Ergonomic Redesign Model to reduce musculoskeletal disorders in a cluster of SMEs in the clothing accessories sector

Daniel Aquino, Engineering BSc[1], Edson Rodríguez, Engineering BSc[1] and Juan Carlos Quiroz-Flores, PhD[1]
[1]Facultad de Ingeniería y Arquitectura, Universidad de Lima, Lima, Perú, 20161781@aloe.ulima.edu.pe, 20152291@aloe.ulima.edu.pe and jcquiroz@ulima.edu.pe

Abstract— **The Peruvian manufacturing industry is one of high impact in Latin America with excellent quality materials and massive productive quantities making it an important industry for the country itself. Even so, with this sector being so significant, the prevalence rate of musculoskeletal disorders (MSDs) remains high for companies with little capital and no investment capacity, such being the small and medium-sized enterprises (SMEs) of the industry. Either due to mishandling of machinery or repetitiveness of labor, musculoskeletal disorders are a prevalent problem for manufacturing industries with little to no information on ergonomic ways of control as well as having a Lean focus to add value to the process. This paper seeks to find the validity of a model to reduce absenteeism and exposure to musculoskeletal disorders using ergonomic and Lean tools to promote safe practices and the preservation of health in turn with work productivity on SMEs from the clothing accessory sector. This model was able to reduce exposure to MSDs by 67.27% and reduced the company's absenteeism rate by 52.85% getting to considering levels for industry standards and validating the effectiveness of similar models.**

Keywords—Ergonomics, Lean, Musculoskeletal Disorders, Accessories, Redesign.

I. INTRODUCTION

At a global level, the importance generated by the textile and clothing sector is unprecedented and outstanding, since it contributes annually 2% to the gross domestic product (GDP) and, in addition, generates and constitutes more than 57 million jobs of which only 24 million belong to the apparel sector [1]. During the next 5 years, in Latin America, certain investigations articulate a 7.2% increase in clothing and footwear spending, which in monetary terms will reach an amount of 220 billion by 2021 [2]. In South America, many countries generate good quality fabric, but the country that exports a greater quantity of clothing is Peru since it has raw materials that differ from the others, such as fibers, wool, and cotton [3]. This investigation will focus on the effect generated by this sector since it is very high in the entire economy of a territory, precisely located in Peru. In Peru, this sector is of enormous contribution since the manufacturing area generates 12.5% of the national Gross Domestic Product and the textile area comprises 7.9% of the collaboration of the manufacturing sector in 2020 and organizing about 398 thousand positions from work to national grade [4]. However, it is important to note that the pandemic was an unpredictable event and generated an 11.2% drop in Peru's GDP since 2019 [5].

Even in this way, before these events, exports of clothing, except leather and fur garments, have had an increase of 7.9% which contributed to the growth of national exports in 2019, indicating an optimal previous path in the national collaboration of this sector [6]. José Salardi, Minister of Production, expressed his perspective for 2020, before the pandemic disease, stating that he expected to achieve a 5% growth in exports in the sector and reach 2 billion dollars in national exports [7]. These results show the enormous importance and collaboration that the manufacturing area has in Peru, carrying out its most relevant analysis due to its high cost to achieve the reactivation of the economy. In an active population, the most common and primary cause of occupational injury and disability in industrialized and developed nations, such as first world countries, is musculoskeletal signs (MSS) [8]. Generally, there is a high risk of occupational accidents for the clothing sector because the operators carry out tasks and material handling processes which involve equipment that generates a high rate of repetitions of work, exerting on the muscles of the workers, and hence, they cause work-related musculoskeletal disorders (WMSD). Currently, WMSD is one of the major occupational health problems since it causes more than 2.2 million deaths per year and is caused by accidents and occupational diseases [1].

To solve the problem described, the application of combined ergonomic tools is sought together with lean manufacturing tools, so that, in addition to offering an approach to workers, a different way can be discovered to add cost to the process and improve productivity [9]. RULA, REBA, and NIOSH are the main ergonomics tools that analyse the work environment and anthropometry, which will be part of the process to be implemented through this research. The Kaizen procedure is fundamentally for the lean tools of which the use of the 5S is highlighted to decide the added cost that can be produced when doing a study. Even in this way, more information is needed concerning this model in the textile area, especially in Latin America, realizing that a need arises to continue with the investigation. [10].

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II. STATE OF THE ART

A. *Musculoskeletal disorders in the textile sector:*

The appearance of musculoskeletal disorders in the workplace is a very recurrent problem for any manufacturing sector, affecting productivity, costs, and absenteeism rates. It was found in articles on the subject, a very high permanence of absenteeism for countries with slow industrial development and little ergonomic implementation for the consideration of the average worker's health. The smaller the investment size in these companies, the higher the exposure rate to musculoskeletal disorders are presented, finding a low priority correlation to health for small businesses. These factors demonstrate the little care and management of the appearance of musculoskeletal disorders in the textile sector, evidencing the low rates of productivity and the high costs due to absenteeism, failures, and lost time [8], [9].

B. *Ergonomics:*

The definition of ergonomics refers to the discipline of analysis of workplace designs, tools to be used, and the tasks that are carried out in these areas in a way that evaluates the physical, psychological, and anatomical capacities in the performance of a worker to preserve your health. In turn, your goal is to achieve work efficiency by considering employee safety and managing employee effort to cause less stress on the body. The tools to be implemented address posture problems that generate annoyances either due to the amount of load, poor work posture, or poor design of the work area, generating manufacturing delays and low productivity in the operational field. Common studies such as RULA and REBA evaluations are efficient ways of obtaining field data while alternative tools such as ErgoSMED and 5S Audits encompass the application of direct productivity control methods. [10], [11].

C. *Ergo-Lean in the textiles sector:*

The implementation of ergonomic and Lean models has previously proven effective, conveniently affecting productivity and manufacturing company times. Improvement values of 16% were noted in operators and 58.5% in heavy operators, as well as in another case that indicates a reduction in non-productivity of 87% and defective in 66%, verifying the relevance of this type of model [12], [13], [14].

III. CONTRIBUTION

A. *Fundamentals:*

The presented proposal attempts to attack the problem of absenteeism through the tools found in the state of the art with the expectation that, through its integration, positive results will be found to solve this problem. The Vista solution targets the ergonomic parts of the job to correct annoyances and avoid absenteeism through analysis and redesign proposals with RULA, REBA, and NIOSH evaluations, as well as evaluations of the economy of motion. In this way, together with the application of a Lean method, it is expected to ensure an improvement in exposure to musculoskeletal disorders and consequently reduce absenteeism from work.

B. *Proposed Model:*

The integration of the model is based on the use of ergonomic assessment techniques and process analysis from which the RULA, REBA, NIOSH assessments, and the 5S tool are identified along with an environmental analysis.

The improvement tools seen below allow you to verify the validity of the model in comparison to its current state through the output indicators.

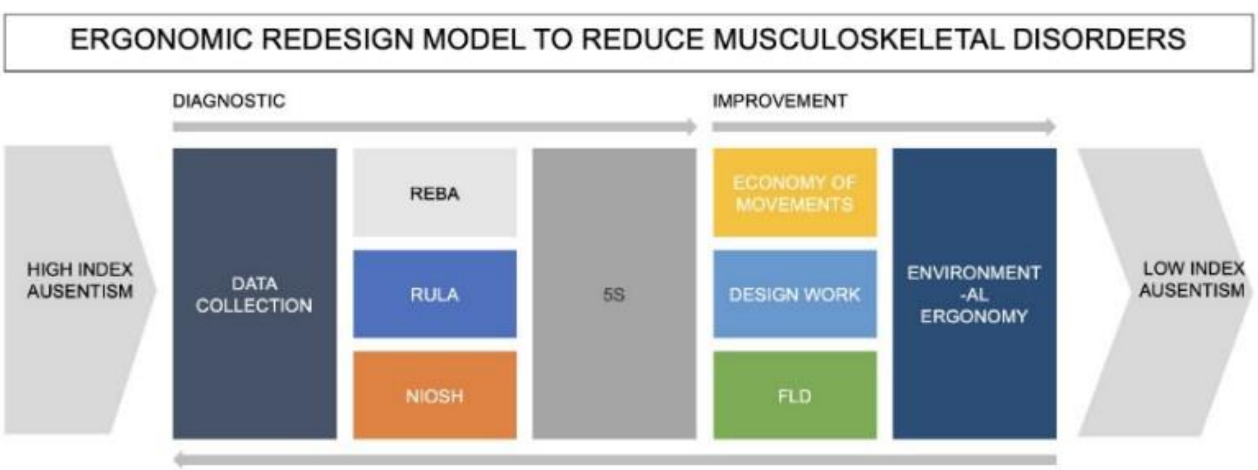

Fig 1. Proposed model.

C. Components of the Model:

1) Component 1: Data registry:

The information collected from current activities is analysed through diagnostic tools applying ergonomic and lean terms. These results will be used to verify and compare the model through its indicators later.

2) Component 2: Ergonomic application:

This stage seeks to attack the problems previously encountered to positively affect the proposed indicators. The improvement tools are those for managing the economy of movement, the Facility Layout Design (FLD), environmental ergonomics, and the redesign of workstations.

3) Component 3: Ergo-Lean Analysis:

The final stage consists of checking and comparing the results of the proposed model with the current state so that the indicators can show the expected improvement.

D. Model indicators:

1. Reduction in the Level of Exposure to MSDs (RLEMSDs):

Expectation: 60% reduction.

RLEMSDs (%) = $\sum$ (($\sum$ (Initial evaluation score i – Final evaluation score i) / Initial evaluation score i) / # Evaluations) * Current exposure) * 100. (1)

- Explanation: Reduction measured based on the results between each evaluation.

2. Reduction of Total Absenteeism (RTA):

Expectation: 50% reduction.

RTA (%) = ((Current annual absenteeism – (External absenteeism + MSDs absenteeism * (1 – RLEMDs))) / Current annual absenteeism) * 100. (2)

- Explanation: Total absenteeism reduction based on the REMSDs indicator.

3. Reduction of Ergonomic Indicators in Workstations (REI):

Expectation: 60% reduction.

REI (%) = ($\sum$((Initial score i – Final score i) / Initial score i) / # Evaluations)*100. (3)

- Explanation: Reduction of ergonomic evaluation.

IV. VALIDATION

A. Initial Diagnosis:

The current situation of the case study shows a company with an absenteeism rate of 4.03% having losses of 12.68% of net profit. The required standards of the manufacturing sector indicate that the absenteeism rate must be below 2.30% and the percentage of absenteeism that is caused by musculoskeletal disorders is 80%. The 80m2 plant has a distribution of 4 sectors where there are problems of movement restriction, very high weight load, bad design of jobs in repetitive tasks, and incorrect hauling techniques. These problems are subject to evaluation for improvement in the proposed model.

For the plant's layout, the aim is to achieve a change in the design of the distribution of work areas and furniture for better transit and greater ease of work in terms of the established operational line. This stage is associated with the FLD and economy of movement in which at first glance, it can be seen the need to distribute the material entry areas in such a way that a constant material flow can be generated. As seen in the Figure 2, the optimized model starts from the removal of the raw material to its final storage, having passed through the operational sectors that would transform the product.

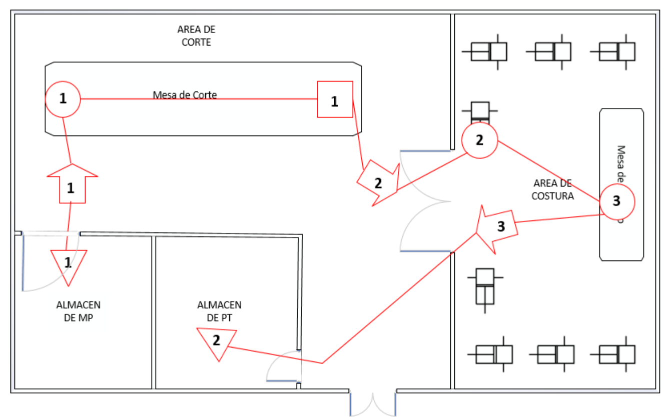

Fig 2. FLD model with task flowchart.

Subsequently, the ergonomic levels of the work areas involved in the redistributed sectors are evaluated using a tool that allows it. As mentioned before, 80% of absenteeism is caused by musculoskeletal disorders, indicating a high capacity for change in the proposed indicators. A comparison should be made using the same tool to verify the validity of some model and make the pertinent adaptations to unacceptable values. It is expected to obtain high change results and at least reach the legally allowed rate of absenteeism.

B. Validation Design and Comparison with the Initial Diagnosis:

To make a comparison between the proposed model and the current state, simulations will be carried out for the jobs in question. Following the work procedure through the components, the work areas are physically analysed using ergonomic evaluations relevant to these, completing the collection of information. This information is evaluated by means of a tool called "Ergonautas", whose program allows obtaining results from ergonomic evaluations, as previously specified for the current diagnosis. Information is collected on weight management, average worker height, posture characteristics, and environmental characteristics so that such assessments can be accurate. For the RULA and REBA evaluation, data on postural angles focusing on postural load in seated, standing and differently loaded workers were required. Meanwhile, the NIOSH evaluation focused on the proper handling of heavy loads and the limitations of the body that could be affected, being an important factor to consider the maximum load weight together with the environmental characteristics for the worker.

The results of these evaluations concluded in unacceptable evaluations for ergonomic standards with very high results in each of them, leading the current indicators to the results shown later.

TABLE I. INDICATOR OBJECTIVES

Indicator	Current situation	Objective
Exposure level	4	1
Absenteeism rate	4.03%	1.6%
RULA ergonomic indicator	5	1
NIOSH ergonomic indicator	2.5	1
REBA ergonomic indicator	11	2

As highlighted in Table I, having found the indicators through the formulas presented above, we can identify a very bad state for the level of exposure and absenteeism in operations as they are in a high-risk ergonomic level, indicating in each case the need to urgently implement an improvement to start avoiding MSDs. In addition, it should be noted that the absenteeism ratio must reach a maximum of 2.30% according to the law to be considered an acceptable value. In this case, this indicator is well over the limit with a value of 4.03% of absenteeism and an exposure level of 4, it being the highest risk value for exposure of MSDs.

C. Proposed Validation Design:

The model can be correctly implemented thanks to the development of the simulation through the Delmia V5 tool, a program specialized in spatial designs and space management for ergonomic evaluations of work environments. Four different simulations were carried out for each of the sectors seen in the case study.

Firstly, each one of the work environments is modelled to then simulate with a mannequin the activities carried out according to the necessary improvements. These improvements involve better space management, changing furniture dimensions and their effect on the mannequin's body. At first glance, the improvement measures are consistent with ergonomic principles in terms of working angles, working height in relation to the body, reach distances and other factors as seen in Figure 3.

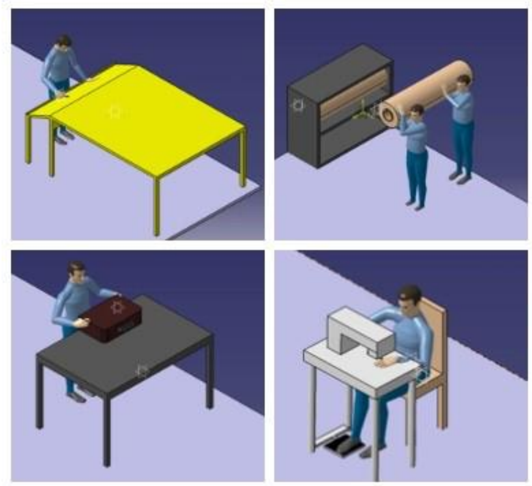

Fig 3. Simulation models.

Next, in the same way as the evaluation of the current state, the "Ergonautas" tool is used, hoping to obtain better results. In each of the simulations, the ergonomic, environmental, and labour economy tools were put to the test to guarantee the correct optimization of the work environment.

TABLE II. INDICATOR RESULTS

Indicator	Current situation	Proposed model
Exposure level	4	1
Absenteeism rate	4.03%	1.9%
RULA ergonomic indicator	5	2
NIOSH ergonomic indicator	2.5	1
REBA ergonomic indicator	11	2

As highlighted in Table II, the final comparison between the current situation and the results of the proposed model for the main indicators is shown. It can see how the ergonomic results of the simulations reached acceptable levels in the RULA evaluation with a risk level of 2, in the NIOSH evaluation with a risk level of 1 and in the REBA evaluation with a risk level of 2. These values indicate a good ergonomic working state that suggests the well-being of the workers among its implementations. The exposure level values reached their objective of level 1, although the absenteeism value did not reach the expected objective of 1.6% absenteeism, since it was expected that the RULA risk assessment level would have a level 1, obtaining a level 2 and causing the indicator to grow to 1.9% absenteeism.

Overall, thanks to the data collection in the evaluation of the simulations, successful results were, indicating an improvement of 67.27% of the current situations MSDs exposure levels.

D. *Results comparison:*

The comparison of each of the results found from the ergonomic evaluations will be carried out, of which parts of the state of the art will be justified with the relevant articles. The study areas are characterized by the activities that are carried out, these being: loading area, cutting area, sewing area and control area.

Starting with the results of the RULA evaluations, the cutting, sewing, and control areas are seen, from which improvements of 66.67%, 60% and 50% are obtained, respectively, reducing their results from 6, 5 and 4 to a level 2, averaging the improvement in 58.89% (3). Consider the first research [15], which found that employing the pressed RULA from 6 to 2 enhanced performance by 72.92 percent. Similarly, another research [16], they improved the RULA evaluations from 7 to 2, with a 53.71 percent gain. It can be demonstrated that the suggested model's improved outcomes are consistent since they surpass the predicted average by 60%.

Next, the REBA model used for the cargo area is seen with an initial value of 11 and reaching an improvement of 81.82%, which leaves it at a level of 2 (3). Similarly in another research, an efficiency value of 91.98 percent raised the value from 11 to 0.29, illustrating the linkage of the outcomes by improving the repeatability aspect and active work state [17].

Finally, the NIOSH evaluation is seen, which also sees the cargo area whose effect was a reduction of 60%, taking the value of the results from a level 2.5 to a level 1, ending with the evaluations and confirming that each of them reaches acceptable levels (3). Likewise, in another study, relevant findings were obtained, with a reduction of 59.15 percent from 1.64 to 0.67, resulting in an acceptable value [18].

E. *Future improvement analysis:*

The redesign sought in this paper has managed to reduce the relevant ergonomic indicators, although the ergonomic analysis of the environment was left aside, giving rise to a new range of musculoskeletal disorders that involve breathing problems, vision problems or even psychosocial aspects. For this problem, a global ergonomic evaluation would be required through the LEST tool whose purpose is to evaluate the physical, mental, and psychosocial conditions of the work environment.

In addition, it should be sought to reach the objective levels of the RULA evaluations in which a level below what was expected was obtained, thus affecting the objective result of the absenteeism ratio in turn. By analysing the reason why said improvement was not obtained, there will be a greater understanding and the possibility of maintaining the desired indicators at a low level.

IV. CONCLUSIONS

The result of the simulations indicated a total value of reduction of exposure to MSDs in 67.27% indicating a considerable improvement from the current state (1). The results of the comparative evaluations reached the expected values apart from the RULA indicator. With improvements of 60%, 60%, and 81.82% in the RULA, NIOSH, and REBA evaluations respectively, an improvement in the work environment is evidenced by planning a better distribution allowing greater ease of work and less risk of musculoskeletal disorders [19].

After the implementation of the model, a reduction of the absenteeism rate of 52.85% is seen, reaching 1.9%, being a value below the standard allowed limit of 2.30%, further demonstrating the efficiency of the proposed model (2).

For future work, it is advisable to focus the environmental analysis, even more, to be able to evaluate more detailed details of the work environment. An investment in the company could solve environmental problems found in the said analysis if the limitations of the area already proposed are considered.

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