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Evaluation of Ergonomic Models and Methods Applicable in Basic Industries

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Abstract: To evaluate ergonomic models and methods and to know which one or ones to apply are the most common questions, so this research aims to evaluate different models and methods to know the key factors for improvement in the workplace. A bibliographic review was carried out, being from the methodological point of view a descriptive study. It was determined that the methods applied evaluate the efforts in function of the postures that determine musculoskeletal disorders in a general way, indicating only the levels of risks without considering actions for change, and as for the models, these are focused on safety, quality and labor productivity to increase the effectiveness of the improvements. Finally, a holistic model is presented that synthesizes the key variables for evaluations and improvement actions in the basic sector of the primary aluminum industry.

Keywords: Evaluation, Ergonomic Methods, Workstations, Musculoskeletal Disorders.

Evaluación de Modelos y Métodos Ergonómicos Aplicables en Industrias Básicas

Resumen: Para realizar las evaluaciones de los modelos y métodos ergonómicos y saber cuál o cuáles aplicar son las interrogantes más comunes, por lo cual la presente investigación tiene como objetivo evaluar distintos modelos y métodos para conocer los factores claves de mejoras en los puestos de trabajo. Se realizó una revisión bibliográfica siendo desde el punto de vista metodológico un estudio de carácter descriptivo. Se determinó que los métodos aplicados evalúan los esfuerzos en función de las posturas que determinan los trastornos musculo-esqueléticos de manera general indicando solamente los niveles de riesgos sin considerar acciones de cambio, y en cuanto a los modelos, estos se enfocan hacia la seguridad, la calidad y la productividad laboral para incrementar la efectividad de las mejoras. Finalmente, se presenta un modelo holístico que sintetiza las variables claves para evaluaciones y acciones de mejora en el sector básico de la industria del aluminio primario.

Palabras Clave: Evaluación, Métodos Ergonómicos, Puestos de Trabajo, Trastornos Musculo-Esqueléticos.

I.INTRODUCTION

Ergonomics is a science that was born as a consequence of the musculoskeletal ailments or disorders that workers manifest when performing their tasks or activities. The Spanish Ergonomics Association defines ergonomics as the interaction of a multidisciplinary team with the aim of adapting products, systems and artificial environments to the needs, limitations and characteristics of their users, optimizing efficiency, safety and well-being [1].

In order to carry out evaluations to determine the risks associated with the postures adopted by the worker, researchers created ergonomic evaluation methods. Each method was created by a multidisciplinary team in order to incorporate variables and factors that allow comprehensive data to be analyzed and improvement actions to be taken.

Regarding the methods, they are classified according to their applicability. For example, there are those that allow evaluating the general working conditions, load handling, repetitiveness, and postural load, among others. For the purposes of the research, it was determined to evaluate those of postural load because they are the most used. It could be inferred that this could be because the most common occupational diseases are musculoskeletal disorders, which represent the highest proportion other than cancer. It is appropriate to point out that the most reported diseases in 2004 were musculoskeletal diseases. It could be inferred that these figures are increasing from previous years. [2], [3], [4].

However, according to theoretical and practical evaluations carried out with each of the methods, it was detected that to evaluate postural loads it is necessary to apply more than one method because the information generated is very ambiguous. This situation leads to apply other methods in order to have more reliable results. However, it was also determined that applying several methods to the same task generates results that lead to confusion regarding the actions to be considered in relation to the level of risk obtained.

There are innumerable methods proposed for the recording and evaluation of postural loads, or other factors associated with musculoskeletal disorders, but they are applied to specific cases, which lead to a comprehensive assessment and thus more effective actions [5].

Both the Rapid Entire Body Assessment (REBA) and Rapid Upper Limb Assessment (RULA) methods do not consider organizational factors, a fundamental aspect for ergonomic assessments, in addition, neither the work rhythm, the duration of recovery periods, nor the number of workday breaks. On the other hand, it was detected that if the load is greater than 10 kilograms, it always produces a similar result. Therefore, it is recommended that these methods be applied to obtain preliminary information and then use other methodologies to better specify the information and the action to be taken. [6], [7].

As for (Ovako Working Posture Analysis System) OWAS is one of the most used methods for being useful, for the identification of inadequate postures, however, it cannot be used to determine the precision of the degrees of inclination that the body would have when performing the tasks. They also indicate that, although it allows a combination of codifications that represent posture as well as strength, the results are very general. Likewise, another aspect that was detected is that a certain time of observations is required to determine the most significant frequencies and postures. [7], [8], [9].

Due to the above considerations, the objective of the research is to evaluate the ergonomic methods and models in basic industries, with the purpose of knowing the significant elements and/or factors, to create a holistic model, which synthesizes the key variables for evaluations and improvement actions, in the basic sector of the primary aluminum industry.

For the determination of the factors, a bibliographic review and research of works where ergonomic methods were applied were carried out. From the methodological point of view, the study is of a documentary and descriptive nature in order to validate the applicability of the models. Thus, a comparative analysis was carried out which generated conclusive results.

II.DEVELOPMENT

There are several models and methods used by specialists in order to evaluate jobs according to the risks that may be present in the inherent activities towards the worker. Each one has different variables to consider in order to obtain feasible results that contribute to improve and minimize risks and musculoskeletal disorders.

Regarding the methods, as each one has its purpose and relevance, several classifications were made, such as: Postural Load, Load Handling, Forces and Biomechanics, Repetitiveness, Office Positions; Global Assessment; Thermal Environment and Utilities [10].

For the purposes of the research, the authors considered evaluating those classified in the Postural Load. Having made the above observation, the methods to be developed are: RPE, OWAS, RULA and REBA. In this order of ideas

we have the following:

A.EPR Method (Rapid Postural Evaluation)

The EPR is a tool that allows a general and preliminary evaluation to determine the static load. It should be noted that the assessment system used is the LEST method (Laboratory Method of Economics and Sociology of Work), so the EPR proposes a performance level between 1 and 5. It should be noted that the EPR makes a global assessment of the different postures adopted and the time they are maintained. Fourteen possible generic positions are specified [11].

Depending on the result obtained and because it is preliminary diagnostic information, it is advisable to carry out a more in-depth study using one of the postural loading methods such as OWAS, REBA, RULA, in that order of application.

B.OWAS Method (Ovako Working Posture Analysis System)

OWAS was created in 1977 by a multidisciplinary team in order to promote postural evaluations due to the fact that workers were suffering from ailments and thus had little effectiveness in performing their tasks. This method is based on observation with the purpose of defining the posture and classifying it. The code is established according to classification and an evaluation of the risk level is obtained to specify corrective actions in order to improve the workplace. It is a method that has generated important contributions, as well as other methods. It should be noted that the most widely applied methods to assess the physical postural load are OWAS, RULA and REBA. [12], [13].

C.RULA Method (Rapid Upper Limb Assessment)

RULA is a method developed by McAtamney and Corlett for use in assessments involving the human body, specifically the upper limbs.

To apply it, the division of the body must be considered, i.e., right and left side separately. Based on the posture, a score is established which leads to a total value according to the crossing of the variables. Thus determining the level of risk and the action considered, in order to take the necessary steps for improvement and minimize the possible musculoskeletal disorder.

It should be added that the RULA method does not provide detailed information, such as finger position. So it is advisable to collect information in a general way, and thus use other more comprehensive ergonomic assessment tools [14].

D.REBA Method (Rapid Entire Body Assessment)

This method is based on RULA parameters in order to incorporate variables that allow more viable results towards postural load assessments.

The purpose of the method is to determine the levels of risk associated with the task performed by the worker that is why individual postures are considered for its application. It should be noted that the correct posture is the Neutral position, so those that are outside this condition are considered, in addition to the duration or frequency. For this purpose, the method allows a comprehensive evaluation of the positions adopted by the upper body members (arm, forearm, and wrist), trunk, neck and legs. In addition to this, it considers other variables such as the force performed at the moment of manipulating a load, as well as the type of grip performed.

It should be noted that this method is the most widely used in practice because it is particularly sensitive to tasks involving unexpected changes in posture. In this sense, there are many studies that endorse the REBA as one of the most widely used tools in postural load analysis. [15], [16].

In short, it can be said that the method generates important contributions in the evaluations, however, it is necessary to contrast it in order to detect its advantages and disadvantages, for example, one of the ways to evaluate is to observe the posture and to see the inclination angle that it has in the joint of the evaluated part. Regardless of the angle, the method tells you to consider a fixed score.

The aforementioned methods allow a broader perspective of risk situations with a view to an integral or holistic model in ergonomic matters.

E.Ergonomic Management Models

The purpose of the occupational health and safety model, with integrated management for the sustainability of organizations, is to promote healthy lifestyles among workers, as well as to improve working conditions and care of the

environment with quality and productivity [17]. Figure 1 shows the model and it can be seen that one of the factors considered was ergonomics.

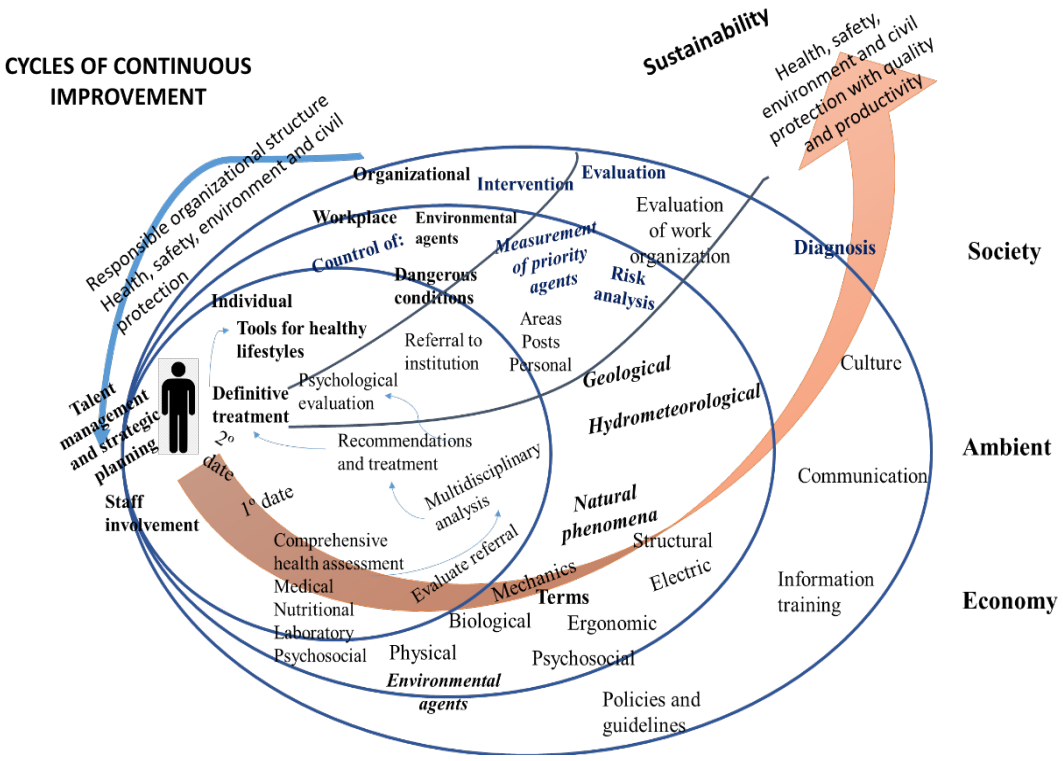

Fig. 1. SSeTGIS model. Components by levels of action and process.

For the development of the model, the author considered as important components: health, hygiene conditions at work, and safety conditions at work, environmental care, as well as quality and productivity as integral management. It should be noted that among her conclusions she states that her model differs from others because it focuses on taking health and safety at work as a perspective centered on people as the first beneficiaries and participants in the work culture it promotes.

On the other hand, the ergonomics maturity model for companies, is presented so, that they can evaluate the capabilities they possess, and based on the results, be able to draw up strategies aimed at introducing, applying and developing ergonomics in companies, integrating it into processes and contributing to the fulfillment of the organization's objectives [18].

The aforementioned authors considered several levels where a set of characteristics related to the recognition of ergonomics were proposed for each level, thus generating the model represented in Figure 2.

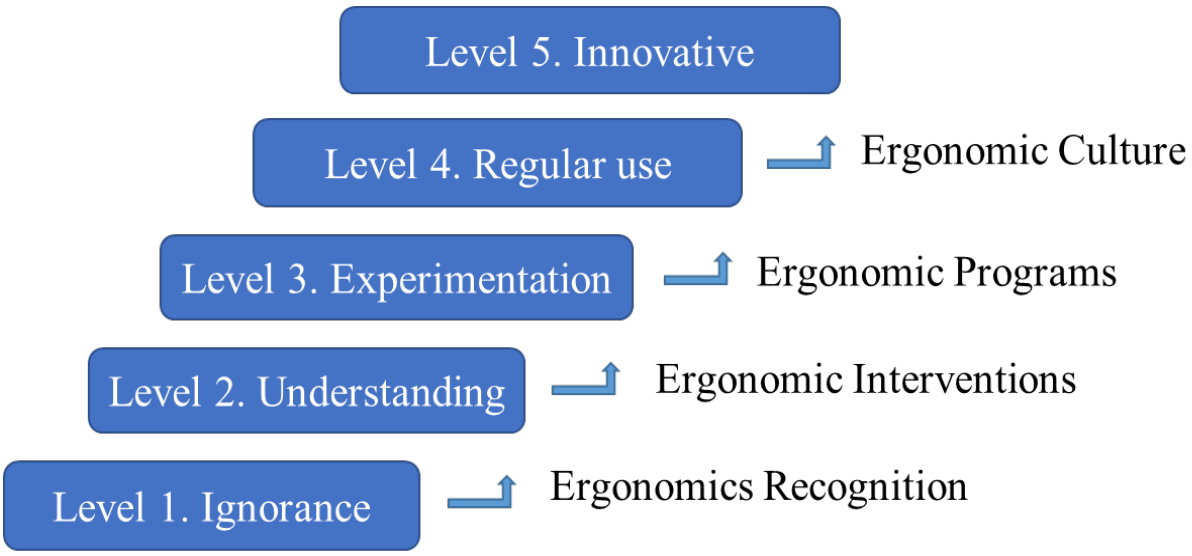

Fig. 2. Ergonomics Maturity Model for Companies

Level 1 refers to the lack of knowledge of ergonomics and the benefits it generates for the development of production processes, as well as improvements in the worker's quality of life.

Levels 2 and 3 emphasize the benefits and application of ergonomics in order to minimize possible illnesses, as well as worker safety. Towards level 3, small projects are developed hand in hand with the ergonomist and the engineer.

Level 4 focuses on training and qualification of workers, but mainly to senior management, with the purpose of assuming commitments and recognizing ergonomics as a means that contributes to the achievement of objectives. And finally, level 5 promotes the successful integration of ergonomics as part of management strategies. At this level, the employee plays a very important role because their opinions are the basis for the implementation of improvements. Likewise, there are already indicators to monitor and make adjustments according to the deviations that may occur.

Now, for the evaluation of the model they considered a company where the maximum level reached was Level 2, however, of the evaluated elements , two of them were positioned in level 1; then, they concluded that their classification is located in the lower level 1 (Ignorance). The information obtained from the model allows the companies to see how they are doing, and thus carry out improvement actions towards the implementation of ergonomic programs.

In the same order of ideas, the strategic model for the implementation of ergonomics in operations management is presented. Its implementation will allow organizations to apply ergonomics knowledge to production operations, in relation to technologies, work organization and human resources [19].

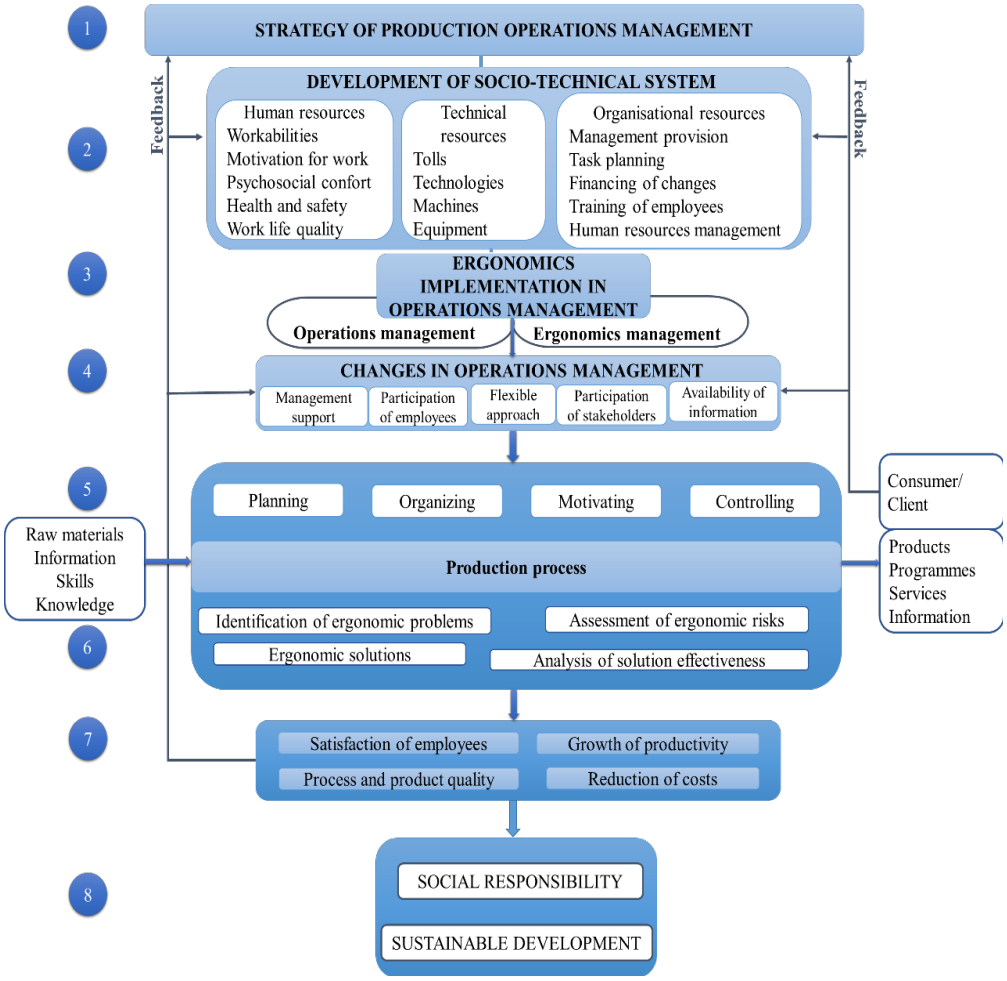

Fig. 3. Model "Ergonomics Implementation in operations management.

Figure 3 show that the application of the model leads companies to achieve Social and Sustainable Development as a result.

The authors state that the application of ergonomics should be carried out in terms of operation and ergonomics management. That is why in level 3 they present the integration of both. They state that the results will be more effective because the quality standards will also be taken into account.

In addition to the above, they considered at level 4 aspects such as worker participation, management support, flexibility, availability of information and stakeholder participation. Indicating that the lack of any of them would significantly decrease the effectiveness of ergonomic solutions.

In addition to the above, the aspects at level 6 were considered because they are the ones that will allow to control the deviations in the process. Because at this level it will be possible to identify problems and thus analyze them in order to carry out corrective actions aligned with management strategies. However, they also considered the client as a fundamental piece because he is the main consumer and therefore the one that allows feedback towards management improvements.

Finally, they express that the elements indicated by levels add up to a whole and influence each other, generating results towards a social responsibility that is the basis for the sustainable development of the organization.

On the other hand, it is important to refer to the ISO 45001 safety management system standard because it provides a new model that can be used as an effective system to manage ergonomics [20]. ISO 45001 is an international safety management system standard that was published on March 15, 2018; its content is aligned with the Deming Cycle. The model for managing ergonomics based on ISO 45001 states that all levels of the company must be engaged and empowered in ergonomics processes. Each responsibility must be well defined, as well as their ergonomics education and training. In addition to the above, it indicates that effective controls must be applied in risk reduction, both in the

workstations and in the task performed by the worker. And with this, the necessary resources must be established, as well as the review of ergonomic operations.

III MATERIALS AND METHODS

In order to validate the results of the methods applied to different tasks, several evaluations were made at the documentary level based on the search for data, its capture and critical analysis to interpret data from primary and secondary sources reflected in reports and information of the study subject matter in the company taken as a reference.

The sources and documents obtained were of a secondary nature from the works of other authors referenced where appropriate, and in accordance with their research nature; the source came from textbooks, specialized articles, reports and case studies, and reports of the company selected for the study, which was CVG VENALUM, the only primary aluminum reducing company that allowed the development of the research.

Due to the above conditions, the research is descriptive because the characteristics were identified, which allowed comparisons between the methods and analysis of the models, in order to determine the variables contained in each one and to define the advantages and disadvantages. In this aspect is the study of the variables independently, it is part of describing the characteristics, in addition to determining the behavior of the variables [21].

This research is circumscribed as documentary type because bibliographic sources were used to be analyzed and evaluated in order to respond to the subject under study. And field research because we interacted in the selected company with the processes and personnel involved in the tasks evaluated in the reduction area. [22].

It is appropriate to point out that, for the selection of papers, articles or information for the evaluation, the selection criteria were those that presented results focused on the limitations or weaknesses of the methods. Thus, excluding those that only considered for the evaluations the use of the methods in order to generate specific results for a particular position or task.

As for the sample studied, thirty-five works were evaluated, corresponding to degree theses, internships and articles in indexed journals. The research was carried out in databases such as: PUBmed, Dialnet, and Scielo.

IV RESULTS

Each method has important contributions to the evaluation of risks associated with postural load, so it is necessary to contribute with other variables and factors that strengthen the postural load evaluations. Table 1 below shows the details of the methods, showing the advantages and disadvantages of each one, as well as their objectives.

Table 1. Characteristics of the methods.

Method	Target	Features	Advantages	Disadvantages
EPR (Rapid Postural Evaluation)	It allows a first and brief assessment of the postures adopted by the worker throughout the day.	• EPR uses the LEST method static load rating system.	• Performs an overall assessment of the different postures adopted and the time they are maintained.	• It does not evaluate any specific position. • It considers 14 generic positions.
OWAS (Ovako Working Analysis System)	Improve work methods, based on the identification and elimination of forced postures.	• Evaluates positions jointly. • The positions are classified in 252. • It distinguishes four risk categories for each posture. • Validated in tasks of risk for the lumbar area.	• Individual risk category. • Results with a confidence level of 90% or more. • Very didactic. • Applicable for different types of jobs	• Overall results. • Registration ranges from 20 to 40 minutes. • A minimum of 100 samples is required. • Use wide ranges of categories.
RULA (Rapid Upper Limb Assessment)	To evaluate the exposure of workers to risk factors that cause a high postural load and that can cause disorders in the upper limbs of the body.	• Evaluates individual positions. • The measurements on the postures adopted are fundamentally angular. • Evaluations of the sides (right and left) are performed separately. • Observations are made for several cycles.	• Evaluates a working posture and the associated level of risk in a short period of time. • Brief results of previous musculoskeletal injuries. • It is useful for comparing existing and proposed workstation designs.	• Assesses upper extremities • It was not designed to provide detailed postural information. • Does not provide a sub classification for different regions of the body
REBA (Rapid Entire Body Assessment)	Assess the degree of exposure of the worker to risk due to the adoption of inadequate postures.	• Based on RULA • Evaluation of the upper extremities. • Analyzes as a whole the positions adopted • Evaluates the load and grip • It assesses muscle activity (both in static and dynamic postures). • Coding for muscular activity originatedby static, dynamic postures,	• Sensitive to musculoskeletal risks. • Analyzes the impact of load handling on postural load. • Assess postures with abrupt or unexpected changes. • Generates a level of action with indication of priority or urgency.	• Applies only to postural load evaluations. • It evaluates individual postures and not a set or sequence of postures. • It does not provide a sub classification for different regions of the body. • evaluates left and right side separately.

It is evident that, although the methods focus on the evaluation of postures, they agree on an evaluation system that indicates the level of risk and action to be taken according to the task being evaluated. Likewise, they allow detecting inadequate postures. It was determined that REBA and RULA are similar in their application. Both consider the right and left sides separately. They differ in that REBA considers the handling of loads. These methods differ from OWAS in the type of results. That is, OWAS provides more general results and the others, more specific.

Table 2 shows some of the tasks evaluated in the aluminum company, specifically the reduction area, which, according to the results of medical evaluations, is the area with the highest incidence of MSDs (MusculoSkeletal Disorders). The results of the methods applied in ergonomic evaluations are as follows:

Table 2. Results of the REBA and RULA methods in ergonomic evaluations.

Activity	REBA	RULA
Anodic Current Distribution Measurement in Cell	**Score: 4** **Risk Level**: Medium **Action**: Action is necessary.	**Score: 3** **Risk Level**: Medium **Action**: Redesign of the task is required.
Bath and Metal Level Measurement	**Score: 6** **Risk Level:** Medium **Action:** Action is necessary.	**Score: 5** **Risk Level:** Medium **Action:** Redesign of the task is required.
Maneuver Cell Side Cover	**Score: 11** **Risk Level:** High **Action:** Immediate action is necessary.	**Score: 7** **Risk Level:** High **Action:** Urgent changes in the task are required.
Oven Crust Breaking	**Score: 10** **Risk Level:** High **Action:** Action is needed as soon as possible.	**Score: 7** **Risk Level:** High **Action:** Urgent changes in the task are required.
Measure Worn Anode	**Score: 6** **Risk Level:** Medium **Action:** Action is necessary.	**Score: 4** **Risk Level:** Low **Action:** Changes in the task may be required; further study is desirable.
Hole Skimming	**Score: 11** **Risk Level:** Very High **Action:** Immediate action is necessary.	**Score: 7** **Risk Level:** High **Action:** Urgent changes in the task are required.
Extraction of Coal Bits	**Score: 11** **Risk Level**: Very High **Action:** Immediate action is necessary.	**Score: 7** **Risk Level**: High **Action**: Urgent changes in the task are required.

It is determined that the methods have very similar results in almost all tasks, although they have different scores. In general, the levels of action are oriented towards improvements or changes that will benefit the worker in the operating conditions. It could be inferred that the similarity is due to the fact that the creation of the REBA method was based on the variables contained in RULA.

However, with respect to the application of the OWAS method in conjunction with some of the two previous methods, very similar results emerge in terms of risk levels and actions. Table 3 shows the evaluation of some activities and their results according to the method considered.

Table 3. Results of the OWAS, RULA and REBA methods in ergonomic evaluations. REBA methods in ergonomic evaluations.

	Risk Level: Very High Action: Corrective action is required immediately.	Risk Level: High Action: Urgent changes in the task are required.
Hole Skimming	**Score: 3** Risk Level: High Action: Corrective action is required as soon as possible.	**Score: 7** Risk Level: High Action: Urgent changes in the task are required.
Activity	**OWAS**	**REBA**
Oven Crust Breaking	**Score: 2** Risk Level: Medium Action: Corrective actions are required in the near future.	**Score: 10** Risk Level: High Action: Action is needed as soon as possible.
Positioning Lid to cover cells	**Score: 3** Risk Level: High Action: Corrective action required as soon as possible	**Score: 9** Risk Level: High Action: Action is needed as soon as possible.

Table 3 shows different scores and risk levels in some tasks. However, in general, the actions are very similar. The results may cause uncertainty in the evaluators at the time of performing or executing appropriate improvement actions.

It should be noted that the methods do not indicate in depth the action to be taken, so it will be the evaluator, together with a multidisciplinary team, who will decide on the changes to improve the worker's conditions. However, it is important to continue with studies and research that generate methods that include variables that allow the collection of more in-depth information, as well as recommendations for broader actions aimed at the effectiveness of the processes.

However, in general, some models allow companies to be evaluated in a comprehensive manner in order to determine their management capabilities, and to carry out improvement actions towards the implementation of ergonomic programs, as in the case of this study.

The purpose of the models is to integrate each department of the company because they consider that the commitment must be promoted from the top management in order to assume the cultural changes of the worker. In addition, they promote an integral strategic management where health, environment, hygiene at work, quality, productivity, but above all, worker's commitment, are considered as fundamental pillars. Finally, it is evident the importance of creating a model that considers the interrelation of the strengths of the methods already created with the purpose of having an advance in the results of the evaluations of the postural loads. Figure 4 shows the ergonomic management model created by the authors.

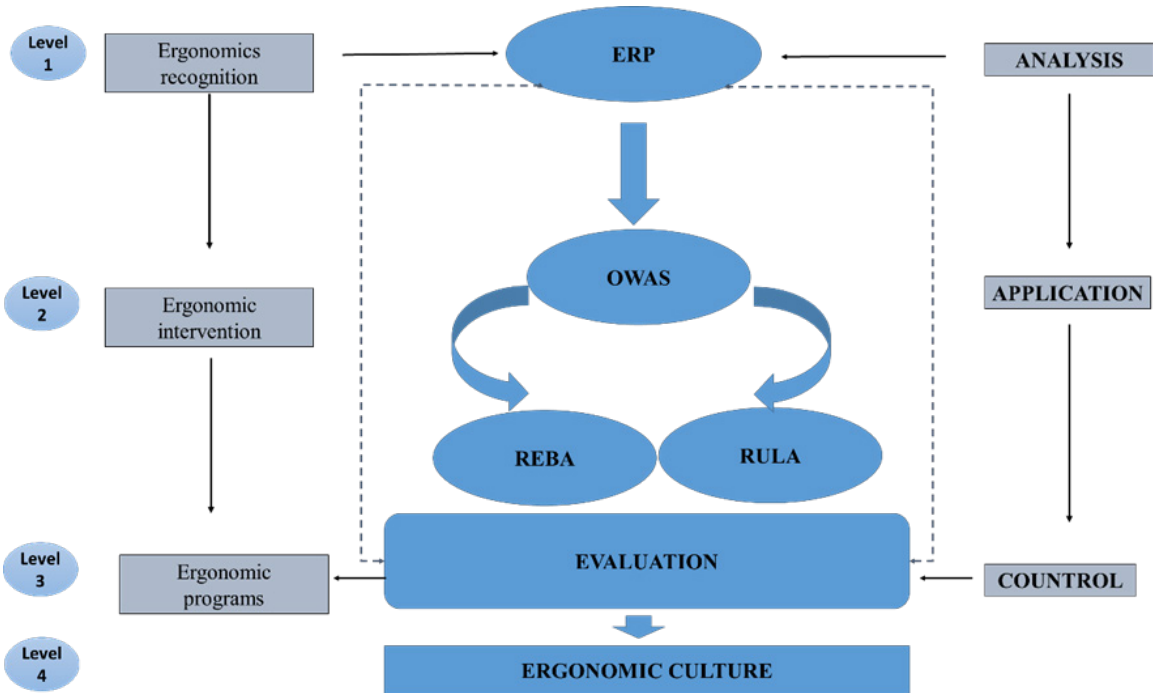

Fig. 4. Ergonomic management evaluation model for manufacturing processes Source: Authors

With the model shown in Figure 4, it is intended to demonstrate that companies must recognize that ergonomics is essential for the effective development of management, because it will allow them to have workplaces that are in accordance with the worker and the established occupational health and safety standards. Therefore, the first level presents the recognition, aligned with the analysis of postural loads with the EPR methodology, in order to obtain a first approximation or diagnosis of postural risks in the worker. Next, level 2 emphasizes the ergonomic intervention by applying the OWAS, REBA and RULA methods, complementing the information that will allow detecting the levels of risks associated with the task performed by the worker.

Level 3 establishes the importance of creating ergonomic programs aligned with occupational health and safety standards in order to be applied, evaluated and controlled, based on indicators or criteria that the company considers to measure the quality of its processes.

Finally, at level 4, by considering the integration and participation of the worker in the implementation of ergonomics, the commitment and culture of behavior based on safety and health will be encouraged.

V.CONCLUSIONS

The study reflects, after a comparative analysis, some methodologies that evaluate the efforts according to the determining postures in musculoskeletal disorders, based on general evaluations that only indicate risk levels without considering actions for change, while other methodologies focus on safety at work, quality and business productivity.

In particular, the Rapid Postural Evaluation (EPR) methodology allows for a general and preliminary evaluation in order to determine the static load. In this sense, the EPR performs a global assessment of the different postures adopted and maintained over time and the result obtained is preliminary information that recommends a more in-depth study using one of the postural load methods.

The Ovako Working Posture Analysis System (OWAS) methodology starts with observation in order to define the posture and classify it. It establishes a code according to classification and facilitates anassessment of the level of risk, and thus the corrective actions to improve the work posture are specified.

The Rapid Upper Limb Assessment (RULA) method evaluates actions that involve the human body, specifically the upper limbs. It is applied considering the division of the body into right side and left side separately. Based on the posture, a score is established which leads to a total value according to the crossing of the variables, thus determining the level of risk and the action considered for the management of improvement in minimizing possible musculoskeletal disorders.

As for the Rapid Entire Body Assessment (REBA) method, it determines the levels of risks associated with the task performed by the worker, which is why it considers individual postures for its application. The method allows a comprehensive evaluation of the positions adopted by the upper body members (arm, forearm, and wrist), trunk, neck and legs, and the force performs by worker when handling a load, as well as the type of grip.

The comparative evaluation of ergonomic study methodologies revealed a gap that is filled by integrating into one model, the multiple methodologies that take into account the key variables, of ergonomic management, in the basic industrial sector.

The model in its first phase, allows to make a recognition of ergonomics in the company with the EPR methodology. In a subsequent step, it proposes to carry out the ergonomic intervention, combining the OWAS, RULA and REBA methods that give the framework of integrality. Finally, programs are applied to consolidate the ergonomic culture.

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