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Procedure for Preventing Musculoskeletal Disorders: Application to Underground Mining Works

Procedimiento para la prevención de desórdenes musculoesqueléticos: aplicación en trabajos de minería subterránea

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ABSTRACT

Keywords: Ergonomics; musculoskeletal diseases; occupational risks; risk factors.

The incidence and prevalence of work-related musculoskeletal disorders are currently one of the most important challenges to the mining sector. This paper proposes a procedure to prevent these diseases based on the active participation of workers. The procedure is structured in four stages: hazard identification, risk assessment, proposed improvements, and implementation and follow-up. To support the application of the procedure, a set of ergonomic methods and tools appropriate for mining work are outlined. The main results of the application of the procedure to an underground mine in Peru demonstrate its practical value, as well as its usefulness in improving working conditions and creating a preventive culture. The proposed procedure is expected to serve as a reference in the prevention of musculoskeletal disorders in mining works.

RESUMEN

Palabras clave: ergonomía; enfermedades musculoesqueléticas; riesgos laborales; factores de riesgo.

La incidencia y prevalencia de los desórdenes musculoesqueléticos de origen laboral es en la actualidad uno de los desafíos más importantes que enfrenta el sector minero. En este trabajo se propone un procedimiento para prevenir estas enfermedades, sustentado en la participación activa de los trabajadores. El procedimiento quedó estructurado en cuatro etapas: identificación de peligros, evaluación de riesgo, propuesta de las mejoras e implementación y seguimiento. Para apoyar la aplicación del procedimiento fueron propuestos un conjunto de métodos y herramientas ergonómicas apropiados para los trabajos de minería. Se muestran los principales resultados de la aplicación del procedimiento en una mina subterránea de Perú, lo que evidencia el valor práctico de este, así como su utilidad en la mejora de las condiciones de trabajo y en la creación de una cultura preventiva. Se espera que el procedimiento propuesto sirva de referencia en la prevención de los desórdenes musculoesqueléticos en trabajos de minería.

INTRODUCTION

Ergonomics has been universally used to improve the quality of human life[1]. It is defined as the scientific discipline that studies the interactions between people and the other elements of a system and as the profession that applies theory, principles, information, and methods to optimize human well-being and the overall performance of a system[2]. Ergonomics professionals design interfaces between humans and other elements of the system to improve health, safety, comfort, and productivity, including quality and reducing human error[1].

One field where the ergonomic design of jobs and work systems has had a great impact is the prevention of occupational musculoskeletal disorders (MSDs), defined as disorders in and damage to the musculoskeletal system that have a proven or hypothetical causal relationship with a work component[3]. Currently, MSDs are a common health problem and the leading cause of work disability[4,5]. Hence, the importance of directing efforts to the primary prevention of these diseases, which are generally associated with poor ergonomic conditions[6,7].

In mining work, certain factors contribute to the emergence and aggravation of these work-related injuries such as workers' adoption of awkward postures, the high biomechanical effort required by some activities, inadequate work and rest systems, as well as unfavorable environmental conditions [8-10]. Given this, the worker himself and his managers must acquire the knowledge and tools to prevent this type of injury. Therefore, they need practical methods that are easy to understand, do not require a large consumption of resources, and involve them actively.

Participatory ergonomics has been an approach frequently used in ergonomic interventions in both developed and underdeveloped countries[7,11]. This approach has been given other names, such as worker participation and participatory management[12]. Participatory ergonomics has been approached from different perspectives, hence several definitions. Hignett et al.[13] refer to Wilson's definition of participatory ergonomics: "the involvement of 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 desirable goals." Hendrick and Kleiner[12], on the other hand, state that when work analysis and design involve workers, it is referred to as participatory ergonomics.

A very important element when participatory ergonomics is used as an approach is to take advantage of the knowledge and experience that the worker has accumulated during the performance of his tasks and revert it in the improvement of his working conditions.

Several procedures and guidelines for the prevention of MSDs have been proposed[8,14,15] and although their usefulness is unquestionable, they present characteristics that make their application more complex. The lack of preventive procedures or methodologies that are easy to apply and understand is a barrier the mining sector must overcome, which is the focus of this study.

This research proposes a procedure for the prevention of MSDs based on the active participation of workers and presents the results of its application to underground mining works.

MATERIALS AND METHODS

In this research, a descriptive cross-sectional study was conducted in a mining unit in Peru, where musculoskeletal symptoms and their associated risk factors were identified in a sample of workers.

Population and sample

This study focused on the development and construction stage of a conventionally executed underground mining project.

The total study population was about 131 operational mining workers. A sample of 64 male mining workers was taken from this population. Participation was voluntary. This sample was non-probability because of the hard access to the workplace and restricted time availability. The average age of the workers was 30.4 years (ranging between 19 and 44 years).

The sample of 64 workers was distributed as follows: 12 in rock scaling workers, 12 in structure support, 10 in rock-blasting, 14 in jackleg-drilling, and 16 in cleaning.

Proposed procedure for the prevention of MSDs

This study proposes the intervention procedure shown in Figure 1. For the application of the procedure, five tasks were selected that are commonly performed in the development and construction stage of an underground mining project. The selection criteria of the tasks relied upon the possibility of interacting with the workers that carried them out, the access to the locations where the tasks took place and to information. The tasks were rock scaling, structure support, jackleg-drilling, rock-blasting, and cleaning.

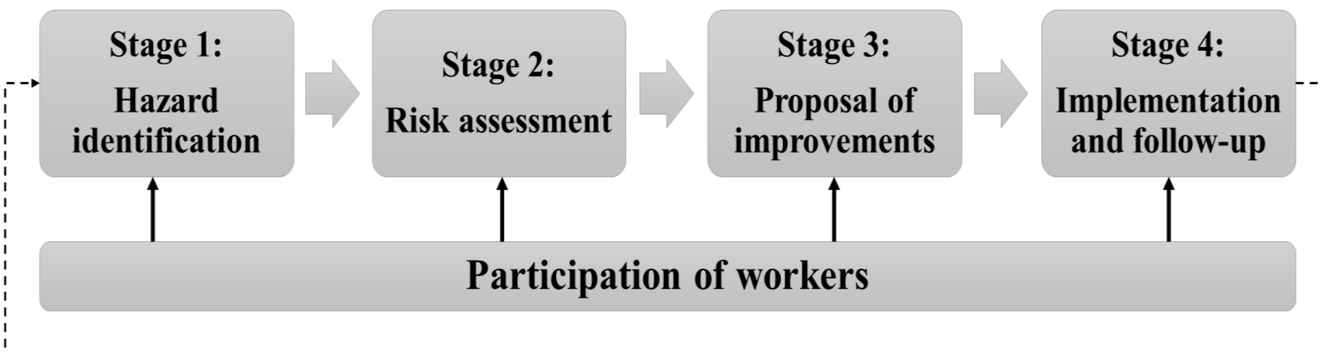


Figure 1. Proposed procedure for the prevention of MSDs.

In Stage 1 of the procedure, the five tasks were analyzed. Then, the most critical task was selected according to the possible presence of MSDs risk factors, which was jackleg-drilling. This task was taken as the subject matter of this study to demonstrate how the proposed procedure was applied. For this reason, only the results obtained from the analysis of jackleg-drilling will be presented in this paper.

The premise for its effective implementation is the actual and active participation of workers at all levels of the organization, using the valuable experience and knowledge they possess. The reasons that support this approach are the following[8,16]:

- Workers are the ones who best know the problems related to their area and job. They are best positioned to propose and prioritize solutions and evaluate their effectiveness.
- The participation of workers in the planning and implementation of improvement proposals makes them more committed to the objectives of the company.

Therefore, this study proposes simple and easy-to-use tools, although this does not imply discarding other more sophisticated tools that require a higher level of expertise on the part of the personnel who use them. The procedure incorporates the philosophy of ongoing improvement, which makes stage application cyclical. It is recommended that the Occupational Safety and Health (OSH) and/or Ergonomics department, area, or leader in the company lead its implementation.

The stages of the procedure are described below.

Stage 1: Hazard identification

This stage aims to identify and prioritize existing hazards with the help of workers. The activities proposed at this stage are:

1. Search the company's records for MSDs statistics (if available), jobs with high rates of

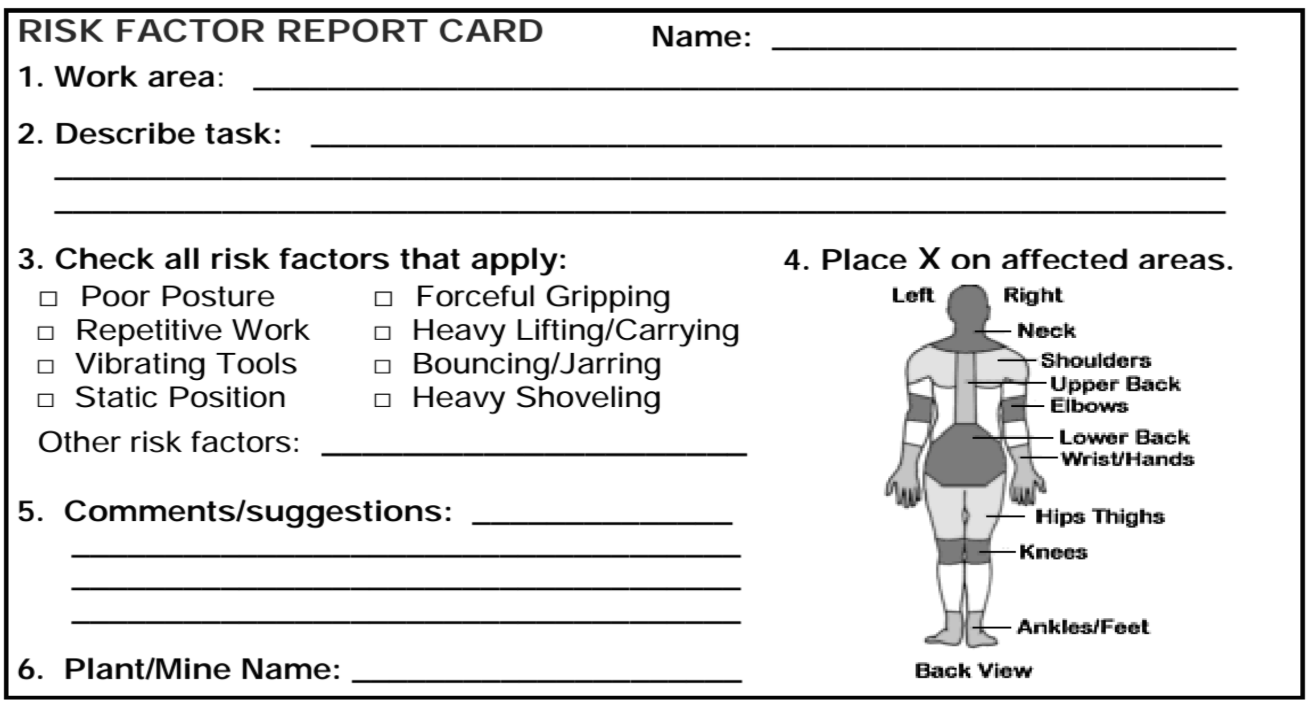
staff turnover, low productivity, accidents at work, among other indicators.

2. Ask workers which activity/task requires them to make more physical effort and why.
3. Conduct studies of musculoskeletal symptoms. This approach is proactive; it anticipates the occurrence of MSDs, as pain is a precursor to the onset of the disease.
4. Train workers in the identification of risk factors and instruct them on how they can solve their problems. The goal is for everyone to contribute to improving their working conditions. Management should support these activities and get involved in the training to demonstrate their commitment.
5. Assess the possibility of eliminating tasks identified as putting workers' health at risk due to the presence of MSDs risk factors. If this is not possible, an analysis should be conducted, as described in Stage 2.

At this stage, risk factor report cards can be used for workers to report their opinions about the tasks they perform. Checklists and questionnaires of musculoskeletal symptoms can also be used, which can be self-administered by the workers or through interviews[8].

Risk factor report card

Figure 2 shows the Risk Factor Report Card. This tool aims to involve workers in the ergonomics process by obtaining information on possible exposure to risk factors and identifying discomfort symptoms in the human body[8].


RISK FACTOR REPORT CARD Name: ____________________

1. Work area: ____________________

2. Describe task: ____________________

3. Check all risk factors that apply:

- ☐ Poor Posture
- ☐ Repetitive Work
- ☐ Vibrating Tools
- ☐ Static Position
- ☐ Forceful Gripping
- ☐ Heavy Lifting/Carrying
- ☐ Bouncing/Jarring
- ☐ Heavy Shoveling

Other risk factors: ____________________

4. Place X on affected areas.

5. Comments/suggestions: ____________________

6. Plant/Mine Name: ____________________

Figure 2. Risk Factor Report Card[8].

The information obtained through the Risk Factor Report Card can be used to identify which tasks and risk factors require efforts for ergonomic assessment and intervention[8]. In this work, the Risk Factor Report Card was used for that purpose.

It is recommended that the card be used in training or to provide information on how to modify tasks. It should also be posted in places visible to workers, such as bathrooms and dining rooms[8]. It should be noted that this card was translated into Spanish before its administration to the mining workers who participated in this case study.

Stage 2: Risk assessment

The objective of this stage is to evaluate the magnitude of the risk present in jobs/tasks. The information provided will make it possible to take measures aimed at minimizing or eliminating the risk. It is essential to involve the workers who perform the tasks to be evaluated. The proposed activities are:

1. Select the risk assessment tools to be used as appropriate. Consideration should be given to the body parts each tool evaluates, risk factors and the accuracy of results, the limitations of the tools, the resources and time required for the evaluation, as well as the level of knowledge of the person who will use them.
2. Train the workers involved in the use of the evaluation tools they will use.
3. Evaluate the tasks in which the presence of risk factors was identified.
4. Analyze the evaluation results. If more than one evaluation tool has been used, the results should be compared in each case.

At this stage, checklists can be used for the evaluation of risk factors, as well as easy-to-use and fast-application evaluation methods. It is advisable to film and photograph the activities.

Ergonomic assessment methods were used in this work, including the Individual Risk Assessment (ERIN)[17,18] and Rapid Entire Body Assessment (REBA)[19]. Ergonomics and occupational safety and health practitioners frequently use these observational ergonomic methods to evaluate tasks and jobs. There are several reports about the acceptable levels of inter-/intraobserver reliability and validity of the ERIN method[17,18,20] and the REBA method[21,22]. Observational ergonomic methods are considered universally applicable and can be used in different contexts[22,23].

Individual Risk Assessment Method (ERIN)

ERIN is an easy-to-use observational method developed for non-expert personnel with relatively little training to evaluate individuals exposed to risk factors associated with MSDs[17,18,24,25]. Risk factors are evaluated through seven variables:

1. Interaction between posture and frequency of trunk movement
2. Interaction between posture and frequency of arm movement
3. Interaction between posture and frequency of wrist movement
4. Interaction between posture and frequency of neck movement
5. Rhythm, given by the speed of work and the effective duration of the task
6. Intensity of effort, result of effort, and its frequency
7. Worker's self-assessment/perception of stress for the task performed

The total risk value is calculated by adding the risk for the seven variables. ERIN proposes four levels of risk according to the total risk obtained and recommends actions for each level.

- Total risk score of 6–14. Low: No changes are required
- Total risk score of 15–24. Medium: Further investigation is needed and changes may be required
- Total risk score of 25–34. High: Investigation and changes are required soon
- Total risk score ≥ 35. Very high: Investigation and changes are required immediately

The evaluation process with ERIN requires little time, allowing the study of many jobs/tasks in different sectors of the economy at minimal cost and without interrupting the work. For its application, the field sheet of the method and a pencil[17,18] or the ERIN app for mobile devices available for free in Google Play can be used.

Rapid Entire Body Assessment Method (REBA)

REBA is a method developed to perform a postural assessment of the whole body in health sector activities and other industries. With this method, it is possible to analyze static and dynamic postures in a relatively short time. The scores assigned to the postures of the evaluated body segments increase as they deviate from the neutral position[19,26].

Group A includes the trunk, neck, and legs, while group B includes the arms, forearms, and wrists. A group of available tables transforms the 144 possible combinations into a score representing the level of musculoskeletal risk. Other aspects that are analyzed and contemplated in the evaluation are load handling, load coupling, and physical activity[19,26]. REBA proposes five levels of risk and recommends actions accordingly.

- REBA score of 1. Negligible: No action necessary
- REBA score of 2–3. Low: Action may be necessary
- REBA score of 4–7. Medium: Action necessary
- REBA score of 8–10. High: Action necessary soon
- REBA score of 11–15. Very high: Action necessary NOW

Stage 3: Proposal for improvements

The objective of this stage is to propose measures aimed at reducing or eliminating workers' exposure to MSDs risk factors. The proposed activities are:

1. Prioritize the tasks and positions that will be intervened. Some aspects that should be considered are the incidence and prevalence rates of MSDs, the level of risk involved in the evaluation, the number of workers exposed, the economic-productive aspects, and the opinion of workers.
2. Propose improvements aimed at reducing or eliminating workers' exposure to MSDs risk factors. Several alternatives have been used to control MSDs[27], including the ergonomic redesign of the task or job, the selection of workers to increase correspondence between their abilities and the demands of the job to be performed, as well as the training of workers in adequate work methods. The desired solution from the ergonomics perspective is to eliminate hazards or move the miner to a place where he is not exposed. An additional measure is programs aimed at increasing the physical skills and training of workers.

Decision matrices, brainstorming, re-evaluations with the methods used to assess risk, and cost-benefit analysis can be carried out.

Stage 4: Implementation and follow-up

The objective is to implement the most appropriate measures and ensure that they are carried out properly. The proposed activities are:

1. Design a prototype to implement physical redesigns (machines, tools) of workstations to minimize errors. This allows testing the effectiveness of the proposals before extending them to other positions/areas of the company.
2. Keep records of the situation "before" and "after" changes. Photographic evidence, MSDs statistics, productivity indicators are examples of aspects that must be documented and kept on file. This helps to justify future changes.
3. Monitor changes made. After a solution has been implemented, it should be followed up to ensure the effectiveness of the change and avoid new risks.
4. Involve workers in implementation. This allows eliminating the inconveniences that arise during the implementation process and adjust the measures to the real context where they will be applied; it also increases workers' acceptance of changes.

At this stage, it is advisable to review documents and databases and to film and photograph the tasks.

Statement of compliance with ethical standards

This study protected the information the company and its workers provided. Workers' participation was voluntary. The information collected was used for scientific purposes and kept confidential in accordance with ethical standards.

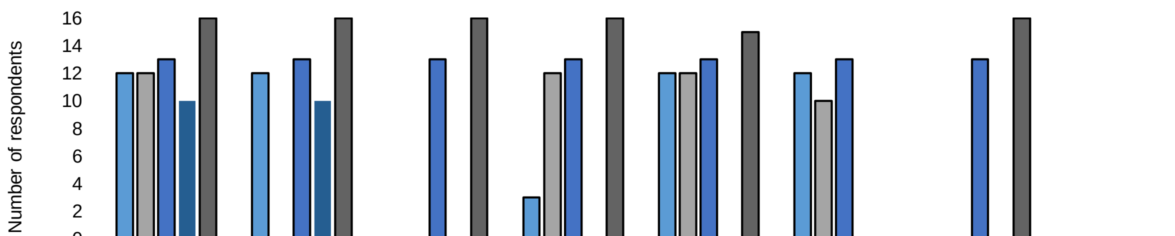
RESULTS

Stage 1: Hazard identification

At this stage, it was not possible to search the information in the company's records because statistics related to occupational MSDs were not collected. Training was given to the mining workers to teach them how to identify hazards during the performance of their tasks.

Due to their simplicity and usefulness, the miners were trained in the use of the Risk Factor Report Card that was presented in the Materials and Method section (Figure 2). The Risk Factor Report Card was administered to the 64 workers who participated in the process. This tool allowed these workers to report their opinions on their working conditions.

Figure 3 shows the results of Question 3 of the Risk Factor Report Card, in which the presence of risk factors is evident in each of the tasks studied.



	Poor Posture	Repetitive Work	Vibrating Tools	Static Position	Forceful Gripping	Heavy Lifting/Carrying	Bouncing/Jarring	Heavy Shovelling
Scaling of rocks	12	12	0	3	12	12	0	0
Structure support	12	0	0	12	12	10	0	0
Jackleg drilling	13	13	13	13	13	13	13	0
Rock blasting	10	10	0	0	0	0	0	0
Cleaning work	16	16	16	16	15	0	16	0

Figure 3. Risk factors reported by task.

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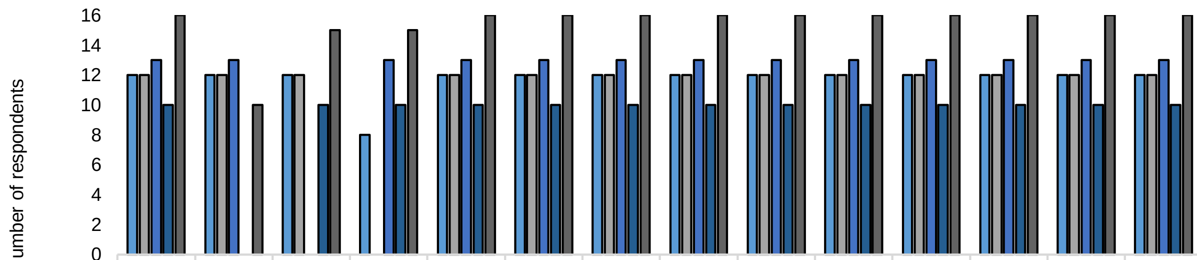

	Neck	Upper Back	Lower Back	Hips Thighs	Shoulder (L)	Shoulder (R)	Elbow (L)	Elbow (R)	Wrist/Hand (L)	Wrist/Hand (R)	Knee (L)	Knee (R)	Ankle/Foot (L)	Ankle/Foot (R)
Scaling of rocks	12	12	12	8	12	12	12	12	12	12	12	12	12	12
Structure support	12	12	12	0	12	12	12	12	12	12	12	12	12	12
Jackleg drilling	13	13	0	13	13	13	13	13	13	13	13	13	13	13
Rock blasting	10	0	10	10	10	10	10	10	10	10	10	10	10	10
Cleaning work	16	10	15	15	16	16	16	16	16	16	16	16	16	16

Figure 4. Parts of the body affected by task.

Figure 4 shows the results of Question 4 of the Risk Factor Report Card. In this case, workers reported discomfort or pain in most body parts in the five tasks analyzed.

According to the opinion of the workers surveyed, jackleg-drilling was identified as the task with the largest number of risk factors. On the other hand, it can be observed how workers reported impacts (pain and discomfort) on most of their body parts. This denotes that the task requires a great deal of physical effort on the part of the miners that if not controlled, could cause serious damage to health (e.g. MSDs). Also, among the comments of the workers collected through the card, 70 % reported having felt discomforts such as muscle contractures, low back pain, and shoulder pain.

Therefore, in this case, jackleg-drilling was selected to demonstrate how the proposed procedure was applied to the mining unit under study.

Stage 2: Risk assessment of jackleg-drilling

For the ergonomic evaluation of the physical work for jackleg-drilling, photographs and footage of the activity were taken. This was difficult and cumbersome given the unfavorable conditions of the underground mines.

Drilling is the first operation in the preparation of a blast. Its purpose is to open cylindrical holes in the rock called drills, which are intended to house the explosive and its initiating accessories. The principle of drilling is based on the mechanical effect of percussion and rotation, whose blow-and-friction action produces the chipping and crushing of the rock. In this mining unit, the workers use a machine called Jack-Leg for drilling.

The ERIN[17,18] and REBA[19] ergonomic evaluation methods were used to evaluate this task. The results of these assessments for jackleg-drilling are shown in Table 1. Figures 5 and 6 show the critical positions selected to perform the ERIN and REBA assessment, respectively.

Table 1. Results of the ergonomic assessment with the ERIN and REBA method for the jackleg-drilling task.

Ergonomic assessment using the ERIN method			
Variables			ERIN Score
Posture and frequency of trunk movement			3
Posture and frequency of arm movement			8
Posture and frequency of wrist movement of the			4
Posture and frequency of neck movement			6
Rhythm			2
Intensity of effort			8
Self-assessment			2
Global risk			33
Level of risk			High
Recommended ergonomic action: Investigation and changes are required soon			
Ergonomic assessment using the REBA method			
Variables	Posture 1	Posture 2	Posture 3
Trunk	2	4	2
Neck	2	1	2
Leg	1	1	2 = 1 + 1
Table A	3	3	4
Load/Force	2	0	2+1
A score	5	3	7
Arm	1	2 = 3 - 1	4
Forearm	2	1	2
Wrists	1	1	1
Table B	1	1	5
Grip	0	0	2
B score	1	1	7
C score	4	2	9
Muscle activity	0	+1 *	+1* + 1 **
REBA Score	4	3	11
Risk	Medium	Low	Very high
Recommended action	*Ergonomic intervention is needed*	*Ergonomic intervention may be necessary*	*Immediate ergonomic intervention is needed now*

* *Rapid and/or extensive changes of posture or unstable surface*

** *Repeated movements of the same joint group*

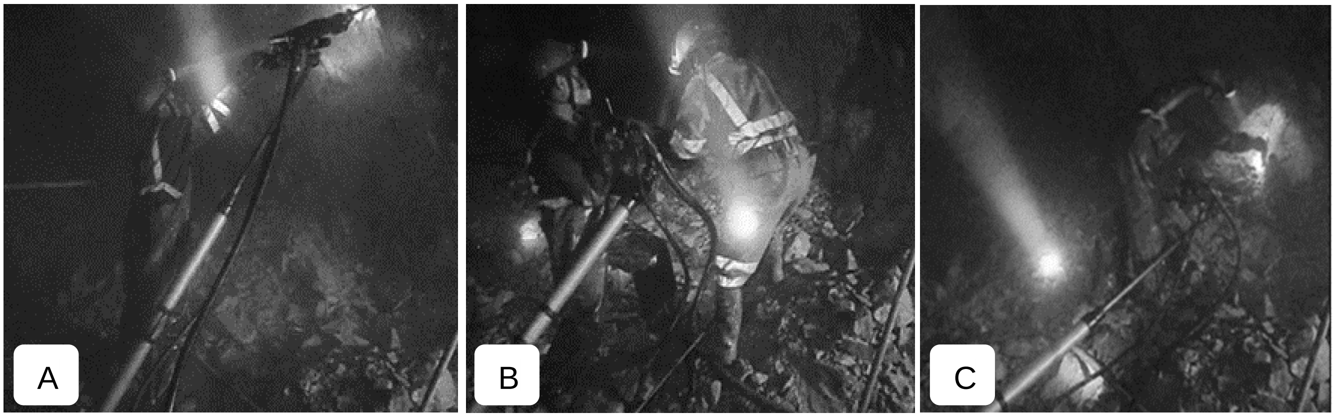

Figure 5. Postures evaluated with ERIN for jackleg-drilling.
Figure 5A shows the critical posture for the arm and neck, Figures 5B and 5C show the critical posture for the trunk.

Figure 6. Postures evaluated with REBA for jackleg-drilling.
Figure 6A shows Posture 1: Transportation of the Jack-Leg drilling machine, Figure 6B shows Posture 2: Preparation for drilling and Figure 6C shows Posture 3: Drilling in the upper part.

Evaluation with the ERIN method indicates that the risk for jackleg-drilling is high. As shown in Figure 5, this is the moment when the worker must drill on elevated surfaces. The results obtained indicate that this task is risky for the worker's musculoskeletal system and, therefore, measures should be proposed to minimize exposure.
One of the final activities at this stage was to share the results of the evaluations with the workers and supervisors. The scores obtained with each method and their meaning, the main body parts affected, and the critical postures adopted during jackleg-drilling were explained.

Stage 3: Proposed improvements for jackleg-drilling

In making these proposals, it was considered that the technology used and the environment in which the work is carried out entail risks that are difficult to control. The proposals listed below for the jackleg-drilling are based largely on the opinion of the workers and supervisors of the mining unit.

1. Instruct the assistant drillmaster in the use of the Jack-Leg drilling machine, so that they can alternate during the performance of the task (work and rest).
2. Train workers in the use of correct techniques for manual load lifting and on-the-job safety.
3. Train workers in physical exercises for the recovery and relaxation of the most affected body parts.
4. Ensure proper maintenance of the Jack-Leg drilling machine to reduce the magnitude of vibrations.
5. Establish a work-and-rest system considering the number of holes drilled.

It is important to note that any work modification that is implemented to reduce the risk of MSDs must be easier, faster, or more efficient than previous work methods. If this is not the case, the likelihood that new work methods will be accepted is reduced, and constant monitoring is then necessary to ensure that they are applied[8].

Stage 4: Implementation and follow-up

Sometimes management may oppose redesigning jobs because of the costs that this may entail. However, many companies have learned that adjusting the tasks using ergonomic principles is a good investment, as compensation costs are reduced and increased productivity can be achieved. Determining the payback period of the investment is a very useful indicator to convince management of the effectiveness of implementing ergonomic measures[28].

In the mining unit under study, although the proposed measures were accepted and cataloged as beneficial, they were not implemented immediately. The company has a protocol for approving the investment budget, which is planned at least one year in advance. However, the workers created a movement to improve working conditions using ergonomics. The proposals made were discussed directly with those involved. This is considered the beginning of a future formalization of the behaviors and safe methods to be followed under ergonomics.

DISCUSSION

This work focuses the discussion on three aspects that, according to the experience of the authors, are very important for the application of ergonomics to the mining industry and were covered by this research: (1) the gradual and orderly introduction of the ergonomic approach into the mining activity through a prevention procedure; (2) the ergonomic evaluation of mining jobs and tasks; and (3) the actual participation of workers in actions and decisions related to ergonomics.

Concerning the first aspect, it should be mentioned that it was the first time that ergonomics was applied in an orderly and systematic way to the mining unit under study. Despite this, the company's managers and employees showed enthusiasm and interest in the subject. Such a lack of previous experience or training in ergonomics (typical scenario of mining companies in Peru) showed the relevance of the approach and tools proposed in the procedure.

There are several studies related to the prevention of MSDs in the mining sector[8,14]. However, mining companies' access to this information has been limited. The complexity of procedures and tools; the language in which this information is published, often unknown to supervisors and workers in the sector; and how information is disseminated or distributed, often through scientific articles to which workers do not have access are some of the aspects that have prevented the introduction of ergonomics projects into mining companies.

For this reason, ergonomists are committed to adopting ergonomics procedures, tools, methods, and techniques that are easy to learn and apply. This will facilitate the introduction of ergonomics, encourage the generation of ideas to solve ergonomics problems within the company and allow replication of good practices.

About the second aspect, the application of easy-to-use tools and methods such as the Risk Factor

Report Card, the ERIN method, and the REBA method are highlighted as examples of some of the available resources. An effective risk management process requires that all workers identify the risk factors to which they are exposed and their relationship to the emergence of MSDs[8]. By completing the Risk Factor Report Card, workers were able to quickly identify the presence of risk factors during the performance of their tasks and report the main parts of the body affected by pain. Besides, during the training, it was possible to explain plainly and with the support of this tool, the relationship between the exposure to the risk factors detected by them and the symptoms exhibited.

The workers, supervisors, and managers of the company considered this tool very useful. Its easiness, the little time required for its application and potential massive use to collect a great amount of information contributed to adopting the tool for future evaluations.

On the other hand, the result of the evaluation with ERIN indicated that the risk for the jackleg-drilling task is high (33 points) given primarily by the high frequency of arm, neck, and wrist movements, in addition to the frequent occurrence of considerable stresses. The efforts made during the performance of the task were due to the constant lifting of the Jack-Leg machine, its positioning for drilling into the rock, and its constant handling by the worker. Together with the adoption of extreme postures, they indicated that the activity is risky for the worker's musculoskeletal system and therefore measures should be proposed to minimize exposure.

The ERIN method can be very useful for the company since workers and those in charge of Health and Safety at Work can be trained in its use and does not require a high level of knowledge on the part of the evaluator. In this way, the workers could identify improvement actions, which must be subsequently discussed and, if feasible, implemented. This strategy could broaden the participation of workers in upgrading their working conditions, fostering a culture of participation and continuous improvement.

Table 1 shows how the risk is very high when the worker has to drill elevated areas (Figure 6C: Posture 3), according to REBA. This posture involves the greatest risk for the musculoskeletal system and therefore requires more attention. Although the risk for other postures is lower, this does not imply that measures should not be taken, for example, to reduce the frequency and distances of manual transfer of the Jack-Leg machine (Figure 6A: Posture 1).

As mentioned above, miners adopt unstable and awkward postures during their activities. The REBA method is an instrument that allows evaluating the effect of these postures before and after an intervention. Its use requires little time and evaluates other risk factors present in many of the mining activities such as grip types, the weight of the load handled, the concept of assisted gravity for the upper extremities, dynamic and static work, etc. These characteristics make the REBA method very useful in the hands of properly trained people.

For the third aspect, the use of participative techniques can be considered one of the success factors in the application of the proposed procedure. The participation of workers in the risk identification process, the ergonomic evaluation of their tasks, and the proposals for improvements motivated their interest in ergonomics.

Imada pointed out three fundamental elements that justify the idea of involving the worker in ergonomics: (1) ergonomics is an intuitive science which in many cases simply organizes the knowledge the worker is already using, (2) people prefer to support and adopt solutions in which they feel responsible, and (3) developing and implementing technologies enable workers to continually modify and correct problems[16].

A characteristic of participatory ergonomics is to ensure that the knowledge and experience that the worker has about the tasks he or she performs are used, involving the worker in the improvement of his or her jobs. Important elements that contribute to the success of interventions based on participatory ergonomics are management's commitment and the provision of resources, which includes the appointment of a person responsible for promoting the process; workers' and management's understanding of the most relevant concepts and techniques of ergonomics, and a process for efficiently developing and implementing the proposed controls[8].

In this study, management was involved throughout the process. Resources such as time, physical space, and human resources were allocated. Training related to ergonomics and the use of evaluation tools was conducted, in which managers, supervisors, and mining workers actively participated. In addition, based on the results obtained and the experience gained during this and other research, the authors of this paper will outline some ideas and approaches that we believe will be useful for researchers, practitioners, and mining companies or other sectors interested in the prevention of MSDs.

To achieve a greater impact on preventive outcomes, it is necessary to use the systemic approach that promotes ergonomics (macro approach). At present, the predominant approach focuses mainly on the job and the task (micro approach). This micro approach ignores the importance and influence of other elements of the work system in the emergence of MSDs, as well as the influence of context. For example, most companies purchase equipment, technologies, tools, and software without performing a prior ergonomic analysis. This can potentially cause incompatibilities between people and the work system, resulting in illnesses, low levels of productivity, and accidents. This systemic approach is not new[1,29]; however, in Latin America, its introduction at the enterprise level has been very limited.

Workers are expected to carry out and support the proposed procedure. However, the experience gained in this research shows that, if better results are to be achieved in the short term, the company must have internal personnel qualified in ergonomics to provide greater technical support and leadership in the implementation of the proposed procedure. In this study, this aspect limited the implementation of some measures.

Lastly, it should be mentioned that the legal and regulatory context of the region or country may influence the degree of implementation of the proposed procedure. In many cases, companies focus their actions on complying with the established minimum standards, limiting the impact of these preventive ergonomics and occupational safety and health processes.

CONCLUSION

Preventing work-related MSDs has become a major focus of attention for many disciplines and professionals. The mining sector does not escape from this problem and therefore it is necessary to take concrete preventive actions. The procedure proposed in this work was designed for mining organizations themselves to use it and move from a reactive to a preventive philosophy in terms of Safety and Health at Work.

Based on the application of this procedure to the company under study and the experiences in other sectors, we consider that if organizations manage to actively involve their mining workers and managers, have a methodological guide on how to carry out actions, and use the systemic approach that promotes ergonomics, it will be possible to achieve concrete advances in the prevention of these diseases. A reductionist view of the MSDs phenomenon (e.g. focused only on biomechanics) will offer limited results.

Finally, it should be mentioned that the factors (legal, cultural, economic, geographical, and political) of the context in which the mining organization operates play an important role in the success or failure of the implementation and operation of the preventive programs devised. Therefore, they should be considered at all stages of the proposed procedure.

DECLARATION OF CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

AUTHORS' CONTRIBUTIONS

Yordán Rodríguez-Ruíz has contributed to conceiving the study and structuring the article, analyzing and interpreting data, writing the article, critically reviewing the article, and approving the final version.
Elizabeth Pérez-Mergarejo has contributed to conceiving the study and structuring the article, analyzing and interpreting data, writing the article, critically reviewing the article, and approving the final version.
Walter Alejandro Barrantes-Pastor has contributed to collecting data, obtaining permission to access the subject matter of this study, analyzing and interpreting results, and approving the final version.

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