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Systematic Review of Ergonomic Risks in Musculoskeletal Disorders of Workers in an Industrial Company

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Abstract*– This research has the purpose of understanding and interpreting the interventions applied to Ergonomic Risks in musculoskeletal disorders of workers in an industrial company. A methodology associated with the PICO and PRIS-MA methods was used to search for articles in academic databases and the precision of inclusion and exclusion criteria of research documents respectively. The results of the systematic literature review (SLR) indicate that ergonomic methodologies significantly reduce the prevalence of musculoskeletal disorders (MSDs) by minimizing physical load and stress on workers. Effective interventions include job rotation, posture analysis tools like REBA, and advanced technologies such as exoskeletons. These measures improve worker safety, reduce absenteeism, and enhance productivity. Studies confirm the broad efficacy of these approaches across various industries, with comprehensive and personalized interventions showing the greatest impact. In conclusion, addressing ergonomic risks through both traditional and advanced methods effectively improves worker health and productivity. For the Peruvian industrial context, adopting these methodologies and technologies can significantly enhance operational efficiency and worker well-being. Further research is needed to validate the effectiveness of new technologies and tailor strategies for specific industries.

Keywords*-- Ergonomic risks musculoskeletal, disorders, techniques, reduction, prevention.

I. Introduction

Ergonomic risks (ER) in the workplace and their relationship to musculoskeletal disorders are crucial aspects in the field of industrial engineering. ER are the working conditions that can cause disorders, physical or mental stress in the job positions. These can lead to musculoskeletal injuries, fatigue, stress, and negatively affect the health of workers, as well as their productivity and job performance. These risks can arise from repetitive activities, uncomfortable postures, lifting heavy loads, prolonged use of tools or inadequate equipment, among other factors. It is worth noting that there are methodologies based on approaches and techniques to investigate, evaluate, and mitigate ER in the workplace. This can range from traditional ergonomic evaluation methods, such as the Rapid Upper Limb Assessment (RULA) [1] or the Lifting Index (LI), to more innovative approaches involving emerging technologies, such as systems that capture workers' movements based on sensors or digital human models [2], [3], [4].

Likewise, hearing loss and musculoskeletal disorders are global concerns that affect workers' well-being and impair their productivity [1]. While hearing loss caused by continuous noise exposure has been widely studied, other occupation-al exposure factors, such as hand-arm vibration, can also contribute significantly to this condition [2]. Additionally, with the introduction of Industry 4.0, the intercommunication between human-robot and the implementation of sensor technologies are transforming the way ER are evaluated and managed in industrial environments [5]. At the local level, in Peru, where industry and manufacturing play an important role in the economy, it is crucial to understand how ER impacts workers' efficiency and health. Therefore, research on this topic in Peru is limited, highlighting the need for a systematic literature review (SLR) that addresses this issue.

The importance of this research lies in its relevance to the quality of life of workers and the productivity of industrial companies in Peru. Addressing ER not only aims to improve the work environment and employees' quality of life but can also influence the reduction of expenses related to occupational injuries and absenteeism [6]. Given the lack of specific studies on ER in the Peruvian context, this SLR can provide valuable information for companies intending to promote safe and healthy working environments in the country. Furthermore, by integrating the available scientific evidence and the latest research perspectives, this review can serve as a guide for updating standards and practices in ER management in the era of Industry 4.0 [5].

Finally, this SLR aims to understand and interpret the interventions applied to ER in workers' musculoskeletal disorders in an industrial company, as this will provide a comprehensive view of current practices in ER evaluation and management, as well as potential areas for future research and improvements in industrial practices. (or ribbon).

II. Methodology

Through this research process, the implemented methodology corresponds to a systematic literature review (SLR) using the Patient, Intervention, Comparison, and Outcome (PICO) methodologies. The purpose is to identify relevant information, focus search objectives, and exclude unnecessary data for key decision-making. Additionally, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework was used, which focuses on reducing potential biases by applying inclusion and exclusion criteria during the final selection of information. This is

supported by [7] and [8], who state that both method-ologies are used in this type of research to develop an efficient search equation in reliable databases, allowing the researcher to clearly define the inclusion and exclusion criteria for the reviewed literature.

It is important to note that the main objective of this research process is to in-crease productivity in industries, a crucial area that is part of the Peruvian economy. Therefore, it was decided to apply ergonomic intervention methodologies. For the development of the SLR, the methodology followed the required standards and is described in Table 1, where an extract of its application is presented.

During the data collection process, only scientific articles published in journals and SLRs in English or Spanish were considered. To verify the authenticity and quality of the report, the Scopus abstract database was used, parameterizing articles that allow free access to documents. Furthermore, documents from the years 2019 to 2024 were delimited, thus guaranteeing current primary sources and allowing a broad data collection since in recent years there has been an in-crease in new sources of scientific research. Keywords were combined to in-crease results, using Boolean operators AND and OR throughout the considered database. Truncation marks specifying the search for better results ("insert phrase") were also used. Following these standards, it was ensured that no duplicate articles were obtained. The obtained articles will go through evaluation process, and the most suitable ones will be selected. Table 1 summarizes the methodology applied for this SLR.

TABLE I
SUMMARY OF THE METHODOLOGY USED FOR THE SEARCH

PICO structure	Questions
P	What are the effects of ergonomic methodologies on work-ers in an industrial company who are exposed to ergonomic risks and develop musculoskeletal disorders?
I	What specific types of ergonomic methodologies can be im-plemented to reduce ergonomic risks and prevent musculo-skeletal disorders in workers in an industrial company?
C	What is the difference in the incidence of ergonomic risks and musculoskeletal disorders between workers exposed to different types of ergonomic methodologies in an industrial company?
O	What impact do ergonomic methodologies have in reducing ergonomic risks and preventing musculoskeletal disorders in workers in an industrial company?
General Equation	(TITLE-ABS-KEY ("Ergonomic risks"OR"Musculoskele-tal disorders") AND TITLE-ABS-KEY (methodolo-giesORtechniquesORprogramsORstrat-egies) AND TITLE-ABS-KEY (comparativeORdifference) AND TI-TLE-ABS-KEY (effectivenessORimpactORreductionORpreven-tionORmitigationORincidence))

Following the established guidelines for the search, no duplicate articles were obtained. This search yielded 216 results in Scopus. The combination of keywords using Boolean operators resulted in 0 duplicate articles, which were determined to be excluded from the data source to continue with the selection. According to these guidelines, 216 potential articles were considered for the Systematic Literature Review (SLR), excluding 165 records. Additionally, a manual review was conducted to identify relevant articles for the systematic review, obtaining 8 results. Through the interpretation of the abstracts, 25 articles were identified, which will be used in the SLR results. Image 1 shows the PRISMA flow diagram used to select the scientific articles that meet the guidelines.

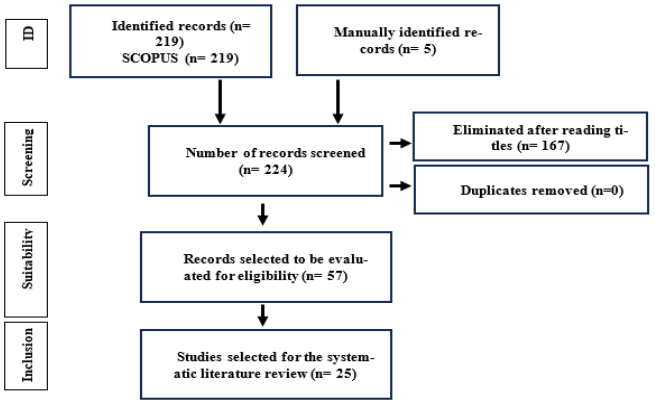

Fig. 1 PRISMA flow diagram in four levels.

III. Engineering Results

A. *Bibliometric results*

For the following research, the articles were classified according to their year of publication and country of origin. Figure 2 shows that the ER of musculoskeletal disorders have been discussed since 1986 but have gained greater relevance in 2021.

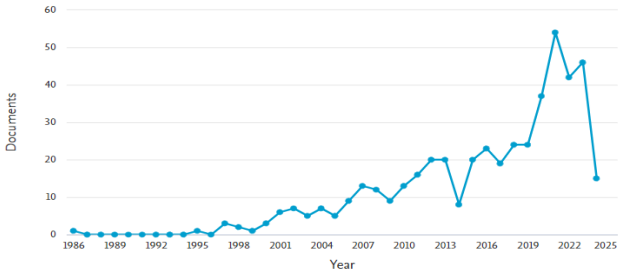

Fig. 2 Representation of publications per year

Likewise, in Figure 3, it can be observed that the United States has the highest number of publications related to the topic under study, with a total of 87 relevant articles. Other contributing countries include Canada, the United Kingdom, Australia, among others.

Fig 3. Graphic representation of publications per year

In the Fig. 4 shows the frequency of keywords used in the reviewed articles, highlighting that “Human” is the most common term, followed by “musculoskeletal disease” and “occupational disease”, among others.

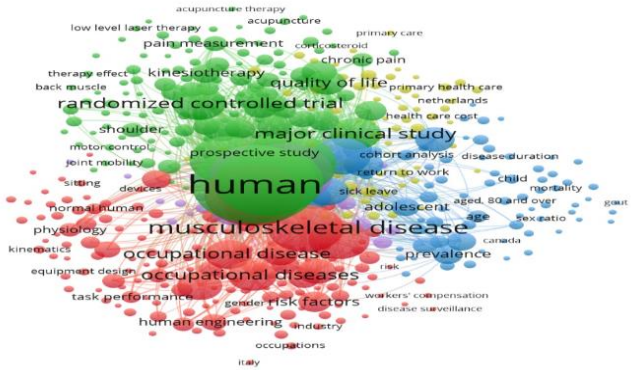

Fig 4. Network Visualization

In the following Figure 5, the trend is evidenced according to the interests of different authors in the use of their keywords in the databases, which in this case is related to musculoskeletal disorders in industries.

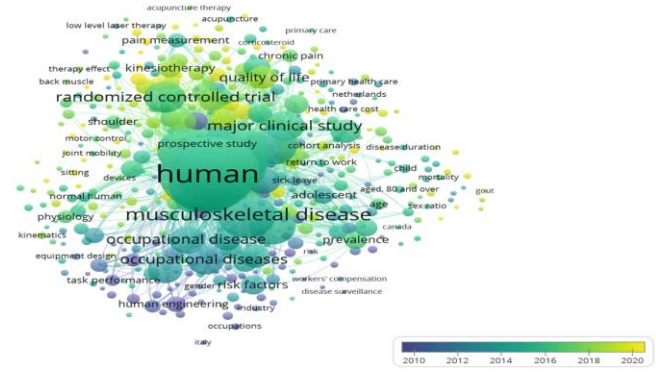

Fig 5. Overlay Visualization

Following the information obtained from the 25 documents collected from the RSL in synthesis with the questions from the PICO structure, namely:

P: What are the effects of ergonomic methodologies on workers in an industrial company who are exposed to ergonomic risks and develop musculoskeletal disorders?

Ergonomic methodologies are effective in reducing the prevalence of musculoskeletal disorders (MSDs), as they minimize physical load and stress on workers through various strategies. One common approach is job rotation, which prevents the overuse of specific muscle groups by diversifying the tasks that workers perform. This not only helps in distributing the physical demands more evenly but also keeps the work more interesting and engaging for employees. Another key component is the use of specific tools such as the "Latin Questionnaire," which assesses ER, and posture analysis methods like the Rapid Entire Body Assessment (REBA) [9], [11] and [12]. These tools are instrumental in identifying and mitigating risk factors associated with MSDs. Furthermore, ergonomic interventions have been shown to significantly decrease the incidence of MSDs in various parts of the body, including the neck, lower back, hips, ankles, hands, and shoulders [14], [16], [18] and [19]. By systematically analyzing work environments and implementing targeted ergonomic solutions, companies can enhance worker safety and comfort. This, in turn, leads to reduced absenteeism, lower healthcare costs, and improved overall productivity. Numerous studies have corroborated these findings, demonstrating the broad efficacy of ergonomic interventions across different industries and job types. Researchers have found consistent evidence that when ergonomic principles are applied, the physical well-being of workers improves markedly, highlighting the critical importance of these practices in occupational health and safety [21], [23], [24], [27], [29], [31], [33].

Moreover, another set of responses highlights that ergonomic methodologies not only reduce the prevalence of musculoskeletal disorders (MSDs) but also improve the overall well-being of workers. In particular, these methodologies include interventions such as proprioceptive derivation, stretching, and the use of exoskeletons. These approaches are designed to enhance the body's natural movements and support, leading to better posture and reduced strain during physical tasks. Additionally, the results show a significant reduction in pain in-tensity and an improvement in body perception. Workers experience less dis-comfort and a greater awareness of their movements, which contributes to a de-crease in disability, associated with MSDs [10], [15] and [20]. Furthermore, the integration of motor control training and corrective exercises significantly contributes to the improvement of physical function. These exercises help workers regain strength and mobility, further enhancing their ability to perform job tasks efficiently and safely. The psychological well-being of workers also benefits, as reduced pain and improved physical function lead to lower stress levels and higher job satisfaction. Overall, ergonomic methodologies create a healthier, more productive work environment, illustrating their critical role in occupational health [25], [26], [28], [30], [32].

On the other hand, the third set of responses focuses on how ergonomic methodologies improve overall working conditions. In this regard, these methodologies not only focus on reducing MSDs and improving physical well-being but also address workload and job satisfaction. For example, the implementation of lumbar exoskeletons reduces muscle activity and fatigue, improving worker performance and comfort. Similarly, methodologies such as REBA allow for the identification and correction of harmful postures, improving safety and efficiency in the workplace. Furthermore, it has been shown that these methodologies can improve the quality of care in sectors such as healthcare, reducing the workload of doctors and increasing patient satisfaction [13], [17], [22].

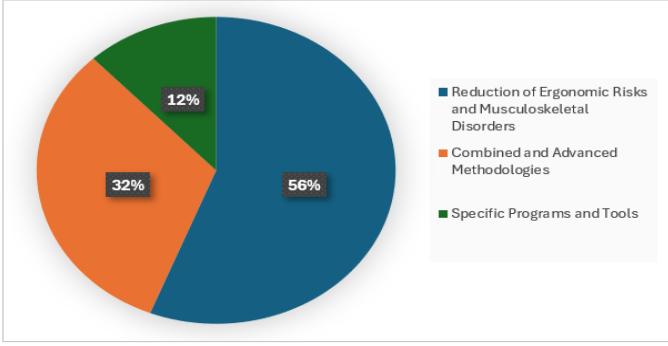

Fig 6. The effects produced by ergonomic methodologies

I: What specific types of ergonomic methodologies can be implemented to reduce ergonomic risks and prevent musculoskeletal disorders in workers of an industrial company?

The importance of adapting and redesigning both workstations and the tools used by workers is highlighted. Firstly, the implementation of ergonomic improvements in the design of tools, equipment, and workstations can minimize physical effort and improve workplace comfort. For example, this includes adjusting chairs and desks, introducing suitable tools, and redesigning tasks to re-duce physical strain [9], [11], [14], [20], [23] and [32]. Additionally, the combination of physical exercise programs with ergonomic education is emphasized. These programs not only enhance the physical health of workers but also in-crease their awareness of best ergonomic practices. Moreover, task rotation and continuous education are crucial for maintaining good ergonomics in the workplace [10], [12], [18], [29], [31] and [33].

Furthermore, the use of exoskeletons, both passive and active, and advanced technologies such as EMG (electromyography) and MoCap (motion capture) are covered. These technological tools help reduce the physical load on workers and provide additional support for physically demanding tasks [22], [27], and [28]. Similarly, the focus is on the application of advanced assessments, such as the REBA (Rapid Entire Body Assessment) method, along with technologies like neural networks and neuro-fuzzy models to improve the accuracy of ergonomic risk evaluations [13]. These methodologies allow for a more detailed and personalized analysis of ER [17] and [25].

Additionally, this group includes advanced physiotherapy practices, stretching training, and the use of innovative therapies such as body illusions and mirror therapy. The importance of case manager support and healthcare programs in managing and preventing musculoskeletal disorders is also highlighted [15], [26] and [30].

There is also a focus on the equitable distribution of workload through task rotation and scheduling regular breaks. These practices help prevent fatigue and reduce continuous exposure to uncomfortable postures or repetitive tasks, which is essential for maintaining the ergonomic health of workers [12], [19] and [31]. Therefore, the implementation of health monitoring programs and continuous assessments is advocated, using tools such as ergonomic evaluation questionnaires and methods like QEC (Quick Exposure Check) and REBA. In summary, these evaluations help identify and proactively mitigate specific ER [16], [21] and [24].

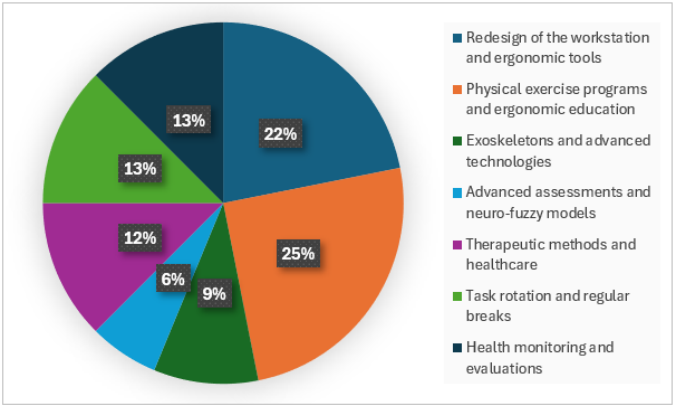

Fig 7. Types of methodologies that can be applied for the prevention of musculoskeletal disorders

C: What is the difference in the incidence of ergonomic risks and musculoskeletal disorders among workers exposed to different types of ergonomic methodologies in an industrial company?

Studies show that comprehensive and customized ergonomic interventions are the most effective in reducing the incidence of musculoskeletal disorders (MSDs) among industrial workers, as these programs combine various approaches [24]. A clear example is combined programs of exercise and psychological support, as well as active ergonomic training [10], [15], [18], [31], and [33]. These programs focus not only on physical activity but also on the mental well-being of workers, contributing to an overall

improvement in their health and productivity. Moreover, comprehensive programs that include multiple approaches such as exercise, massage, and education have a considerable positive impact on reducing ER [12], [14], [21], and [29]. Including massages and education in these programs helps workers had better understand how to manage and prevent MSDs, enhancing their ability to maintain proper posture and perform tasks safely.

Additionally, interventions that employ higher-order controls show greater effectiveness in reducing ER compared to lower-order controls. Therefore, workers exposed to higher-order controls experience a lower incidence of musculoskeletal disorders [9] and [11]. This is because technological and automated solutions can significantly reduce risk factors, while lower-order controls only mitigate the effects of existing risks.

Consequently, the use of advanced technologies and innovative methods, such as exoskeletons and the REBA method, offers a more precise and rapid assessment of ER [17]. Moreover, exoskeletons have been shown to reduce the incidence of MSDs among workers who use them compared to those who do not [22] and [27]. In turn, the implementation of these advanced methods facilitates more effective and personalized ergonomic intervention, reducing muscle activity [28].

Likewise, job rotation and proprioceptive posture techniques can influence the reduction of musculoskeletal complaints, although they must be properly implemented to avoid increasing the risk of injuries, as mentioned in various sources [16], [19], and [20]. Additionally, stretching programs and methodologies based on body awareness have proven effective in reducing pain and improving functionality in workers, according to recent studies [23], [25], [26], [30], and [32]. However, the literature indicates a lack of detailed information and rigorous conclusions about some ergonomic task distribution models, suggesting the need for more research and critical evaluation to validate these practices [13]. The approach aims not only to improve the physical well-being of employees but also to optimize productivity and reduce absenteeism, thus creating a healthier and more efficient work environment.

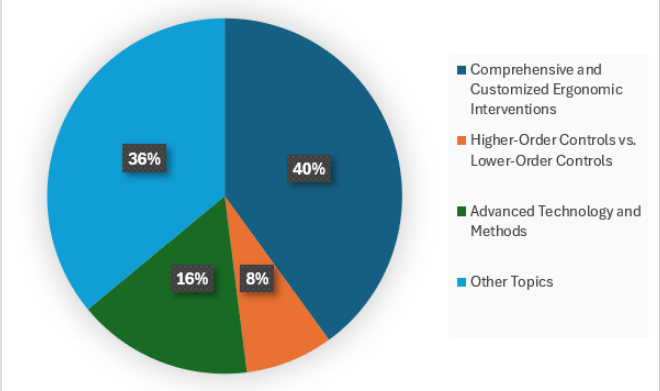

Fig 8. The incidence of ergonomic risks and musculoskeletal disorders

O: What impact do ergonomic methodologies have on reducing ergonomic risks and preventing musculoskeletal disorders among workers in an industrial company?

Effective and well-implemented ergonomic methodologies in the workplace have a significant impact on reducing ER and preventing musculoskeletal disorders (MSDs) [15], [16], [20], and [21]. These methodologies include workplace assessments, adaptation of tools and equipment, and training employees in safe and healthy practices [24], [31], [32], and [33]. In fact, studies indicate that these interventions improve the health and well-being of workers, decreasing the prevalence of MSDs and increasing workplace productivity [11], [25], and [30]. Moreover, the implementation of ergonomic programs also contributes to reducing costs associated with absenteeism and employee turnover, as healthier workers tend to stay longer in their positions and require fewer sick days. Thus, in-vesting in ergonomics not only benefits employees but also proves to be cost-effective for companies in the long term [12], [14], and [23].

Additionally, combined and advanced ergonomic methodologies, such as the use of exoskeletons and the integration of the Rapid Entire Body Assessment (REBA), offer solutions that not only reduce muscle activity and fatigue but also automate risk assessment, providing faster and more accurate evaluations [17] and [29]. In this way, the combined approach significantly reduces MSDs, enhancing worker performance and well-being [10], [22], [26], and [27].

On the other hand, specific training programs and ergonomic tools, such as job rotation and comprehensive programs, play an important role in reducing MSDs [18] and [19]. Since these methodologies improve musculoskeletal health and production quality in the work environment [29], they help to reduce workload and increase overall worker satisfaction, contributing to a healthier and more productive work environment

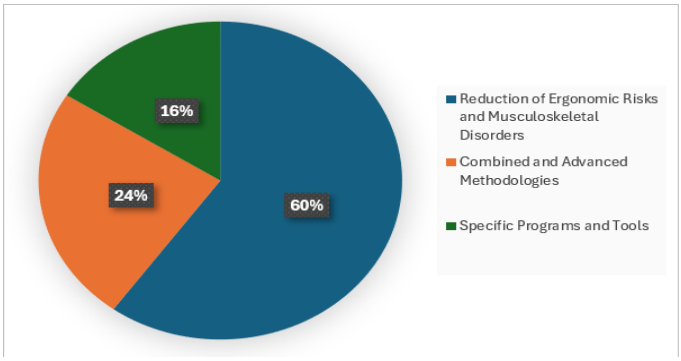

Fig 9. Impact of ergonomic methodologies on the reduction of ergonomic risks and prevention of musculoskeletal disorders

IV. Discussion

ER in the workplace, particularly their relationship with musculoskeletal dis-orders (MSDs), are a critical focus in industrial engineering. These risks, which arise from factors such as repetitive activities, awkward postures, and heavy lifting, can cause injuries, fatigue, and stress, negatively affecting workers' health and productivity [11]. Therefore, this discussion underscores the importance of investigating, evaluating, and mitigating ER through traditional methods like the Rapid Upper Limb Assessment (RULA) and the Lifting Index (LI), as well as innovative technologies involving sensor-based systems and digital human models.

Firstly, hearing loss and MSDs are global issues that compromise workers' well-being and efficiency. Although hearing loss due to noise exposure is well-documented, other factors like hand-arm vibration also contribute significantly [21]. Additionally, the advent of Industry 4.0, with human-robot interaction and sensor technologies, is revolutionizing the evaluation and management of ER in industrial settings. However, in countries like Peru, where industry and manufacturing are fundamental, there is limited research on ER, making a systematic literature review (SLR) necessary to address this gap [17].

Furthermore, the research highlights the relevance of ER to workers' quality of life and industrial productivity. Addressing ER can improve the work environment, employee health, and reduce costs associated with occupational injuries and absenteeism [19]. Consequently, this SLR aims to provide valuable information for Peruvian companies that wish to foster safe and healthy work environments, potentially guiding updates in ER management standards and practices in the industry 4.0 era [10].

Moreover, the methodology adopted for this research includes a systematic literature review (SLR) using the PICO framework and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to minimize biases. The focus is on increasing industrial productivity through the application of ergonomic intervention methodologies [15]. Data collection considered articles published between 2019 and 2024, ensuring current and comprehensive sources. The search process, detailed in Table 1, used Boolean operators and truncation marks to optimize results, yielding 216 potential articles, of which 25 were selected for the SLR.

In this regard, engineering results indicate that ergonomic methodologies significantly reduce the prevalence of MSDs by minimizing physical stress through strategies such as job rotation and posture analysis [30]. Tools like the "Questionaries Latino" and REBA are crucial for identifying and mitigating MSD risks [16]. These interventions lead to a decrease in MSD incidence, improved worker safety, reduced absenteeism, lower healthcare costs, and increased productivity [24]. Additionally, advanced technologies like exoskeletons and sensor-based assessments also help reduce ER [28]. Comprehensive ergonomic programs that combine physical exercise, psychological support, and ergonomic education show significant effectiveness [25]. These interventions not only improve physical well-being but also psychological health, reduce stress, and increase job satisfaction [32].

V. Conclusion

The systematic literature review on ER and musculoskeletal disorders (MSD) in the industrial sector highlights the importance of identifying, evaluating, and mitigating these risks to improve workers' health and productivity. ER, arising from repetitive activities, uncomfortable postures, and heavy lifting, can cause injuries and stress, negatively affecting job performance. Traditional methodologies like RULA and LI, along with innovative technologies involving sensors and digital human models, were employed to address these risks. The research emphasizes the importance of these studies in Peru, given their limited availability, and their potential to guide improvements in ER management in the industry 4.0 era. The methodology included an SLR using the PICO and PRISMA frameworks, considering articles from 2019 to 2024. The results indicate that ergonomic methodologies, such as task rotation and postural analysis, are effective in reducing MSD, improving worker safety and well-being, reducing healthcare costs, and increasing productivity. Additionally, advanced technologies like exoskeletons and sensor-based assessments significantly contribute to mitigating ER.

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