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Analysis of Ergonomic Factors in Carpentry Assistants' Activities: Application of a System for Comparing Productive Movement Patterns and Fatigue.

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Análise de Fatores Ergonômicos em atividades de serventes de carpintaria: Aplicação de Sistema para comparação entre padrões de movimento produtivo e fadiga.

RESUMO

Objetivo - avaliar os impactos dos fatores ergonômicos na saúde e produtividade nas atividades do servente de carpinteiro na indústria da construção civil.

Metodologia – O estudo adotou uma abordagem quantitativa e qualitativa, com foco exploratório, visando comparar padrões de movimentação produtiva com padrões de movimentação associados à fadiga. Foram empregados métodos inovadores ,incluindo o uso *software Kinobot* para monitoramento de movimentos e a aplicação do questionário Bipolar de dor para avaliação da fadiga, além de um formulário elaborado para coletar dados do perfil dos trabalhadores. O estudo envolveu amostra de 15 participantes, e buscou relacionar fatores ergonômicos com a produtividade nas atividades diárias.

Originalidade/relevância – O gap teórico é a correlação dos fatores ergonômicos com análise de padrões de movimento a partir do *software* kinobot para verificação desses movimentos e suas correlações com a produtividade.

Resultados – Em relação à Revisão Sistemática de Literatura, observou-se que há poucos estudos relacionando a ergonomia e produtividade aplicados a canteiros de obras. Verificou-se que questões como mudanças climáticas, fase da obra com etapas em conclusão apresentando ritmo de trabalho mais lento e a fadiga podem interferir no desenvolvimento das atividades. Percebeu-se que os diferentes períodos das obras sejam considerados, pois se tornam fator determinante para percepção da fadiga.

Contribuições teóricas/metodológicas – embora existam trabalhos que abordem questões metodológicas, bem como a aplicação em etapas de questionários para identificar fatores ergonômicos, sua integração com a produtividade representam uma contribuição diferenciada.

Contribuições sociais e ambientais - Do ponto de vista social, este estudo é relevante por contribuir para a melhoria das condições de trabalho, promovendo o bem-estar físico e psicológico dos trabalhadores da construção civil. Além disso, a redução da fadiga e o aumento da eficiência podem gerar benefícios econômicos significativos, tanto para os trabalhadores quanto para as empresas do setor e, por sua vez, contribuições ambientais com a melhor gestão e aproveitamento de recursos para fins de cumprimento dos Objetivos do Desenvolvimento Sustentável.

PALAVRAS-CHAVE: Ergonomia. Produtividade. Fadiga no Trabalho.

Analysis of Ergonomic Factors in Carpentry Activities: Application of a System for Comparing Productive Movement Patterns and Fatigue.

ABSTRACT

Objective - to assess the impacts of ergonomic factors on health and productivity in the activities of carpenters in the construction industry.

Methodology - The study adopted a quantitative-qualitative approach, with an exploratory bias in order to compare productive movement patterns with movement patterns associated with fatigue, using innovative methods such as Kinobot software for movement monitoring and the Bipolar Pain Questionnaire for fatigue assessment, in addition to a form for surveying the profile of workers with a sample of 15 participants, relating ergonomic factors to productivity in daily activities.

Originality/relevance – The theoretical gap is the correlation of ergonomic factors with the analysis of movement patterns using Kinobot software to verify these movements and their correlations with productivity.

Results – Regarding the Systematic Literature Review, it was noted that there are few studies that relate ergonomics and productivity applied to construction sites. It was found that issues such as climate change, the phase of the work with stages in completion presenting a slower work pace, and fatigue can interfere with the development of activities. It was noted that the different periods of the works should be considered, as they become a determining factor for the perception of fatigue.

Theoretical/methodological contributions – although there are studies that abo methodological issues, in addition to the application of questionnaires in stages to identify ergonomic factors, their application and interfaces with productivity represent a differential.

Social and environmental contributions – From a social perspective, this study is relevant because it contributes to improving working conditions, promoting the physical and psychological well-being of construction workers. In addition, reducing fatigue and increasing efficiency can generate significant economic benefits for both workers and companies in the sector and, in turn, environmental contributions through better management and use of resources to meet the Sustainable Development Goals.

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KEYWORDS: Ergonomics. Productivity. Fatigue at Work.

Análisis de factores ergonómicos en las actividades de los carpinteros: aplicación de un sistema para comparar los patrones de movimiento productivo y la fatiga.

RESUMEN

Objetivo: evaluar los impactos de los factores ergonómicos en la salud y la productividad en las actividades de los carpinteros en la industria de la construcción civil.

Metodología: el estudio adoptó un enfoque cuantitativo-cualitativo, con un sesgo exploratorio desde la perspectiva de comparar los patrones de movimiento productivo con los patrones de movimiento asociados a la fatiga, a partir de métodos innovadores, como el software Kinobot para el seguimiento de movimientos y la aplicación del cuestionario Bipolar de dolor para evaluar la fatiga, además de un formulario para recopilar el perfil de los trabajadores con una muestra de 15 participantes, relacionando los factores ergonómicos con la productividad en las actividades diarias.

Originalidad/relevancia: la brecha teórica es la correlación de los factores ergonómicos con el análisis de los patrones de movimiento a partir del software Kinobot para verificar estos movimientos y sus correlaciones con la productividad.

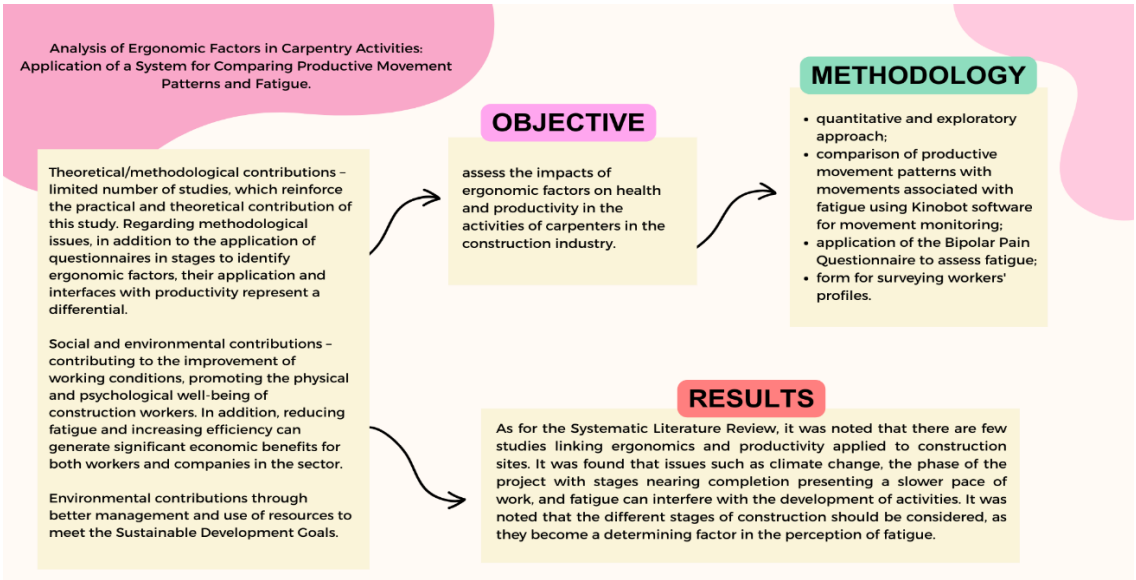
Resultados: en cuanto a la revisión sistemática de la literatura, se observó la escasa cantidad de estudios que relacionan la ergonomía y la productividad aplicadas a las obras de construcción. Se comprobó que cuestiones como el cambio climático, la fase de la obra con etapas en fase de finalización que presentan un ritmo de trabajo más lento y la fatiga pueden interferir en el desarrollo de las actividades. Se observó que deben tenerse en cuenta los diferentes periodos de las obras, ya que se convierten en un factor determinante para la percepción de la fatiga.

Contribuciones teóricas/metodológicas: aunque existen trabajos que abordan la ergonomía y la productividad aplicadas a las obras de construcción, aún hay pocos estudios, lo que refuerza la contribución práctica y teórica del presente estudio. En cuanto a las cuestiones metodológicas, además de la aplicación de cuestionarios por etapas para identificar los factores ergonómicos, su aplicación e interfaces con la productividad representan un diferencial.

Contribuciones sociales y ambientales: desde el punto de vista social, este estudio es relevante porque contribuye a la mejora de las condiciones de trabajo, promoviendo el bienestar físico y psicológico de los trabajadores de la construcción civil. Además, la reducción de la fatiga y el aumento de la eficiencia pueden generar importantes beneficios económicos, tanto para los trabajadores como para las empresas del sector y, a su vez, contribuciones medioambientales con una mejor gestión y aprovechamiento de los recursos con el fin de cumplir los Objetivos de Desarrollo Sostenible.

PALABRAS CLAVE: Ergonomía. Productividad. Fatiga en el trabajo

RESUMO GRÁFICO



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1 INTRODUCTION

The Civil Construction Industry (CCI) plays a significant role in the global economy, given its involvement in strategic projects for the urban and industrial development of countries (Silva et al., 2024). The CCI is directly related to each country's modernization process through its participation in the construction of hospitals, schools, housing developments, and industrial facilities (Souza Júnior *et al*., 2024).

In Brazil, the CCI, in addition to contributing to social commitments by addressing housing needs, supports economic growth through the execution of infrastructure and building projects, expanding access to income and employment opportunities across the country (Medeiros *et al*., 2024).

Phenomena such as globalization have intensified activities in these sectors in the pursuit of higher quality, lower costs, and shorter execution times. However, operational processes that fall outside an ideal market scale have negatively affected service quality, leading to work overloads and losses in productivity and technical efficiency (Fries; Hostalk, 2021).

In modern industrial society, the drive to intensify productivity, aimed at improving work processes and production methods at the lowest possible cost, has increasingly been conditioned by the demand for enhanced worker performance (Sampaio; Levezo; Coutinho, 2020). Nevertheless, in the construction sector, this disproportionate acceleration in task execution is intrinsically linked to an increase in risk situations in environments that are unfavorable to workers' physical conditions (Sampaio; Lavezo; Coutinho, 2020). As a result, work-related illnesses and accidents occur, affecting the lives of these professionals in multiple ways (Sampaio; Lavezo; Coutinho, 2020).

According to Mohamed and Addow (2022), to ensure the overall performance of construction projects, companies must integrate ergonomic and occupational safety conditions in a coordinated manner so that operational efficiency and productivity are accompanied by effective practices aimed at protecting workers' health and well-being, thereby reducing risks and preventing occupational accidents. In this regard, Boakye *et al.* (2023) argue that activities inherent to the construction sector require prolonged physical effort, handling, transportation, and unloading of materials, exposure to external and unsafe conditions, and the adoption of postures that place workers in continuous vulnerability.

Sampaio, Lavezo, and Coutinho (2020) state that the rate of occupational accidents in the construction sector is among the highest, highlighting the urgent need to adopt preventive and awareness measures to mitigate risks and prevent accidents at construction sites through investments in process management, identification of contributing factors, and the promotion of ergonomically satisfactory working environments.

According to data from the Ministry of Social Security, published in the Statistical Yearbook of Occupational Accidents (AEAT), 724,228 occupational accidents were recorded in Brazil in 2024, representing an increase of 15.11 percent compared with 2020. Construction activities ranked sixth nationwide, with 10,641 occupational accidents, distributed by category as follows: accidents reported with a Work Accident Report (CAT), 9,189; typical occupational accidents, 7,719; commuting accidents, 1,362; work-related diseases, including repetitive strain injuries and work-related musculoskeletal disorders, 108; and accidents without registration for

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CAT issuance, 1,452 (Brazil, 2024). In 2024, a total of 724,228 occupational accidents were recorded nationwide, representing an increase of 11.3 percent compared with 2023. Another relevant finding is that construction activities ranked fifth nationally, with 15,320 occupational accidents related specifically to building construction (Brazil, 2024).

Low levels of professional qualification, inadequate educational attainment, high unemployment rates, and insufficient regulatory oversight are factors that contribute to negligence by companies in the civil construction sector, thereby increasing the occurrence of accidents and the expansion of ergonomic risks, which in turn lead to occupational diseases, workplace accidents, and absenteeism (De Souza Júnior *et al.*, 2024). In light of these factors, scientific research seeks alternatives to eliminate or mitigate the conditions to which these workers are exposed, aiming to ensure solutions that promote improved productivity while safeguarding physical health and well-being in the work environment (Souza Júnior *et al.*, 2024).

In this context, occupational safety and health, through its various lines of research, highlights ergonomics as a factor that must be continuously revisited from the perspective of adapting work to people, so that they can perform efficiently with comfort and safety (Couto, 2021). According to Lop *et al.* (2019, p. 1272), "ergonomics is a broad science encompassing a wide variety of working conditions that can affect worker comfort and health, including ergonomic factors."

Within the scope of Brazilian legislation, Regulatory Standard No. 17 (NR-17), established by the Ministry of Labor and Employment, aims to ensure adequate ergonomic conditions in the workplace in order to preserve workers' health and safety (Brazil, 2011). NR-17 sets forth guidelines covering several aspects, such as work organization, workstations, equipment, furniture, and environmental conditions, with the purpose of minimizing adverse health impacts and preventing occupational diseases, especially those related to repetitive efforts and inadequate postures (Brazil, 2011). According to Souza and Georges (2020), the ISO 45001 standard establishes guidelines for the systematic management of emerging risk profiles, contributing to workforce health maintenance, reduction of downtime, and achievement of optimal productivity levels.

Thus, it is observed that these uncontrolled factors, based on the working conditions identified at construction sites, may result in injuries or health-related problems, including the development of Repetitive Strain Injuries (RSI) and Work-Related Musculoskeletal Disorders (WRMSD) (Souza Júnior *et al.*, 2024).

According to Brazil (2012), RSI and WRMSD are conditions associated with repetitive efforts, lifting and handling of loads, inadequate postures, and fatigue, circumstances to which construction workers are particularly exposed, either due to improper execution of tasks or due to overload and repetitive efforts that ultimately affect worker productivity.

In this way, ergonomics is consolidated as a field that studies the interactions between individuals and the components of the work system, seeking to adapt working conditions to the physical and psychological capacities of workers. From this perspective, Mori and Demori (2019, p. 218) emphasize that "the recognition of ergonomic risks by construction managers and workers can contribute to their elimination or mitigation."

Souza Júnior *et al.* (2024, p. 11–12) highlight that the labor activity of construction helpers generally leads to exposure and, consequently, health risks. This occurs because these

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workers often lack technical knowledge and therefore perform tasks that require substantial physical effort.

The labor activity of a construction helper is generally the first role undertaken by individuals who seek to acquire other construction-related skills. Most of these workers do not possess technical knowledge of many tasks performed at construction sites. The helper acts as an assistant who supports construction activities by assembling and dismantling frameworks, cleaning areas, excavating trenches, transporting materials such as sand in wheelbarrows, preparing plaster and cement mixtures, sieving sand, finishing reflecting pools, among other tasks. This clearly indicates that the helper performs a function that requires considerable physical effort and repetitive movements, which consequently exposes these workers to health risks (De Souza Júnior *et al.*, 2024, p. 11–12).

Therefore, this factor was decisive in the selection of these individuals for the investigation of the problem addressed in this study. In addition to recognizing helpers as one of the professional groups most affected by working conditions in civil construction, it is also evident that technology can become a major ally in addressing challenges at construction sites (Couto, 2021). In this sense, the use of systems to compare productive movement patterns and fatigue-related movement patterns represents an innovation that can be applied across various sectors of the construction industry. Beyond improving productivity, such systems can provide objective data to support more accurate ergonomic interventions (Couto, 2021).

With technological advancements, ergonomic analyses have benefited from portable systems that enable real-time monitoring of workers, offering accurate and continuous data on movements, postures, and physiological conditions during task performance (Golabchi *et al.*, 2017). Technologies such as wearable sensors, 3D cameras, software such as Kinebot, and physiological monitoring devices have emerged as effective tools for collecting ergonomic data in dynamic work environments like civil construction (Golabchi *et al.*, 2017).

Recent studies published in the National Journal of City Management emphasize the importance of deepening knowledge regarding the applicability of digital technologies in the pursuit of productivity and efficiency, thereby promoting improved practices in the civil construction sector (Sampaio *et al.*, 2024).

Accordingly, this research begins with an analysis of how ergonomic aspects, supported by new technologies, can contribute to accident reduction and improvements in working conditions in the civil construction industry. The aim is to promote a safe work environment and to identify feasible pathways toward improved productivity and enhanced quality of life for workers, while also reducing absenteeism due to health problems arising from ergonomic inadequacies.

It is assumed that ergonomic factors and fatigue can impact the productivity of carpentry helpers' activities in civil construction, particularly in reinforced concrete formwork and stripping tasks. Therefore, the present study will be conducted through a comparison between productive movement patterns and movement patterns associated with fatigue.

2 OBJECTIVES

2.1General Objective

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To evaluate the impacts of ergonomic factors on fatigue and productivity in the activities of carpentry helpers in the civil construction industry through the use of technology.

3 METHODOLOGY

3.1 Research Design

This study adopted an exploratory and descriptive research design which, according to Gil (2011), allows for greater depth and familiarity with the research problem, as well as improved dissemination of knowledge regarding the specific characteristics of the phenomenon under investigation. The research approach was quantitative in nature, enabling the generalization of common results identified through statistical treatment and data analysis, as well as the measurement of predefined variables based on the frequency of occurrences (Oliveira; Guimarães; Ferreira, 2023).

The methodology was structured in stages: (1) Systematic Literature Review (SLR) with meta-analyses following the PRISMA guidelines; (2) literature review based on books, master's dissertations, and doctoral theses; and (3) definition of the object of study through field research.

With regard to the Systematic Literature Review, it was conducted to support scientific investigation through methodical analyses based on predefined criteria, drawing on existing publications that address ergonomics and productivity within the context of civil construction (Jesus; Fucale; Rabbani, 2022).

The second stage of the study involved field research aimed at achieving the proposed research objectives, grounded in theoretical contributions related to ergonomic factors associated with productivity. At this stage, the data collected underwent processes of collection, analysis, and interpretation of phenomena that reflect reality from the perspective of the individuals involved (Marconi; Lakatos, 2017).

3.2 Research Participants and Study *Lócus*

A large construction company headquartered in Recife was selected, specifically operating in the stages of formwork and stripping of reinforced concrete. The research participants were carpentry helpers engaged in activities involving the assembly and disassembly of reinforced concrete formwork, aged 18 years or older.

Data collection was carried out directly at the construction sites where the participants performed their activities. The research instruments, including questionnaires and complementary tools, were administered in person in the work environment in order to ensure greater participant familiarity with the context of the activities under analysis.

The study was conducted with eight carpentry helpers from two construction companies in Recife. The purpose of this preliminary test was to assess the logistical feasibility

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of applying the instruments, as well as to verify the clarity and comprehension of the questions by the workers, thereby allowing for methodological adjustments prior to the main data collection phase.

3.3 Data Collection Instruments and Analysis

Data collection was carried out in two distinct stages, employing a mixed approach that combined questionnaires and ergonomic assessment tools. In Stage 1, the Worker Profile Questionnaire, covering sociodemographic and occupational aspects, was applied. This standardized instrument was used to characterize the workers' profiles, including information such as age, length of experience, job function, and health history. Subsequently, the Bipolar Fatigue Assessment Questionnaire (QBAF) was administered, a validated scale designed to measure participants' subjective perceptions of fatigue levels (Couto, 2020).

The method involved administering the questionnaires at different times in order to assess distinct work scenarios. Participants completed the instrument at the beginning, middle, and end of the workday. The questionnaire consists of 14 items, in which participants marked 1 if they felt no discomfort or pain and 7 if they experienced high-intensity discomfort or pain. A score of 4 could be selected to represent an intermediate condition, while scores of 2 or 3 indicated lower levels of fatigue and scores of 5 or 6 indicated higher levels of fatigue. It should be noted that an identification code was assigned to each worker; however, participants did not have access to their previous responses recorded at the beginning of the workday.

Data collection also took place at the workstation through the Preliminary Ergonomic Assessment form, with the objective of evaluating aspects related to work organization, equipment, load handling, and postures adopted during task execution.

During site visits, it was identified that the construction phase selected for the study, namely the assembly and stripping of reinforced concrete formwork for the construction of slabs in a 24-story building, was nearing completion. At the same time, other construction phases were underway, such as the construction of the building's swimming pool and garage. Consequently, the application of the Worker Profile Questionnaire and the Bipolar Fatigue Questionnaire took place during a period of lower productivity at the site, which was also considered relevant for the purposes of the analysis. In total, eight carpentry helpers participated in the study.

The questionnaires were administered at three different times during the workday: at the beginning of the shift at 8:00 a.m., in the middle of the shift at 11:30 a.m., and at the end of the shift at 4:30 p.m. Each participant completed three questionnaires, resulting in a total of 24 questionnaires administered.

3.4 Data Analysis

For the analysis of quantitative data, the findings related to the workers' profiles and the bipolar items used to assess fatigue were examined using descriptive statistics.

4 RESULTS

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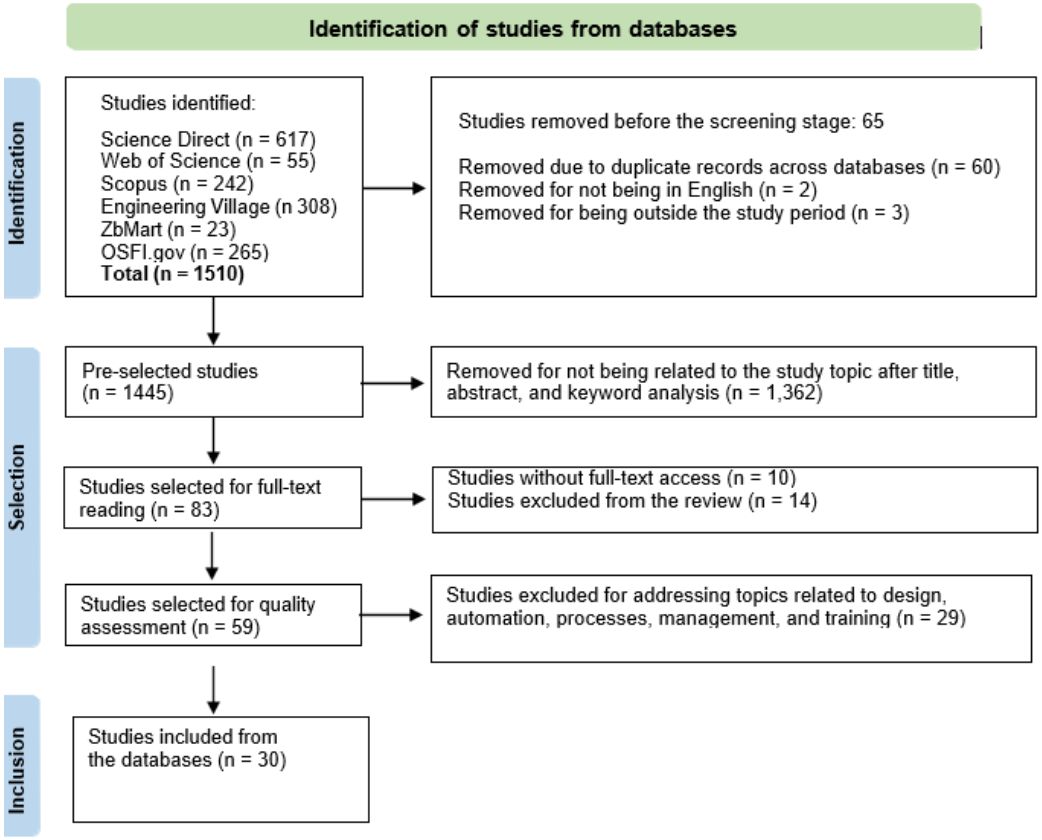
4.1 Results Of The Systematic Literature Review Mapping

The articles were retrieved from scientific databases and organized with the support of the StArt (State of the Art through Systematic Review) software, which is freely provided by the Software Engineering Research Laboratory (LaPES) of the Federal University of São Carlos (UFSCar). The articles were cataloged according to authorship, title, year of publication, database, and country of origin. After extracting all identified articles, duplicates were removed, and an initial screening was conducted to apply the remaining inclusion and exclusion criteria. Subsequently, a full-text reading of the selected articles was carried out to extract data relevant to the research questions. In the initial search, 1,510 articles were identified. After applying the selection criteria, the PRISMA flow diagram presented in Figure 1 was obtained:

Figure 1 – PRISMA flow diagrama



Source: Authors

After documentary analysis through the reading of the selected and evaluated articles, 30 studies composed the Systematic Literature Review, providing the theoretical foundation for the development of the present study.

Regarding the bibliometric results, according to the databases consulted, the articles were predominantly found in the following sources: ScienceDirect, accounting for 41 percent of the included articles; Engineering Village, with 20 percent; and Scopus, with 16 percent. The

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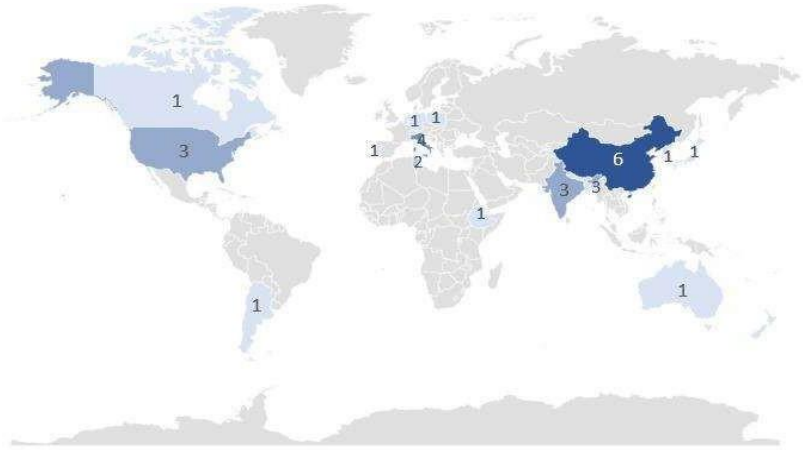
analysis also revealed that several countries have conducted studies on this topic, with China and Italy standing out in terms of the number of published articles, as shown in Figure 2:

Figure 2 – Distribution of Publications by Country



Source: Authors

The analysis of the distribution of publications related to the topic highlights the geographic diversity of scientific production, underscoring the global interest in ergonomic factors and their implications for productivity. China leads with the highest number of publications (6), followed by Italy (4), India (3), and the United States (3), reflecting the central role these countries play in scientific and technological research. Other countries, such as Tunisia (2), indicate growing regional interest in the topic, while countries including Canada, New Zealand, Ethiopia, Australia, Japan, Argentina, Korea, Portugal, Germany, the Netherlands, and Poland each contributed one publication. This distribution suggests a collective effort, albeit concentrated in certain regions, to deepen the understanding of ergonomic and productivity-related aspects across different labor activities.

Through the Systematic Literature Review, it was possible to gather information on the scope of research on this topic in different countries, as well as to identify challenges, benefits, and limitations reported in other studies. These findings were important for identifying research gaps and for investigating ergonomic factors, productivity, and fatigue in carpentry helpers' activities. Moreover, the reviewed studies revealed the existence of productive movement patterns and fatigue-related movement patterns, with an emphasis on ergonomic factors and health prevention related to occupational diseases in the civil construction sector.

The bibliometric analysis enabled the identification of patterns in co-authorship networks and allowed for the recognition of national and international influences, as it represents an essential tool in the management of scientific production (Lima *et al.*, 2019). In this way, it was possible to assess the representation of publications and growth within this line of research. Initially, the number of publications over the last ten years (2014–2024) was examined in order to evaluate the evolution of the topic, as shown in Figure 3.

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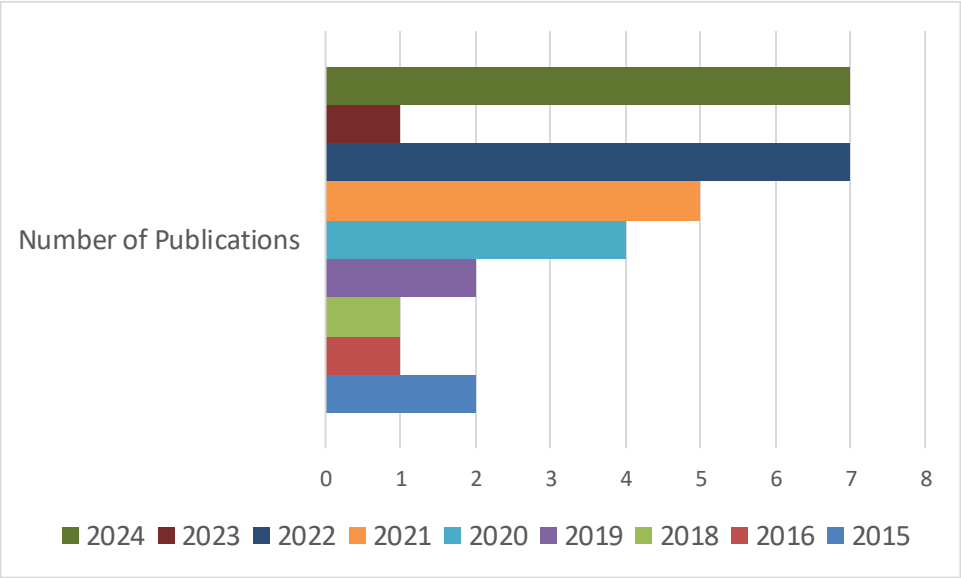
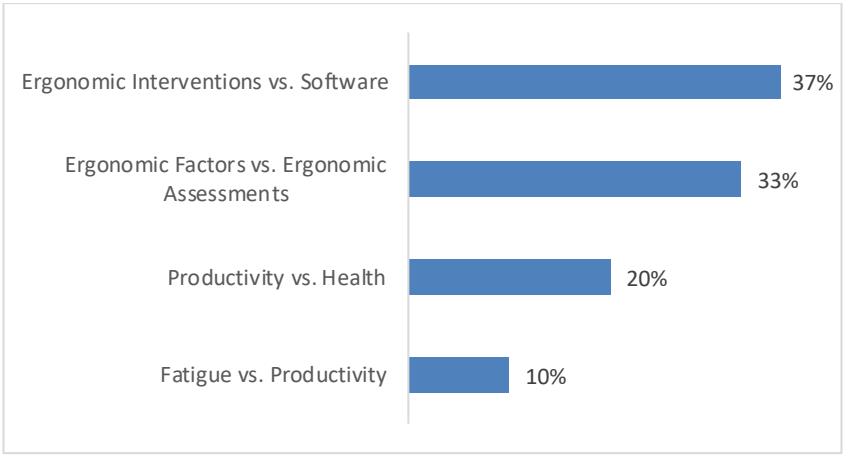
Figure 3 – Distribution of publications by year



Source: Authors

Publications in journals related to the topic showed a growth trajectory over the years. Between 2015 and 2019, the number of publications remained relatively stable, with an average of one to two publications per year. From 2020 onward, a continuous increase was observed, as the number of publications doubled compared with the previous year, reaching higher levels of scientific output. After analyzing the 30 articles included in the Systematic Literature Review, it was possible to group them into thematic axes in order to identify how the studies address the research object, as presented in Figure 4:

Figure 4 - Thematic axes of the articles



Source: Authors

As shown in Figure 4, the thematic axis **Ergonomic Interventions and Software** stands out, accounting for 37 percent of the analyzed articles. In these studies, the use of technological tools is emphasized as a mechanism to accelerate results within shorter timeframes. At the same time, it is observed that traditional ergonomic assessment methods are also gaining prominence

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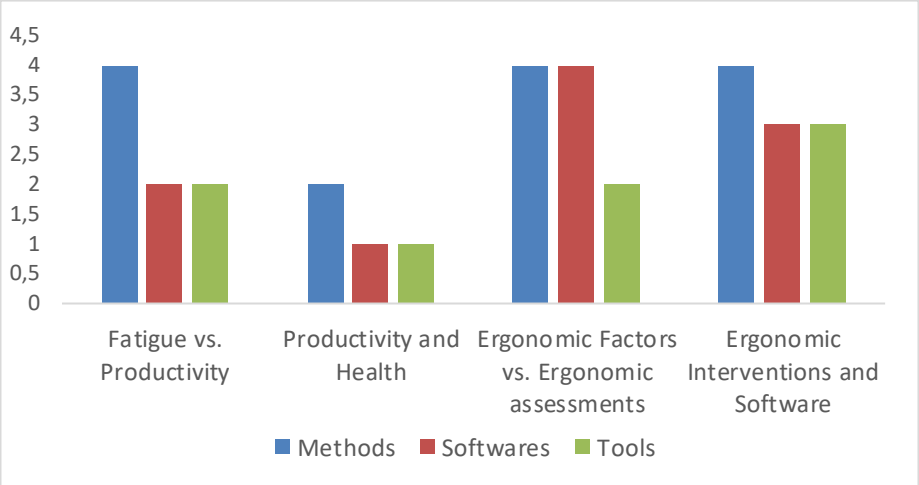
in examining the relationship between work activities and workers' health across various sectors. This trend has encouraged researchers to seek alternative approaches to reduce occupational diseases and to promote work environments with higher quality standards and improved productivity.

Figure 5 – Comparison of ergonomic methods and assessments



Source: Authors

In parallel, Figure 5 presents a comparison of ergonomic methods and assessments, analysis tools, and the use of software, according to the articles reviewed.

4.2 Experimental sample – analysis of questionnaire data

The questionnaire was divided into five sections: general data; education and professional experience; working conditions; health and well-being; and psychological and social aspects. Accordingly, the main aspects used in the analysis are highlighted below.

Regarding general data, all participants were male. The age groups of 31–40 years and 41–50 years each accounted for 37.7 percent of the sample (3 participants each). The age group of 51–60 years represented 12.5 percent (1 participant), as did the group aged over 60 years, also with 12.5 percent (1 participant). In terms of marital status, the largest group consisted of married workers, corresponding to 57.1 percent of the sample, followed by single workers, with 42.9 percent.

With respect to education and professional experience, 62.5 percent of the participants reported incomplete elementary education, while 37.5 percent had completed secondary education. This highlights the educational issue, which directly affects learning processes, as it influences how knowledge related to occupational safety and health prevention can be transmitted through training programs. An important finding is that all participants had received training related to Occupational Safety, including Regulatory Standards covering personal protective equipment, machinery and equipment, ergonomics, work at height, first aid, and occupational safety and health in the civil construction industry.

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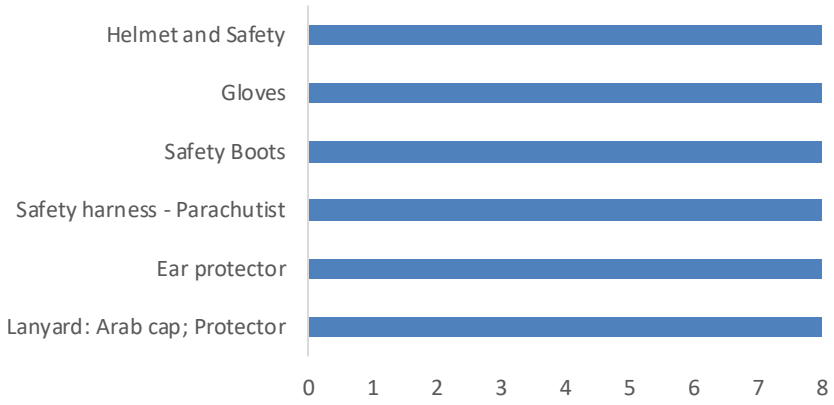
Regarding working conditions, 100 percent of the workers reported working more than eight hours per day, following a schedule from 7:00 a.m. to 12:00 p.m. and from 1:00 p.m. to 5:00 p.m. from Monday to Thursday, and from 7:00 a.m. to 12:00 p.m. and from 1:00 p.m. to 4:00 p.m. on Fridays. It is noteworthy that these working hours vary according to the construction phase; in this case, the project was in the finishing phase, with some stages still underway toward completion.

Regarding difficulties in performing activities in the work environment, 100 percent of the participants identified climatic conditions as an unfavorable factor. With respect to the use of Personal Protective Equipment (PPE), all workers reported regular use, corresponding to 100 percent compliance, as illustrated in Figure 6. The figure presents the types of PPE appropriate to the identified risks, including physical, chemical, biological, and accident-related risks, according to the activities performed at the construction site. PPE use was supported by individual delivery records and monitored by the occupational safety technical team.

Figure 6 – Personal Protective Equipment (PPE)



Source: Authors

Considering the health and well-being dimension addressed in the questionnaire, it was observed that 25 percent (2 participants) had experienced occupational accidents, specifically falls and a cut to the index finger of the right hand. This finding, combined with the consistently high rates of accidents in the civil construction sector, reinforces the need to intensify daily preventive actions at construction sites, highlighting their critical importance for raising awareness among both workers and leadership. Due to the repetitive movements and postures involved in carpentry helper activities, 25 percent of the workers reported experiencing bodily pain. This may indicate that the upper limbs and or other body regions require greater attention and preventive measures to avoid injuries or work-related musculoskeletal disorders (WRMSD).

According to Couto (2020), fatigue constitutes a priority area within ergonomics, and under conditions of overload, workers tend to exhibit symptoms of exhaustion. Fatigue can manifest in different forms and may contribute to ergonomically related injuries. As shown in Figure 7, 62.5 percent (5 participants) exhibited moderate fatigue, while 37.5 percent (3

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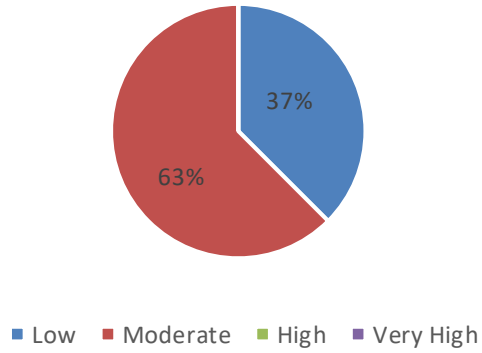
participants) reported low levels of fatigue at the end of the workday. Despite these findings, all participants reported feeling motivated (100 percent) to perform their work activities.

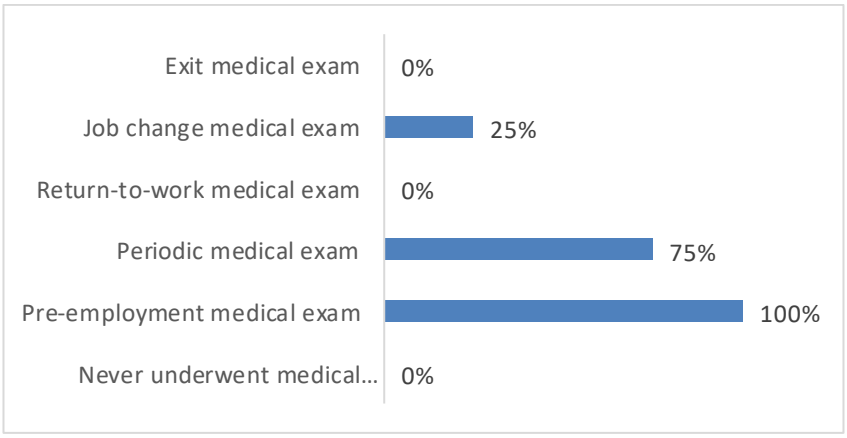
Figure 7 – Level of fatigue at the end of the workday



Source: Authors

Medical monitoring was assessed through the analysis of medical examinations, in accordance with Regulatory Standard NR-06. As shown in Figure 8, 100 percent (8) of the participants underwent pre-employment medical examinations, 75 percent (6) underwent periodic examinations, and 25 percent (2) underwent medical examinations related to job function changes. This represents a relevant aspect to be considered, as it reflects the company's compliance with legal requirements and the monitoring carried out by the medical team aimed at preventing occupational diseases.

Figure 8 – Medical examinations performed



Source: Authors

With regard to the identification of findings related to the bipolar pain questionnaires, this method was developed by Nigel Corlett from Nottingham, England, based on the same criteria as qualitative tests known as Likert scales (Couto, 1996), with further refinement by ergonomist Hudson Couto. The method allows the assessment of individuals' subjective

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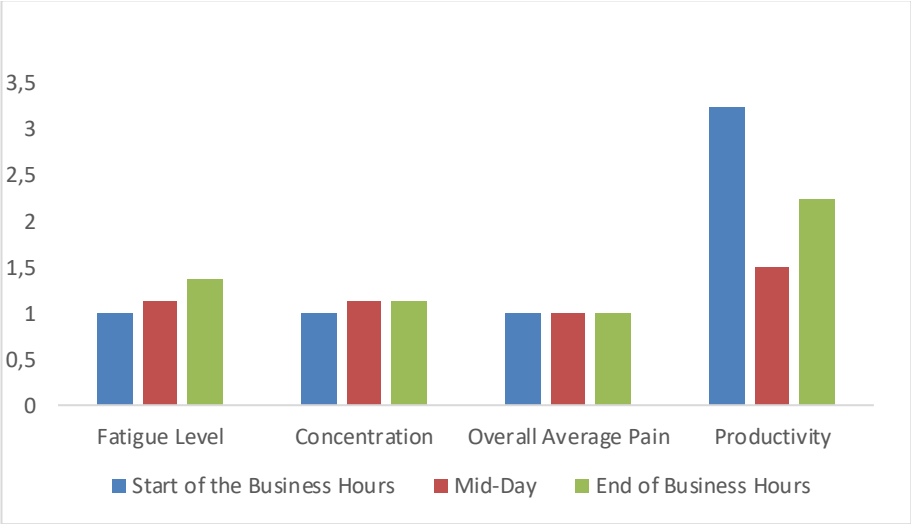
perceptions through a bipolar questionnaire consisting of a sequence of paired adjectives, in which respondents answer the questions by referring to their sensations at a given moment during work. This questionnaire represents a significant contribution to fatigue assessment.

In this study, the questionnaire was administered to eight carpentry helpers in June, during formwork assembly activities, specifically the construction of the swimming pool, and stripping activities on the first floor slabs and columns of the vertical building. Workers with movement limitations, a prior diagnosis of chronic musculoskeletal disorders such as repetitive strain injuries or work-related musculoskeletal disorders, herniated discs, or tendinitis, as well as those undergoing physical rehabilitation, were excluded from the study. Data collection generated three questionnaires per participant, administered at the beginning, middle, and end of the workday, and workers did not have access to information regarding their previous responses.

Accumulated fatigue was considered present when the first questionnaire showed a score equal to or greater than 4 in the following aspects: pain in the neck and shoulder muscles and pain in the arms, in addition to the continuity of complaints throughout the workday. The level of fatigue was determined based on the final questionnaire, administered at the end of the workday, according to the following criteria: absence of fatigue, scores up to 3 in each item; moderate fatigue, scores of 4 or 5 in any item, provided that the score at the beginning of the workday was not higher than 3; and intense fatigue, scores of 6 or 7 in any of the items. When a score equal to or greater than 3 was recorded in the first questionnaire, subsequent questionnaires were analyzed to determine whether there was an increase in the score over the course of the workday.

Figure 9 – Mean values of the bipolar scale



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Mean Values for 8 Workers (Scale from 1 to 7)			
Parameter	Beginning of the Workday	Mid-Workday	End of the Workday
Level of Fatigue	1	1.125	1.375
Concentration	1	1.125	1.125
Overall Mean Pain	1	1	1
Productivity	3.25	1.5	2.25

Source: Authors

The mean values of the bipolar scale showed no changes in the level of fatigue, concentration, or overall body pain, which remained at a low intensity during the middle and end of the workday. This stage of the study was important for examining the relationship between fatigue and low productivity, as well as the interferences identified for the analysis. Therefore, the research will be continued at other construction sites, during phases with higher productivity levels and involving the assessment of additional groups. Nevertheless, this stage was essential for verifying the applicability of new field research procedures.

5 FINAL CONSIDERATIONS

The results of the Systematic Literature Review initially contributed to identifying the perspectives of practices and theoretical approaches adopted by authors who have previously investigated this topic. It was observed that, although there are studies addressing ergonomics and productivity applied to construction sites, the number of such studies remains limited, which reinforces the practical and theoretical contribution of the present research.

With regard to the application of questionnaires, visits were conducted to two construction companies in the Metropolitan Region of Recife, allowing the identification of potential challenges related to participants' comprehension, time availability, and the effectiveness of the data collection instruments used. It was found that factors such as climatic changes, construction phases nearing completion with slower work rhythms, and worker fatigue may interfere with task performance. Therefore, it is necessary to conduct observations at different moments and to consider the specific phases of construction projects, as these aspects become determining factors in the perception of fatigue.

The results are aligned with the principles of the 2030 Agenda, especially Sustainable Development Goal 8 (SDG 8), which aims to promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all. More specifically, this research directly contributes to target 8.8 by providing technical and scientific evidence to protect labor rights and promote safe and secure working environments for all workers in the civil construction sector. In this sense, the adoption of ergonomic practices based on movement data not only strengthens the commitment to decent and safe work, but also proves to be a viable strategy for increasing productivity, reducing absenteeism, and fostering the social and economic sustainability of the sector.

REFERENCES

ABERGO – **Associação Brasileira de Ergonomia.** Disponível em: http://www.abergo.org.br. Acesso em: 03 de Fev. de 2025.

ISSN 2318-8472, v. 14, n. 91, 2026

ABOBAKR, A. *et al.* RGB-D ergonomic assessment system of adopted working postures.**Applied ergonomics**, v. 80, p. 75–88, 2019.

AMARILLA, R. S. D.; WICNWWSKI, .L C.s; CATAI, Rodrigo Eduardo. Aplicação da Ergonomia para reduzir os fatores de risco de distúrbios osteomusculares em trabalhadores da construção civil. V. 82 – **Special Edition** – Article II -2012- (http://fiepbulletin.net)

ANDRADE, Rodrigo Carvalho; TONIN, Luiz Antônio. Análise ergonômica do trabalho: O caso de uma instituição federal de ensino superior-contraste entre o trabalho presencial e o remoto. Revista Ação Ergonômica, v. 17, n. 1, p. 1-17, 2024.

BATTINI, D. *et al.* WEM-Platform: A real-time platform for full-body ergonomic assessment and feedback in manufacturing and logistics systems. **Computers & industrial engineering**, v. 164, n. 107881, p. 107881, 2022.

BELAY, G. T.; WOLDEGIORGIS, B. H.; PRASETYO, Y. T. **Structural equation modeling approach for the analysis of ergonomics risk factors and occupational injuries among building construction workers in Bahir Dar City-Ethiop**ia. Heliyon, v. 10, n. 11, p. e32234, 2024.

BOAKYE, M. K.; ADANU, S.; ADU-GYAMFI, C.; *et al.* A Relative Importance Index Approach to On-Site Building Construction Workers' Perception of Occupational Hazards Assessment. **Medicina del Lavoro**, v. 114, n. 3, p. 189 196. Disponível em: https://dx.doi.org/10.23749/mdl.v114i3.14240. Acesso em: 20 ago. 2024. 2023.

BORMIO, Mariana Falcão *et al.* Consultório Odontológico: uma AET utilizando-se da EWA. **Projética**, v. 2, n. 1, p. 53-68, 2011.

BOUZGARROU, L. *et al.* Biomechanical risk factors of the upper limbs' musculoskeletal disorders among carpet weavers in Tunisia: Semi-quantitative ergonomic assessment. **Indian journal of occupational and environmental medicine**, v. 27, n. 2, p. 148-154, 2023.

BRAATZ, Daniel; ROCHA, Raoni; GEMMA, Sandra (org.). Engenharia do trabalho: saúde, segurança, ergonomia e projeto. **Santana de Parnaíba: Ex-Libris Comunicação Integrada**, 2021, 552. Disponível em: <http://engenhariadotrabalho.com.br/>. Acesso em 21 jul. 2025.

BRASIL. **Ministério da Previdência Social.** Anuário Estatístico de Acidentes de Trabalho (AEAT), Brasília, 2024.

BRASIL. Ministério da Saúde. **Dor relacionada ao trabalho: lesões por esforços repetitivos (LER): distúrbios osteomusculares relacionados ao trabalho (DORT).** Brasília, 2012. Disponível em: https://bvsms.saude.gov.br/bvs/publicacoes/dor_relacionada_trabalho_ler_dort.pdf

BRASIL. Ministério do Trabalho e Emprego. **Norma Regulamentadora NR-17: Ergonomia**. Disponível em: <https://www.gov.br/trabalho-e-previdencia/pt-br/assuntos/seguranca-e-saude-trabalho/normatizacao/normas-regulamentadoras/nr-17>, 2011. Acesso em: 18 dez. 2024.

BRASIL. **Ministério do Trabalho e Emprego. NR 17: Ergonomia.** Manual de Legislação Atlas. São Paulo: Atlas, 64ª ed., 2011.

BRUNO, F.; BARBIERI, L.; MUZZUPAPPA, M. A Mixed Reality system for the ergonomic assessment of industrial workstations**. International Journal on Interactive Design and Manufacturing (IJIDeM)**, v. 14, n. 3, p. 805–812, 2020.

CARDOSO, A. *et al.* A new human-centered methodology for assessing safe conversion of collaborative manual workstations. **Safety Science**, 2024. Disponível em: https://doi.org/10.1016/ssci.2024.106685. Acesso em: 21.11.2024

CARVALHO, Laísa Cristina. **Influência das Condições Ergonômicas do Trabalho na Produtividade da Mão de Obra na execução do serviço de armação**. 202.185 f. Tese. Programa de Pós-graduação em Eng Civil. Universidade Federal de São Carlos. São Carlos, 2020.

ISSN 2318-8472, v. 14, n. 91, 2026

CASTRO, Lúcio Rafael Linhares de. **A importância da ergonomia para a construção civil**. 2021. 30f. Trabalho de Conclusão de Curso (Graduação em Engenharia Civil) - Centro de Tecnologia, Universidade Federal do Rio Grande do Norte, Natal, 2021.

CHIASSON, M.-È. *et al.* **Influence of musculoskeletal pain on workers' ergonomic risk- factor assessments**. Applied ergonomics, v. 49, p. 1–7, 2015.

CORRÊA, Vanderlei Moraes. **Ergonomia: fundamentos e aplicações**. Porto Alegre: Bookman, 2015.

COSTA, G. B. B.; PINTO, R. M. F. P.; ROBERTO, J. C. A.; ALMEIDA, V. da S. A importância da ergonomia na prevenção de lesões musculoesqueléticas relacionadas com a profissão de pedreiro. **Revista Contemporânea**, [S. l.], v. 3, n. 11, p. 21359–21383, 2023. DOI: 10.56083/RCV3N11-076. Disponível em: https://ojs.revistacontemporanea.com/ojs/index.php/home/article/view/2212. Acesso em: 13 jul. 2025.

COSTA, V.M.D; SILVA, D.C..D; LYRA, M.W.C. **A Perspectiva da Atividade na Construção Civil Através de uma Abordagem Ergonômica.** VI Congresso Nacional de Pesquisa em Ciência. Editora realize. Conapesc, 2021. Acesso em: 09 de out. 2023.

COUTO, Hudson de Araújo; COUTO, Dennis Carvalho. Ergonomia e a Revolução 4.0. In: **Ergonomia 4.0: dos conceitos básicos à 4ª revolução industrial**. Belo Horizonte: Ergo Editora, 2021. p. 260-301.

CRAWFORD, J *et al.* Musculoskeletal health in the workplace, **Best Practice & Research Clinical Rheumatology**, v.34. n.5. p.10-20,2020.

DASGUPTA, P. S. *et al.* Does drywall installers' innovative idea reduce the ergonomic exposures of ceiling installation: A field case study. **Applied ergonomics**, v. 55, p. 183–193, 2016.

DOZZA, Marcos Antônio; SANTOS, Gabriel Machado; SOUSA, Vanessa Leal. Processos ergonômicos: determinantes de produtividade do trabalho. **Humanidades & Inovação**, v. 10, n. 9, p. 281-288, 2023.

FRANCISCO, William Gervasio. MEDEIROS, Albertina Pereira. Análise ergonômica: estudo de caso do depósito de uma empresa de materiais para construção da grande Florianópolis. **Da Pesquisa**, v.11, n.15, ano 2016.

FRIES, C. E.; HOLSTAK, D. Evaluation of efficiency trends in the Brazilian construction industry. **Proceedings of the International Conference on Industrial Engineering and Operation Management**, p. 2929-2940. Disponível em: https://dx.doi.org/10.46254/sa02.20210318. Acesso em: 20 ago. 2024. 2021.

FRIES, C. E.; HOLSTAK, D. Evaluation of efficiency trends in the Brazilian construction industry. **Proceedings of the International Conference on Industrial Engineering and Operations Management,** p. 2929-2940. Disponível em: https://dx.doi.org/10.46254/sa02.20210318. Acesso em: 20 ago. 2025.

GIL, Antônio Carlos. **Métodos e Técnicas de Pesquisa Social**. 6. ed. São Paulo: Atlas, 2011.

GOLABCHI, A., HAN, S., FAYEK, A. R. & Abourizk, S. Stochastic modeling for assessment of human perception and motion sensing errors in ergonomics analysis. **Journal of Computing in Civil Enginering,** 31(4), 1-11, 2017.

GOMES, Haroldo Pereira. **Construção civil e saúde do trabalhador: um olhar sobre as pequenas obras**. Escola Nacional de Saúde Pública Sergio Arouca, Rio de Janeiro, 2011.

GREENE, R. L. *et al.* Visualizing stressful aspects of repetitive motion tasks and opportunities for ergonomic improvements using computer vision. **Applied ergonomics**, 65,p. 461–472, 2017.

HUANG, Yuecheng; YU, Yiqin; WANG, Yao; BOTÃO, Gu. Factors influencing fatigue of construction workers in hypoxic environments: A survey study. **Safety science**, v. 177, n. 106569, September, 2024. Disponível em: https:// doi.org/10.1016/j.ssci.2024.106569. Acesso em: 30 de Jan. de 2025.

IIDA, Itiro. BUARQUE, Lia. **Ergonomia: projeto e produção**. Editora Blucher, 2016. p. 02.

ISSN 2318-8472, v. 14, n. 91, 2026

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO). **ISO 45001:2018 — Sistemas de gestão de saúde e segurança ocupacional — Requisitos com orientação para uso**. Genebra: ISO, 2018.

ITO, T. *et al.* Development of working posture monitoring system for ergonomics manufacturing work environment. In: **Transdisciplinary Engineering Methods for Social Innovation of Industry** 4.0, v. 7, p. 1112-1121, Japão, 2018.

JEONGEUN, P. *et al.* Multi-label material recognition model and human risk factors for safety management on construction sites. **National Safety Council**, Coreia do Sul, 2024. Disponível em: https://doi.org/10.1016/j.jsr.2024.10.002. Acesso em: 22 jun. 2025.

JESUS, S.; FUCALE, S.; RABBANI, E. R. K. Resíduos de ACM como fonte de materiais para produção de pavimentos flexíveis sob ótica de economia circular: uma revisão da literatura. **In: Revisão sistemática da literatura: Abordagens e aplicações na engenharia civil**. Porto Seguro, BA: UFSB, 2022. p. 37.

KLEIN, Alison Alfred; LIMA, Rodrigo Araújo Fiuza; GRANDI, Leonardo Felipe; MARINHO, Cauê. Kinebot**: inteligência artificial na ergonomia** [livro eletrônico em PDF].1. ed. Curitiba, PR: Kinobot, 2023. Acesso em: jul. 2025.

KOLUS, Ahmet *et al.* Adaptive neuro-fuzzy inference systems with k-fold cross-validation for energy expenditure predictions based on heart rate. **Applied ergonomics,** v. 50, p. 68-78, 2015.

KRISHA, L. SHIVA RAMA; REDDY, P. RAVINDER. Increasing safety and productivity across the entire route through the use of ergonomic principles-**A case study. Materials** Today: Proceedings, 2022. Disponível em: https://doi.org/10.1016/j.matpr.2022.04.444. Acesso em: 30 de nov. de 2024.

LAKATOS, Eva Maria; MARCONI, Marina de Andrade. **Fundamentos de metodologia científica**. 5. ed. São Paulo: Atlas, 2017.

LEE, Y. C. A proactive, strategy-centered, deep learning-based ergonomic risk assessment system for recognizing risk postures. **Advanced Engineering Informatics**, v. 53, 2022. Disponível em: https://doi.org/10.1016/j.aei.2022.101717. Acesso em: 21 de nov. de 2024.

LIBERATI, A. IOANNIDIS, J. P. A. CLARKE, M, DEVEREAUX, P. J. Kleijnen, J & Moher, D. 2009.**The PRISMA statement for reportin systematic reviews and meta-analyses of studies that evaluate healthcare intervention; explanation an elaboration.** Disponível em https:/www.bmj.com/content/339/bmj.b2700. Acesso em: 01 de dez. 2024.)

LOP, NOR SUZILA BINTI; SALLEH, NORAZLIN MAT; ZAIN, FAIRIZ MIZA YOP; SAIDIN, MOHAMAD TAJUDIN. Ergonomic Risk Factors (ERF) and their Association with Musculoskeletal Disorders (MSDs) among Malaysian Construction Trade Workers: Concreters. **International Journal of Academic Research in Business and Social Sciences**, v. 9, n. 9, p. 1269-1282, 2019. Disponível em: https://doi.org/10.6007/IJARBSS/v9-i9/6420. Acesso em: 5 dez. 2024.

MACIEL, Amanda Patricia. **Estudo dos fatores que afetam a produtividade em canteiros de obra de empresas brasileiras.** 2022. Dissertação (Mestrado em Engenharia Civil) - Universidade Tecnológica Federal do Paraná, Curitiba, 2022.

MAGALHÃES, Stefany Rodrigues; MAROCHI, Rafael. **A Ergonomia na Construção Civil: Análise do Posto do Pedreiro na Alvenaria Convencional**. Trabalho de Conclusão de Curso. Faculdade Anhanguera, 2022. Publicação em anais.

MASSIRIS FERNÁNDEZ, Manlio; FERNÁNDEZ, J. Álvaro; BAIXO, Juan M.;DELRIEUX, Cláudio A. Ergonomic risk assessment based on computer vision and machine learning. **Computers & Industrial Engineering,** Argentina, v. 149, n. 106816, 2020. Disponível em: https://doi.org/10.1016/j.cie.2020.106816. Acesso em 14 de set. 2024

MATIAS, Bianca Moreira Matias Moreira *et al.* A importância da ergonomia no setor da construção civil. **Revista Interdisciplinar de Tecnologias e Educação**, v. 3, n. 2, 2017.

MATIRINGE, Ronald Kwadzayi; PYAZA, Grayyna. **Ergonomics vs economics in the construction logistics: a case study from the "Hexagon Construction" company. Archives of Production Engineering, Poland,** 2022. ISSN 2353-7779 (online). DOI 10.30657/pea.2022.28.49.

ISSN 2318-8472, v. 14, n. 91, 2026

MEDEIROS, B.; LIMA, M. M. de J. P.; LAURENTIZ, V. E. V. de; ANJOS, A. P. dos. A importância da ergonomia e segurança do trabalho em uma construtora para uma construtora de obras civil. **REVISTA FOCO**, [S. l.], v. 17, n. 10, p. e6348, 2024. DOI: 10.54751/revistafoco. V.17n10-018. Disponível em: https://ojs.focopublicacoes.com.br/foco/article/view/6348. Acesso em: 11 jul. 2025.

MENEZES, Carlos Eduardo Meira de. **Um método ergonômico para diagnóstico e controle de implantação de sistemas informatizados – o MIDAS (Método integrado para implantação e avaliação ergonômica de sistemas). Estudo de caso: Sistema SCADA para Supervisão de Oleodutos.** Dissertação (Mestrado) – Universidade Federal de Pernambuco. Centro de Artes e Comunicação. Programa de Pós-Graduação em Ergonomia, 2021– Recife, 2021. 359p.

MHAMDI, A. *et al.* Analyse ergonomique du travail dans une entreprise de confection en Tunisie. **Archives des Maladies Professionnelles et de l'Environnement,** Tunísia, v. 76, p. 447-449, 2015.

MOHAMED, M. A.; ADDOW, Yasin Ahmed. Study on labour safety for construction companies in Mogadishu, Somalia. **Journal of Civil Engineering Research & Technology**. SRC/JCERT-139. DOI: doi. org/10.47363/JCERT/2022 (4), v. 138, p. 2-5, 2022.

MOHAN, Sreejith; PATEL, Ganesh; SIVAPIRAKASAM, S.P.; RAJUL, M.; TEJA, K.S.R.
Ergonomic risk assessment and fatigue analysis during manual lifting tasks in agricultural activities. **International Journal of Occupational Safety and Health**, v. 14, p. 17-29, 2024.

MOREIRA, A. S.; LUCCA, S. R. de. Apoio psicossocial e saúde mental dos profissionais de enfermagem no combate ao covid-19. **Enfermagem em foco,** 2020. Disponível em: https://cofen.gov.br. Acesso em: 10 ago. 2024.

MORI, L. M; DEMORI, J. L. S. **Segurança e saúde do trabalho na indústria da Construção Civil: ergonomia física na construção civil.** São Carlos: Editora Scienza, p. 217-242, 2019.

NATH, N. D., AKHAVIAN, R. & BEHZADAN, A. H. Ergonomic analysis of construction worker's body postures using wearable mobile sensors. **Applied Ergonomics,** 62(1), 107-117, 2017.

OLIVEIRA, SILVANEY DE; GUIMARÃES, ORLINEY MACIEL; FERREIRA, JACQUES DE LIMA. As entrevistas semiestruturadas na pesquisa qualitativa em educação.
Revista Linhas, Florianópolis, v. 24, n. 55, p. 210-236, maio/ago. 2023.

OLIVEIRA, Kaline Araujo de. **Impacto do trabalho na força e fadiga musculoesquelética de pedreiros: uma análise eletromiográfica.** 2019. 145 f. Dissertação (Mestrado em Engenharia de Produção) - Universidade Tecnológica Federal do Paraná, Ponta Grossa, 2019.

ONYINYECHUKWU ADIBELI, J. *et al.* Ergonomic analysis in nuclear decommissioning: A comprehensive path planning strategy for workers well-being. **Nuclear engineering and design**, v. 426, n. 113409, p. 113409, 2024.7

OZDEMIR, R. *et al.* Fuzzy multi-objective model for assembly line balancing with ergonomic risks consideration. **International journal of production economics**, v. 239, n. 108188, p. 108188, 2021.

PADMANATHAN, V., JOSEPH, L., OMAR, B. & NAWAWI, R. Prevalence of Musculoskeletal Disorders and Related Occupational Causative Factors amoung Electricity Linemen: a narrative Review. **International Journal of Occupational Medicine and Environmental Health**, 29(5), 725-734, 2016.

PARAVIZO, Esdras *et al.* How Ergonomics and Related Courses Are Distributed in Engineering Programs? an Analysis of Courses from Brazilian Universities. In: **Congress of the International Ergonomics Association**. Cham: Springer International Publishing, 2021. p. 567-574.

PITANGA, Ângelo Francklin. Pesquisa qualitativa ou pesquisa quantitativa: refletindo sobre as decisões na seleção de determinada abordagem. **Revista Pesquisa Qualitativa**, [S. l.], v. 8, n. 17, p. 184–201, 2020. DOI: 10.33361/RPQ.2020. v.8. n.17.299. Disponível em: https://editora.sepq.org.br/rpq/article/view/299. Acesso em: 13 jul. 2025.

ISSN 2318-8472, v. 14, n. 91, 2026

RAJENDRAN, Manikandan; SAJEEV, Athul; SHANMUGAVEL, Rajesh; RAJPRADEESH, T. Ergonomic assessment of workers during manual material handling. **Materials Today Proceedings**, [S.l.], 2021. DOI: 10.1016/j.matpr.2021.02.283.

REGAL, Jorge Luiz de Oliveira. A importância da Ergonomia na Construção Civil. **Revista Científica Semana Acadêmica**. Fortaleza, ano MMXIX, Nº 000164, 2019.

RIASCOS, Carmen Elena Martinez; GONTIJO, Leila Amaral; MERINO, Eugênio André Diaz. Ergonomia no Sistema de Gestão da Segurança e Saúde no Trabalho. **Revista Ação Ergonômica.** Rio de Janeiro, 15(2), 2021.

SÁ, Eduardo Albuquerque; RAMON, Mazukyevicz; SOUZA, Luciane Albuquerque Sá de. Ergonomia na Construção Civil: Análise da Produção Científica de 2017 a 2021. **Revista Mangaio Acadêmico**. V.7, n.1, 64-91 (2022).

SAMPAIO, A. T.; LAVEZO, A. E.; COUTINHO, G. D. Segurança do trabalho e medidas de proteção na construção civil / Work safety and protective measures in civil construction. **Brazilian Journal of Development,** [S. l.], v. 6, n. 3, p. 9983–9997, 2020. DOI: 10.34117/bjdv6n3-032. Disponível em: https://ojs.brazilianjournals.com.br/ojs/index.php/BRJD/article/view/7324. Acesso em: 11 jul. 2025.

SAMPAIO, G. M.; AMORIM, E. S.; LORDSLEEM JÚNIOR, A. C**.** Tecnologias digitais em empresas construtoras: estudo de caso no contexto da construção 4.0. **Revista Nacional de Gerenciamento de Cidades , v. 12, n. 87**, 2024. **DOI:** 10.17271/231884.72128720245335.

SANTOS, Isis Moreira. **Análise ergonômica dos trabalhadores em alvenaria estrutural na construção civil. 2017. 41f. Monografia** (Especialização em Engenharia de Segurança do Trabalho) - Universidade Tecnológica Federal do Paraná. Londrina, 2017.

SCALONA, E. *et al.* Identification of movement phenotypes from occupational gesture kinematics: Advancing individual ergonomic exposure classification and personalized training. **Applied ergonomics**, v. 115, p. 104182, 2024.

SEO, H. *et al.*A case study of biomechanical assessment based on movement data to identify and evaluate ergonomic interventions in reinforced concrete work**. Developments in the Built Environment**, [s.l.], v. 16, December 2023, 100236. Disponível em: https:// doi.org/10.1016/j.dibe.2023.100236. Acesso em: 30 de Jan. de 2025.

SHANAHAN, J. C., VI, P., SALAS, E. A., REIDER, V. L., HOCHMAN, L. M. L. & MOORE, A. A comparison of rula, reba and strain index to four psychophysical scales in the assessment of non-fixed work. **Work**, 45(3), 367-378, 2013.

SHIN, W.; PARK, M. Ergonomic interventions for prevention of work-related musculoskeletal disorders in a small manufacturing assembly line. **International journal of occupational safety and ergonomics**: JOSE, v. 25, n. 1, p. 110–122, 2019.

SILVA, *et al.* **A interface usuário - ambiente escolar: o emprego da metodologia EWA em estudo desenvolvidos no Programa de Pós-Graduação em Desenho Industrial - FAAC/UNESP.** Arcos Design (Online), Rio de Janeiro/RJ - BRASIL, p. 33 - 42, 01 jan. 2009

SILVA, Felipe Alves *et al.* ANÁLISE ERGONÔMICA NA CONSTRUÇÃO CIVIL: uma revisão de literatura. **Revista Multidisciplinar do Nordeste Mineiro**, v. 1, n. 1, 2019.

SILVA, H.; ALVES DA SILVA, D.; OLIVEIRA, S.; VASCONCELOS VALÉRIO, B.;
GORGA LAGO, E. M.; DA Cruz, F. M. Análise de Desempenho da Segurança do Trabalho em uma Obra de Estrutura de Concreto Moldada in loco. **Revista de Engenharia e Pesquisa Aplicada**, v. 9, n. 2, p. 41-50, 5 abr. 2024.

SILVA, JCP., e PASCHOARELLI, LC., orgs. **A evolução histórica da ergonomia no mundo e seus pioneiros** [online]. São Paulo: Editora UNESP; São Paulo: Cultura Acadêmica, 2010. 103 p. ISBN 978-85-7983-120-1. Available from SciELO Books.

ISSN 2318-8472, v. 14, n. 91, 2026

SOUZA, Pedro Henrique Marciano de; GEORGES, Marcos Ricardo Rosa. Sistemas de Gestão Integrado em Meio Ambiente e Segurança do Trabalho e Sustentabilidade: Um estudo sobre as certificações no contexto das operações empresariais. **Revista Nacional de Gerenciamento de Cidades,** v. 08, n. 64, p.30; 2020.

SOUZA JÚNIOR, Célio Brito *et al.* Análise ergonômica de atividades realizadas por serventes em canteiros de obras: uma revisão da literatura. **Cuadernos de Educación y Desarrollo,** v. 16, n. 11, p. e6448-e6448, 2024.

STRADIOTO, Juliano Prado. Análise dos distúrbios músculo-esqueléticos na construção civil: Uma revisão sistemática de literatura. **International Journal of Professional Business Review:** Int. J. Prof. Bus. Rev., v. 9, n. 9, p. 5, 2024.

VAN DER MOLEN, Henk F.; VISSER, Steven. A Health-Impact Assessment of an Ergonomic Measure to Reduce the Risk of Work-Related Lower Back Pain, Lumbosacral Radicular Syndrome and Knee Osteoarthritis among Floor Layers in The Netherlands. **International Journal of Environmental Research and Public Health**. [s.l.]: MDPI, 2023. Disponível em: https://www.mdpi.com/journal/ijerph. Acesso em: 28 de novembro de 2024.

VIEIRA, Marina Helena Pereira; Montedo, Uiara Bandineli. A ergonomia no brasil: análise das publicações brasileiras na última década indexadas na web of science. **Revista Ação Ergonômica**, v. 18, n. 2, p. 1-39, 2024.

WANG, D.; DAI, F.; NING, X. Risk Assessment of Work-Related Musculoskeletal Disorders in Construction: State-of-the-Art Review. **Journal of Construction Engineering and Management**, 141(6), 2015.

WANG, JINGLUAN; CHEN, DENGKAI; ZHU, MENGYA; SUN, YIWEI. Risk assessment for musculoskeletal disorders based on work posture characteristics. **Automation and Construction,** [S.l.],November, 2021. Disponível em: https://doi.org/10.1016/j.autcon.2021.103921. Acesso em: 21 de Dezembro de 2024

XING, QING-JUN; SHEN, YUAN-YUAN; CAO, RUN; ZONG, SHOU-XIN; ZHAO, SHU-XIANG; SHEN, Yan-Fei. Functional movement screen dataset collected with two Azure Kinect depth sensors. **Scientific Data**, v. 9, n. 1, p. 104, 2022. Disponível em: https://doi.org/10.1038/s41597-022-01188-7. Acesso em: 12 Nov. 2024.

ZHANG, B. *et al.* Incorporating ergonomic and psychosocial stressors: A comprehensive model for assessing miners work-related musculoskeketal disorders. **Safety science,** v.176, n.106564, p.106564, 2024

ZHANG, Q. *et al.* A pilot study of biomechanical and ergonomic analyses of risky manual tasks in physical therapy. **International journal of industrial ergonomics**, v. 89, n. 103298,

ISSN 2318-8472, v. 14, n. 91, 2026

DECLARATIONS

AUTHOR CONTRIBUTIONS

When describing each author's contribution to the manuscript, the following criteria should be used:

- **Conceptualization and Study Design: Bruno Maia, Felipe Mendes da Cruz, and Symone Figueiredo do Nascimento** conceived the central idea of the study and defined its objectives and methodology.
- **Data Curation: Felipe Mendes da Cruz and Symone Figueiredo do Nascimento** organized and verified the data to ensure quality and reliability.
- **Formal Analysis: Bruno Maia, Felipe Mendes da Cruz, and Symone Figueiredo do Nascimento** conducted the data analyses using appropriate analytical methods.
- **Funding Acquisition: Felipe Mendes da Cruz and Eliane Maria Gorga Lago** secured the financial resources required to carry out the study.
- **Investigation: Felipe Mendes da Cruz, Eliane Maria Gorga Lago, and Symone Figueiredo do Nascimento** carried out data collection and practical investigations.
- **Methodology: Bruno Maia, Eudes Arimatéa, Felipe Mendes da Cruz, Eliane Maria Gorga Lago, and Symone Figueiredo do Nascimento** developed and refined the methodologies applied in the study.
- **Writing – Original Draft: Felipe Mendes da Cruz and Symone Figueiredo do Nascimento** prepared the initial draft of the manuscript.
- **Writing – Critical Review: Bruno Maia, Eudes Arimatéa, Felipe Mendes da Cruz, Eliane Maria Gorga Lago, and Symone Figueiredo do Nascimento** reviewed the manuscript, improving clarity and coherence.
- **Review and Final Editing: Bruno Maia, Eudes Arimatéa, Felipe Mendes da Cruz, Eliane Maria Gorga Lago, and Symone Figueiredo do Nascimento** reviewed and edited the manuscript to ensure compliance with journal standards.
- **Supervision: Felipe Mendes da Cruz and Symone Figueiredo do Nascimento** coordinated the research activities and ensured the overall quality of the study.

DECLARATION OF CONFLICTS OF INTEREST

We, **Bruno Maia de Guimarães, Eudes Arimatéa Rocha, Felipe Mendes da Cruz, Elaine Maria Gorga Lago, and Symone Figueiredo do Nascimento**, declare that the manuscript entitled **"Analysis of Ergonomic Factors in Carpentry Activities: Application of a System for Comparing Productive Movement Patterns and Fatigue"** has no conflicts of interest ".

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