Ergonomic improvement in a roll-forming station for a metal-mechanical company

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Abstract

The present research seeks to design and implement an ergonomic improvement in the roll-forming station of a metal-mechanical company, where the incidence rate for low back pain is 29.4%. The methodology used to evaluate the situation prior to the improvement was the NIOSH equation, where the risk of injury was found to be 3.30 at the origin and 3.57 at the destination. According to NIOSH benchmarks, these factors constitute a high risk of injury and urgent intervention. Following the design and implementation of the improvement, the NIOSH equation was again used to demonstrate the decrease in risk presented by the operation. An improvement of 81.5% in the rate of lifting at the origin and 73.4% at the destination was achieved. The research presented validity in the NIOSH equation, helping to corroborate the effectiveness obtained by the design and implementation of an ergonomic improvement, thus reducing the probability of injury,and increasing job satisfaction.

Keywords
Manual Load Operations, Ergonomic Design, NIOSH Equation, Musculoskeletal Trauma, Low Back Pain Trauma.

1. Introduction

The design of ergonomic workstations improves productivity of operations and generates an adequate environment for management of occupational safety, the main element of any design should bethe human factor (Torres and Rodriguez, 2021). In manufacturing companies, the incidence rate of low back pain related to diseases caused by exposure, repetition and intensity of overexertion is one of the most recurrent symptoms (Neusa-Arenas et al. 2020). In the case study presented, a high rate of low back injuries was identified in a specific area of the production plant, a bad design of the workstation was diagnosed,and a solution is proposed under an ergonomic improvement. The task identified is a manual load handling operation that involves constantly picking up and moving heavy materials from one position to another. The area where this workstation is located is the roll forming area. The production line generates a coarse chip that is collected in a steel tray and then transferred to the compressor, where a compact block of metal is formed.

Figure 1. Empty tray before burr exits the machine and Copper burr in station

Manual load handling occurs when transferring the chip tray to the compressor. In this task, which has a not negligible frequency, is where many operators are often injured due to the lack of ergonomic design at the workstation (Figure 1).

This paper has been structured as follows: Sections 2 and 3 describe the literature reviewed and our research methodology. Section 4 discusses data treatment and collection processes. Section 5 provides results and the improvements proposed. Finally, Section 6 presents our conclusions and recommendations for future lines of research on the subject matter.

1.1 Objectives

The objective of this research is to design and implement an ergonomic improvement for the selected workstation. The implementation seeks to reduce the risk of occupational injuries by relieving the manual burden on operators and to increase job satisfaction. Through these objectives, it also seeks to test the validity of the National Institute for Occupational Safety & Health (NIOSH) equation and corroborate the effectiveness of the obtained indexes.

2. Literature Review

Ergonomics is a discipline that studies methods to analyze the tasks performed by operators with the different work tools used. To ensure occupational health and worker productivity, it is important to design workstations ergonomically for the users performing the tasks (Lowe et al. 2018). Factors such as age, gender, experience, education level, height, and weight are believed to influence the likelihood of worker injury (Mahboobi et al. 2020).
With a steady increase in the population of workers who carry heavy objects, 84% of them report low back pain as a major problem (Yong et al. 2019; Delp et al. 2021). Back injuries are common in jobs involving prolonged standing and long hours (Kamani and Kalwar2021). Likewise, it is monotonous manual jobs that have a high rate of injury potential (Schwartz et al. 2019). As long as there is a high-frequency task that demands a lot of effort in an inadequate posture, the probability of occurrence of this disorder will be higher (Caroly et al. 2010).

The use of ergonomic implements helps to alleviate stress generated in specific areas by intense work activity, according to (Mirka et al. 2010). This results in improved operator performance, increased job satisfaction and a reduced occupational injury rate.

The implementation of ergonomic measures not only aids in worker safety and health but can also reduce process times; resulting in increased productivity (Resnick et al. 1994). By implementing ergonomic measures at a weight-loading station, injuries such as scoliosis, spinal osteoarthritis, hernias, and more are prevented (Caneiro et al. 2018). Adapting to a more ergonomic workstation will not only reduce injuries in the short and long term, but also represent economic savings in worker insurance and increased productivity (Sadeghi Naeiniand Zolfaghari2020).

To increase the productivity of the production line, increasing the number of operators is not the solution, according to the findings of (Rego Monteil et al. 2013). The implementation of ergonomic solutions not only reduces injury risks, but also reduces times and increases line productivity.

The implementation of ergonomic measures can result in an economic increase for both the company and the worker (Susihono et al. 2021). However, studies have shown that in many cases workers ignore recommendations or critical aspects of the station, which worsen the ergonomic situation (Fansayaand Shofuluwe2018). That is why ergonomic improvements present quite a few obstacles in their implementation.

3. Methods

The goal of the NIOSH Equation is to reduce the incidence of low back pain, or low back pain, related to lifting tasks. The mathematical equation considers three aspects of the task: biomechanical load, metabolic load, and psychophysical workload. Informationcollectedis:

- Object weight
- Horizontal and vertical location of the hands with respect to the midpoint between the ankles
- Frequency of hauling
- Carrying time
- Type of grip (coupling) between the loader's hands and the object.

Revised NIOSH 1991 LiftEquation

$$RWLNiosh\ 1991 = 23\ kg * HM * VM * DM * AM * FM * CM$$

$$\acute{I}ndicedeLevantamiento = \frac{CargaLevantada}{RWL}$$

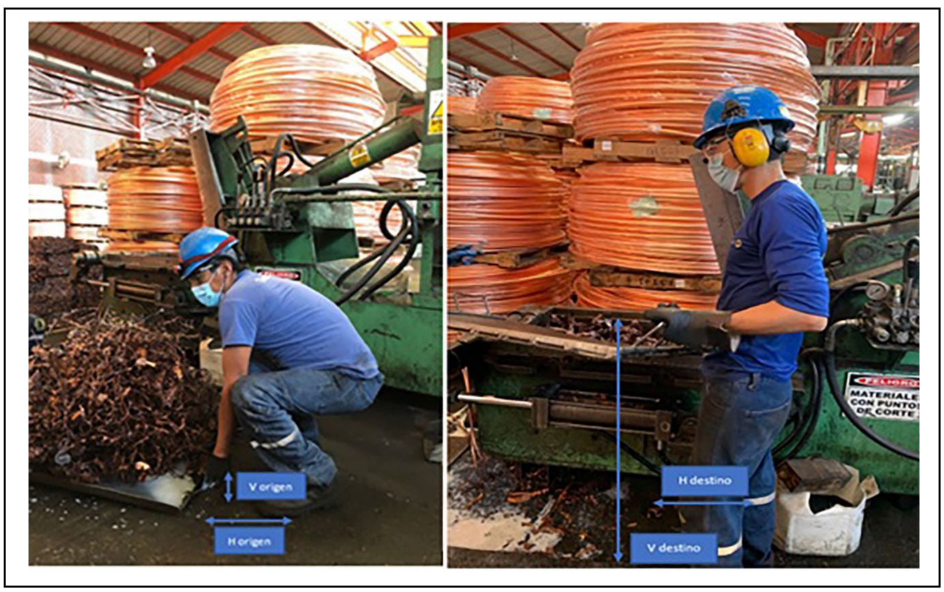

Figure 2. Body position at origin; Body position at destination

As for the measurements, "H origin" is the horizontal distance from the midpoint of the feet to the hands in the initial position, "V origin" is the vertical distance from the ground to the grip of the hands in the initial position, "H destination" is the horizontal distance from the midpoint of the feet to the hands in the final position, and "V destination" is the vertical distance from the ground to the grip of the hands in the final position (Figure 2). Due to the shape of the grip, which molds well to the operator's hands, the grip type rating is "good". Because there is no body torque, the asymmetry multiplier is considered a value of one. (Waters et al. 1994).

4. Data Collection

The data was obtained from the profiling process of a leading company in the Peruvian market dedicated to the metallurgical transformation of copper and its alloys. The company has a manufacturing plant in the city of Lima and had a turnover of approximately US$180 million in 2020. The products are copper bars and wires, as well as copper-zinc, copper-phosphorus, and copper-silicon alloys. Although a large percentage of the operations in the production process are automated, there are still some that require manual handling of loads. Table 1 shows incidence rate for different employee positions.

Table 1. Incidence rate per job post

Post	Incident Rate
TREASURY ANALYST	2.9%
SALES ASSISTANT	2.9%
PRODUCTION ASSISTANT	5.9%
PRODUCTION COORDINATOR	5.9%
EXTRUDER	2.9%
MELTER	8.8%
QUALITY INSPECTOR	2.9%
LINE INSPECTOR	8.8%
LAMINATOR	2.9%
WAREHOUSE FORKLIFT OPERATOR	2.9%
PRODUCTION FORKLIFT OPERATOR	5.9%
MAINTENANCE TRAINEE	2.9%
REFRACTARIST	5.9%
TOOLING SUPERVISOR	2.9%
PHYSICAL ANALYST TECHNICIAN	2.9%
TOOLING TECHNICIAN	2.9%
PROFILER	29.4%

The values of the five operators measured, and the average, are shown in table 2.

Table 2. Measurements before improvement implementation

	Average of 5 workers
H origin	39 cm
V origin	5 cm
H destination	48.4 cm
V destination	108.4 cm
D (V destination - V origin)	103.4 cm
Weight	28.2 kg
Frequency	0.2 times/minute
Hours per day	2< X <=8
Grip Type	Good

5. Results and Discussion

5.1 Numerical Results

By performing the corresponding calculations, the following values are obtained:

$$RWLorigen = 8.55$$
$$RWLdestino = 7.85$$
$$ÍndicedeLevantamientoenelorigen = 3.30$$
$$ÍndicedeLevantamientoeneldestino = 3.57$$

Table 3. Risk index

IL < 1	Low Risk
1 <= IL < 2	ModerateRisk
IL >= 2	High Risk

These results refer to the high risk (Table 3) of lumbar injury that exists due to the loading and unloading actions at workstation 1600 (roll forming station). If this activity continues to be performed in the same way, operators will continue to be injured in the medium and long term.

An incorrect weightlifting action leads to a decrease in the height of the intervertebral discs. As loading stresses persist, the articular facets begin to deform due to weight overload (Carbajal Romero et al. 2004).

5.2 Graphical Results

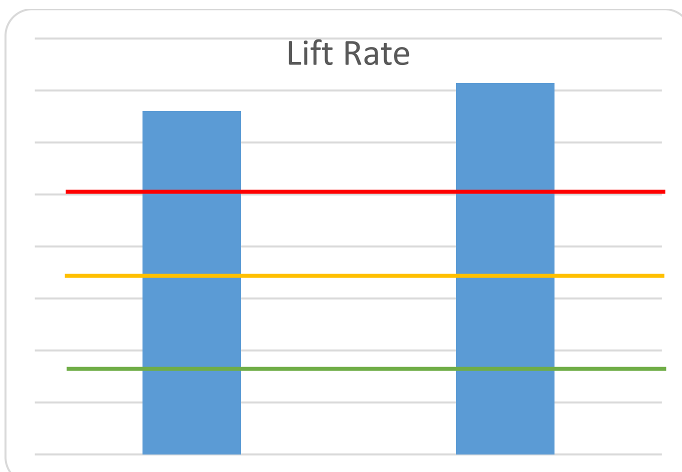

Figure 3. Load lifting index

The graph shows the uplift index for both origin and destination. The axes in units 1, 2 and 3 represent the risk limits; either low, medium, or high respectively. As can be seen in Figure 3, both situations are at high risk of injury and urgent intervention.

From a clinical point of view, the predominant symptom of an incorrect lifting is lumbar pain, due to the decrease in height of the discs. In addition, in some cases, pain from one or both legs may be added, with cramping sensations. Also, long-term consequences include spondylolisthesis, which is the displacement of one vertebra over another, and hyper lordosis: an excessive curvature of the spine in the lower back (Tejeda Barreras et al. 2016).

5.3 Proposed Improvements

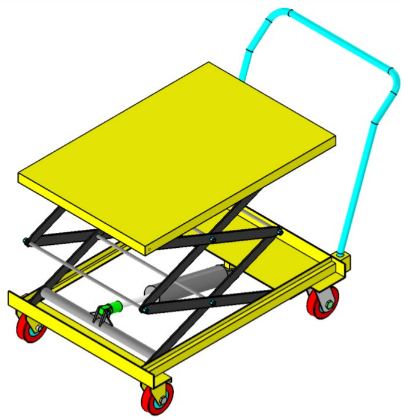

Figure 4. Improvement design

For the improvement, a hydraulic table was presented, which with the help of a pedal raises and lowers in height. This helps to avoid the constant torque and bending of the back, reducing the effort exerted on the back both in the movement and in the loading of the material (Ruiz 2011). The design of the improvement is presented in Figure 4, and the NIOSH equation will then be applied to demonstrate the reduced risk of injury. The table is 50.8cm wide and 76.2cm long, rises in level to 110cm and can support 100kg (Figure 5).

Figure 5. New conveyor improvement

5.4 Validation

The average measured distances for the five workers is showed in table 4:

Table 4. Measurements after improvement implementation

	Average of 5 workers
H origin	12 cm
V origin	76 cm
H destination	18 cm
V destination	90 cm
D (V destination - V origin)	14 cm
Weight	28.2 kg
Frequency	0.2 times/minute
Hours per day	2< X <=8
Grip Type	Good

Entering these data into the NIOSH equation gives the following values:

$RWL\ origin = 46.27$

$RWL\ destination = 29.58$

$Lifting\ Index\ at\ the\ origin = 0.61$

$Lifting\ Index\ at\ destination = 0.95$

Looking at the table, the lifting rates of both the origin and destination are in the "Low Risk" category. This means that, after implementing the hydraulic table improvement, the objective was met and the risk of injury was reduced from "High Risk", where changes were urgently needed, to "Low Risk". The lifting rate at origin improved by 81.5%, while that at destination improved by 73.4%.

6. Conclusion

The purpose of this work was to find a solution to the problem found, which dealt with ergonomic failures in the profiling workstation. Through different methods and instruments, the risk of lumbar injury of the operators in the mentioned area was reduced. Also, job satisfaction was increased, and this was verified after surveying workers at workstation.

Using the revised NIOSH equation, it was possible to measure the risk of injury before and after the implementation of the improvement, which was significantly reduced, and improved by 81.5% at the starting position and 73.4% at the destination. Some limitations found throughout the study were the suitability of the hydraulic table for the workstation, as it needed to be relatively small and easy to maneuver, and the initial investment of the table, which will eventually reduce visits to the physician and save costs.

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Biographies

Martin Cametis a Senior Supply Chain Analyst at a Peruvian company in the food industry. He holds a bachelor's degree in industrial engineering from the University of Lima. He has previous experience working in the areas of project coordination and process improvement in large volume factories, previously working in Peru's main chocolate producer and exporter. He has knowledge in the areas of lean manufacturing and ergonomics, having taken those elective courses, and experience in the metal-working field. Mr. Camet currently works managing the supplies and inventory of a Peruvian premium food company and is presently improving the distribution methods for a better consumer experience. His main interests are on predictive analytics, ergonomic improvements, 5s methodology, and supply chain in industry 4.0.

Frank Tweddle holds a bachelor's degree in Industrial Engineering from University of Lima, where he led a project about ergonomic improvement in a metal-transforming plant in Lima, Peru. Frank counts with experience on Trade Marketing from the CPG industry where he developed commercial and negotiating skills besides learned about strategic plans of the company. He is currently developing as a mineral concentrate traffic trainee in a global trading firm. Mr. Tweddle is currently aiming to further specialize on international commerce and logistics at the mining industry.

José Antonio Taquía is a Doctoral Researcher from Universidad Nacional Mayor de San Marcos and holds a Master of Science degree in Industrial Engineering from Universidad de Lima. He is a member of the School of Engineering and Architecture teaching courses on quantitative methods, predictive analytics, and research methodology. He has a vast experience on applied technology related to machine learning and industry 4.0 disrupting applications. In the private sector he was part of several implementations of technical projects including roles as an expert user and in the leading deployment side. He worked as a senior corporate demand planner with emphasis on the statistical field for a multinational Peruvian company in the beauty and personal care industry with operations in Europe and Latin America. Mr. Taquía has a strong background in supply chain analytics and operations modeling applied at different sectors of the industry. He is also a member of the Scientific Research Institute at Universidad de Lima. His main research interests are on statistical learning, predictive analytics, and industry 4.0.