Participatory Ergonomics in a Manufacturing Company in Peru

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Abstract

To improve working conditions at the welding station in a manufacturing company**,** the participatory ergonomics methodology was used to improve the working conditions of a manufacturing company. For its application, we used techniques such as observation and surveys. Relevant measures at the station that did not adapt to the anthropometry of the worker were identified, as well as risks, such as congested working area, inadequate work postures, highly repetitive tasks and uncomfortable chairs. The intervention demonstrates that the problems can be identified and solutions can be carried out by applying this methodology, due to the worker's involvement in the process and the commitment of the top management to develop them.

Keywords
Participatory ergonomics, station analysis, musculoskeletal disorders, occupational health, prevention at work

1. Introduction
Participatory ergonomics is defined according to Haines and Wilson (as cited in Pinto, 2015) as "A strategy that involves people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve specific goals, related to the control of ergonomics issues".

Rost and Alvero (2020) explain that there are unifying elements between participatory ergonomics and participatory safety management. Participatory ergonomics programs are a more effective means of eliminating, or redesigning, manual tasks with the aim of reducing the incidence of occupational musculoskeletal disorders (Burgess-Limerick, R. 2017). In order for participatory ergonomics to be executed, a prevention commitment by the company is mandatory (García *et al*. 2012). Participatory ergonomic intervention needs management support for its application to be successful (Anizar, Matondang, A. R., Ismail, R. & Nazaruddin, 2020).

García (2009) establishes that this methodology empowers workers, because they are the ones who identify risks and injuries due to the work they do, and support the search for solutions without the use of complex technical protocols. Workers are encouraged to give their opinions, develop and propose solutions to identify negative situations (Castro & Paz, 2013).

As Visser *et al*. (2019) indicate participatory strategies aim to stimulate the change of behaviour of stakeholders to increase the use of ergonomic tools, having the face-to-face interventions the same effect as by electronic means.

An intervention carried out in Brazil by Dos Santos and others (2013), proposed a methodology for the design of nuclear equipment, applying the principles of participatory ergonomics. Bernardes *et al*. (2012) focused on the prevention of lumbar diseases and justified their investigation specifically into these diseases, arguing that more than 50% of them related to musculoskeletal disorders during the period of 2001-2003.
A study in a Brazilian footwear company also demonstrated that the problems and solutions can be identified through this methodology, involving workers to achieve positive personnel, health and production (Guimarães, 2014).

Another intervention in a furniture factory aimed for the redesigning of the manufacturing process, obtaining a reduction in the operators' workload as well as seeking an improvement in the productivity of the process (Guimarães, 2015).

The National University of Colombia has formulated a proposal to improve working conditions in companies in the region, specifically in tea leaf harvesters, who have musculoskeletal lesions, for this purpose, the Rapid Entire Body Assessment (REBA) method of the participatory ergonomics was used, achieving the improvement of their quality of life and physical well-being (Castro and Paz, 2013). Battevi, (2013), concludes in his study that, thanks to changes in the design and organization at the workplace, productivity was increased by 16% and risk levels decreased by 22.7%.

Bortolini *et al*. (2020) present the results of the Motion Analysis System (MAS) as a valuable hardware / software architecture for evaluating a manual manufacturing / assembly workstation, highlighting the productive and ergonomic aspects of potential enhancements (workstation design, location of tools or components, musculoskeletal workload, etc.), this represents the starting point to continue studying manufacturing workplace improvement.

Under the Kaizen approach - a methodology of continuous improvement- it should be borne in mind that many kinds of waste may be present at the workplace and in the processes, but not all waste is noticeable. According to Shingo (1991), it often appears in the guise of useful work and recommends looking under the surface and capturing the essence. In all the cases cited, the group analysis facilitates the relationships between participatory ergonomics and the risks to which workers are exposed (Morag and Luria, 2018).

The rationale of this study is to carry out a pilot intervention considering participatory ergonomics as an appropriate strategy to integrate occupational risk prevention in the workplace to improve working conditions.

2. Material and Methods

An intervention following the participatory ergonomics approach was proposed, a methodology oriented at improving workstations. This methodology allows the use of various qualitative and quantitative techniques. Among them, observation, survey and semi-structured interviews. The validity of the procedure was guaranteed with a constant review of the sequence, triangulation and use of recordings, and photographic records.
For the intervention, we used the participatory ergonomics methodology, which includes the dimensions indicated in Table 1.

Table 1. Dimensions to consider in the intervention

Dimension	Category	Description
Continuity	Temporary	The project was carried out from November 2019 until February 2020.
Participation	Direct	The worker participates in decisions that affect his work.
Level of action	Plant	It is developed in the manufacturing plant, specifically in the welding area.
Decision making	Individual consultation	Each worker can express their point of view and proposals, management makes the final decision.
Team composition	Workers, Supervisors, Management	All personnel involved in the welding area.
Level of requirement	Voluntary	Participation is voluntary
Object	Processes and equipment	The intervention was carried out in the tasks and the equipment where the welding of the pieces of the potato press is executed.
Project scope and team functions	Project planning and structure	The project is designed and organized.
	Problem identification	Opportunities for improvement in jobs
	Solutions proposal	Ergonomic solutions
	Solution implementation	The opinion of workers is considered
Human factor engineering advisor	Initiator and project guide	Key in the implementation and organization of the project.
	Team member	He is involved in the project to understand and give input on ergonomic solutions
	Available for consultation	Provide time for consultations

Source: García, (2009)
Own elaboration

The process of participatory ergonomics has developed in the following stages: introduction, analysis, proposal of solutions and finally the implementation and evaluation. (Pinto, 2015; Guerrero & Quintero, 2016). The intervention is a pilot project carried out at FACUSA, a manufacturing plant located in Lima - Peru, which produces cutlery and kitchen utensils. This company is a medium-sized company with more than 100 workers and has implemented quality and environmental systems.

3. Results

In the first stage, the research team was presented, and the objectives and methods of the intervention involving the workers were discussed with the senior management. The selection of workstations was agreed with the management and supervisors, considering the selection criteria being one of the products with the highest demand and where manual operations are present, with the objective of identifying opportunities for improvement in the workplace. Thus, the intervention in the spot-welding station for the assembly of the parts of the potato press was defined. The work team for this pilot intervention was shaped by the senior management, the plant manager, the plant supervisors, the occupational health and safety chief and the quality manager. During the analysis of the job, the following aspects, recommended by Párraga, (2003) were considered.

3.1 Work Method by Station

In the welding area there are three workstations, for the intervention were selected the second and third work stations and the activities involved with the support of the shift supervisor. The operators' job is to take the main piece of a container that is placed on the floor and other secondary parts located on a table, take them to the welding machine, position them and operate the machine with a pedal to make the welding points. Subsequently, remove the welded piece, check them and place them in another container, which is located on a Pallet. Standard time was determined for the production, which is shown in Table 2.

Table 2. Activities involved and times

Workstation	Activity	Tstd
First	Side Cap Welding	13.0 seconds
Second	Welding with handle stop	44.08 seconds
Third	Perforated cup welding and cup reinforcement.	30.3 seconds

Own elaboration

3.2. Operators Physical Conditions

The company through the occupational safety and health department, carries out an annual evaluation of the physical conditions of the workers; according to the records, the operators present the anthropometry of the average Peruvian worker, the average height being 1.65 m. and a weight of 68 kilograms.

3.3. Workplace dimension

Relevant measures were identified, such as the height of the table, the height of the chair, the working height and the height of the finished product containers, as shown in Table 3 and Figures 1 and 2.

Table 3. Measures identified

Element	First station	Second station	Third station
Height of the table	78.5 cm.	79.0 cm.	80.0 cm
Working height	92.0 cm.	93.5 cm	92.5 cm.
Height of the chair	52.0 cm.	48.0 cm.	50.0 cm.
Height of the containers	30.0 cm.	30.0 cm	30.0 cm.
Sitting height of elbow	22.0 cm	22.0 cm	22.5 cm
Sitting eye height	117.0 cm	109.0 cm	105.0 cm.

Own elaboration

As the figures show, the height of the seated eye is greater than the height of the welding point, making the operator have to lower his head (15.5 cm and 12.5 cm respectively) to see what he is going to weld. The height of the table is higher than the height of the sitting elbow plus the height of the chair, so he must raise his arm. In the third station, the height of the bag is very low to leave the processed product, so the operator must bend down. All these conditions generate musculoskeletal trauma.

Second Station

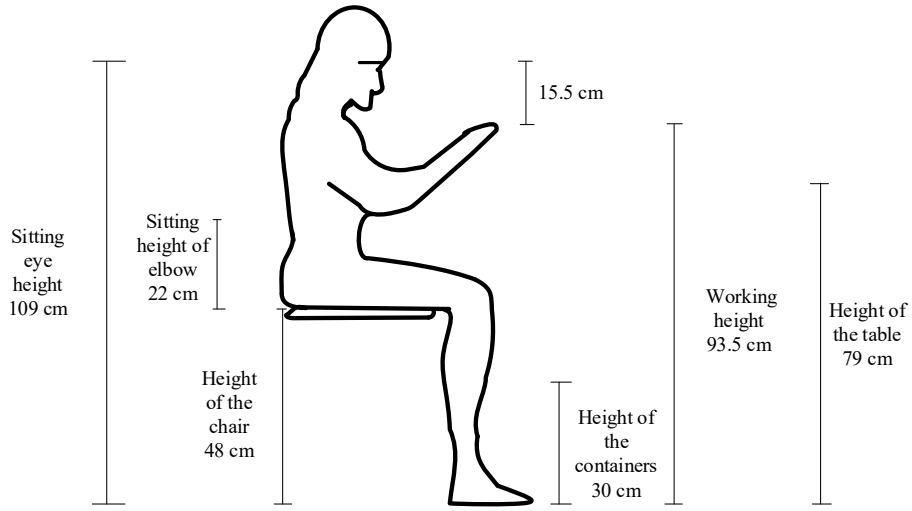


Figure 1. Second Station

Third Station

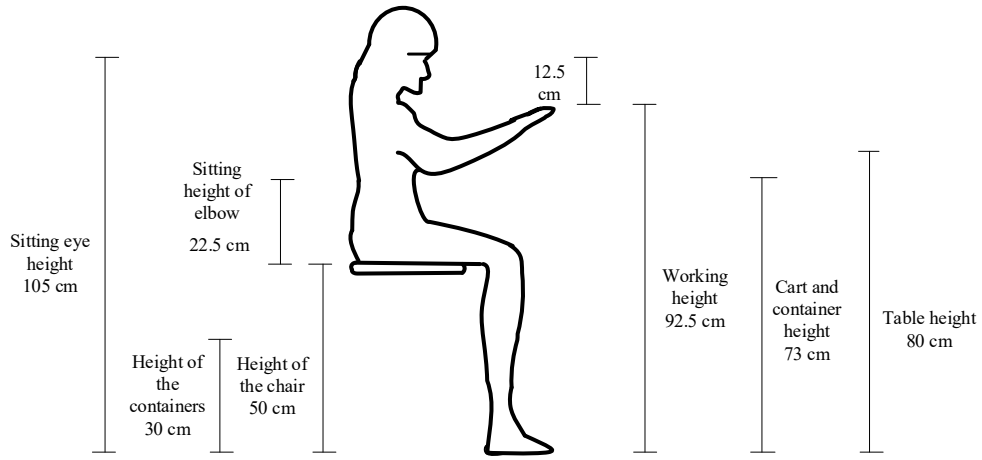


Figure 2. Third Station

3.4 Work Environment

According to the working conditions observed in the workplace, we considered the following risks:

- Excessive noise
- Environments with high temperatures
- Deficient ventilation and air circulation
- Congested work area with parts and pieces arranged in disorder.
- Inappropriate working positions as shown in the figures, where containers and tables are located away from the normal work area.
- Highly repetitive tasks.
- Uncomfortable chair, which does not have backrest to support the lower back or a comfortable seat.

The company provides the worker with the appropriate work clothes (drill shirt and pants), as well as the personal protective elements (protective lenses, earmuffs, gloves and steel toe boots), according to standards established by the department of occupational safety and health, which they wear permanently.

3.5 Social Aspect

The company has a worker induction procedure, in which the organization's values are explained and it is instructed on the safety and health mechanisms at work. Teamwork is promoted and there is a very close relationship between the supervisors and the management, who is permanently guiding and supporting the worker in their tasks. Workers are permanently motivated to participate in the identification of opportunities for improvement considered in their integrated management system, where Kaizen is a fundamental part of their philosophy.

There is a training program oriented to the development of the worker's abilities to perform in the workplace. After the job analysis, a survey on working conditions and a musculoskeletal evaluation were applied to the three workers who perform the tasks, to complement the study, considering the musculoskeletal survey presented by Brunette *et al.* (2016).

The results of the survey on the general aspects of their tasks, the organization at work and working conditions, are presented below:

- 100% of the workers indicate that the work they do is always important for the company, their performance is reviewed and evaluated by their superior and they receive the necessary instructions to carry them out.
- 67% of workers indicate that they always have the tools and help they need to do their job, and sometimes their opinion about working conditions is appreciated.
- 67% of workers indicate that the work done exceeds their work ability, demanding a lot of effort and demanding quicker results.
- 100% of workers express that sometimes they can modify the pace (speed) with which they work.

The results of the health and safety survey are presented below:

- 100% of the staff say they receive training, training and induction talks during the year.
- All workers interviewed confirm compliance with the workplace, because the place is free of accidents, there are rules and regulations to avoid them, they receive training, they are provided with equipment and clothing for personal protection, danger notices are placed in critical areas, there is regular maintenance on the machines and work incidents are avoided or corrected.
- All workers indicate qualify the working conditions in this company are adequate.

In relation to the results of the musculoskeletal evaluation survey, 100% of the workers report that they have lower back and neck pain. Considering the above, pilot designs were developed for workstations, with the support of operators, plant supervisors, the occupational health and safety manager and the quality manager.

The management team recognizes that, given the working conditions, musculoskeletal disorders of labour origin can occur in the plant, for which actions have been taken in most cases. The company addresses the issue of ergonomic problems through the implementation of improvement teams, the 5S program and ongoing training.

The improvements implemented in the plant are mainly focused on the quality of the products, the process and the machinery; direct improvements in the ergonomic conditions of workstations are less frequent.

4. Discussion

Tappin *et al*. (2016) states that the existence of a group of key stakeholders is an important factor for the implementation of participatory ergonomics, this is an aspect that the company under study has shown, having provided the necessary information and made improvements even from the first intervention. As Pazell *et al*. (2016), for the design process the participation of the workers, the selection of tasks and the ergonomic capabilities of the work team are important.

The key element of these programs is the worker and the participatory strategy involves workers in decision making by getting them to better understand the origin of the risks to which they are exposed, while making managers better understand the reasons for lack of well-being in workers focused on prevention (García, 2009; Cerón, 2017).

During the intervention, a work team was formed with the participation of the workers, who showed a total involvement in the participatory ergonomics project, providing information, suggestions and proposals for

improvement (Sabadin, R.K.; Severo, E.A. & De Guimarães, J.C.F., 2019). The support of the chief of occupational health and safety was important to validate the results obtained. Uncomfortable postures and repetitive movements are observed, due to the situations indicated in Table 4.

Preventive actions have been proposed, considering that ergonomics has as its objective that the work adapts to man and not only limits himself to identifying risk factors and molds. The solutions consider take into account the feasibility of its implementation, the effective potential of the users and the economic viability of the company.

Table 4. Risk situations

Observed situation	Possible causes	Preventive action
S1 When collecting the parts to assemble, the worker adopts an inadequate posture to collect the pieces.	The containers where the pieces are deposited are at a height less than the height of the sitting elbow and are located slightly behind the operator's position.	We recommend incorporating points of support to the containers to raise the height and facilitate the collection of materials.
S2 When taking the pieces of the table to take them to position to weld, it is observed difficulty of the worker to take the piece.	The height of the table is greater than the height of the sitting elbow.	To improve the height of the worktable, in order to facilitate the taking of the pieces.
S3 We observed an inadequate posture of the neck and back, in the placement of the welding piece,	The chairs used have a height that does not allow the worker to perform the operations at the level of the height of his sight, so he tilts his neck and back a little.	Use ergonomic chairs and level the height of the position for the knitted soldier.
S4 During the welding operation, sparks are sometimes generated within a radius of one meter around the workstation, which may affect the same worker or a worker who may be in a nearby position.	The copper device used for welding is frequently worn out by the work done, when it loses uniformity on its surface, the worker sands it to mould it, but not being uniform, sparks are generated in contact with the workpiece.	Check the frequency of change of that device, considering that the plant has an armoury, these spare devices can be stored in the workstation. As indicated, changing this device requires less time for periodic sanding of the day.
S5 When finished welding, the worker places the piece with difficulty in the container, and sometimes he must stop to perform this activity, which takes additional time.	Containers are stacked at the exit of the welding operation, for this reason the height is greater than the height of the sitting elbow, and they are slightly away from the position of the worker.	Keep at the exit of the operation only one or two levels of stacked containers, so that it is at an adequate height and facilitates the activities of the worker.

Own elaboration

Montiel *et al*. (2006) demonstrates that the adoption of inadequate postures in the workplace leads to a high risk of musculoskeletal disorders as a result of exposure to physical stress for prolonged periods during the workday. Gomathi and Rajini (2019) in their research concluded that the employees are working for long hours in same position, doing the same task at their workplace which involves lots of machines where the alignment between man and machine plays a predominant role, and it is important to study for these variables to improve the physical workplace environment.

The team, implemented the preventive actions of situations S1 and S5, the workers positively evaluated these actions, since they no longer have uncomfortable positions. Rasmussen *et al*. (2017), point out in their study that simple ergonomic physical changes, such as the introduction of new tools or equipment, were easier to implement. Like Forsman *et al*. said (2012), the impact on the reduction of disorders in many cases is difficult to assess, but for the worker, even a small improvement has a positive effect.

The proposals implemented in the workstations have been low cost, this is a result of the implementation of the continuous improvement that Kaizen promotes, as Imai (1998) indicates, is a simple example that illustrates the benefits of Kaizen in terms of costs.

For situation S2, the armoury will be preparing the tables with the appropriate measures. In relation to the S3, two models of chairs have been tested in collaboration with the worker, but a definitive design for the station has not

been reached. For situation S4, the possibility of developing replacement devices to make periodic changes in the workday is being evaluated.

Research carried out shows that there is a direct correlation between improved working conditions and increased worker productivity (Salazar, 2017; Gomes, 2014; Torres, et al. 2012). The participatory ergonomics project generated an increase in the level of production, the improvement results are shown in Table 5.

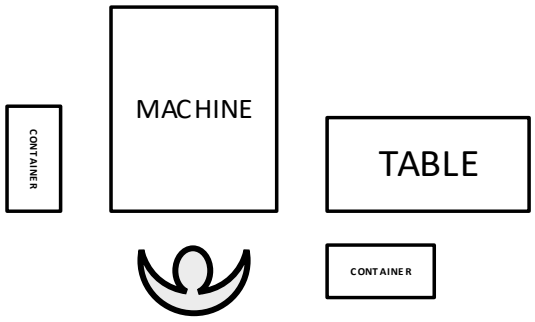
Table 5. Results of participatory ergonomics project

Workstation	Activity	Production before (pieces/hour)	Production after (pieces/hour)	% variation
Second	Welding with handle stop	62.5	83.2	33.12%
Third	Perforated cup welding and cup reinforcement.	62.5	81.0	29.60%

Own elaboration

Finally, a standard operating sheet is proposed for the design stage of the job (Taylor and Francis Group, 2002), It describes the operating conditions and technical standards, presenting the current situation at the station, allowing an analysis, proposing the necessary improvements and also preparing it for the audit processes. For the design of the workstations in the plant, it is recommended to use a standard operating sheet, as shown in Table 6.

Table 6. Standard Operating Sheet

<table>
<tr><td colspan="2">STANDARD OPERATING SHEET (Proposal)</td></tr>
<tr><td>Date: 02/13/2020</td><td>Approved by: Plant supervisor</td></tr>
<tr><td>Operation: Welding of pressed potato pieces</td><td>Workstation dimensions</td></tr>
<tr><td>Operation conditions:
The welding machine must be calibrated for spot welding.
The copper electrode must be profiled to ensure proper welding</td><td rowspan="2"> 
</td></tr>
<tr><td>Technical Standards:
Maintain the amperage according to the standard of the piece to be welded.
Verify the calibration on the machine control panel.
Use a file to eliminate wear on the copper electrode.</td></tr>
<tr><td>Operator physical conditions:
The operators present the anthropometry of the average Peruvian worker</td><td>Work method:
Take main piece
Take secondary pieces
Weld pieces
Check welding
Place welded pieces in the container</td></tr>
<tr><td>Social aspects:
Induction process for the new worker
Team work for continuous improvement
Training program
Permanent support to workers by plant supervisors
Team of participatory ergonomics project</td><td>Work environment:
Excessive noise
(Use of personal protective equipment)
Environments with high temperatures
(Place ventilation equipment)
Highly repetitive tasks.
(Active breaks at work)</td></tr>
</table>

Source: The Productivity Press Development Team, (2002)
Own elaboration

5. Conclusions

The pilot intervention result was satisfactory. Through it, the management team learned about participatory ergonomics as an appropriate strategy to integrate occupational risk prevention in the workplace, agreeing to develop the proposed program on a larger scale. The opinion of the supervisors and the commitment of management in the improvement of working conditions, ensure the maintenance of the actions undertaken. The changes in the design of the workstation improve the workstation conditions, in this way the operator no longer bends down to pick up pieces, and no longer raises his arm to leave pieces in the containers or pick up other pieces.

Workstations are in order, avoiding the loss of time in the selection of parts for assembly, as well having as greater fluidity of materials between positions. The participation of workers in the application of this methodology favours its implementation and maintenance accommodation time of the products in process, therefore, the reduction of lost time and improvements in working conditions increase productivity. The Kaizen as a methodology of continuous improvement implemented in the plant facilitates the adoption of participatory ergonomics, in this intervention it was confirmed that senior management gives permanent support to this type of improvement.

Although from a better design of the work station, it has been possible to demonstrate the improvement of productivity, as well as a favorable opinion of the workers, the direct benefits such as the elimination of cumulative traumas, should be evaluated in the medium term. It is recommended to continue with the ERGOPAR program for the other workstations in the plant and from the results develop a methodology applicable to processes involving the work of man and machine. The possibility of a study supported by software such as the Motion Analysis System to systematize the quantitative analysis is also open.

Recognition

The work team thanks the company FACUSA (https://www.facusa.com.pe) for being able to carry out this pilot study of participatory ergonomics intervention.

References

Anizar, Matondang, A. R., Ismail, R., and Nazaruddin, Management Support in Enhancing Participatory Ergonomic Interventions in Palm Oil Industry. In *IOP Conference Series: Materials Science and Engineering*, vol. 851, no. 1, pp. 012016, 2020.

Battevi, N., and Vitelli, N., Ergonomia e produttivitá: un esempioaplicato ad una industria manifatturiera, *Medicina del lavoro*, vol. 104, no. 3, pp. 203-212, 2013.

Bernardes, J., Wanderck, C., and Moro A.C., Participatory ergonomic intervention for prevention of low back pain: Assembly lines redesign case, *Work*, vol. 41, no. 1, pp. 5993-5998, 2012.

Bortolini, M., Faccio, M., Gamberi, M., and Pilati, F., Motion Analysis System (MAS) for production and ergonomics assessment in the manufacturing processes, *Computers & Industrial Engineering*, vol. 139, pp. 105485, 2020.

Brunette, M. J., Albarracín, C. M., Araníbar, M. T. N., and Andrade, N., Identificación de malestares músculo-esqueletales en una planta de manufactura en Los Olivos, Lima-Perú, *Ingeniería Industrial*, no. 34, pp. 27-54, 2016.

Burgess-Limerick, R., Participatory ergonomics: Evidence and implementation lessons, *Applied Ergonomics,* vol. 68, pp. 289-293, 2017.

Castro, E., and Paz, L., Diseño Industrial y Ergonomía Participativa: una combinación clave para influenciar espacios de trabajo saludables, *ProducãoemFocoArtigo*, vol. 3, no. 1, pp. 31-58, 2013.

Cerón, S., and Espinosa, M., *Aplicación piloto de un programa de ergonomía participativa para la prevención y control de los factores de riesgo ergonómico en la empresa fabricante de bandas transportadoras y de transmisión de la ciudad de Popayán 2015*, 2017.

Dos Santos, I., Farias M., Toledo F., Haddad A., and Hecksher S., Human factors applied to alarm panel modernization of nuclear control room, *Journal of Loss Prevention in the Process Industries*, vol. 26, no. 6, pp. 1308-1320, 2013.

Forsman, M., Bernmark, E., Nilsson, B., Pousette, S., and Mathiassen, S.E., Participative development of packages in the food industry - Evaluation of ergonomics and productivity by objective measurements, *Work*, vol. 41, no. 1, pp. 1751-1755, 2012.

García, A., Gadea, R., Sevilla, M. J., Genís, S., and Ronda, E., Ergonomía participativa: Un modelo para la prevención de trastornos musculoesqueléticos ocupacionales, *Revista Española Salud Pública*, vol. 83, no. 4, pp. 509-518, 2009.

García, A., Sevilla, MJ., Gadea, R., and Casañ, C., Intervención de ergonomía participativa en una empresa del sector químico, *Gaceta Sanitaria*, vol. 26, no. 4, pp.383-386, 2012.

Gomathi, K., and Rajini, G., Organizational Ergonomics: Human Engineering leading to Employee Well-Being, *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, vol. 8, no. 10, 2019.

Gomes, J. O., El papel de la ergonomía en el cambio de las condiciones de trabajo: perspectivas en América Latina, *Revista ciencias de la salud*, vol. 12, pp. 5-8, 2014.

Guerrero, A. P., and Quintero, A. M. G., Evolución de la ergonomía participativa: conceptos y aproximaciones metodológicas, *Revista Colombiana de Rehabilitación*, vol. 15, no. 1, pp. 76-82, 2016.

Guimarães, L. B. M., Anzanello, M., Duarte, J., and Abreu, T., Participatory ergonomics intervention for improving human and production outcomes of a Brazilian furniture company, *International Journal of Industrial Ergonomics*, vol. 49, pp. 97-107, 2015.

Guimarães, L. B. M., Ribeiro, J. L. D., Renner, J. S., and De Oliveira, P. A. B., Worker evaluation of a macroergonomic intervention in a Brazilian footwear company, *Applied Ergonomics*, July 2014, vol. 45, no. 4, pp. 923-935, 2014.

Imai, M., *Cómo implementar el Kaizen en el sitio de trabajo* (gemba), Mc Graw Hill Interamericana, S.A., Santafé de Bogotá, 1998.

Montiel, M., Romero, J., Lubo Palma, A., Quevedo, A. L., Rojas, L., Chacin, B., and Sanabria, C., Valoración de la carga postural y riesgo musculoesqueletico en trabajadores de una empresa metalmecánica, *Salud de los Trabajadores*, vol. 14, no. 1, pp. 61-69, 2006.

Morag, I., and Luria, G., A group-level approach to analyzing participative ergonomics (PE) effectiveness: The relationship between PE dimensions and employee exposure to injuries, *Applied Ergonomics*, vol. 68, pp. 319-327, 2018.

Párraga, V. M., Diseño correcto de la estación de trabajo, *Revista Industrial Data*, vol. 6, no. 1, pp. 95-98, 2003.

Pazell, S., Burgess-Limerick, R., and Horberry, T., Case study: Process and outcome review of a participative ergonomics project in an asphalt production plant, *51st Annual Conference of the Human Factors and Ergonomics Society of Australia 2016: Healthy, Safe and Productive by Design, Gold Coast, Australia*, November 6-9, 2016.

Pinto, R., Programa de ergonomía participativa para la prevención de trastornos musculoesqueléticos: Aplicación en una empresa del Sector Industrial, *Ciencia & Trabajo*, vol. 17, no. 53, pp. 128–136, 2015.

Rasmussen, C. D. N., Lindberg, N. K., Ravn, M. H., Jørgensen, M. B., Søgaard, K., and Holtermann, A., Processes, barriers and facilitators to implementation of a participatory ergonomics program among eldercare workers, *Applied ergonomics*, vol. 58, pp. 491-499, 2017.

Rost, K.A., and Alvero, A.M., Participatory approaches to workplace safety management: bridging the gap between behavioral safety and participatory ergonomics, *International Journal of Occupational Safety and Ergonomics*, vol. 26, no. 1, pp. 194-203, 2020.

Sabadin, R.K., Severo, E.A., and De Guimarães, J.C.F., Innovation in ergonomics: a survey in the agribusiness sector of Brazil, *International Journal of Industrial and Systems Engineering*, vol. 34, no. 1, pp. 124-143, 2019.

Salazar, M., The Effects of Climate on Output per Worker: Evidence from the Manufacturing Industry in Colombia, *Revista Desarrollo y Sociedad*, no. 79, pp. 55-90, 2017.

Shingo, S., *Producción sin stocks: el Sistema Shingo para la mejora continua*, Tecnologías de Gerencia y Producción S.A., Madrid, 1991.

Tappin, D. C., Vitalis, A., and Bentley, T. A., The application of an industry level participatory ergonomics approach in developing MSD interventions, *Applied Ergonomics*, vol. 52, pp. 151-159, 2016.

The Productivity Press Development Team, *Standard Work for the Shopfloor*, Taylor & Francis Group, Florida, 2002

Torres, V. G. L., Vargas, M. E. M., & Álvarez, M. C. A., Ergonomía y Productividad: variables que se relacionan con la competitividad de las plantas maquiladoras, Ingeniería Industrial, *Actualidad y Nuevas Tendencias*, vol. 3, no. 9, pp. 17-32, 2012.

Visser, S., Van der Molen, H. F., Sluiter, J. K., and Frings-Dresen, M. H., Evaluation of the effects of two alternative participatory ergonomics intervention strategies for construction companies, *Ergonomics*, vol. 62, no. 1, pp. 42-51, 2019.

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