Redesign of a workstation in the cutting area of a company in the textile sector to increase productivity

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Abstract

Peru stands out as a country with a textile industry in constant development, which has made world-class brands set their eyes on its productive quality. Likewise, in order to achieve the growth of these industries, the workers of these industries have to work long and arduous hours, without taking the importance that is due, in some cases, to the well-being and comfort of each worker. Ergonomics allows to identify the environment that helps to avoid occupational diseases and productivity. A workstation in the right conditions allows an increase in productivity since the human resource is something very important and is not yet fully prioritized by all industries. In the present work, the ergonomic factors of a cutting station, as well as its physical conditions of lighting and noise, are considered in order to redesign it. The objective of this project is, through the implementation of appropriate ergonomic and physical conditions in a workstation in the cutting area of a textile company, to increase productivity and reduce the risks of occupational diseases. An analysis of the three postures that caused the most fatigue to the operators was carried out through the ERP (Rapid Postural Evaluation) method, in order to identify the level of performance required and the improvements that the station needed. In addition, five KPI's were used to measure productivity before and after the redesign and identify its increase. The results obtained were positive, as an increase of up to 20% in productivity and in the level of operator satisfaction was evidenced.

This work will serve as a guide to be implemented in future stations in the textile industry and provide a clear methodology for evaluating ergonomics and measuring productivity.

Keywords
Ergonomics, productivity, occupational diseases, workstation, ERP method.

1. Introduction
Since pre-Hispanic times, Peru has been classified as a textile country, not only for the quality of its raw materials and fibers, but also for the quality of its yarns. Its high levels of quality position Peru as a country with a differentiation superior to the rest of its competitors (Pino, 2012). However, it is remarkable the impulse that must be generated on the textile industry; however, to achieve such growth it is necessary to focus on the labor force in charge within the industries. For this, long hours of hard work will be necessary, so it will be vital to offer the ideal conditions in their respective work area. The concept that encompasses these concepts is ergonomics and its application to the workplace. It relates the presence of the worker and their respective workstation during its use, in addition to establishing a series of benefits around it (Rodríguez-Ruiz & Pérez-Mergarejo, 2010). For the present research, the cutting area, composed of 25 workstations of a Peruvian textile company, was used as the object of observation. For confidentiality reasons,

the name of the company cannot be mentioned. The general objective of the present study is to redesign a workstation in the cutting area of a textile company in order to increase productivity.

1.1 Objectives

The general objective of this project is to redesign a workstation in the cutting area of a textile company in order to increase productivity. Likewise, this study has two specific objectives: To determine if the redesign of the inadequate lighting allows to have a high productivity in a workstation of the cutting area of a textile company and to reduce the inadequate noise conditions to avoid having a low productivity in a workstation in the cutting area of a company in the textile sector.

2. Literature Review

Ergonomics, as an interdisciplinary, investigates the relationship of the human system, machine and environment, which achieve the objective of optimizing human-machine performance by identifying and reducing risk factors at work at an early stage (Du et al. 2021). It is valid to speak of higher levels of productivity as a function of ergonomics, because the higher the satisfaction indexes of the collaborators, the higher the performance achieved by them will be, since they associated the concept of "work" not as an obligation, but as a synonym of pleasant. Thus, the results obtained from their work will be ideal. In addition, by establishing adequate ergonomic parameters, the presence of occupational diseases, typical of the activities, is prevented. Likewise, not only occupational risks are prevented, but also their consequences (Javier and Barrionuevo 2017). Occupational accidents place considerable burdens on individuals, companies, and society in general. The analysis of trend changes in the evolution of time series related to occupational health indicators is an important tool to help determine to what extent economic or structural changes in the industry, agriculture, construction and service sectors, have been able to influence the behavior of these indicators (Gallego Blasco et al. 2020).

The implementation of appropriate workstations will reduce the ergonomic risk of workers. Understanding the problems, it is crucial to improve the condition of the workstations. Designing the right workstations can improve the productivity and time efficiency of workers (Sukania et al. 2020).

The present research, in reference to the theoretical justification, has as its main intention the redesign of a workstation through the improvement of the ergonomic conditions of the station, and in this way, achieve the increase of productivity, with the intention of demonstrating the benefits not only for the users, in this case, the textile operators, but also in terms of the results related to productivity obtained by the company. That is why, according to the collection of information, all possible arguments related to ergonomics and its presence in the textile industry will be presented, with the purpose of generating an academic debate, in addition to the contrast of the results obtained in the productivity and occupational health approaches.

With respect to the methodological justification, the aim is to obtain alternatives and proposals for workstations that comply with the ergonomic standard, present in textile companies; through an analysis of the positive consequences generated by the application of ergonomic parameters in the work center of the cutting area of a textile company. For this, by means of tools obtained throughout the industrial engineering career, a list will be delimited according to the order of importance of the information and data collected, with the purpose, in the case of the occupational health aspect, of determining the consequences that ergonomics has, before and after being applied. Thus, this research can contribute to the theoretical framework of any other research of a similar nature.

Finally, regarding the practical justification, for the occupational health approach, first a series of surveys will be applied to know the status of the workers and their level of satisfaction as a reference point and, after the application of the redesign, the opinions of the collaborators and their impressions will be collected again according to their level of satisfaction and comfort. For the productivity factor, it will be necessary to analyze the numerical results before the redesign and use it as a benchmark. Also, a confrontation table will be used with weightings according to the criticality of the most frequent problems, in order to give priority as appropriate based on the scores obtained.

Etymologically, the word "ergonomics" derives from two Greek words: “ergos” meaning work and “nomos” meaning law (Normand 1997). It is an interdisciplinary science that analyzes the relationship between the individual and his workstation, governed by three main aspects: geometric, environmental and temporal. The first is based on the link between man and the measures established for his workstation, as well as the measures that the instruments used by

the worker must comply with. The second is related with respect to his physical environment close to the workstation, it is also related to the subjective state of being psychologically well: from it, occupational hygiene is derived; and the third, related to the external time of the context, studies the fatigue/rest relationship (Esteva 2015).

In industries, ergonomics is an important aspect that cannot be left aside, since it plays an important role in the effectiveness of the company, so it is considered as a determining factor. Likewise, the various aspects of ergonomics must be considered as an essential part of the relationship between the worker and his workplace. On the other hand, problems related to ergonomics can affect workers in negative ways, which will lead to, in addition to occupational diseases, the reduction of the company's productivity. (Balasundaram et al. 2017).

From the perspective of productivity, the increase in productivity is related to the optimization of all the company's resources and, human capital is part of the company's resources; then, it is valid to deduce that, by optimizing the human factor of the company through ergonomics, a more effective use of resources is being made (Solano 1999).
On the other hand, from the occupational health point of view, the promotion of ergonomics within companies is a solid basis for the prevention of occupational hazards. Ergonomics promotes comfortable environments, where the workstations offer the best conditions to their users at the time of work. When an operator goes through problems related to occupational health, it is practically definitive that the individual will not work at 100%, generating losses of time, money, among other resources. (Ergonomics 2016).

3. Methods

The object of this research is a company in the textile sector, where the cutting area and the workstations were selected. The scope of the research is descriptive, since it analyzes and describes the facts or characteristics of the variables under study, their measurements and the data collected. With respect to the orientation of the work, it's related to the modeling of change in the processes; it responds to a positivist paradigm and has a mixed approach.

The population analyzed for this station redesign is 25 operators, Table 1 which represents 100% of the workers in the area in a single work shift. Data were collected from all personnel such as repetitive movements, postures deviated from the natural position and frequent efforts, factors that increase the probability of occupational diseases, which allowed measuring the selected variables and dimensions.

The variables for this research work are two. On the one hand, ergonomics as the independent variable; that is, to verify that the postures of the operators are correct and do not cause any type of discomfort or fatigue to the workers. This was analyzed with a detailed observation and using a documentary instrument, in this case a questionnaire to measure the satisfaction of each operator according to the task they perform. Each operator was interviewed with questionnaires to capture the results in a criticality grading matrix to know the satisfaction of each operator. An analysis was then carried out using the ERP method, which consists of classifying in which of the 4 levels the operators are located. To identify the opportunity for redesign, data on the physical conditions of the work area will be collected through the measurement of lighting and noise using a digital luxmeter UNIT-T model UT-383 and a Fluke Standard sound level meter, respectively.

Table 1. Number of operators present in the area

Description	Quantity
Female operators	16
Male operators	9
Total operators observed	25

As for the workstations, they are arranged in groups of 5 on a Table 9 meters long by 2.8 meters wide. On one side of the table there are 3 stations 3 meters long by 1.4 meters wide for cutting smaller pieces: and on the other side, there are 2 stations 4.5 meters wide by 1.4 meters long. In addition, each of the stations has a movable vertical cutter, through metal structures connected to the plant roof, located 50 cm above the worktables for operator comfort.
Graphically, the workstations are arranged as follows: (Figures 1& 2)

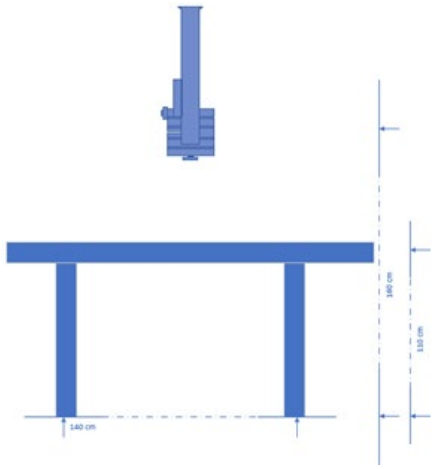

Figure 1. Workstation profile view

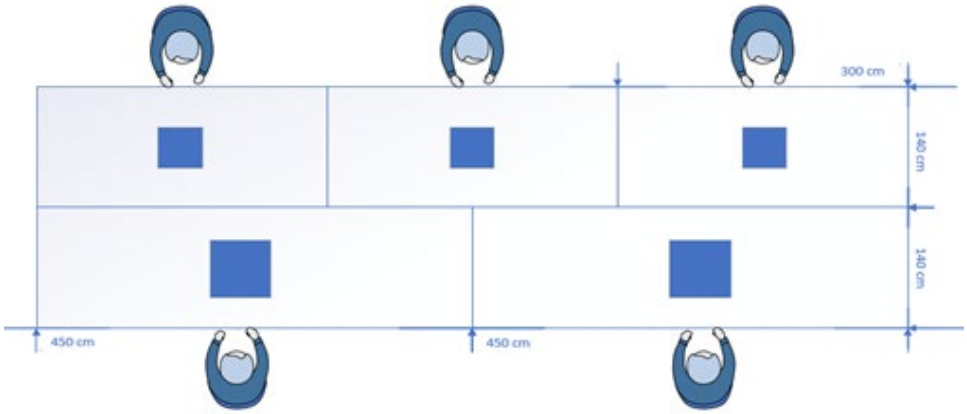

Figure 2. Top view of 5 workstations

On the other hand, productivity as the dependent variable, where the production data before and after the redesign was taken into account to measure its increase, through KPIs such as production cycle time, yield and rejection rate obtained in the cutting area. When determining the productivity (in units produced per man hour) before and after the study, the following was obtained: (Figure 3)

Before	1 (5hrs)	2 (5hrs)	3 (5hrs)	4 (5hrs)	5 (5hrs)	6 (5hrs)	7 (5hrs)	8 (5hrs)	9 (5hrs)	10 (5hrs)
Units produced	4630	4616	4642	4614	4667	4632	4637	4599	4675	4631
Units accepted	3704	3693	3714	3691	3734	3706	3710	3679	3740	3705
Units rejected	926	923,2	928,4	922,8	933,4	926,4	927,4	919,8	935	926,2
Productivity	308,67	307,73	309,47	307,60	311,13	308,80	309,13	306,60	311,67	308,73

Figure 3. Productivity before the study

At the beginning of the observation, with data provided by the company and later verified by the research, an efficiency of 82.75% was obtained as follows:

$$E = \frac{Prod\ Actual_0}{Prod\ máx\ theoretical} = \frac{11000}{13292.31} = 82.75\%$$

It should be noted that the theoretical production was obtained by dividing the time available in seconds, 43,200 seconds that a shift lasts, by the standard unit time per garment, 3.25 seconds.

With respect to the quality performance managed, by policy a range of no less than 80% is established. During the initial observation period, 82% quality was determined as follows:

$$\text{FTT} = \frac{Units\ produced\ - Units\ Rejected}{Units\ produced} = \frac{11000 - 1980}{1980} * 100 = 82\%$$

Finally, with respect to the use of raw material, considering 20/1 jersey as a base, with a grammage of 190 grams, a yield of 2.8 m/kg and a roll of 20kg, a nominal yield of 60.15m and 56m was obtained at the end of the cutting of cloths, which were 16 cloths of 3. $5m^2$.

As mentioned above, after identifying the population and the work performed by each operator in this area, a survey will be applied to them, which consists of 10 questions related to satisfaction and working conditions with a range of answers from strongly agree to strongly disagree. However, before its application, the statistical validation of this questionnaire was carried out through the Jamovi 2.2.5 program (https://www.jamovi.org/download.html), where the result of the Cronbach's alpha coefficient determined the reliability of all the items of the questionnaire, since they respond directly to the conditions to be redesigned in the area. (Tables 2 & 3)

Table 2. Reliability analysis

	Mean	Sd	% Of Cronbach
Scale	3.75	0.613	0.840

Table 3. Validation

Component	SS Loadings	% Of Variance	Cumulative %
1	3.23	29.4	29.4
2	2.54	23.0	52.3

4. Data Collection

The quantitative data obtained by the company and validated during the observation are shown below:

- Observation period before and after redesign: 10 days
- Hours of observation per day: 5
- Operators: 25
- Shifts observed: 1
- Hours per shift: 1
- Daily units produced: 1100
- Estimated efficiency rate: 80%- 82%.
- Unit std time: 3.25 s
- Title observed: Jersey 20/1
- Weight: 190g/m2
- Tubular width: 0.9m
- Yield: 2.8m/kg
- Bale weight: 20kg
- Cloth size: 3.5
- Cutting capacity (nominal): 5in (143u)
- Cutting capacity (actual): 3.5in (100u)

5. Results and Discussion

The questionnaire applied to the workers began with the questions of sex and age range, in these characteristics 64% of the workers were female and 68.3% belonged to the range between 18 and 35 years of age, since for the work in the cutting area it is preferred to have workers who maintain greater agility.

5.1 Ergonomics conditions

The questionnaire was composed of 10 items, which were validated in the previous chapter, and the results obtained after its application are as follows: (Table 4)

Table 4. Survey results before redesign

Question	Answer					Total
	1	2	3	4	5	
Height of the work surface is not adequate for the type of task or for the dimensions of the worker.	0	1	5	11	8	25
Workstation design makes it difficult to maintain a comfortable working posture.	0	0	5	9	11	25
Repetitive movements of arms / hands / wrists.	0	1	4	12	8	25
Forced working postures on a regular or prolonged basis.	0	1	2	13	9	25
Tasks with high visual demands or high thoroughness.	0	1	2	15	7	25
There is insufficient lighting in your workstation or work environment.	0	3	4	8	10	25
You have visual disturbances with respect to lighting at your workstation or in your work environment.	0	2	7	10	6	25
Environmental noises that are annoying or cause difficulty in concentrating on work.	0	1	7	12	5	25
Frequent disturbances attributable to the quality of the indoor environment (foul air, bad smells, dust, cleaning products, etc.)	0	1	4	15	5	25
The work area does not meet the appropriate conditions to prevent fatigue	0	2	6	12	5	25

On one side, the questions from 1 to 10 are shown: and in the other four columns, the weightings of the answers. It should be noted that the answers were weighted with values from 1 to 4 for "totally disagree", "disagree", "agree", "totally agree". This, when added to the total number of responses obtained, gives the total number of operators working in the area.

This same questionnaire was taken after the redesign, to rate the operators' satisfaction with the new changes in chairs, tables, lighting and noise, as needed. The results were as follows: (Table 5)

Table 5. Survey results after redesign

Question	Answer					Total
	1	2	3	4	5	
Height of the work surface is not adequate for the type of task or for the dimensions of the worker.	10	11	4	0	0	25
Workstation design makes it difficult to maintain a comfortable working posture.	15	8	2	0	0	25
Repetitive movements of arms / hands / wrists.	0	7	14	4	0	25
Forced working postures on a regular or prolonged basis.	7	13	5	0	0	25
Tasks with high visual demands or high thoroughness.	8	11	6	0	0	25
There is insufficient lighting in your workstation or work environment.	14	8	3	0	0	25
You have visual disturbances with respect to lighting at your workstation or in your work environment.	16	8	1	0	0	25
Environmental noises that are annoying or cause difficulty in concentrating on work.	16	9	0	0	0	25

Frequent disturbances attributable to the quality of the indoor environment (foul air, bad smells, dust, cleaning products, etc.)	14	11	0	0	0	25
The work area does not meet the appropriate conditions to prevent fatigue	13	11	1	0	0	25

As evidenced in the responses to the questionnaire of all operators, it is verified that there is greater satisfaction on the part of workers after the redesign.

Regarding ergonomics and the postures of each operator to see the opportunities for improvement, a study was carried out through the ERP method, which consists of a global evaluation of the different postures adopted during the work shift and the time they are maintained.

This analysis began by placing the data for the evaluation of this method, where three postures that caused greater fatigue to the operators were chosen, which are: Standing arms in frontal extension, inclined sitting and inclined standing. (Figures 4, 5 and 6)

Figure 4. Operator in standing position arms in front extension

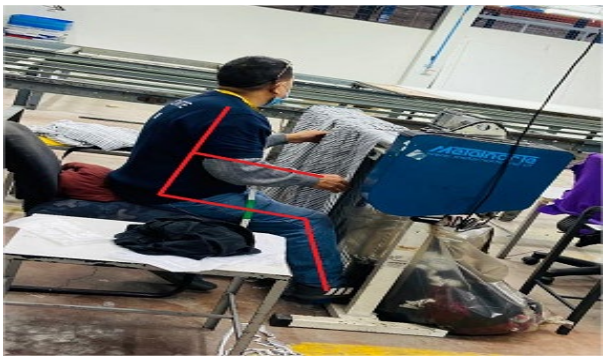

Figure 5. Operator in inclined seated posture

Figure 6. Operators in inclined standing posture

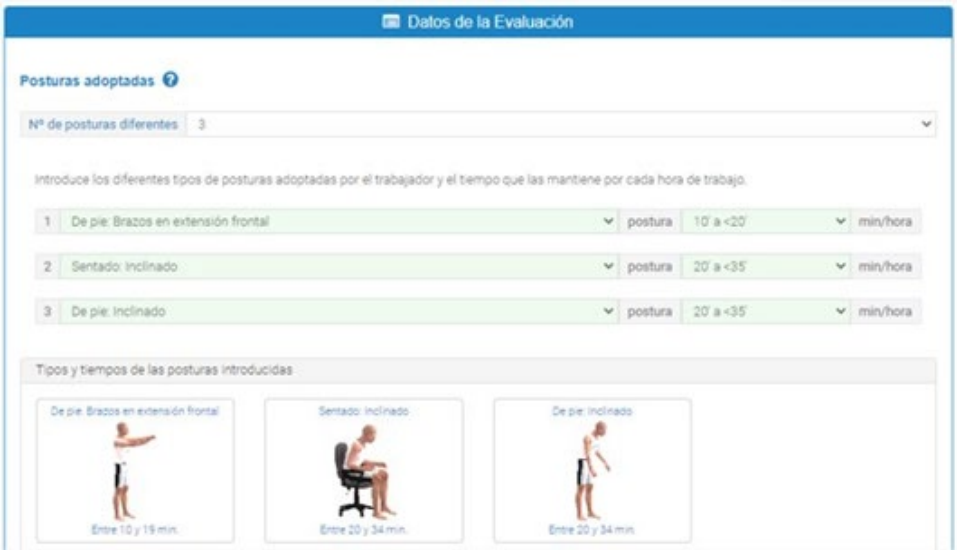

Figure 7. Evaluation data, ERP method

Figure 8. Results of risk levels before redesign, ERP Method

As can be seen in the previous images, these constant postures generate strong discomfort and pain in the workers. (Figure 7) For this reason, these tables and chairs were redesigned so that the operators maintain the correct posture in their workstations. (Figure 8) The correct postures that these operators must maintain straight postures, both standing and sitting. Thus, the tables and chairs of the operators were changed so that these conditions are respected. (Figure 9)

Figure 9. Table before redesign

Figure 10. Tables after redesign

After the change of tables and chairs, the questionnaires were carried out again to see the level of improvement and, as shown at the beginning of the chapter, the results were positive. (Figures 10 & 11) Then the analysis was performed again in the ERP method and the performance level is 2, which means that there is no longer the amount of discomfort or fatigue in the operators.

Figure 11. Results of risk levels after redesign, ERP Method

5.2 Physical conditions

Regarding the dimensions of lighting and noise, through the survey it was observed that there is a certain level of discomfort in terms of visibility, since some tasks are very thorough. For this reason, a luxmeter and a sound level meter were used to measure the real values of the station. In addition, it was found that the lighting was below the standard allowed in the textile industry, since it should be within 750 lux per m^2. As for noise, the standard allowed for a 12-hour shift is 83 dB and the station had 84 dB. (Tables 6 & 7)

Table 6. Physical conditions of the workstation prior to redesign

Lighting (lux)		Noise (dB)	
Standard	Real	Standard	Real
750	700	83	84

The area of the station of this study is 300 m^2, for which the necessary lumens are 225,000; however, there are only 2,100,000 lumens, since there are 21 luminaires of 100 watts. Figure 12 Therefore, 15 new 150 watts luminaires were placed in the station, which provide the amount of lux needed for the 300 m^2.

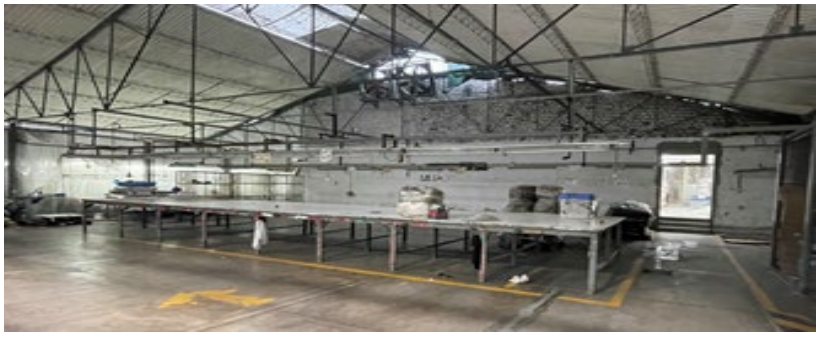

Figure 12. Luminaires at the workstation before the redesign

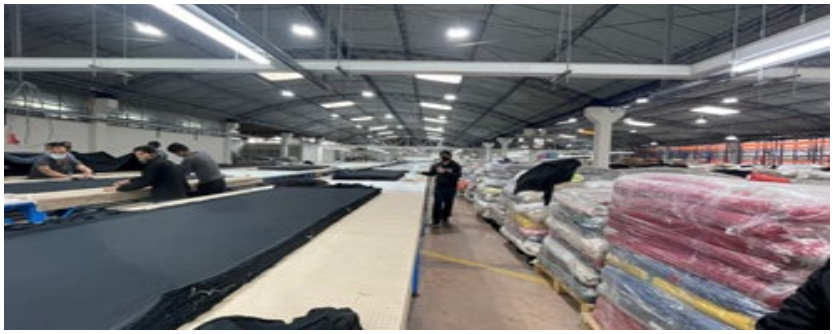

Figure 13. Luminaires at the workstation after the redesign

In addition, it can be seen that noise exposure is not higher than what is allowed by the standard; however, safety hearing equipment was added for the operators and a machine maintenance plan was also implemented to ensure that the machines do not emit noise that bothers the workers. For this reason, the old machines were replaced with more automated machines that emit less noise than the old saw cutters. (Figure 15)

Figure 14. Antique manual sawing machine

Figure 15. Current automated machine

Table 7. Physical condition of workstation after redesign

Lighting (lux)		Noise (dB)	
Standard	Real	Standard	Real
750	750	83	81

5.3 Productivity results

With respect to the productivity objective, after the redesign applied to the production plant, the following values were obtained (in units produced per man hour). (Figure 16) These values were determined over a period of 10 days during 5 hours of observation per day.

After	1 (5hrs)	2 (5hrs)	3 (5hrs)	4 (5hrs)	5 (5hrs)	6 (5hrs)	7 (5hrs)	8 (5hrs)	9 (5hrs)	10 (5hrs)
Units produced	4731	4756	4621	4793	4749	4832	4763	4783	4799	4793
Units accepted	4494	4533	4386	4544	4455	4531	4480	4492	4521	4501
Units rejected	237	223	235	249	294	301	283	291	278	292
Productivity	374,50	377,75	365,50	378,67	371,25	377,58	373,33	374,33	376,75	375,08

Figure 16. Productivity after redesign

In relation to efficiency, a final value of 86% was obtained by dividing the actual production by the theoretical production of 5 hours of a shift. Likewise, the average quality yield obtained was 98.32%. In addition, the rate of accepted units increased from 82.75% to 94.1%, an increase of 11.35% over the initial observation period.
The details of the data obtained after the application are shown below: (Figure 17)

	1 (5hrs)		2 (5hrs)		3 (5hrs)		4 (5hrs)		5 (5hrs)		6 (5hrs)		7 (5hrs)		8 (5hrs)		9 (5hrs)		10 (5hrs)	
	Nominal	Real	Nominal	Real	Nominal	Real	Nominal	Real	Nominal	Real	Nominal	Real	Nominal	Real	Nominal	Real	Nominal	Real	Nominal	Real
Units produced	4883	4731	4883	4756	4883	4621	4883	4793	4883	4749	4883	4832	4883	4763	4883	4783	4883	4799	4883	4793
Units accepted	4004	4494	4004	4533	4004	4386	4004	4544	4004	4455	4004	4531	4004	4480	4004	4492	4004	4521	4004	4501
Accepted units rate	82	95	82	95	82	95	82	95	82	94	82	94	82	94	82	94	82	94	82	94
Units rejected	879	237	879	223	879	235	879	249	879	294	879	301	879	283	879	291	879	278	879	292
Productivity	407	394	407	396	407	385	407	399	407	396	407	403	407	397	407	399	407	400	407	399

Figure 17. Data collected

5.4 Discussion

The redesign of the cutting area workstation increased productivity by 21.38%. Likewise, adequate lighting was achieved by improving the number of lumens required by this station, replacing the previous lights with 150 watts that complied with the textile industry standard of 750 lux per m2. This means that there is no discomfort for the workers, such as eye fatigue, headaches or other visual discomforts that the operators mentioned in the questionnaire before the redesign. It should be noted that, unlike other papers, the present research applied the redesign in a practical

way so that the observation experience provided further enrichment to the project. Also, the current noise of the cutting station is 81 dB, which is within an acceptable permissible level. This was achieved by replacing the old manual cutting machines with automated machines that emit a lower noise level. In addition, personal protective equipment (PPE) was added for the care and protection of each operator for certain activities or whenever they request it to avoid any discomfort or occupational disease.

The increase in productivity is directly related to the improvement in the physical conditions of the workstation. That is, the change in the tables, chairs, light and noise allow the operators to work with a higher performance, since thanks to the analysis of postures through the ERP method, the three main postures that caused fatigue to the operators were observed, which after the redesign and reapplication of the questionnaire, a greater satisfaction of the workers was observed, This is considered an acceptable level, since it means that the workers' satisfaction and postures are better and their level of risk of occupational diseases is lower. Because, now with chairs and tables adjusted to each task, incorrect inclined and prolonged positions are avoided. The limitation found for the analysis is that the study was only applied to one of the two existing shifts, the ideal would have been to analyze the change generated in all employees of the plant and the two shifts present.

In addition to the main topic of ergonomics and the productivity generated based on it, as an additional contribution, during the experience it was observed that the manufacturing procedure is not ideal, since the analyzed company has 3 different plants in which the procedures are carried out without considering the option of a production line, in such a way that allows the constant and automated flow of raw materials on their way to become the final product.
One limitation of the present study is that the analysis was conducted for only one work shift.

6. Conclusion

With the present research work, it can be concluded that the redesign of a station taking into account the ergonomic factors of this, allows an increase in productivity, since workers are a fundamental part and the level of satisfaction and safety of themselves to work in an area that presents the optimal conditions and without risks.

The activities carried out in good conditions allow the operator to increase his productive capacity. Likewise, there is a reduction of future occupational disorders or diseases due to repetitive tasks that may cause discomfort for long periods of work in inadequate postures that affect any limb.

Through the applied study, it was possible to verify that, although the concept of ergonomics is an important factor in the optimal performance of the collaborators; however, many companies still do not internalize such factor as part of what is offered in the workstations of the workers. There is still a long way to go to reduce the high level of indifference towards ergonomics and employee satisfaction for the benefit of their performance.

It was observed that the inadequate arrangement of workstations, in such a way that it does not consider the order of the operations performed, generates losses of productive time in transporting raw material to each of the plants.

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Biography

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