# Dysergonomic Risk Management Model to improve welding productivity using the Nordic Questionnaire and the REBA and NIOSH methods: Case of the metal-mechanic sector in Lima, Perú.

**Andrea Lara-Lezcano and Sebastian Pizarro-Vásquez**
Facultad de Ingeniería y Arquitectura, Universidad de Lima, Perú
20163218@aloe.ulima.edu.pe, 20163443@aloe.ulima.edu.pe

**Carlos-Augusto Lizárraga-Portugal and Juan Carlos Quiroz-Flores**
Research Profesor
Facultad de Ingeniería y Arquitectura, Universidad de Lima, Perú
clizarra@ulima.edu.pe, jcquiroz@ulima.edu.pe

## Abstract

Due to the nature of the activities performed, the welding position in the metal-mechanical processes exposes its workers to various risks that generate severe damage to their safety and health, affecting both the worker and the company due to the loss of man hours due to medical breaks that impact on lower productivity, as well as economic losses. Dysergonomic risk deserves special attention due to the high frequency and severe consequences of Musculoskeletal Trauma that it can generate in its workers, and in this sense the objective of the research is to improve the productivity of the welding position through the prevention of dysergonomic risk by providing an occupational health management model for its application. By means of the Nordic Standardized Questionnaire, the analysis of musculoskeletal symptoms was carried out, selecting as object of study the welding activities performed for the modification of excavator buckets, observing as risk factors the postural effort and the manual shuffling of parts, from which the REBA (Rapid Entire Body Assessment) and the NIOSH (The National Institute for Occupational Safety and Health) methods were selected for the evaluation of the dysergonomic risk. In conclusion, an 11% increase in average productivity levels has been achieved.

## Keywords
Musculoskeletal trauma, ergonomics, productivity, occupational health, welding station improvement.

## 1. Introduction
Ergonomics is a priority for workplaces, as it is a useful tool to improve productivity and reduce operating costs, so it is considered an investment and not an expense. Peruvian legal regulations are demanding in relation to the elimination of occupational hazards present in work activities, as in the case of the Occupational Safety and Health Law, which states that it is the employer's obligation to "ensure the safety and health of workers in the performance of all aspects related to their work, in the workplace or on the occasion thereof" (Law N.°29783 2011), so the necessary control actions must be adopted being precisely that ergonomic practices receive special attention and that in the Peruvian case is expressed in the Basic Standard of Ergonomics and Dysergonomic Risk Assessment Procedure, noting that regardless of the nature of the activities performed in the company, they must incorporate ergonomic assessment as a component of preventive processes aimed at improving productivity (Ministerial Resolution N.°375-2008-TR).

On the other hand, the ergonomic conditions of the activities performed in the metal-mechanic sector are diverse and involve tasks with manual handling of heavy loads, frequent repetitive movements, forced postures, among other factors, whose consequences are musculoskeletal disorders; a situation that if ignored and not controlled in time can generate chronic and severe damage, and the employer would take corrective actions when he observes that this can affect the organization economically.

The company in the metal-mechanical sector in which the study was carried out has been competing in the sector for 16 years and is in the province of Callao, providing manufacturing and repair services for steel and other metals, performing welding, milling, and turning tasks: turning and facing. When observing their processes, it was found that they do not perform the evaluation of occupational risks, showing that between the years 2020 to 2021 they have registered in the different jobs between 3% and 5% of loss of scheduled hours in the month due to absenteeism and the execution times of tasks have increased by an average of 11%, in both cases as a result of injuries due to postural loads (neck and back pain) operationally damaging the company, reducing its production capacity and raising its costs.

Any investment made to achieve occupational risk-free workplaces will not only benefit the workers but will also usually generate savings for the company.

Studies of dysergonomic risk factors should focus on preventing the consequences that could affect the health and safety of workers, however, understanding that any intervention must be within the framework of the comprehensive management of the company because it involves costs and investments so it is essential to evaluate and prioritize the actions that have a favorable impact on the goals of the organization allowing achievements in compliance with standards, cost and risk reduction, improvement in safety and health, quality and productivity, etc. (García et al. 2011).

### 1.1 Objectives

The research aims to propose a dysergonomic risk management model to improve welding productivity using the Nordic Standardized Questionnaire and the REBA and NIOSH methods.

Specifically, the following objectives are proposed:

- Using the standardized Nordic questionnaire, identify the critical tasks with the highest exposure to Musculoskeletal Trauma for welding technicians.
- By reducing the average time to complete tasks, improving production efficiency by more than 10%.
- Improve productivity by at least 1.5% through reduction.
- Reduce absenteeism due to Musculoskeletal Trauma by less than 1% of the monthly scheduled hours

## 2. Literature Review

The Greek words ergon (work) and nomos (laws) define the concept of ergonomics as a scientific discipline that studies the relationship between man and his work environment, providing knowledge of the worker's capabilities and limitations to integrate them into the design of the work, its environment, tools, materials, methods, and organization (Leirós 2009; Macdonald and Oakman 2021; Torres and Rodríguez 2021;). In the workplace, several dysergonomic risk factors or physical requirements due to postures, force or movements have been identified, consisting of physical overload, repetitive movements, forced postures, twisting, and bending movements, static postures, among others, which when they are greater than the person's response capacity can cause musculoskeletal injuries (Vernaza-Pinzón and Sierra-Torres 2005). Previous studies have found that the main ailment is low back pain, which results in an impoverishment of the worker's quality of life, psychological stress, and disability, besides being the "main cause of loss of productive years" (De Luca et al. 2022). According to the Basic Ergonomics Standard and Dysergonomic Risk Assessment Procedure (Ministerial Resolution N.°375-2008-TR), to initiate an ergonomic intervention, the presence of significant dysergonomic risk factors must be identified, as shown in Table 1.

The reduction of dysergonomic risks, reason for musculoskeletal injuries, is of very high importance due to being the main cause of work absenteeism, disability cost, deficit in productivity and problems in society, because on the worker's health (Medina-Chacón 2020). In addition, it should be considered that factors such as social support or job satisfaction may contribute to the absence of symptoms, while high physical and psychological demands may contribute to the development of symptoms of musculoskeletal disorders (Bispo et al. 2022), affecting the worker physically and psychologically. The workers most exposed to these dysergonomic risks are those working in the industrial area, who have highly technical and physically demanding daily activities (Afonso et al. 2022). In addition, manual material handling is the main risk task, emphasizing the lifting and pushing of loads, tasks in which poor body positions cause damage to the worker and their production capacity (Rajendran et al. 2020; Lin et al. 2022; Smith et al. 2022).

Table 1. Identification of Significant Risk Factors

| Risk Factor | Nature of the task |
|---|---|
| Uncomfortable postures | For more than 2 hours during the workday: Back bent forward more than 30° and/or back extended more than 30°. |
| Frequent lifting | For more than 2 hours during the working day: 25 kg more than twelve times/hour and/or 40 kg once a day. |
| Hand and wrist strain | For more than 2 hours during the workday: flexed wrists extended, rotated or lateralized, gripping with force. |
| Repetitive movements with high frequency | For more than 2 hours during the working day: muscle movement in neck, shoulders, elbows, wrists, hands, etc. more than 4 times/min. |
| Repeated impact | For more than 2 hours during the workday: use of hands or knees as a hammer more than 10 times per hour. |
| Moderate to high hand-arm | vibration Moderate level: plus 30 min/day; high level: plus 2 hours/day |

For a first ergonomic inspection of the workstation, it is recommended, according to the researcher, the Nordic questionnaire, which allows the affected users to answer questions associated with their workstations and the musculoskeletal pain or discomfort that it generates for them (Vachinska et al. 2022). It is also stated that its application makes it possible to obtain data on symptomatology prior to the onset of a disease, so that, based on this evaluation, it is decided whether to conduct an in-depth analysis of these ailments (Adiyanto et al. 2021).

## 2.2 Ergonomic Evaluation Methods

Ergonomic evaluation methods, although multiple and varied in their approach, should also be considered that each one is applicable to certain activities and jobs, complementing different tools for a complete analysis. It is important to note that the determination of the most appropriate assessment techniques will depend on the level of dysergonomic risk factors to which the worker is exposed when performing the specific tasks that correspond to their work and in that sense, the assessment should analyze each task specifically using the technique that best suits that purpose (Asensio et al. 2008). In the welding technician position, after observing their activities, it was found that the task of modifying excavator buckets exposed workers to dysergonomic risk factors due to postural strain and manual handling of loads; the following methods were used to carry out the evaluation: (a) the Nordic Standardized Questionnaire for the analysis of musculoskeletal symptoms; (b) the Rapid Entire Body Assessment (REBA) Method for assessing postural strain; and (c) the National Institute for Occupational Safety and Health (NIOSH) Method for assessing load handling.

## 2.3 The Nordic Standardized Questionnaire for musculoskeletal symptom analysis

It presents standardized questionnaires from an ergonomic or occupational health point of view, using questions on the symptoms most frequently present in a work environment. These questionnaires, one general and the other specific, allow the identification of general, lumbar and neck/shoulder discomfort, resulting in a diagnostic tool of the work environment and the workplace, facilitating the design of solutions to improve a place free of dysergonomic risks for the worker (Kuorinka et al. 1987).

## 2.4 Rapid Whole Body Assessment Method (REBA)

The REBA method allows establishing whether it is necessary to take actions to reduce the effort involved in certain unpredictable dynamic and static work postures, assessing the postural, load and grip components, providing the evaluator with the information to focus on preventive actions required by the task (Asensio-Cuesta et al. 2012, Hignett et al. 2000).

## 2.5 National Institute for Occupational Safety and Health (NIOSH) method

This method, by means of the NIOSH equation, allows the evaluation of tasks in which the lifting of loads is performed, determining the maximum allowable weight value of RWL (Recommended Weight Limit) and the IL (Lifting Index) to avoid possible Musculoskeletal Disorders (Andres et al. 2001). The Recommended Weight Limit is the product of the Constant Load Factor set at 23 kilograms (LC); the Horizontal Load Distance Factor (HM); the Height Factor (VM); the Vertical Displacement Factor (DM); the Asymmetry Angle Factor (AM); the Frequency Factor (FM); the Grip Quality Factor (CM). The Lift Index is then determined by comparing the load lifted in relation to the Recommended Weight Limit. When the Lifting Index is greater than 3 it shows an unacceptable level of dysergonomic risk and should be redesigned (Valois, M.E., and Rivera, J.E. 2019).

## 3. Methods

This is an empirical, quantitative work with a case study approach proposing a dysergonomic risk management model in a company of the metal-mechanic sector.

### 3.1 Proposed Model

As a fundamental part of the study, a dysergonomic risk management model has been developed to improve the productivity of the welding technician position and specifically in the main task of modifying excavator buckets, as shown in Figure 1.

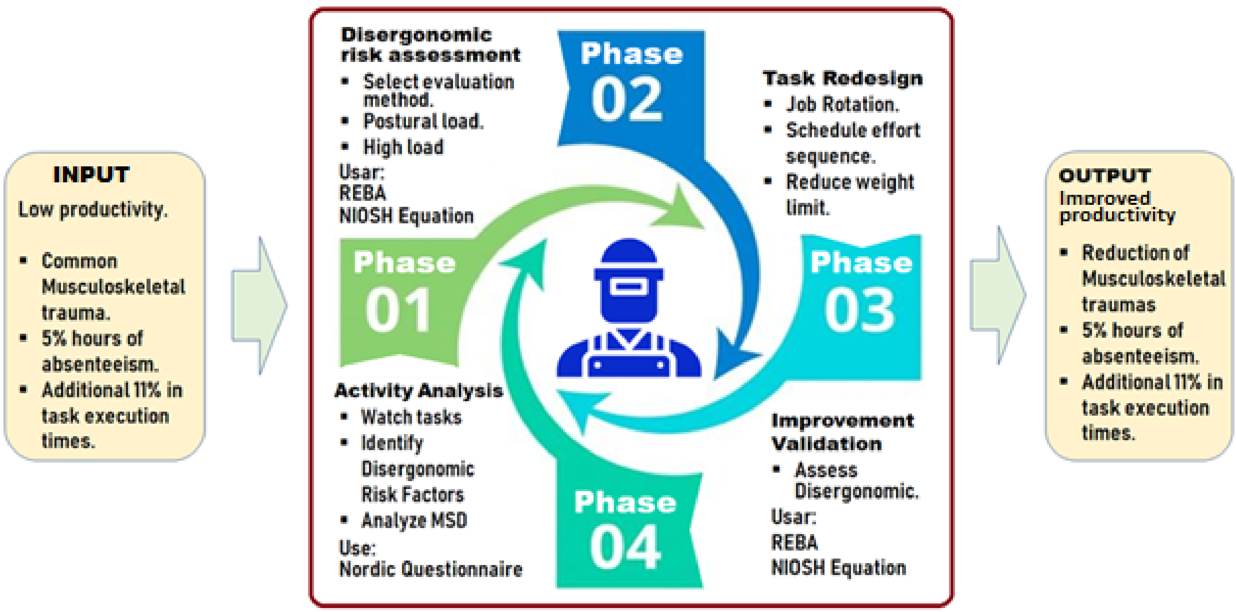


Figure 1. Proposed Model

#### 3.1.1 Phase 1: Activity Analysis

Based on the problems observed, we proceeded to analyze the activity and identify the Dysergonomic Risk Factors, using the Nordic Questionnaire applied to workers in different areas such as lathes, milling and welding, facilitating the identification of the most frequent ailments present in the study sample, which also characterize the metal-mechanical sector, which was then complemented with the history of medical breaks and absences of workers due to injuries suffered. This information facilitated the identification of critical areas that required immediate intervention as a potential source of ergonomic injuries for the workers.

#### 3.1.2 Phase 2: Dysergonomic Risk Assessment

In order to assess the level of dysergonomic risk, it is necessary to select the appropriate methods according to the Dysergonomic Risk Factors present in the analyzed task by determining to use a) the Rapid Entire Body Assessment (REBA) method to assess postural strain; and c) the National Institute for Occupational Safety and Health (NIOSH) method to assess load handling.

#### 3.1.3 Phase 3: Task Redesign

Through the analysis of the results found when developing the evaluation methods, it was determined to apply some improvements such as task redesign to reduce the effort found in the observed situation.

### 3.1.4 Phase 4: Improvement Validation

As recommended by ergonomists, it is necessary to re-evaluate the results of the task by applying the new results in the same methods used to ensure the proposed improvement.

## 4. Data Collection

After applying the Nordic questionnaire in all areas of the metal-mechanic company, a large majority of 53% of the workers belonging to the welding area had body aches, so the study was oriented to improve the welding technician position due to the dysergonomic risk factors and the working conditions it presents.

According to the testimony of the workers surveyed, the factors causing the discomfort are the prolonged positions they hold and the lack of automated tools that facilitate the lifting of heavy objects; as shown in Figure 2, the body regions most affected are the lower back, neck, shoulder, upper back, and knees. Likewise, the degree of pain or discomfort was rated, on a scale of 1 to 5, with 1 being mild discomfort, and 5 for unbearable pain; in this way, 57. This was corroborated with the history of absences and medical rest provided by the company, since there are no absences due to musculoskeletal pain so far in 2022; however, there is a great possibility of becoming serious and chronic injuries in the long term.

During two weeks, the activities performed in the workplace were observed, determining two activities as the most vulnerable to dysergonomic risk factors; on the one hand, the activity of modifying the bucket of an excavator, in which the worker presents a very high postural load performing tasks kneeling, with both arms on the welding machine and the body inclined to have a downward view (see Figure 2); and on the other hand there is the manual loading of parts, in which the worker is frequently exposed to handling heavy loads averaging 30 kilograms. (See Figure 3)

Figure 2. Excavator bucket modification

Figure 3. Manual loading of parts

# 5. Results and Discussion

## 5.1 Numerical Results

### 5.1.1 Dysergonomic risk in the activity of excavator bucket modification

The results of the REBA analysis of the excavator bucket modification activity from the observed postures, according to Figure 2, are shown in detail in Table 2:

Table 2. Evaluation of the observed situation

| Activity: Excavator bucket modification | | |
|---|---|---|
| Neck, leg and trunk strain | | Scoring |
| Neck | Flexion with extension and inclination greater than 20°. | 2 + 1 = 3 |
| Legs | Unstable posture and knee flexion more than 60°. | 2 + 2 = 4 |
| Trunk | Flexion of more than 60° and trunk inclination | 4 + 1 = 5 |
| Score A: Rating (3,4,5) = 9; plus (load > 10 kilos) = 2 | | 11 |
| Forearm, wrist and arm strain | | Scoring |
| Forearm | Flexion > 60° Flexion > 60 | 2 |
| Wrists | Extension > 15° and lateral deviation | 2 + 1 = 3 |
| Arms | 20° to 45° flexion and gravity posture | 3 - 1 = 2 |
| Score B: Rating (2,3,2) = 4; plus (acceptable grip) = 1 | | 5 |
| Score C: Rating (11,5) = 12; plus (Unstable postural changes) = 1 | | 13 |

With the score found, the following decision criteria should be considered:

- No risk if 1 = No improvement actions required.
- Tolerable risk, if between 2 and 3 = May require improvement.
- Moderate risk if it is between 4 and 7 = Requires improvement actions.
- Major risk, if between 8 and 10 = Improvement actions must be implemented soon.
- Intolerable risk, if between 11 and 15 = Requires immediate improvement actions.
- It is concluded that the task requires immediate preventive actions.
- No risk if 1 = No improvement action required-

Therefore, it is concluded that the task requires immediate preventive actions.

### 5.1.2 Dysergonomic risk in the activity of manual loading of parts

The results of the REBA analysis of the excavator bucket modification activity from the observed positions, according to Figure 3, are shown in detail in Table 3:

Table 3. Determination of lifting index

| Equation factor | Rating |
|---|---|
| Constant load factor, LC = 23 kilograms | |
| Horizontal distance factor, H = 30 cm | HM = 25/H: 25 cm / 30 cm = 0,83 |
| Height factor, V = 10 cm | VM = (1 – 0.003 x \| V – 75 \| = 0.81 |
| Vertical Displacement Factor, D = (90 - 10) cm | DM = 0.82 + 4.5 / D = 0.88 |
| Asymmetry factor, A = 90°. | AM = 1 – (0.003 x A) = 0.712 |
| Grip quality factor (good) | CM = 1 |
| Frequency factor: 0.2 times/ minute, in 1 hour | FM = 1 |
| Recommended Load Limit (RWL) = 23 x 0.83 x 0.81 x 0.88 x 0.88 x 0.712 x 1 = 9.69 kilos | |
| Lift Index (Li) = 30 kg / 9.69 kg = 3.10 | |

Counting on the lifting index (Li) the following decision criteria are taken:
- If it is less than or equal to 1; The task can be executed by most workers without harm.
- If it is between 1 and 3; the task may affect some workers; it is convenient to analyze the task and make improvements.
- If it is greater than 3, it can affect most workers, requires immediate improvements.

Consequently, it is necessary to take control actions to reduce the level of risk.

## 5.2 Proposed improvements
Following the results obtained, improvement interventions were implemented to reduce dysergonomic risks, such as:

### 5.2.1 Improvements in the excavator bucket modification activity activity
As a result of the results obtained, actions were applied such as:

- Perform the activity using a workbench with a 2.5 tons resistance to place the excavator bucket at an adjustable height between O.8 and 1.2 m reducing the magnitude of workers' awkward postures, facilitating standing work posture with less flexion and extension (Figure 4).
- A boom crane with a capacity of 2.5 tons is used to lift the excavator bucket.
- Training of personnel on postural loads and active breaks during the execution of activities.

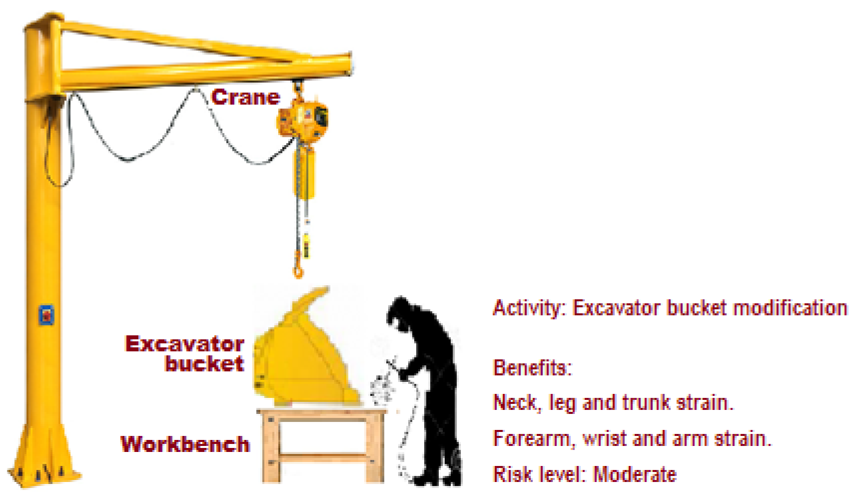


Figure 4. Adequacy of Workbench and Boom Crane

### 5.2.2 Improvements in the manual parts loading activity
Through the NIOSH analysis, the following improvement intervention actions are proposed (see Figure 5):

- Materials should enter the workshop on palettes with a height of 10 cm.
- Materials should be transported to the work area on a light trolley with a resistance of 100 kg and a height of 90 cm.
- Training of personnel on postural loads and active breaks during activities.
- In this way, the worker is required to take the materials on the pallet at 25 cm reducing the effort.
- Another aspect that is reduced is the effort caused by the asymmetric rotation of the mobile cart resulting in a rotation of 20° as opposed to the 90° that was initially given.
- In this way, the recommended acceptable weight improves from 9.69kg to 15.2kg and the lift index in relation to the average load weight (30kg) is reduced from 3.10 to 1.97

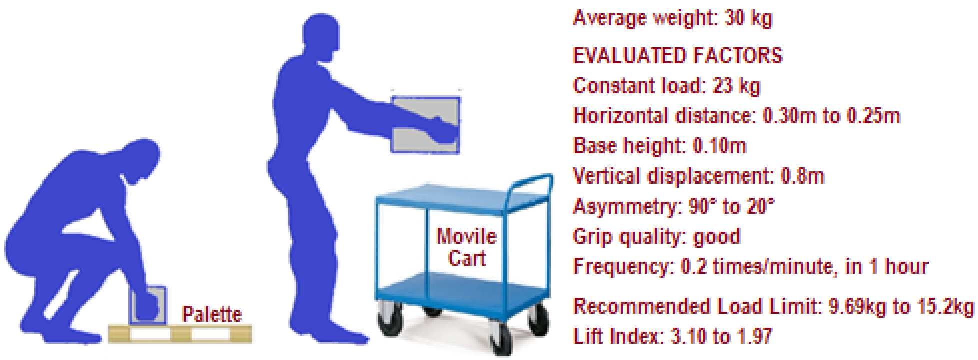


Figure 5. Adequacy of Workbench and Boom Crane

## 5.4 Validation

Based on the interventions performed, exposure to the dysergonomic risk factors present was reevaluated using the methodology initially applied.

### 5.3.1 Dysergonomic risk reduction in the excavator bucket modification activity

The results of the REBA analysis of the excavator bucket modification activity from the positions observed after the intervention are shown in detail in Table 4:

Table 4. Evaluation of the improved situation

| Activity: Excavator bucket modification | | |
|---|---|---|
| Neck, leg and trunk effort | | Scoring |
| Neck | Light flexion less than 20° and twisting | 1 + 1 = 2 |
| Legs | Bilateral standing support, plus slight flexion between 30 and 60°. | 1 + 1 = 2 |
| Trunk | Flexion and extension less than 20°. | 2 |
| Score A: Rating (2,2,2) = 4; plus (load > 10 kilos) = 2 | | 6 |
| Forearm, wrist and arm strain | | Scoring |
| Forearm | Flexion > 60° Wrists Extension > 15° without lateral deviation | 1 |
| Wrists | Extension > 15° without lateral deviation | 1 |
| Arms | Flexion from 20° to 45° without extension with gravity support | 2 - 1 = 1 |
| Score B: Rating (1,1,1) = 1; más (agarre aceptable) = 1 | | 2 |
| Score C: Rating (6,2) = 6; plus (Unstable postural changes) = 1 | | 7 |

The changes made reduced the moderate dysergonomic risk level assessment to a score of 7, indicating a medium dysergonomic risk level, demonstrating a significant reduction from the initially measured value.

### 5.1.2 Dysergonomic risk reduction in manual workpiece loading activity

The results of the NIOSH analysis of manual parts loading activity after making the proposed improvements are detailed as follows:

- Recommended Load Limit = 23 x 1 x 0.81 x 0.88 x 0.94 x 1 x 1 = 15.41 kilos
- Lift Index (Li) = 30 kg / 15.41 kg = 1.95

A significant reduction in the levels of dysegonomic risk can be seen, even though the task could still affect some workers; and in that sense, if the weight is handled by two workers at the same time, the lifting index shows an almost total reduction: (30kg x 0,5 x 15,41: 0.97)

Finally, a pilot test was applied considering a sample of the last 15 similar jobs within the welding area comparing the average time before and after the intervention, which allowed a surplus in production efficiency, having a decrease of 11% of the average time for the completion of tasks and absenteeism due to medical breaks for Musculoskeletal Trauma in less than 1% of the monthly scheduled hours (See Table 5).

Table 5. Variation in operating time

| Time per job | Pre-implementation (Hours) | Post Implementation (Hours) | % Variation |
|---|---|---|---|
| Minimum Time | 10 | 9 | 10% |
| Average Time | 13.467 | 12 | 11% |
| Maximum Time | 24 | 23 | 4% |

## 6. Conclusion

The results of the research have shown that by means of the standardized Nordic questionnaire it was possible to establish that welding technicians were more exposed to Musculoskeletal Traumas and in this way two critical tasks were identified: the modification of excavator bucket and the manual loading of weights, achieving in the short term, through the application of the REBA method and the NIOSH method, an increase of 11% in the average productivity levels in welding work and a rate of less than 1% for worker absences.

Based on the results obtained in this study, it can be affirmed that by reducing dysergonomic risks in the company, greater efficiency in productivity can be obtained, due to the fact that the operator has reduced the risk of seeing his health affected by the dysergonomic risk, improving the average time per job; which is congruent with the study of Gonzales et al. 2016 that presents the application of the REBA method in a tinplate packaging factory demonstrating after the evaluation and the proposed improvements the REBA score was reduced from an average of 11.5 points to 9.25 points with positive effects increasing productivity by 1.95%.

There is evidence of similar works in other sectors, such as the research of Abdullaha et al. 2020, presenting automotive maintenance jobs exposed to uncomfortable and repetitive postures executed at different times of the workday, becoming habits of bad practices and in the absence of inspections or having standards of execution, favor the appearance of musculoskeletal traumas proposing as the best preventive action to regularly apply periods of active breaks with stretching exercises.

It is very remarkable the research of Moradi et al. 2017 that shows that repetitive movements, weight loading, use of tools without ergonomic design, lack of rest breaks and standing for long periods of time are risk factors that frequently generate Work related musculoskeletal disorders (WMSDs), so it suggests that workers should receive proper postural training during the performance of their tasks as well as in the use of appropriate and ergonomic means equipment and hand tools being mechanization and automation two techniques to minimize the risk those jobs.

## References

Abdullaha, S., Kamaliana, N., Ghania, J., & Kurniawanb, R., Posture Evaluation of the Automotive Maintenance Workers: A Case Study, *Jurnal Kejuruteraan,* vol. 3, no. 1, pp. 65-70, 2020.

Adiyanto, O., Effendi, M., Jaafar, R., Abd Razak, J., Faishal, M., Mulaicin, M., and Akramin Mohamad, N., Integrated self-report and observational risk assessment for work-related musculoskeletal disorder in small and medium enterprises. *Engineering and Applied Science Research (EASR)*, vol. 49, pp. 73–80, 2021.

Afonso, M., Gabriel, A., and Godina, R., Proposal of an innovative ergonomic SMED model in an automotive steel springs industrial unit, *Advances in Industrial and Manufacturing Engineering*, vol. 4, 2022.

Asensio, S., Diego, J. and Alcaide, J., Estudio de la aplicabilidad práctica de los métodos de evaluación ergonómica de puestos de trabajo, *Proceedings of the 12th International Conference on Project Engineering*, Zaragoza, 2008

Asensio-Cuesta, S., Bastante-Ceca, M.J., Diego-Más, J., *Evaluación ergonómica de puestos de trabajo*, Paraninfo, 2012.

Bispo, L., Moreno C., Silva, G., Albuquerque, N., and Silva, J., Risk factors for work-related musculoskeletal disorders: A study in the inner regions of alagoas and bahía, *Safety Science,* vol. 153, 2022.

De Luca, K., Briggs, A., French, S., Ferreira, M., Cross, M., Blyth, F., and March, L., Disability burden due to musculoskeletal conditions and low back pain in Australia: findings from GBD 2019, *Chiropractic & Manual Therapies*, vol. 30, no. 22, 2022.

García, M., Sánchez, A., Sebastian, M., Aplicaciones ergonómicas como herramienta de mejora de la actividad proyectual de procesos de producción. *Proceedings of the 15° Congreso Internacional de Ingeniería de Proyectos*, Huesca, 2011

Gonzales, J., Carril, J., Yrene, E., Sánchez, P., Bracamonte, L., Cruz, W., Monzón, A., Córdova, D., Moreno, C., Impacto de un programa ergonómico en la productividad de una empresa de fabricación de envases de hojalata. *Agroindustrial Science*, vol. 6, no. 2, pp. 199-212. 2016.

Hignett S, and McAtamney L., Rapid entire body assessment (REBA). *Applied Ergonomics,* vol. 31, no. 2, pp. 201-205, 2000.

Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Biering-Sorensen, F., Andersson, G., and Jorgensen, K., Standardised Nordic questionnaires for the análisis of musculoskeletal symptoms, *Applied Ergonomics,* vol. 18, no. 3, pp. 233-237, 1987

Leirós, L., Historia de la Ergonomía, o de cómo la Ciencia del Trabajo se basa en verdades tomadas de la Psicología. *Revista de historia de la psicología*, vol. 30, no. 4, pp. 33-53, 2009.

Ley N.° 29783, Ley de Seguridad y Salud en el Trabajo, 2011

Lin, P., Chen, Y., Chen, W. and Lee, Y., Automatic real-time occupational posture evaluation and select corresponding ergonomic assessments, *Scientific Reports*, vol. 12, no. 1, 2022.

Macdonald, M. and Oakman, J., The problem with "ergonomics injuries": What can ergonomists do?, Applied Ergonomics, vol. 103, 2022.

Medina-Chacón, E. R., Evaluation of disergonomic risks in small and medium-size enterprises (SMEs) in Bogotá. *Grupo de Investigación GINTECPRO*, vol. 87, no. 213, pp. 98–104, 2020.

Moradi M, Poursadeghiyan M, Khammar A, Hami M, Darsnj A, Yarmohammadi H., REBA method for the ergonomic risk assessment of auto mechanics postural stress caused by working conditions in Kermanshah (Iran), *Annals of Tropical Medicine and Public Health*, no. 10, pp. 589-94, 2017.

Rajendran, M., Sajeev, A., Shanmugavel, R. and Rajpradeesh, T., Ergonomic evaluation of workers during manual material handling, *Materials Today: Proceedings*, vol. 46, no. 17, pp. 7770-7776, 2020.

Resolución Ministerial N.° 375-2008-TR., Norma Básica de Ergonomía y de Procedimiento de Evaluación de Riesgo Disergonómico, 2008.

Smith, T., Balogun, A., and Dillman, A., Management perspectives on musculoskeletal disorder risk factors and protective safety resources within the stone, sand, and gravel mining industry, *Workplace Health and Safety*, vol. 70, no. 5, pp. 242-250, 2022.

Torres, Y., and Rodríguez, Y. Surgimiento y evolución de la ergonomía como disciplina: reflexiones sobre la escuela de los factores humanos y la escuela de la ergonomía de la actividad, *Revista Facultad Nacional de Salud Pública,* vol. 39, no. 2, e342868, 2021.

Vachinska, S., Markova, V. and Ganchev, T., A Risk Assessment Study on Musculoskeletal Disorders in Computer Users Based on A Modified Nordic Musculoskeletal Questionnaire, Contemporary Methods in Bioinformatics and Biomedicine and Their Applications, vol. 374, pp. 433-444, 2022.

Valois, M. and Rivera, J., 2019. Guía practica para la aplicación de la ecuación de NIOSH en el dolor lumbar. *Universidad Santiago de Cali*, vol. 1, no. 2, pp. 1-7, 2019.

Vernaza-Pinzón, P. and Sierra-Torres, C., Dolor Músculo-Esquelético y su asociación con Factores de Riesgo Ergonómicos, en trabajadores administrativos. *Revista de Salud Pública*, vol. 7, no. 3, pp. 317-326, 2005.

## Biography

**Sebastian Pizarro-Vásquez** Ninth year student of Industrial Engineering at the University of Lima. His research interests include process optimization, ergonomics, project management and agribusiness.

**Andrea Lara-Lezcano** Tenth cycle student of Industrial Engineering at the University of Lima. His research interests include the metalworking industry, ergonomics, and optimization of industrial companies.

**Carlos Augusto Lizárraga-Portugal** Industrial Engineer from Universidad de Lima, Cum Laude. Master's in administration - ESAN; Doctor in Education, Universidad San Martín de Porres. Post Degree in Auditing and Implementation of Integrated Management Systems (Quality ISO9001, Environment ISO 14001, Occupational Health and Safety OHSAS18001, Social Responsibility). Business Consultant specializing in Strategic Planning, Occupational Health and Safety Management Systems, Logistics Management, Purchasing Management, Strategic Inventory Control - Supply Chain Management, Warehouse Management, State Purchasing Process, Costs and Production Management. Experience in Sectors such as Apparel, Plastics, Industrial Footwear, Fishing, Services, Marketing, Training, etc. Professor at the University of Lima in the Industrial Engineering Career, teaching courses on Integral Safety, Maintenance Management, Business Diagnostics and Research Projects. Trainer and facilitator in Seminars on Strategic Planning, Business Organization, Production Management, Operations Management, Strategic Inventory Control, Chain Supply Management, Industrial Safety and Integral Safety Management. Thesis Advisor and Jury.

**Juan Carlos Quiroz-Flores** holds an MBA from Universidad ESAN. Industrial Engineer from Universidad de Lima. PhD. in Industrial Engineering from Universidad Nacional Mayor de San Marcos, Black Belt in Lean Six Sigma. He is currently an undergraduate professor and researcher at the University of Lima. Expert in Lean Supply Chain and Operations with more than 20 years of professional experience in the direction and management of operations, process improvement, and productivity; specialist in implementing Continuous Improvement Projects, PDCA, TOC, and Lean Six Sigma. Leader of transformation, productivity, and change generation projects. Able to form high-performance teams aligned with the company's "Continuous Improvement" strategies and programs. He has published articles in journals and conferences indexed in Scopus and Web of Science. His research interests include supply chain and logistics management, lean manufacturing, lean six sigma, business process management, agribusiness, design work, facility layout design, systematic distribution planning, quality management, Industry 4.0, Digital Transformation, and Lean Manufacturing. He is a classified researcher by the National Council of Science, Technology and Technological Innovation of Peru (CONCYTEC) and a member of IEOM, IISE, ASQ, IEEE, and CIP (College of Engineers of Peru).