hand movements are within 50 centimeters	
2	• If arm/hand movements exceed 50 centimeters	
3	• If there are inclinations, twists, and extreme reaches	
Arm movement contribution (1, 2 ó 3):		2
B.- Walking		
	Average distance walked per minute	
Walking contribution (meters/min):		8
C.- Task Execution		
1	• If most parts weigh less than 1.8 kg	
2	• If most parts weigh between 1.8 and 5 kg	
3	• If most parts weigh more than 5 kg	
Weight contribution (1, 2 ó 3):		3
1	• If there are fewer than 2 cycles per minute	
2	• If there are 2 cycles per minute	
3	• If there are more than 2 cycles per minute	
Frequency contribution (1, 2 ó 3):		2
D.- Manual Handling of Materials (Pull/Push)		
Force contribution pulling/pushing (Kgs):		13
Walking while pulling/pushing (meters/min)		1

Source: Own elaboration

Figure 8. Energy expenditure results at the workstation

METABOLIC ENERGY EXPENDITURE	
Basal Metabolic	117.000 Kcal/hr.
arm movement	50.000 Kcal/hr.
Walking	16.800 Kcal/hr.
task measure	52.800 Kcal/hr.
Manual material handling	33.800 Kcal/hr.
TOTAL	270.400 Kcal/hr.
	4.507 Kcal/min

PHYSICAL WORK CAPACITY	
ISF:	1.160
CTF MEN	6.330
CTF WOMEN	4.735

Maximum time before fatigue occurs (IF CTF > GME)		
MEN	826.187484	Min
WOMEN	470.288495	Min

Recovery time (IF CTF > GME)		
MEN	-305.451979	Min
WOMEN	-38.1912718	Min

Source: Own elaboration

Figure 9. RAPP Tool results

RAPP Equipment on wheel			
		Medium equipment	
Risk Factor		Color	Value
1	Work load		0
2	Posture		0
3	Grip		0
4	Work Rythem		3
5	Walking distance		0
6	Equipment Condition		0
7	Floor Condition		0
8	Obstules in Route		0
9	Other Factors		0
	Total Score	3	

Source: Own elaboration

4.4 *Implementation*

The time study, conducted along with the work instructions, allowed each part of the process to be defined and optimized. Based on the results, a cycle time of 7 minutes was established. With this parameter, the workload was calculated at 85.62% (6 minutes), with a rest time between cycles of 14.38% (1 minute), which remains within the manufacturer's internal standards, ensuring an adequate level of productivity without physical overload.

Figure 10. Example of process sheet

Quality Process System Operator Instruction Sheet (QPS-OIS/JSA) — HERMOSILLO ASSEMBLY — PROPRIETARY

Prior to starting and throughout the day: Verify walking working surfaces are clean, dry, and clear of any obstructions or slip/trip hazards.
If a DEFECT cannot be contained in station, utilize the ANDON process.

2024/11/07

OIS: *1* - Secuenciado de Tanques Operation: Secuenciado de Tanques	Station: CH C4 429-W Operation ID: Q 1 T	Dept/Zone/Workgroup: Secuenciados/Zona 2 Secuenciados/ Model Mix/Process: CX430 P758 Production (1/4/22)	Created By: PMART318 Revised By: PMART318	Creation Date: 2024/07/02 Revision Date: 2024/11/06

KEY: DELTA CRITICAL | SIGNIFICANT | KEYED SEQUENCE | KEY QUALITY POINT | Error Proofing Device | Key Safety Green | Key Safety Yellow | Ergonomics | Environmental | Line Rate 75.000 JPH | Takt Time 48.00

Usage	#	Key Point Symbol	All Work Elements / Work Steps must be done in sequence as listed	Required Hazard Controls and Key Quality Points	Work Sequence Layout
	10		***Place PPE according to the operation to be performed***		
	20		*** Go to the scanner charging cabinet ***		
	30		*** Turn on scanner **		
	40		***Enter the sequencer cell to sequence gasoline tank rack***		
	50		***Verify that the VIN number and the sequenced number of the components match the system ***		
100% UNITS	60		Scan the PLACCARD and sequence barcode (every 12 gasoline tanks)		
			10 Walk to PLACCARD		
			20 Align scanner with PLACCARD		
			30 Press scanner trigger		
			40 Scan PLACCARD *time*		
100% UNITS	70		Scan the ETAG and sequence barcode (every 12 gasoline tanks)		
			10 WALK TO DOLLY TO SEQUENCE		
			20 Align scanner with ETAG		
			30 Press scanner trigger		
			40 Scan ETAG *time*		
100% UNITS	80		Walk to the cart and change the tanks		
			10 Walk to the cart		
			20 Take the cart		
			Walk to the Rack		
100% UNITS	90		Place in sequence the part number, rotation, and location as indicated by the system when sequencing		

Shift Acknowledgments

User Role	Crew A		Crew B		Crew C		Tox. #	Tox. Text	Tox. #	Tox. Text
QPSOPER					JCARRIS0	2024/11/06	N/A			
QPSSUPV					JGAMEZSO	2024/11/06				
QPSTMLD										

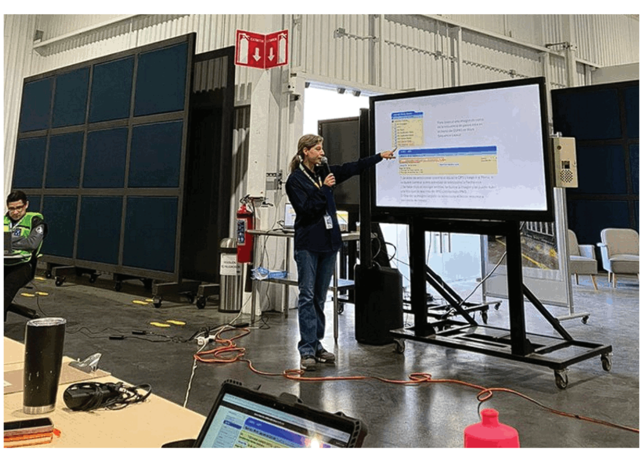
Eye Protection	Hearing Protection	Respiratory Protection	Hand Protection	Foot/Leg Protection	Other Protection	Arm Protection	Other Protection
None Required	None Required	None Required	Kevlar Gloves	Steel toe	None Required	Long Sleeves	Other: chaleco

JSA is Unapproved — This OIS is NOT approved by all approvers

Source: Own elaboration

The implementation process included two additional activities related to understanding the new task workflow. On one hand, process sheets were created (Figure 10), which are documents detailing the steps required for assembly, including operations, machines, tools, time, and materials. They include key icons highlighting critical points, as well as a more in-depth explanation of the subtasks.

Figure 11. Presentation and training meeting



Source: Own elaboration

Finally, meetings were held with both operational and supervisory staff. In these sessions, the redesign was described, along with its benefits for productivity and risk reduction. Operators were trained and shown the station's operational metrics (Figure 11).

4.5 Continuous improvement

As part of the improvement process, an opportunity for enhancement was identified. Therefore, the materials department was requested to implement a new material supply sequence to optimize material flow and improve operational efficiency. This adjustment aims to streamline the distribution of material usage options, ensuring each component is available at the right time and in the correct quantity. Additionally, implementing these options will help reduce waiting times and optimize overall system performance.

Discussion

In the context of existing literature, this study aligns with the increasing importance given to ergonomics in the automotive industry to improve productivity, safety, and job satisfaction. The application of regulations such as NOM-036-STPS-2018 and consideration of international standards (ISO-11228-1, HSE, NIOSH) form the basis of a comprehensive approach to managing ergonomic risks. Likewise, the use of multiple evaluation methods (Sue Rodgers, RAPP, caloric expenditure analysis) provides a holistic view of the physical demands of the task, strengthening the validity of the conclusions.

One limitation of this study could be its focus on a single workstation within the assembly line. The ergonomic evaluation results of the redesigned workstation suggest a substantial improvement compared to previous scenarios where manual load handling posed a potential risk for musculoskeletal disorders (MSDs).

This study, similar to other research findings, supports the idea that designing work environments using a systematic approach and specialized assessment tools represents a significant advancement toward reducing ergonomic risks. The results support the effectiveness of the implemented interventions and highlight the importance of a continuous improvement approach to working conditions from an ergonomic perspective.

The study by García et al. (2021) provides a detailed view of ergonomic challenges in the food industry, specifically in the asparagus packing process. The research revealed that operator fatigue not only reduced productivity but also raised serious concerns regarding worker health and well-being. It was found that repeated stretching over long periods caused fatigue, clearly indicating suboptimal working conditions.

Upon deeper analysis of the packing activities, it was discovered that most of the postures adopted by operators were ergonomically incorrect. This not only increased the risk of long-term injuries but also affected the efficiency of the packing process. The conclusion that a workstation redesign was necessary revealed an opportunity for significantly improving workplace ergonomics.

The redesign proposed by García et al. (2021) suggests integrating adjustable workstations that accommodate the height and reach of each individual operator, thereby minimizing muscle strain and fatigue. Regular breaks and stretching exercises for employees were also recommended, which could help mitigate the effects of standing or remaining in a static position for long periods.

Future research could expand the scope to analyze the impact of similar ergonomic interventions at other workstations where potential risk exists particularly for MSDs. In the medium to long term, it would also be valuable to assess the impact on worker health and process productivity.

Conclusions

The ergonomic design of a sequencing workstation in an automotive stamping and assembly plant was addressed, motivated by the need to mitigate the risk of musculoskeletal disorders (MSDs) associated with manual material handling, in accordance with NOM-036-1-STPS-2018 and the manufacturer's standards. Through a five-phase methodology (analysis, design, validation, implementation, and continuous improvement), the assembly sequence was redefined by developing a new physical layout of the workstation, incorporating facilities and ergonomic aids aimed at optimizing the handling and transport of components in the sequencing phase.

Workstation design validation was conducted through various ergonomic evaluation methods, including Sue Rodgers and RAPP. The moderate score obtained in the work pace assessment highlights an opportunity for optimization, aiming for a balance between productivity and prevention of physical overload. The caloric expenditure analysis indicated that the metabolic demands of the task fall within acceptable limits for both genders during a standard work shift. However, the calculated work capacity for female operators was closer to the shift duration, suggesting the need to monitor fatigue and consider implementing breaks or task rotations if signs of long-term exhaustion are detected.

The results showed a significant improvement in the ergonomic conditions of the redesigned station. During the implementation phase, staff training and the definition of an optimized cycle time began, achieving adequate levels of efficiency and idle time, even exceeding standard process expectations, thus demonstrating the proposal's feasibility in terms of productivity. Finally, the continuous improvement stage lays the groundwork for future adjustments that will allow for sustained optimization of the workstation.

In summary, this research exemplifies the practical application of ergonomic principles in the automotive industry, demonstrating their potential for creating safer, healthier, and more efficient work environments while ensuring compliance with current regulations. The findings of this study may serve as a reference for similar interventions in other production processes involving manual material handling.

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