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Dysergonomic Risk Management Model to Improve Productivity in the Liquefied Petroleum Gas Balloon Filling Process Using RULA and NIOSH Methodologies

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Abstract

The operations in a liquefied petroleum gas plant require risks in the posture of workers during the performance of the operational activities of bottling, which can affect the integrity of the workers, as well as generate excessive operating times and affect productivity. Productivity currently stands at 78%, which is below the company's minimum goal of 85%. Therefore, due to the consequences it generates, it is essential to be a subject of study, so the objective of the research is to improve the productivity of the packaging operation by proposing a dysergonomic risk management model. The evaluation of the criticality of dysergonomic risks by workstation was carried out by means of the Triple Criteria Qualitative Identification and Estimation Matrix in which the activities of injecting liquefied petroleum gas, quality control, sealing and stacking of packaged balloons were defined as those requiring corrective actions due to the adverse effects they cause. The methods for assessing the dysergonomic risks of the activities are carried out by means of the Rapid Upper Limb Assessment (RULA) and the National Institute for Occupational Safety and Health (NIOSH). Finally, there was a 10.4% increase in the productivity of packaged balloons.

Keywords
Ergonomics, hydrocarbon, packaging process, dysergonomic risks, productivity.

1. Introduction
In the work carried out in a liquefied petroleum gas balloon bottling plant, occupational ergonomics is a fundamental factor for the integrity of employees and their work performance; it is necessary to control dysergonomic conditions such as repetitive movements, frequent lifting and forced postures (Loa-Puris et al., 2021). In Peru, the "Basic standard on ergonomics and dysergonomic risk assessment procedure" (Ministerial Resolution No. 375-2008-TR) establishes a procedure for evaluating ergonomic aspects with the objective of contributing to the physical, mental and social well-being of the worker. The company in question is in the district of Villa el Salvador and has been competing in the hydrocarbon sector for more than 20 years, packaging, distributing, and marketing liquefied petroleum gas cylinders with an average production of 1502 cylinders in a workday, packaging an average of 250 cylinders per hour. They currently pack 5 kg, 10 kg and 45 kg capacity balls, and 85% of their production corresponds to 10 kg capacity balls. The problem that motivates the study is that there is a lack of a preventive culture of disergonomic risks, which exposes workers to repetitive lifting with overload during the packaging process, impacting on absenteeism of

operators due to musculoskeletal disorders, affecting productivity. According to Dul and Neumann (2009), setting up an operating space aligned to an optimal ergonomic state contributes to occupational safety, health and well-being as well as improved productivity performance.

1.1 Objectives

The objective of the research is to develop a dysergonomic risk management model to improve the productivity of the liquefied petroleum gas balloon packaging process using RULA and NIOSH methodologies.
Specifically, the following objectives are proposed:

- Elaborate a diagnosis of the current situation by evaluating the main ergonomic risk factors in the production process under study.
- Determine the techniques to evaluate the level of dysergonomic risk in the positions of greatest exposure to ergonomic risk factors.
- Establish the improvement in the workstations to reduce the exposure to the evaluated dysergonomic risk.
- Validate the proposed model by re-evaluating the exposure to dysergonomic risk for the workstations under study.

2. Literature Review

Ergonomics examines the behavioral capabilities and limitations of workers which in turn directly affects work efficiency and productivity (Freitas et al., 2019). The relevance of ergonomics and health work in the workplace is related to participation, safety culture and other implications for participatory ergonomics approaches, for which commitment on the part of workers and management is needed (Nizam and Ramlee, 2024). Its importance lies in the prevention of occupational accidents and reflection on cost reduction in economy and productivity (Christy, 2019).
The expression dysergonomic risk is defined as the probability of suffering an adverse event such as an illness or accident due to factors that are determined in the workplace (Freitas et al., 2019). Factors such as repetition of movements, application of overexertion during activities and awkward postures due to the dysergonomic design of workstations; affect work performance and expose workers in the LPG packaging process to risks of musculoskeletal disorders (Loa-Puris et al., 2021). Musculoskeletal diseases are one of the most common health problems and are part of a considerable burden in society, the consequences involve from chronic pain to physical disability, with back pain being the most common problem (Ingram and Symmons, 2018).

A study conducted in a plant of the LPG sector located in Peru on the application of overexertion and postures during the activities of the manual processes of the plant shows the risk of suffering musculoskeletal disorders (MSD) causing a low efficiency in the process. After an ergonomic evaluation and analysis in the most critical station such as painting and injection, an Ergonomic Model Design is proposed to mitigate the dysergonomic risk and reduce the low work performance. Finally, the result is an increase in efficiency in the operating process from 62% to 81% (Loa-Puris et al., 2021).

The application of the risk identification matrix is used for the evaluation of dysergonomic risks at work, a study makes use of this tool to identify risks of a job and qualifies the level of risk for each activity with the purpose of employing methodologies that allow quantifying the criticality and thus propose ergonomic solution alternatives (Molina et al., 2018).

Research about the implementation of the NIOSH methodology, which consists of manual material handling and lifting, evaluates the main dimensions of the workstations to mitigate the risks related to musculoskeletal disorders, for this the methodology poses an equation that allows to calculate a lifting index for an established action taking according to the criticality (Donisi et al., 2023). Currently, most of the workers in different areas are exposed to musculoskeletal problems caused by poor posture in their activities. A study shows the application of the RULA methodology considering the movements of the upper parts of the body and quickly evaluate the posture to categorize the risks through final scores and define if the activities are acceptable or if changes are needed (Castillo et al., 2022).

2.1 Qualitative Triple Criteria Identification and Estimation Matrix

The method makes it possible to evaluate and weight the dysergonomic risks in the workstations in a production process and identifies those activities that require immediate action. The elaboration of the matrix evaluates the risk with a low, medium or high probability of occurrence and consequences of slightly harmful, harmful or extremely harmful type, the qualification is performed for each activity of the job (Molina, 2018).

2.2 Rapid Upper Limb Assessment (RULA)

The RULA methodology is a useful tool to evaluate jobs and create risk tools by observing the work cycles and the postures performed during its execution, the angles of these postures can be measured using photographs (Rivero et al., 2015). In addition, this method considers the evaluation of the movements of the upper body parts, this is divided into a first group of arm, forearm, wrist and the second group in neck, trunk, legs taking into account flexion, position and extension for the scores (Kohammadi et al., 2016) and is part of an empirical study of rapid observation and evaluation whose results are visualized in a series of scores for each body zone; these scores are determined for each upper body limb, the scores can be modified according to the activity and muscle strength according to the activity to be executed (Simon et al., 2024); finally the final value of both scores of the first and second group provides the final risk contained in the activity. The result defines the action to be taken and possible changes in the activity (Maltry et al., 2020).

2.3 National Institute for Occupational Safety and Health (NIOSH) Method

The method evaluates the lifting tasks by determining the maximum allowable weight value of RWL (Recommended Weight Limit) and LI (Lifting Index) to avoid possible Musculoskeletal Disorders (Dehghan and Arjmand, 2024). The variables of the calculation are load constant (LC) considering that the maximum recommended weight for uninjured lifting is 23 kg, horizontal distance factor (HM), vertical distance factor (VM), vertical displacement factor (DM), asymmetry factor (AM), grip factor (CM) and frequency factor (FM). The recommended weight limit is evaluated with the product of the above variables as follows: RWL = LC x HM x VM x VM x DM x DM x AM x CM X FM and the lifting index by the formula: LI = Object weight / RWL. The result determined if the activity is performed correctly, if it can cause difficulties or can directly affect workers and require immediate improvements (Ruiz, 2011).

3. Methods

The proposed Dysergonomic Risk Management Model is detailed in Fig. 1 and is defined by four phases with the objective of optimizing the productivity of packaging balloons with liquefied petroleum gas. The applied study approach is the empirical method, because the object of study can be observed, measured, quantified and validated (Figure 1).

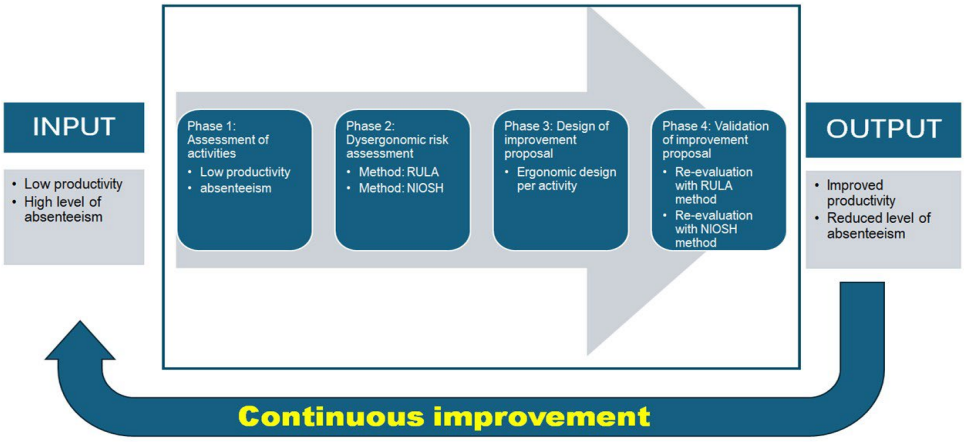

Figure 1. Disergonomic Risk Management Model

Phase 1: Assessment of activities

The evaluation of the criticality of the dysergonomic risks produced by the packaging process was developed using the triple criterion qualitative identification and estimation matrix. First, the study areas and the jobs they include are defined, then the activities are detailed according to the job and the number of workers per job is defined in relation to gender. Once the dysergonomic risks are defined, the qualitative empirical weighting is carried out according to the probabilities and consequences of the affections that each task produces, the qualified risks vary according to the action and timing.

Phase 2: Dysergonomic risk assessment
After defining the activities to be analyzed, the assessment of dysergonomic risks is carried out using RULA and NIOSH methodologies in order to quantify more precisely the exposure of workers to risk factors and the speed of action to be taken in response to the consequences.

Phase 3: Proposal design
Due to the results obtained from the application of the methodologies, it was determined to define an ergonomic design of the activities in order to achieve optimal conditions for their development. The implementation of elements that allow the ergonomic design to be carried out in an efficient and dynamic manner was proposed, in addition to enabling agile adaptability with the operators, ensuring that the implementation is optimal for the workplace.

Phase 4: Improvement validation
The improvement evaluation consists of replicating the RULA and NIOSH methodologies to quantitatively demonstrate the results obtained after their application.

4. Data Collection

Considering that 85% of the production is made up of 10 kg denomination balls, the study was carried out based on their packaging process. The activities begin with the reception, unloading and inspection of empty balls in order to verify their condition; the associated dysergonomic risk is the forced standing position. Next, those balls that are in optimal conditions undergo cleaning where various elements adhered to the ball are removed, then the painting activity is performed with a pressure gun and using as support an element that allows raising the height of the ball at the time of the activity, then the pre-taring is performed where the empty ball is previously weighed to determine the net weight. The next step is the injection of liquefied petroleum gas considering the regulations established by the Regulatory Entity OSINERGMIN, which qualifies as acceptable the balloons that present a net weight within the tolerance range, taking a minimum value of 9.75 kg and a maximum value of 10.25 kg. 25 kg, this activity is performed by a total of 5 operators for consecutive periods with intervals of more than 2 hours and requires high concentration to remove the injector hose on time, the operators perform the activity with the trunk inclined because the mechanical scales are at floor level. Subsequently, the balls pass through quality control to verify the optimum weight, where they are again weighed on an explosion-proof scale and sealed with seals; the operator takes a forced standing position. At the end of the process, the packaged balloons are collected for subsequent loading into the transport units. During the transfer to the stacking areas, the operator loads a total of 2 balloons, exerting physical effort and overload, the weight lifted by each arm is equivalent to more than 20 kg, taking into account that the empty balloon weighs an average of 10 kg and the net weight of the injected balloon is 10 kg. This activity is carried out for more than 2 hours per day and is part of a dysergonomic risk factor. See Figure 2.

Balloon unloading activity	Inspection and cleaning activity	Balloon painting activity	LPG injection activity	Quality control and sealing activity	Balloon stacking activity
					

Figure 2. Packaging production process activities

5. Results and Discussion

5.1 Numerical Results

5.1.1 Qualitative Triple Criteria Identification and Estimation Matrix

The analysis of the activities by workstation in the areas of the balloon packaging process showed that the activities with the highest criticality of disergonomic risks are those of injecting balloons with LPG, quality control, sealing and stacking of the packaged balloons, since the probability of risk is high, and the consequences are harmful. Table 1 shows the results obtained by activity.

Table 1. Qualitative Triple Criteria Identification and Estimation Matrix for the packaging process

Area	Work position	Activities	Number of workers	women	men	Work dimensions	Physical overexertion	Overload	Forced postures	Repetitive movements	Body movement	Forced position (standing)
Warehose	Operator	Unloading of the empty balls	2		2	**M**	**M**	**M**	**M**	**M**	**M**	**M**
	Warehouse manager	Inspection and cleaning	1		1	**T**	0	0	0	0	**TO**	**TO**
Platform	Operator	Painting of the balls	1		1	**TO**	0	0	**TO**	**M**	**T**	**M**
	Operator	Injection of the balls with LPG	5		5	**M**	**I**	**M**	**I**	**I**	**M**	**I**
	Platform manager	Quality control and sealing of packaged balloons	1		1	**M**	**M**	**M**	**I**	**TO**	**M**	**I**
Stacking	Operator	Stacking of packaged balls	2		2	**I**	**I**	**I**	**I**	**M**	**I**	**I**
		TOTAL	12	-	12							

For the interpretation of the method, Table 2 should be considered:

Table 2. Types of activity risk

		Consequences		
		Slightly harmful (LD)	Harmful (D)	Extremely harmful (ED)
Risk probability	Low (**B**)	Trivial risk (**T**)	Tolerable risk (**TO**)	Moderate risk (**MO**)
	Medium (**M**)	Tolerable risk (**TO**)	Moderate risk (**MO**)	Important risk (**I**)
	High (**A**)	Moderate risk (**MO**)	Important risk (**I**)	Intolerable risk (**IN**)

According to the risk estimation, the actions to be taken are detailed in Table 3:

Table 3. Estimation of activity risk

Risk	**Action**
Trivial (T)	No specific action required.
Tolerable (TO)	Solutions should be considered that do not require a significant economic burden and require periodic checks to ensure that the effectiveness of the control measures is maintained.
Moderate (M)	Efforts should be made to reduce the risk by determining precise investments and should be implemented within a given period.
Important (I)	The risk should be remediated in less time than moderate risks, considering considerable resources if necessary to control the risk.
Intolerable (IN)	Work should not commence or continue until the risk is reduced. If it is not possible to reduce the risk, even with limited resources, work should be prohibited.

Therefore, the risk of the activities of injecting LPG cylinders, quality control, sealing and stacking of the packaged cylinders must be remediated in the shortest possible time by using the resources deemed necessary.

5.1.2 Dysergonomic risk in the LPG balloon injection activity.

The results of the RULA analysis of the activity are detailed in Table 4.

Table 4. LPG injection activity evaluation

Activity: Injection of LPG balloons		
Arm, forearm and wrist strain Score		Scoring
Arm	Flexion greater than 20º and less than 45º, shoulders elevated. Pronation in extreme range	2 + 1 = 3
Forearm	Flexion between 60º and 100º, forearm crosses the centerline of the body.	1 + 1 = 2
Wirst	Flexion greater than 15º, radial deviation	3 + 1 = 4
Wirst rotate	Pronation in extreme range	2
Score A: Score (3,2,4,2)		5
Neck, trunk and leg strains		Scoring
Neck	Flexion greater than 20º and head rotation	3 + 1 = 4
Trunk	Flexion greater than 60º and rotation and lateral inclination of the trunk	4 + 2 = 6
Leg strains	Standing with weight distributed on both legs	1
Score B: Score (4,6,1)		8
Score C: Score A = 5, plus (repetitive motion) = 1, plus (load greater than 10 kg) = 3		9
Score D: Score B = 8, plus (repetitive motion) = 1, plus (load greater than 10 kg) = 3		12
Final score: Score (9,12)		**7**

Once the final score is obtained, the following should be considered:

- The posture is acceptable if the task is not maintained or repeated for long periods, if it is between 1 and 2.
- It may require changes and in-depth analysis of the task, if it is between 3 and 4.
- Short-term changes to the task are required, if between 5 and 6.
- Immediate changes to the task are required, if 7.

Therefore, it is concluded that the activity requires immediate changes.

5.1.3 Dysergonomic risk in the quality control activity of the packaged and sealed balloons

The results of the RULA analysis of the activity are detailed in Table 5.

Table 5. Evaluation of quality control and sealing activity

Activity: Quality control and sealing		
Arm, forearm and wrist strain		Scoring
Arm	Flexion greater than 20º and less than 45º.	2
Forearm	Flexion less than 60º, forearm crosses the centerline of the body.	2 + 1 = 3
Wirst	Flexion greater than 0º and less than 15º, radial deviation	2 + 1 = 3
Wirst rotate	Pronation in extreme range	2
Score A: Score (2,3,3,2)		4
Neck, trunk and leg strains		Scoring
Neck	Flexion greater than 20º and head rotated.	3 + 1 = 4
Trunk	Flexion greater than 20º and less than 60º, lateral trunk tilt.	3 + 1 = 4
Leg strains	Standing with weight distributed on both legs.	1
Score B: Score (4,4,1)		7
Score C: Score A = 4, plus (static posture) = 1, plus (load over 10 kg) = 3		8
Score D: Score B = 7, plus (static posture) = 1, plus (load over 10 kg) = 3		11
Final score: Score (8,11)		**7**

Therefore, in accordance with the above interpretation, it is concluded that the activity requires immediate changes.

5.1.4 Dysergonomic risk in the activity of stacking packaged balloons

Los resultados del análisis con la metodología NIOSH de la actividad se detalla en la Tabla 6.

Table 6. Evaluation of the stacking activity of packaged balloons

Activity: Ball stacking		
Equation factor		Score
Load constant	LC = 23 kg	23
Horizontal distance factor, H <= 25 cm	HM = 25 / H	1
Vertical distance factor, V = 60 cm	VM = 1 - 0.003 x (V - 75)	0.955
Vertical displacement factor, D = (65-120) cm	DM = 0.82 + 4.5 / D	0.902
Asymmetry factor, A=20 degrees	AM = 1 - (0.0032 * A)	0.936
Frequency factor (frequency, duration and V)	FM = 4 balls/minute; Duration >= 3 hours, V < 75	0.45
Grip factor (Good)	CM = V <75	1
Recommended load limit	RWL = 23 x 1 x 0.955 x 0.902 x 0.936 x 0.45 x 1	8.345
Lifting rate	LI= 40 kg / 8.345 kg	**4.793**

Taking into account the final score of the lifting index, the following is considered:

- The task can be performed by most workers without causing them problems, if LI is less than or equal to 1.
- The task may cause difficulties for some workers, so the workstation should be analyzed, and appropriate modifications made, if LI is between 1 and 3.
- The task affects most of the workers and improvements should be made immediately, if LI is greater than or equal to 3.

Therefore, it is concluded that the task would affect a large part of the operators and immediate improvements are required.

5.2 Proposed Improvements

According to the results obtained in the analysis of the methodologies, an Ergonomic Model Design is proposed to mitigate the dysergonomic risk.

5.2.1 Mejoras en la actividad de inyectado de balones con GLP

The actions that were carried out for improvements are detailed below (see Figure 3):

- Incorporation of a stainless-steel support adjustable to the height of the operator, it is located under the injection scale and has a resistance of 100 kg.
- The support reduces trunk flexion from > 60° to < 20°, maintaining an upright posture when performing the activity, avoiding rotation and lateral inclination of the trunk, and reduces neck flexion from > 20° to < 10°. restricting the lateral inclination of the neck.
- The operator's wrist stops making extreme turns and presents an appropriate position at the height of the balloon valve.
- Training in the new way of working for LPG injection and raising awareness of the correct use of PPE.

Figure 3. Comparison of the performance of the balloon injection activity

5.2.2 Improvements in the quality control activity of packaged and sealed balls

The actions that were carried out for improvements are detailed below (see Figure 4):

- Carry out the activity incorporating a stainless-steel support adjustable to the height of the operator, identical to that of the balloon injection activity, located under the anti-explosive scale for quality control and sealing.
- The support has a resistant composition to minimize risks of short circuits or sparks and has a resistance of 100 kg.
- The ergonomic design allows neck flexion to be reduced from > 20º to < 20º, eliminating lateral inclination, and trunk flexion is optimized between 0º and 20º, maintaining an upright posture when performing the activity that allows the operator to visualize the weight. on the scale screen without exerting greater flexion.
- Training in the new work method of the quality control and sealing station. Raise awareness in the use of PPE.

Figure 4. Comparison of quality control and sealing activity performance

5.2.3 Improvements in the stacking activity of packaged balls

The actions that were carried out for improvements are detailed below (see Figure 5):

- The transfer of the packaged balls to the stacking areas incorporates a transport cart with a resistance of 85 kg per block and has a height of 1.35 m.

- The element allows the transfer of 4 packaged balls, unlike the traditional manual transfer that makes it possible to transport only 2 balls.
- The ergonomic design allows mitigating physical overexertion and overload during the journey to the stacking area.
- The proposal avoids extreme range turns of the operator's wrist.
- Training on the new work method in stacking packaged balls.
- Awareness of active stretching and movement breaks, in addition to the correct use of PPE.

Current activity of stacking packaged balloons.	Ergonomic design of the packaged balloon stacking activity.
	

Figure 5. Comparison of packaged balloon stacking activity performance

5.3 Validation

5.3.1 Reduction of dysergonomic risk in the activity of injecting LPG cylinders

After the proposed improvement, the RULA analysis is carried out again to validate the changes generated. See Table 7.

Table 7. Dysergonomic risk reduction in the LPG balloon injection activity.

Activity: Injection of LPG balloons		
Strain of arm, forearm and wrist		Scoring
Arm	Flexion greater than 20º and less than 45º.	2
Forearm	Flexion between 60º and 100º.	1
Wirst	Flexion in neutral position	1
Wirst rotate	Mid-range pronation	1
Score A: Score (2,1,1,1)		2
Neck, trunk and leg strains		Scoring
Cuello	Flexion between 0º and 10º	1
Tronco	Flexion between 0º and 20º	2
Piernas	Standing with weight distributed on both legs	1
Score B: Score (1,2,1)		2
Score C: Score A = 2, plus (short duration posture) = 0, plus (load of less than 2 kg intermittently) = 0		2
Score D: Score B = 2, plus (short duration posture) = 0, plus (load of less than 2 kg intermittently) = 0.		2
Final score: Score (2.2)		**2**

In conclusion, the level of dysergonomic risk decreases by 5 and results in 2, in this way a significant reduction is evident, the activity no longer requires changes, and the posture is acceptable if the task is not repeated for long periods.

5.3.2 Reduction of dysergonomic risk in quality control and sealing activity
After the proposed improvement, the RULA analysis is performed again to validate the changes generated. See Table 8.

Table 8. Dysergonomic risk reduction in quality control and sealing activities

Activity: Quality control and stamping		
Arm, forearm and wrist strain		Scoring
Arm	Flexion greater than 20º and less than 45º.	2
Forearm	Flexion between 60º and 100º.	1
Wrist	Flexion in neutral position	1
Wrist rotation	Mid-range pronation	1
Score A: Score (2,1,1,1)		2
Neck, trunk and leg strains		Scoring
Neck	Flexure greater than 10º and less than 20º.	2
Trunk	Flexion between 0º and 20º.	2
Legs	Standing with weight distributed on both legs.	1
Score B: Score (2,2,1)		2
Score C: Score A = 2, plus (short duration posture) = 0, plus (load less than 2 kg intermittently) = 0		2
Score D: Score B = 2, plus (short duration posture) = 0, plus (load less than 2 kg held intermittently) = 0		2
Final score: Score (2,2)		**2**

In conclusion, the level of dysergonomic risk decreases by 5 and results in 2, in this way a significant reduction is evident, the activity no longer requires changes, and the posture is acceptable if the task is not repeated for long periods.

5.3.3 Reduction of dysergonomic risk in the activity of stacking packaged balls
After the proposed improvement, the NIOSH analysis is carried out again to validate the changes generated (see Table 9):

Table 9. Reduction of dysergonomic risk in stacking activity

Activity: Ball stacking		
Equation Factor		Scoring
Load constant	LC = 23 kg	23
Horizontal distance factor, H <= 25 cm	HM = 25 / H	1
Vertical distance factor, V = 60 cm	VM = 1 - 0.003 x (V - 75)	0.955
Vertical displacement factor, D = (65-135) cm	DM = 0.82 + 4.5 / D	0.884
Asymmetry factor, A=20 degrees	AM = 1 - (0.0032 * A)	0.936
Frequency factor (frequency, duration and V)	FM = 4 balls/minute; Duration >= 3 hours, V < 75	0.45
Grip factor (Good)	CM = V <75	1
Recommended load limit	RWL = 23 x 1 x 0.955 x 0.884 x 0.936 x 0.45 x 1	8.181
Lifting rate	LI= 20 kg / 8.181 kg	**2.445**

In conclusion, a reduction in dysergonomic risk is seen in the workplace, which is evidenced by a lifting index of 2.445 and the task no longer affects a large part of the workers (see Table 10).

Finally, to analyze productivity, a preliminary test is carried out taking workdays with the highest demand as a sample. The days of the week chosen for evaluation were Wednesday, Thursday and Friday. According to Kardex, which manages the operational area in which the inventory of balls packaged per day is recorded, results of an average improvement of 10.4% in productivity are evident, ultimately resulting in 88.4% and a reduction in packaging time of 27.5%.

Table 10. Calculation of improved productivity

Evaluation day	Productivity			Packaging time: sample 250 balls		
	Initial	Final	% variation	Initial	Final	% variation
Wednesday	1490	1650	10.74%	1:10:00	0:55:00	21.43%
Thursday	1511	1664	10.13%	1:08:00	0:48:00	29.41%
Friday	1505	1660	10.30%	1:16:00	0:52:00	31.58%
Final total average	1502	1658	**10.4%**	1:11:20	0:51:40	**27.5%**

6. Conclusion

Based on the type of activities carried out in the company under study, it can be stated that the ball packaging process presents forced postures in carrying out the tasks and therefore requires an exhaustive analysis of the jobs to mitigate the risks that occurs, thus confirming its consistency with the study by Castillo et al. (2022).

Firstly, it is specified that by using the qualitative risk identification and estimation matrix, it was possible to determine that the activities of LPG injection, quality control and sealing, in addition to the stacking of packaged cylinders, were the most critical tasks in the packaging process, since they presented a significant risk that meant taking immediate corrective actions. With the activities defined in the evaluation, the risk level was quantified using the RULA and NIOSH tools, where the lack of information and awareness about efficient ergonomics management at work was also witnessed. The use of these tools is consistent with the study by Lara-Lezcano et al. (2023) where it is evident that the quantification of the risk level of the activities under study was possible through methodologies of ergonomic scope. The results of this article indicated that immediate changes were required in the performance of tasks with greater criticality, since the consequences involved a decrease in physical capacity, musculoskeletal disorders and, consequently, a level of productivity below the goal established by the company. . After the implementation of the improvements, the proposals were validated to identify that the level of postural risk was reduced and thus improvements in productivity. On the one hand, the LPG injection activities, as well as quality control and sealing, reduced the risk level by 71.4% in both activities, the risk levels with a score of 7 were reduced to 2. On the other hand, the The activity of stacking packaging balloons had a reduction in the lifting index from 4,793 to 2,445, equivalent to a reduction of 48.9%, this as a result of the load weight no longer requiring the lifting of two balloons simultaneously.

Finally, the preliminary test was carried out with the objective of analyzing the new productivity, an average increase of 10.4% in productivity was evident, as well as a reduction in average packaging time of 27.5%. In this way, the new productivity index results in 88.4%, exceeding the target indicator established by the company under study.

Based on the final results, it was possible to corroborate that with the implementation of an ergonomic model based on ergonomic methodologies, evaluation and analysis of the most critical jobs, greater productivity and a lower risk of harm to collaborators can be obtained, validating the study by Loa-Puris et al. (2021) that presents the evaluation of overexertion and postures in order to propose an ergonomic model design in the LPG cylinder injection and painting position in a plant in the hydrocarbon sector, evidencing improvements in its productivity.

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