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Dysergonomic risks and musculoskeletal injuries in mine operators

Riesgos disergonómicos y lesiones musculoesqueléticas en operadores mineros

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ABSTRACT

The objective of this study was to analyze the dysergonomic risks and musculoskeletal injuries in mining operators of a private company. Methodologically, the study was descriptive with a non-experimental design. The study population consisted of a total of 116 workers in the operative area. Once the research and analysis of results obtained through the questionnaires ISO TR 12295:2014 and standardized Nordic questionnaire for the perception of musculoskeletal symptoms has been developed, it is concluded that there is a clear relationship between dysergonomic risks and musculoskeletal injuries presented by the workers of the company Minervilla S.A. Since the correlation between these variables was demonstrated through the application of Fisher's exact test. The existence of musculoskeletal injuries is confirmed, since 66.30% of the workers suffer from discomfort or discomfort in the lumbar region or back.

Descriptors: health policy; mental stress; emotions. (Source: UNESCO Thesaurus).

RESUMEN

Se tiene por objetivo analizar los riesgos disergonómicos y lesiones musculoesqueléticas en operadores mineros de una empresa privada. Metodológicamente fue descriptiva con diseño no experimental. La población de estudio se constituye con un total de 116 trabajadores del área operativa. Una vez que se ha desarrollado la investigación y análisis de resultados obtenidos mediante los cuestionarios ISO TR 12295:2014 y cuestionario nórdico estandarizado para la percepción de síntomas musculoesqueléticos se concluye que, existe una clara relación entre riesgos disergonómicos y lesiones musculoesqueléticas que presentan los trabajadores la empresa Minervilla S.A. Puesto que se demostró la correlación entre estas variables mediante la aplicación de la prueba exacta de Fisher. Se confirma la existencia de lesiones musculoesqueléticas, puesto que el 66,30% de los trabajadores padece de molestias o disconfort en la región lumbar o espalda.

Descriptores: política de la salud; estrés mental; afectividad. (Fuente: Tesauro UNESCO).

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Research articles section

INTRODUCTION

Musculoskeletal disorders are defined as injuries to muscles, tendons, ligaments, joints, nerves and discs that are caused or aggravated by our actions and/or environment that does not follow safe and healthy work practices; which, produces the most important problems in occupational health being in turn, indisputable cause of job abandonment (Traynor, *et al*. 2015). This allows analyzing dysergonomic risk factors and musculoskeletal pain in mining operators, who must adapt to the task entrusted to them, not knowing the correct posture to adopt when working in front of a machine or mining equipment for more than two continuous hours during a workday (Carlisle, *et al*. 2014).

In this sense; it is essential to have an adequate management of both the work environment and human resources. This situation has led to the development of certain sciences such as ergonomics, which is dedicated to the study and design of adaptation strategies, both in workers and machinery, according to the needs of the workplace, the development of these sciences has made possible the early diagnosis of occupational diseases, as well as the design of strategies to prevent ailments caused by dysergonomic risks (Dempsey, *et al*. 2018), (Sen, *et al*. 2020), (Dempsey, *et al.* 2017).

In accordance with the above; the objective is to analyze the dysergonomic risks and musculoskeletal injuries in mining operators of a private company.

METHOD

Methodologically, the research was descriptive with a non-experimental design. The study population consisted of a total of 116 workers from the operational area working inside the mine of the Minervilla S.A. company.

The questionnaires to be used will be the Technical Report ISO TR 12295: 2014 and the Nordic Standardized questionnaire of perception of musculoskeletal symptoms (de-Almeida, et al. 2017).

The analysis of the ISO/TR 12295-2014 method, represents the initial observation of study to determine the musculoskeletal disorder (MSD) of occupational origin, because in risk identification, several methodological elements are used, which lead to initially estimate the absence or presence of ergonomic risk in the working day, in addition, the working conditions and precautionary measures for the performance of tasks are determined. Therefore, the identification of hazards was executed under 5 axes with a total of 11 questions (Table 1).

Table 1. Questionnaire for the identification of ergonomic hazards.

Identificación de peligro por:	No. de preguntas	Detalle
Levantamiento de cargas	3	Observación de tareas, peso y frecuencia con que se levantan cargas.
Transporte de cargas	1	Tareas que requieran transporte de cargas superiores a 3kg
Empuje y tracción de cargas	3	Verificación de tareas que requieren arrastre o empuje, los objetos arrastrados poseen ruedas, frecuencia de arrastre de objetos.
Movimientos repetitivos de la extremidad superior	2	Tiempo de repetición de las tareas.
Posturas y movimientos forzados	2	Existencia de posturas estáticas con fuerza extrema de alguna parte del cuerpo.

Source: Own elaboration.

It should be noted that, for the risk management procedure and analysis of results, each axis is analyzed independently, based on the answers to the questions that compose it. In order to estimate the existence of dysergonomic risk in any axis, it is necessary that all the questions that compose it are affirmative, otherwise, if there is only one negative answer, the absence of

dysergonomic danger is discerned.

The standardized Nordic questionnaire of perception of musculoskeletal symptoms is also used. This is a tool that helps to detect musculoskeletal symptomatology prematurely, before occupational diseases occur, given its eminently preventive character. It uses questions based on the clinical symptoms presented by workers, mainly those who are subjected to physical demands of biomechanical origin (Table 2).

Table 2. Structure of the Nordic standardized questionnaire for the perception of musculoskeletal symptoms.

Composición	Sección	Detalle
Cuestionario General: detección simple, basado en la percepción del encuestado, respecto de molestias, dolor o disconfort.	Primera	1. Datos generales: fecha de realización, peso, año de nacimiento, sexo, tiempo actividad, y horas de trabajo. 2. ¿En algún momento durante los últimos 12 meses, ha tenido problemas (dolor, molestias, disconfort)? -Incluye una gráfica del cuerpo humano para señalar áreas afectadas.
	Segunda: Aplica solo si en la pregunta de la primera sección existe una respuesta afirmativa.	1. ¿En algún momento durante los últimos 12 meses ha tenido impedimento para hacer su trabajo normal (en casa o fuera de casa) debido a sus molestias? 2. ¿Ha tenido problemas en cualquier momento de estos últimos 7 días?
3 cuestionarios específicos: inducen al análisis profundo de las molestias existentes derivadas del impacto laboral.	Espalda baja Cuello Hombros	Los tres cuestionarios constan de 8 preguntas donde se examina de forma minuciosa las afecciones, para ello se verifica si ha existido hospitalización por el dolor, cambio de trabajo o rol, tiempo de molestia en los últimos 12 meses, consecuencias en el trabajo o el hogar, concurrencia con un profesional de salud y molestias en los últimos 7 días.

Source: Own elaboration.

Process for obtaining results

The association of musculoskeletal affectations with the dysergonomic risks developed by the mining operator personnel of the company Minervilla S.A, was evaluated through the technical criteria of ISO TR 12295:2014 that estimates the presence or absence of dysergonomic hazards, through the consideration of the 5 axes previously detailed, with which the presence or absence of ergonomic risks will be estimated.

Once the presence of dysergonomic hazards has been verified, the standardized Nordic questionnaire was applied in order to determine the exact musculoskeletal ailments that the workers of Minervilla S.A. suffer or could suffer. With this questionnaire, sociodemographic data, discomfort, pain or discomfort in the organs of locomotion, working hours, among other issues included in the standardized Nordic questionnaire of perception of musculoskeletal symptoms were obtained (See Table 2). Aspects related to the distribution of personnel by work areas, gender, laterality, age, working time, and musculoskeletal symptomatologies were also identified.

With the results obtained from both questionnaires, the variables with negative impact are analyzed and related by means of Fisher's exact test, where the probability value will be verified to be lower than alpha ($p < \alpha=$), in order to verify the association between dysergonomic hazards and musculoskeletal ailments.

In this way, the company Minervilla S.A. is offered a current situational diagnosis on dysergonomic hazards and musculoskeletal ailments so that the company can design a long-term strategic plan to prevent such disorders derived from the work activity and an annual action plan, which will

facilitate the use of resources necessary for the health and welfare of workers, and simultaneously improve the company's productivity.

RESULTS

The 100% of those surveyed are male, and 73% of the workers are occupationally categorized as field workers, followed by 22.5% as mine and quarry operators and only 4.5% as drilling assistants. With regard to age, it can be seen that there is a mostly young population, as 49.4% of the workers are between 19 and 26 years old, followed by workers between 27 and 34 years old, who represent 32.6%, then there is a significant decrease in older workers, with a range between 35 and 42 years old representing 16.9% and finally those over 43 years old only 1.1%.

Another factor that stands out is the time they have worked in the company, since 73.1% of the workers have not worked for more than one year, only 19.1% of the employees have worked for the company for four years, 5.6% of the workers have worked for 5 to 7 years, and finally, the remaining 2.20% represent those who have worked for the company for 8 to 10 years.

The hours of work per week are variable among the employees, mainly 80.9% of them work from 40 to 45 hours, in a lower range of 13.5% there is a work period of 46 to 51 hours, followed by 4.5% of personnel working from 52 to 57, concluding with a percentage of 1.1% who meet or exceed 58 hours of work per week.

With reference to the level of education, the majority of workers have primary education (96.6%) and the rest have secondary education (3.4%). As a last parameter of analysis, the marital status of those surveyed is presented, with a higher percentage of people who maintain a free union with 58.4%, and a smaller number of married and single employees with 58.4% and 31.5% respectively.

Table 3. Identification of the ergonomic hazard.

Peligro ergonómico por:	**Estimación del riesgo**			
	Presencia		**Ausencia**	
	Recuento	Porcentaje	Recuento	Porcentaje
Levantamiento de cargas	85	95,5%	4	4,5%
Posturas y movimientos forzados	79	88,76%	10	11,24%
Transporte de cargas	21	23,6%	68	76,4%
Movimientos repetitivos de la extremidad superior	14	15,73%	75	84,27%
Empuje y tracción de cargas	10	11,2%	79	88,8%

Source: Own elaboration.

With the results shown in Table 3, through the application of the ISO TR 12295:2014 questionnaire, it is initially deduced the presence of dysergonomic hazards in the company Minervilla S.A., where the axis of lifting loads is one of the most dangerous, since 95.5% of the operators indicate that among their work there are manual tasks in which they must lift, deposit or hold objects, same that regularly exceed 3kg and, such tasks are frequently performed in the workplace; which implies a direct occupational risk for employees.

Subsequently, it is inferred that the axis of postures and forced movements also constitutes an ergonomic hazard, since 88.8% of those surveyed responded affirmatively to the presence of harmful conditions related to static postures of the trunk and/or extremities that include the use of extreme force, in addition to working in dynamic postures of the trunk, head, arms or other parts of the body.

On the other hand, the absence of ergonomic hazards in the other axes is determined, since there is a considerable decrease in the percentage of hazards. In the transport of loads there is 23.6% of danger, due to the fact that the manual lifting or lowering of loads greater than 3kg are not transported at distances greater than 1 meter. Consequently, the axis of repetitive movements of the upper extremity represents 15.73% of danger, due to the absence of tasks that involve

repetitive movement of the shoulders, wrists, elbows or hands and, if there is any activity of this type, it does not last more than one hour of the working day.

Finally, the axis with the least impact is the pushing and pulling of loads, which indicates 11.2% of danger, the result is due to the fact that the tasks that involve dragging or pushing objects manually, have sufficient facilities for workers through the use of cages, wheelbarrows, pallet trucks, among others. It should be noted that manual dragging or pushing activities are not frequently performed, and that the appropriate machinery is mainly used.

In summary, it is determined that there are two indicators of dysergonomic risks for the operating personnel, the risk factors are: lifting loads and postures and forced movements, in which a high percentage of critical conditions that lead to a significant and unacceptable risk were evidenced. While with a low percentage are the factors of load transport, repetitive movements of the upper extremity and pushing and pulling loads, which present acceptable working conditions.

Once the presence of dysergonomic risk has been estimated and the risk factors have been identified, it is necessary to observe the possible musculoskeletal consequences derived from these factors. In this regard, the results of the application of the standardized Nordic questionnaire for the perception of musculoskeletal symptoms are presented below.

Another factor that stands out is the time they have worked in the company, since 73.1% of the workers have not worked more than one year, only 19.1% of the employees have had a fourth year of activities, 5.6% of the workers have worked from 5 to 7 years and, finally, the remaining 2.20% represent the people who have worked 8 to 10 years in the company.

The hours of work per week are variable among the employees, mainly 80.9% of them work from 40 to 45 hours, in a lower range of 13.5% there is a work period of 46 to 51 hours, followed by 4.5% of personnel working from 52 to 57, concluding with a percentage of 1.1% who meet or exceed 58 hours of work per week.

With reference to the level of education, the majority of workers have primary education (96.6%) and the rest have secondary education (3.4%). The last parameter of analysis is the marital status of the respondents, with a higher percentage of people who are in a free union with 58.4%, and lesser numbers of married and single employees with 58.4% and 31.5% respectively.

Table 4. Detection of problems in the organs of locomotion.

Problemas de dolor, molestias, disconfort en:	Existencia de padecimiento			
	Si		No	
	Recuento	Porcentaje	Recuento	Porcentaje
Espalda baja (región lumbar)	59	66,30%	30	33,70%
Cuello	28	31,46%	61	68,54%
Hombros	23	25,84%	66	74,16%
Espalda alta (región dorsal)	20	22,5%	69	77,5%
Muñeca	18	20,2%	71	79,8%
Rodillas	15	16,9%	74	83,1%
Cadera / piernas	11	12,4%	78	87,6%
Tobillos y pies	11	12,4%	78	87,6%
Codos	7	7,9%	82	92,1%

Source: Own elaboration.

Table 4 shows that there were 59 affirmative answers to the single question of the general questionnaire (section one). That is to say, 66.29% of the workers affirmed having or having had pain, discomfort or discomfort in any of the locomotion organs during the last 12 months. Therefore, according to the responses collected, the most affected body area among the workers is the lower back or lumbar area, since 66.29% of the workers state that they have pain or discomfort in this area. This is followed by the neck with 31.46%, the shoulders with 25.84%, the upper back or dorsal region with 22.5%, wrists with 20.2% and, finally, the body parts with the

least discomfort are the knees with 16.9%, hips, legs, ankles and feet with 12.4% and elbows with 7.9%.

Given that 59 affirmative answers to section one of the general questionnaire have been evidenced, it is essential that the second section of the general questionnaire be applied to this group, where the existence of problems in the locomotor apparatus and the consequences caused will be ascertained. Therefore, the following table shows the results obtained.

Table 5. Consequences of pain or discomfort in the musculoskeletal apparatus.

Problema	Existencia del problema			
	Si		No	
	Recuento	Porcentaje	Recuento	Porcentaje
¿En algún momento durante los últimos 12 meses ha tenido impedimento para hacer su trabajo normal (en casa o fuera de casa) debido a sus molestias?	59	100%	0	0%
¿Ha tenido problemas en cualquier momento de estos últimos 7 días?	43	72,88%	16	27,12%

Source: Own elaboration.

Considering the results of Table 5, it is confirmed that the various musculoskeletal ailments have disrupted the normal development of work and daily activities of the workers of the company Minervilla S.A. Since, under the perception of the 59 workers, the presence of musculoskeletal problems that have prevented the performance of their work tasks or domestic activities at some point in the last 12 months is confirmed. Also, 43 of the 49 workers said that they had been limited in certain activities due to musculoskeletal problems in the last 7 days.

After having analyzed the perception of the workers regarding problems, discomfort or discomfort in some locomotion organs, it is discerned that the most affected area of the workers is the lower back or lumbar area. It should be noted that this condition has also deteriorated the quality of life of the workers, since they have suffered limitations in their daily work performance. Therefore, we proceeded with the application of the specific questionnaire on the low back, in order to go deeper into the symptomatology, functional impact, professional attention, among other aspects.

Table 6. Problems derived from pain or discomfort in the lower back (lumbar region).

Problemas de espalda baja han causado:	Existencia del problema			
	Si		No	
	Recuento	Porcentaje	Recuento	Porcentaje
Molestias en últimos 7 días.	41	69,49%	18	30,51%
Impedimento para hacer actividades laborales, de ocio o del hogar	33	55,93%	26	44,07%
Concurrencia con el médico, fisioterapista u otros	11	18,64%	48	81,86%
Cambio de trabajo o deberes	7	11,86%	52	88,14%
Hospitalización	3	5,08%	56	94,92%

Source: Own elaboration.

Once the specific questionnaire regarding problems in the lumbar spine was applied, it was observed that the workers do indeed suffer from discomfort or discomfort in this area, since 69.49% of those surveyed said that they had experienced discomfort in the last 7 days. Consequently, 55.93% stated that they have been limited in the performance of work, leisure or

home activities. These two variables allow inferring that musculoskeletal ailments of the lumbar region should be treated immediately (Table 6).

Also, it is evident that 18.64% of the workers have had recourse to a doctor, physiotherapist or other professionals and, finally, 11.86% of those surveyed have opted for a change of job or activities in the work center, and only 5.08% have been hospitalized at some time due to lower back discomfort.

Application of Fisher's exact test

From the results obtained from the application of the ISO TR 12295 questionnaire and the standardized Nordic questionnaire, it is inferred that there is a relationship between the variables: dysergonomic hazards and musculoskeletal problems. In this sense, in order to ratify the association between these qualitative variables, Fisher's exact test is used. Therefore, the variables with the greatest impact that were previously examined will be used.

From the ISO TR 12295 questionnaire, the existence of two dysergonomic hazards was deduced: lifting loads and forced postures and movements. On the other hand, as a result of the application of the standardized Nordic questionnaire, the lumbar spine was determined as the main ailment. Therefore, the following null and alternative hypotheses are proposed:

H_0: The lumbar spine ailment of the workers is independent of the dysergonomic danger of lifting loads.

H_1: The lumbar spine condition of the workers is related to the dysergonomic hazard of lifting loads.

Once the statistical value of Fisher's exact test has been verified, it is determined that the P-value is equal to 1.00, which is not a significant result and as a consequence the null hypothesis is rejected.

H_0: The lumbar spine condition of the workers is independent of the dysergonomic danger of forced postures and movements.

H_1: The lumbar spine condition of the workers is related to the dysergonomic hazard of forced postures and movements.

DISCUSSION

In relation to the results obtained, (Neusa-Arenas, *et al*. 2019), assert that in Ecuador there is a high rate of exposure of workers to dysergonomic risks derived from industrialization processes, especially in the productive sector. Generally, there is evidence of exposure to musculoskeletal injuries, due to the conditions and posture in which people work, which causes absenteeism of workers and work performance deficits. Early diagnosis of dysergonomic risks and ailments in workers allows for better health care and prevention of other occupational diseases.

The presence of occupational diseases derived from dysergonomic hazards in the mining field is not the exception, since (Hermoza, 2016), states that, mining is one of the productive activities that provide greater wealth to a country, however, subway mining work activities require great effort for the operators, in addition to carrying several risk factors, which make mining one of the most dangerous branches of work, since it compromises health and safety.

In the mining industry, mining workers perform repetitive movements with the shoulder, neck, wrist and elbow as often as four times a minute. In addition, they manipulate weights greater than 40 kg one or more times a day, situations that generate nervous fatigue, energy wear, and musculoskeletal pain that is affecting bones, ligaments, joints, muscles, tendons, blood vessels or nerves mainly (Balderas-López, *et al*. 2019).

In mining work, workers adopt working positions in which one or several anatomical regions differ from their natural function, limiting comfort and employing postures that involve hyperflexions, hyperextensions, and/or osteoarticular hyper-rotations, thus inducing the production of overload injuries. Thus, working positions such as trunk inclination, carrying heavy or difficult-to-handle items, exposure to whole-body vibration and high frequency of repeated movements of the lumbar

spine influence the presence of pain in the lumbar region, and intradiscal pressure in the lumbar spine (Sadeghi, *et al*. 2022).

Musculoskeletal disorders cause absenteeism due to illness, worker dissatisfaction due to work overload and dissatisfaction with salary incentives, and also have repercussions on the physical, mental and social well-being of workers in the labor union. Ergonomic risks in turn have an intrinsic impact on work performance, greatly diminishing their physical and professional capabilities. This is corroborated by the results obtained in the present research, where it is observed that more than 50% of workers have musculoskeletal ailments, which have had repercussions on normal work performance, in addition to affecting the development of daily or leisure activities (Okello, *et al*. 2020).

CONCLUSION

Once the research and analysis of results obtained through the questionnaires ISO TR 12295:2014 and standardized Nordic questionnaire for the perception of musculoskeletal symptoms has been developed, it is concluded that there is a clear relationship between dysergonomic risks and musculoskeletal injuries presented by the workers of the company Minervilla S.A. Since the correlation between these variables was demonstrated through the application of Fisher's exact test. The existence of musculoskeletal injuries is confirmed, since 66.30% of the workers suffer from discomfort or discomfort in the lumbar region or lower back. This is due to the adoption of working positions that cause one or more body regions to limit their natural position of comfort, to adopt a position that generates hyperextensions, hyperflexions and/or osteoarticular hyper-rotations, leading to the production of overload injuries. In lesser impact are injuries to the neck with 31.46%, shoulders with 25.84%, upper back with 22.5% and wrists with 20.2%; injuries that do not represent a major danger, but should be kept under constant surveillance to avoid aggravating the health of workers.

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CONFLICT OF INTEREST

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