Participatory Ergonomic Intervention Approach on Musculoskeletal Disorder (MSD) in Construction Sectors: A Systematic Review

Siti Maisarah Binti Amdan[1,2*], Siti Nurhafizah Saleeza Binti Ramlee[3] and Dian Darina Indah Binti Daruis[4]

[1] Faculty of Defence Studies and Management, National Defence University of Malaysia

[4]Faculty of Technology and Applied Sciences, Open University Malaysia

[2] Faculty of Defence Studies and Management, National Defence University of Malaysia

[3] Faculty of Engineering, National Defence University of Malaysia

***Corresponding Author**

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ABSTRACT

Musculoskeletal disorders (MSDs) remain a critical occupational health concern in the construction sector due to the physical demands of repetitive lifting, awkward postures, and heavy manual handling. This systematic literature review examines the role of participatory ergonomic (PE) interventions in reducing MSDs and explores the use of technology to enhance ergonomic risk assessment and prevention. Guided by PRISMA methodology, articles published between 2019 and 2024 were retrieved from Scopus, ScienceDirect, and PubMed, with 30 studies meeting the eligibility criteria. Findings indicate that PE interventions, including exoskeletons, workstation redesign, semi-automation, and task reorganization, significantly reduce biomechanical strain, discomfort, and MSD prevalence while improving productivity and worker satisfaction. However, limitations such as cost, device-related discomfort, and organizational barriers affect long-term sustainability. In addition, technological solutions such as wearable sensors, machine learning, cyber-physical training, and vision-based monitoring demonstrated high accuracy in detecting ergonomic risks and provided real-time feedback for prevention. Despite their effectiveness, issues such as secondary risks, acceptance, and cost justification must be addressed. Overall, the review highlights that integrating participatory approaches with technological innovations offers substantial potential to reduce MSDs among construction workers. Success depends on tailoring interventions to task-specific demands, ensuring organizational commitment, and adopting a holistic view that considers both physical and psychosocial dimensions of worker health.

Keywords: Participatory ergonomics; Musculoskeletal disorders; Construction; Technology

INTRODUCTION

Musculoskeletal Disorders (MSDs) represent a significant concern in the construction industry, known for its physically demanding nature and high incidence of work-related injuries (Chatterjee & Sahu, 2018). Construction workers frequently perform tasks involving repetitive motions, awkward postures, and heavy lifting, which contribute to the development of MSDs. These disorders affect muscles, nerves, tendons, and joints, leading to pain, functional impairment, and, consequently, a decline in productivity and quality of life. The economic burden of MSDs is substantial, encompassing direct costs related to healthcare and indirect costs such as lost workdays and decreased efficiency.

In recent years, there has been a growing recognition of the need for effective interventions to mitigate the risks associated with MSDs. Traditional approaches, often reactive and compliance-driven, have shown limited success in reducing the prevalence of these disorders. As a result, there is a shift towards more proactive and participatory strategies that involve workers in the identification and resolution of ergonomic issues.

Participatory Ergonomic (PE) interventions have emerged as a promising approach, leveraging the insights and experiences of workers to design and implement solutions that are practical, sustainable, and context-specific (Bernardes et al., 2021; Lin et al., 2022; Lund Rasmussen et al., 2022).

Participatory Ergonomic interventions focus on engaging workers at all levels in the ergonomic improvement process. This collaborative approach not only empowers workers by valuing their input but also fosters a sense of ownership and commitment to the implemented changes. The use of Ergonomic Data Sheets (EDS) is a critical component of this approach, providing a structured method for documenting ergonomic risks and facilitating communication between workers and management (Katode et al., 2021; Morse et al., 2001; Varghese & Panicker, 2022). EDS serve as a tool for capturing detailed information about specific tasks, identifying risk factors, and prioritizing interventions based on their potential impact.

The construction sector, with its diverse and dynamic work environment, presents unique challenges and opportunities for the application of PE interventions. The variability in tasks, work settings, and worker demographics requires tailored solutions that can adapt to the specific needs of different construction sites. Effective PE interventions in construction involve a multi-faceted approach, including ergonomic training, regular assessments, and continuous feedback mechanisms (Hignett et al., 2005; Visser et al., 2014; Zhang & Lin, 2024). By integrating ergonomic principles into daily practices and promoting a culture of safety and health, PE interventions aim to create a more sustainable and resilient workforce.

Numerous studies have highlighted the effectiveness of PE interventions in reducing MSD risks and improving worker well-being (Lallemand, 2012). These interventions have been shown to lead to significant reductions in discomfort and pain, improvements in work practices, and enhanced overall job satisfaction (Batubara & Dharmastiti, 2017; Ketola et al., 2002). Moreover, the participatory nature of these interventions often results in higher levels of compliance and sustained ergonomic improvements, as workers are more likely to adhere to changes they helped design.

In conclusion, the Participatory Ergonomic Intervention Approach offers a robust framework for addressing MSDs in the construction sector. By involving workers in the ergonomic improvement process and utilizing tools like EDS, this approach not only addresses the immediate ergonomic risks but also fosters a proactive and inclusive safety culture. As the construction industry continues to evolve, the adoption of PE interventions represents a critical step towards enhancing worker health, safety, and productivity.

LITERATURE REVIEW

The application of Participatory Ergonomics (PE) has received growing attention across multiple industries as an effective approach to reduce Musculoskeletal Disorders (MSDs). In the construction environment, where physical workloads, irregular postures, and temporary workplaces are common, PE offers a structured method for improving safety through active worker involvement. The reviewed literature can be conceptually grouped into three main themes: studies directly within construction, studies from other industrial sectors offering transferable insights, and cross-sector analyses identifying research gaps and practical lessons. This thematic organisation helps clarify how participatory approaches function across different contexts while emphasising their relevance to construction work.

PE has shown measurable success in improving health and productivity outcomes. Fonseca et al. (2016) reported that an ergonomic intervention programme in an industrial plant improved worker satisfaction and reduced strain by engaging employees in identifying and resolving workplace design issues. Similarly, Choobineh et al. (2021) found that participatory interventions in a steel manufacturing complex, supported by training and workstation redesign, resulted in significant reductions in Work-Related Musculoskeletal Disorders (WMSDs). Both studies demonstrate that continuous participation and management commitment are vital elements for sustaining ergonomic improvement. Mishra et al. (2021) strengthened this argument by proposing a structured framework for PE implementation and highlighting critical factors for success, such as clear objectives, top-management support, and participatory feedback mechanisms.

Although these studies originate primarily from manufacturing environments, their approaches are applicable to the construction sector. Jakobsen et al. (2016) investigated a participatory organisational intervention that improved assistive-device use in healthcare. Despite the different work settings, the study demonstrates that engaging workers in the intervention process increases compliance and adoption of ergonomic tools an outcome directly relevant to construction sites where safe equipment use often depends on behavioural participation. Likewise, Colim et al. (2020) examined robotic-aid development in furniture manufacturing, showing that worker input during validation ensured design practicality and comfort. These results underline the universal benefit of participatory decision-making in ergonomics, regardless of industry.

In contrast, several studies highlight contextual challenges that limit PE effectiveness. Norouzi et al. (2021) implemented a participatory health-promotion model among Iranian housewives and confirmed reductions in MSD symptoms but noted that psychosocial factors were equally important as physical modifications. This observation is critical for construction workers, where psychosocial stress and fatigue are often intertwined with biomechanical risk. Stock et al. (2018), through a systematic review of work-organisation interventions, found moderate evidence that rest breaks reduce MSD symptoms but identified inconsistencies in the strength of other interventions. These findings point to a need for higher-quality, longitudinal research especially in dynamic work environments such as construction.

Despite its advantages, PE implementation is not without obstacles. Rodríguez and Pérez (2021) analysed a Colombian manufacturing company where ergonomic redesigns were proposed through participatory methods but were only partially implemented due to resistance and lack of follow-up. Such organisational barriers mirror those in construction, where subcontracting structures and project-based employment can disrupt continuity. Arikan and Erdem (2023) also emphasised that ergonomic strategies must account for task variability and environmental constraints to remain effective. These limitations underscore the importance of sustained leadership involvement and institutional support throughout the intervention process.

Studies specific to construction demonstrate the practicality of PE in addressing job-site risks. Boulefaa et al. (2020) described ergonomic improvements in sewer pipe rehabilitation projects, where collaboration among all stakeholders helped identify hazards and align preventive measures with performance goals. The participatory approach led to both safety and productivity gains, illustrating how inclusion of different hierarchy levels fosters sustainable ergonomic practices. Similarly, Mallampalli (2024) reported notable decreases in lower-back, hand, and shoulder MSDs among female workers after a participatory redesign of task-specific workstations. Although conducted in the cashew industry, the study's findings reinforce the potential benefits of participatory design in repetitive or manual construction tasks.

Rostami et al. (2022) further confirmed the role of participatory approaches in improving worker health and productivity. Their ergonomic intervention programme in the steel industry reduced MSD prevalence and occupational fatigue while improving resource efficiency. Barbosa et al. (2022) also demonstrated that participatory feedback in a textile factory allowed workers to identify posture-related risks, resulting in effective and sustainable workstation redesigns. Lima and Coelho (2019) evaluated the Ergo@Office programme, noting reductions in musculoskeletal complaints and higher job satisfaction when employees were engaged in preventive strategies. Chanchai et al. (2016) found similar benefits among hospital orderlies, reporting decreased symptoms and improved psychosocial conditions following participatory ergonomics training. These studies collectively highlight that participatory models are adaptable and effective across sectors, providing valuable frameworks for the construction industry.

Nevertheless, not all studies show consistent results. Hoe et al. (2018) reviewed ergonomic interventions aimed at preventing upper-limb and neck MSDs among office workers and concluded that while participatory methods show promise, the evidence base remains inconsistent due to variations in research design and outcome measures. This observation mirrors challenges in construction ergonomics, where short project cycles and diverse job types make it difficult to collect long-term follow-up data. Moreover, recent meta-analyses, such as those by Varghese and Panicker (2022) and Zhang and Lin (2024), have stressed the importance of standardised evaluation criteria and industry-specific evidence recommendations particularly pertinent to construction research.

Comparative analysis across sectors suggests several recurring themes. Active worker involvement consistently leads to greater ownership of ergonomic change, while management engagement ensures institutional continuity. Yet, despite widespread reporting of biomechanical improvements, few studies evaluate long-term adoption or include economic outcomes such as cost–benefit analyses or return on investment. Another gap lies in integrating psychosocial risk factors alongside physical ergonomics, an omission that limits understanding of how participatory interventions affect overall well-being and productivity. Furthermore, the heterogeneity of outcome measures ranging from subjective discomfort ratings to electromyographic data restricts cross-study comparability. Addressing these methodological inconsistencies would enable stronger synthesis and clearer evidence on intervention effectiveness.

The reviewed literature collectively supports PE as an effective and flexible approach to reducing MSDs and enhancing workplace health across diverse sectors. The inclusion of workers in identifying hazards, developing solutions, and monitoring results promotes both safety and performance improvements. However, for the construction sector, further research is required to evaluate long-term outcomes, psychosocial integration, and scalability of interventions under field conditions. Given the sector's project-based and transient nature, participatory ergonomics represents a practical strategy that aligns health and productivity objectives, provided that implementation is supported by consistent management commitment and structured feedback systems.

Research Question

The following are the research questions for this study:

1. How effective are participatory ergonomic interventions in reducing musculoskeletal disorders among construction workers?
2. How can technology be used in participatory ergonomics to assess and reduce ergonomic risks in construction work?

Material and methods

This review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure a structured, transparent, and replicable approach. PRISMA is widely recognised in systematic review research for its focus on minimizing bias and improving the clarity and quality of reporting. The framework divides the review process into four main phases: identification, screening, eligibility, and data extraction (refer to Figure 1). In the identification phase, relevant literature was gathered using carefully constructed search strings that combined key terms related to participatory ergonomics, musculoskeletal disorders (MSDs), and the construction sector. Searches were performed across three major academic databases: Scopus, ScienceDirect, and PubMed. These databases were selected for their extensive indexing of peer-reviewed journals and broad subject coverage in both technical and health-related disciplines. It is acknowledged, however, that no single database is comprehensive. Therefore, using multiple databases helped reduce the risk of missing relevant studies due to coverage gaps or indexing limitations.

During the screening process, articles were first reviewed for duplication and then assessed based on predefined inclusion and exclusion criteria, which considered publication year, language, document type, and relevance to the research questions. Only full-text, peer-reviewed journal articles published in English between 2019 and 2024 were considered. Non-article formats such as conference papers, books, and editorials were excluded to maintain quality and consistency. The eligibility phase involved a more detailed evaluation of the remaining articles, focusing on their alignment with the scope of the

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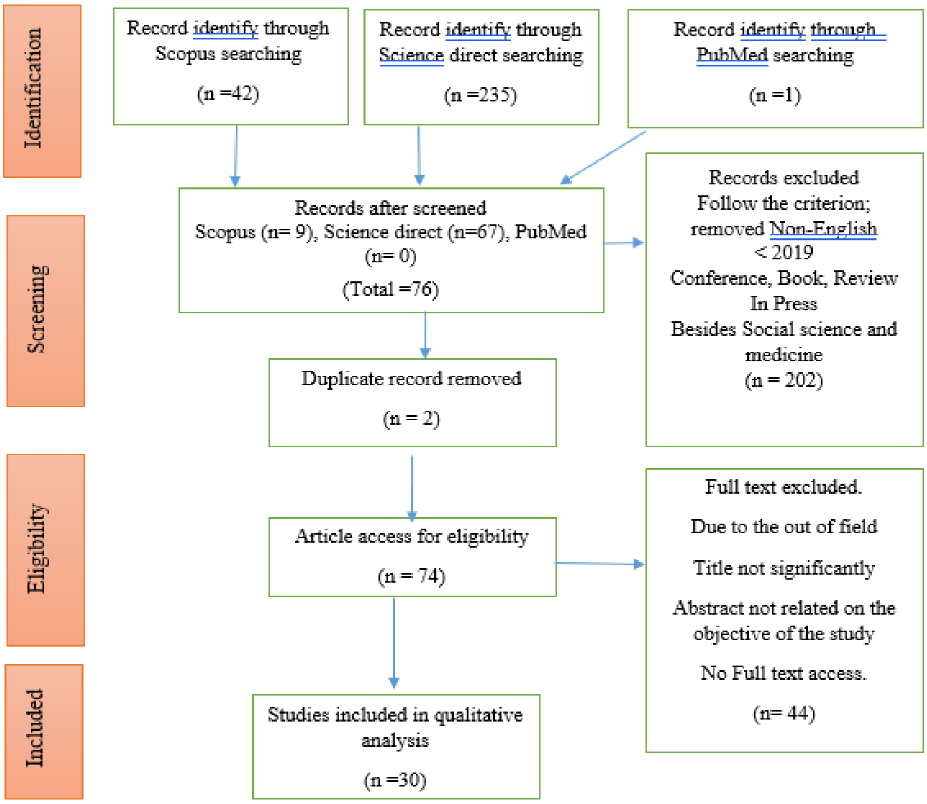
review. Studies that lacked empirical evidence, addressed unrelated topics, or had inaccessible full texts were excluded. In the final phase, data extraction was performed by synthesising key information from each included study, such as the intervention type, assessment method, outcomes measured, and contextual relevance. This rigorous methodological process ensured the selection of high-quality studies and enabled a comprehensive synthesis of evidence on participatory ergonomic interventions for preventing musculoskeletal disorders in construction work environments

FIGURE 1. Flow diagram of the proposed searching study (Moher D, Liberati A, Tetzlaff J, 2009)



Identification

At the outset of this review, a structured approach was applied to retrieve a broad range of relevant studies. The process began with identifying key search terms and then extending them through the use of dictionaries, thesauri, reference materials, and previous research to ensure comprehensive coverage. These terms were systematically compiled to develop search strings for PubMed, ScienceDirect, and Scopus databases (refer to Table 1). Using this strategy across the three selected databases produced an initial pool of 278 publications related to the study topic.

Table 1 The search string.

Scopus	TITLE-ABS-KEY (("participatory ergonomic" OR "ergonomic intervention") AND ("musculoskeletal disorder" OR "musculoskeletal injuries") AND ("construction" OR "construction industry")) AND PUBYEAR > 2018 AND PUBYEAR < 2025 AND (LIMIT-TO (DOCTYPE , "ar")) **Date of Access: August 2024**
Science direct	(("participatory ergonomic" OR "ergonomic intervention") AND ("musculoskeletal disorder" OR "musculoskeletal injuries") AND ("construction" OR "construction industry")) **Date of Access: August 2024**
PubMed	(("participatory ergonomic" OR "ergonomic intervention") AND ("musculoskeletal disorder" OR "musculoskeletal injuries") AND ("construction" OR "construction industry")) **Date of Access: August 2024**

Screening

In the screening phase, all potentially relevant studies were reviewed to determine their alignment with the predefined research focus on Participatory Ergonomic Intervention Approaches targeting Musculoskeletal Disorders (MSDs) in the Construction Sector. This stage included an initial filtering to remove duplicate records. Following this, a total of 202 publications were excluded based on the inclusion and exclusion criteria, resulting in 76 articles selected for further assessment (see Table 2). The primary focus was on literature offering practical and empirical insights; therefore, non-research formats such as reviews, meta-analyses, book chapters, conference proceedings, and other grey literature were excluded. Additionally, only studies published in English between 2019 and 2024 were considered eligible. During this process, two duplicate publication was identified and removed.

TABLE 2 The selection criterion is searching

Criterion	**Inclusion**	**Exclusion**
Language	English	Non-English
Time line	2019 – 2024	< 2019
Literature type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press

Eligibility

In the eligibility phase, a total of 74 articles were initially shortlisted for detailed assessment. At this stage, the titles and core content of each article were examined closely to confirm compliance with the established inclusion criteria and relevance to the research objectives. Following this evaluation, 44 papers were excluded because they were outside the study's scope, had insufficiently relevant titles or abstracts, lacked alignment with the research aims, or did not provide full-text access supported by empirical evidence. Consequently, 30 articles were retained for the final stage of the review.

Quality of Appraisal

Based on the recommendations of Kitchenham and Charters (2007), once the primary studies were identified, it was necessary to evaluate their quality and make quantitative comparisons. For this review, the quality assessment method proposed by Abouzahra et al. (2020) was adopted, which includes six specific criteria tailored for systematic literature reviews. Each study was rated using a three-point scale: "Yes" (Y) with a score of 1 when the requirement was fully satisfied, "Partly" (P) with a score of 0.5 when the condition was partially met but showed some limitations, and "No" (N) with a score of 0 when the requirement was not fulfilled.

TABLE 3 The Quality Assessment

Quality Assessment	Expert 1	Expert 2	Expert 3	Total Mark
Is the purpose of the study clearly stated?	Y	Y	Y	3
Is the interest and the usefulness of the work clearly presented?	Y	Y	Y	3
Is the study methodology clearly established?	Y	Y	Y	3
Are the concepts of the approach clearly defined?	Y	Y	Y	3
Is the work compared and measured with other similar work?	Y	Y	Y	3

The table summarises the quality assessment (QA) process, which was applied to evaluate each study based on defined questions. Three reviewers independently assessed the studies, and each criterion was scored as Yes (Y = 1), Partly (P = 0.5), or No (N = 0). The criteria are as follows:

1. **Is the purpose of the study clearly stated?**
   This assesses whether the research objectives are explicitly described, as a clear aim provides proper direction and scope for the work.
2. **Is the interest and usefulness of the work clearly presented?**
   This examines whether the study's significance and expected contributions are well explained, reflecting its relevance and impact.
3. **Is the study methodology clearly established?**
   This criterion evaluates whether the research methods are well defined and appropriate to meet the objectives, which is essential for validity and reproducibility.
4. **Are the concepts of the approach clearly defined?**
   This checks if the theoretical framework and main concepts are articulated with clarity, ensuring that the approach can be properly understood.
5. **Is the work compared and measured with other similar work?**
   This considers whether the study has been benchmarked against related research, helping to position it within the broader academic field and highlight its contributions.

Each study was evaluated independently by the three experts using the specified criteria. The individual scores were then combined to calculate a total quality score. To qualify for inclusion in the next stage, a study had to achieve an overall score greater than 3.0. This cut-off point was applied to ensure that only research meeting the required quality standards was retained for further analysis.

Data Abstraction and Analysis

An integrative analysis approach was applied in this study to evaluate and synthesise findings from various research designs, with a primary focus on quantitative methods. The purpose of this stage was to identify key themes and subthemes relevant to the research topic. The data collection process served as the initial step in theme development. As illustrated in Figure 1, a total of 30 selected studies were carefully reviewed to extract statements and content relevant to the scope of Participatory Ergonomic Intervention Approaches addressing Musculoskeletal Disorders (MSDs) in the construction industry.

Each study was assessed in terms of its methodology and reported outcomes. Following this, the primary researcher collaborated with co-authors to identify, group, and refine emerging themes grounded in the collected evidence. Throughout the analysis, a logbook was maintained to document reflections, observations, and analytical decisions made during the coding and interpretation process. Where differing interpretations arose, they were resolved through discussion and consensus among the research team, ensuring consistency and reliability in the final thematic structure.

The produced themes were eventually tweaked to ensure consistency. The analysis selection was carried out by three experts: one is a researcher in ergonomics (Dr Ayuni Nabilah, researcher and academician), one in industrial hygiene (Dr Hari Krishnan, consultant in ergonomics), and the other in industrial design (Dr Nor Ziratul Aqma, expert in human factors), to determine the validity of the problems. The expert review phase ensures the clarity, importance, and suitability of each subtheme by establishing the domain validity.

The authors also compared the findings to resolve any discrepancies in the theme creation process. Note that if any inconsistencies in the themes arose, the authors addressed them with one another. Finally, the developed themes were tweaked to ensure their consistency. To ensure the validity of the problems, the examinations were performed by three experts, one specialising in anthropometric, the other in industrial ergonomic and industrial design. The expert review phase helped ensure each sub-theme's clarity, importance, and adequacy by establishing domain validity. Adjustments based on the discretion of the author, based on feedback and comments by experts, have been made.

Result and Finding

Background of Selected Study

Author-title-journal-data from (Scopus, Science Direct, PubMed)

Table 4 The Selected Study

No	Authors	Title	Year	Journal	Scopus	Science Direct
1	Seo H.; Pham H.T.T.L.; Golabchi A.; Seo J.; Han S.	A case study of motion data-driven biomechanical assessment for identifying and evaluating ergonomic interventions in reinforced-concrete work	2023	Developments in the Built Environment	/	/
2	Antwi-Afari M.F.; Li H.; Anwer S.; Li D.; Yu Y.; Mi H.-Y.; Wuni I.Y.	Assessment of a passive exoskeleton system on spinal biomechanics and subjective responses during manual repetitive handling tasks among construction workers	2021	Safety Science	/	/
3	Carlan N.; Vi P.; Yung M.; Du B.; Bigelow P.L.; Wells R.P.	Evolving pipe joining methods and their association to musculoskeletal symptoms for residential plumbers	2023	Work	/	
4	Kim S.; Ojelade A.; Moore A.; Gutierrez N.; Harris-Adamson C.; Barr A.; Srinivasan D.; Rempel D.M.; Nussbaum M.A.	Understanding contributing factors to exoskeleton use-intention in construction: a decision tree approach using results from an online survey	2023	Ergonomics	/	
5	Kusmasari W.; Sutarto A.P.; Dewi N.S.; Yassierli; Yudhistira T.; Muslim K.; Sanjaya K.H.; Haqiyah A.; Lestari W.D.	Exploring the interaction between physical, psychosocial, and neck pain symptoms in construction workers	2024	Journal of Occupational Health	/	
6	Gonsalves N.J.; Yusuf A.; Ogunseiju O.; Akanmu A.	Evaluation of concrete workers' interaction with a passive back-support exoskeleton	2023	Engineering, Construction and Architectural Management	/	
7	Zhang H,Lin Y	Modeling and evaluation of ergonomic risks and controlling plans through discrete-event simulation	2023	Automation in Construction		/
8	Motabar H,Nimbarte AD	The effect of task rotation on activation and fatigue response of rotator cuff	2021	Applied Ergonomics		/

		muscles during overhead work				
9	e Silva Nascimento JM,Bispo LG,da Silva JM	Risk factors for work-related musculoskeletal disorders among workers in Brazil: A structural equation model approach	2024	International Journal of Industrial Ergonomics		/
10	Garosi E,Mazloumi A,Jafari AH,Keihani A,Shamsipour M,Kordi R,Kazemi Z	Design and ergonomic assessment of a passive head/neck supporting exoskeleton for overhead work use	2022	Applied Ergonomics		/
11	Li J,Chen G,Antwi-Afari MF	Recognizing sitting activities of excavator operators using multi-sensor data fusion with machine learning and deep learning algorithms	2024	Automation in Construction		/
12	Ogedengbe TS,Abiola OA,Ikumapayi OM,Afolalu SA,Musa AI,Ajayeoba AO,Adeyi TA	Ergonomics Postural Risk Assessment and Observational Techniques in the 21st Century	2023	Procedia Computer Science		/
13	Zhang Z,Lin KY	Applying implementation science to evaluate participatory ergonomics program for continuous improvement: A case study in the construction industry	2024	Applied Ergonomics		/
14	Ijaz M,Ahmad SR,Akram M,Khan WU,Yasin NA,Nadeem FA	Quantitative and qualitative assessment of musculoskeletal disorders and socioeconomic issues of workers of brick industry in Pakistan	2020	International Journal of Industrial Ergonomics		/
15	Antwi-Afari MF,Qarout Y,Herzallah R,Anwer S,Umer W,Zhang Y,Manu P	Deep learning-based networks for automated recognition and classification of awkward working postures in construction using wearable insole sensor data	2022	Automation in Construction		/
16	Maciukiewicz JM,Whittaker RL,Hogervorst KB,Dickerson CR	Wrapping technique and wrapping height interact to modify physical exposures during manual pallet wrapping	2021	Applied Ergonomics		/
17	de Souza DS,da Silva JM,de Oliveira Santos	Influence of risk factors associated with musculoskeletal disorders	2021	International Journal of		/

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	JV,AlcÃ¢ntara MS,Torres MG	on an inner population of northeastern Brazil		Industrial Ergonomics		
18	Akanmu AA,Olayiwola J,Ogunseiju O,McFeeters D	Cyber-physical postural training system for construction workers	2020	Automation in Construction		/
19	Seo J,Lee S	Automated postural ergonomic risk assessment using vision-based posture classification	2021	Automation in Construction		/
20	Kumar A,Pramanik A,Singh JK,Tiwari RK,Jena S	An ergonomic intervention for manual load carrying on Indian farms	2021	International Journal of Industrial Ergonomics		/
21	Ryu J,McFarland T,Banting B,Haas CT,Abdel-Rahman E	Health and productivity impact of semi-automated work systems in construction	2020	Automation in Construction		/
22	Cuny-Guerrier A,Savescu A,Tappin D	Strategies to commit senior subcontractor managers in participatory ergonomics interventions	2019	Applied Ergonomics		/
23	GonzÃ¡lez Fuentes A,Busto Serrano NM,SÃ¡nchez Lasheras F,Fidalgo Valverde G,SuÃ¡rez SÃ¡nchez A	Work-related overexertion injuries in cleaning occupations: An exploration of the factors to predict the days of absence by means of machine learning methodologies	2022	Applied Ergonomics		/
24	Das B	Improved work organization to increase the productivity in manual brick manufacturing unit of West Bengal, India	2021	International Journal of Industrial Ergonomics		/
25	Wurzelbacher SJ,Lampl MP,Bertke SJ,Tseng CY	The effectiveness of ergonomic interventions in material handling operations	2020	Applied Ergonomics		/
26	Okunola A,Akanmu A,Jebelli H	Fall risk assessment of active back-support exoskeleton-use for construction work using foot plantar pressure distribution	2024	Advanced Engineering Informatics		/
27	Adeyemi HO,Adejuyigbe SB,Adetifa BO,Akinyemi OO,Martins OO	Safe lifting ergonomics program for truck-loaders in Nigerian block making industries: A multi-site case study with qualitative and econometric analyses	2020	Scientific African		/

28	Virmani N,Ravindra Salve U	Assessment of key barriers for incorporating ergonomics inventions and suppress work-related musculoskeletal disorders	2021	Materials Today: Proceedings		/
29	Umer W	Simultaneous monitoring of physical and mental stress for construction tasks using physiological measures	2022	Journal of Building Engineering		/
30	Cruz AM,Murphy J,Chohan AK,Quiroga Torres DA,Izquierdo Martinez LC,Rincon Martinez DC,Liu L,Rios Rincon AM	Comparing the biomechanical and perceived exertion imposed on workers when using manual mechanical and powered cargo management systems during ladder loading and unloading tasks	2021	International Journal of Industrial Ergonomics		/

Participatory ergonomic interventions effectiveness in reducing musculoskeletal disorders among construction workers

Research evidence confirms that participatory ergonomic interventions are effective in lowering the risk of musculoskeletal disorders (MSDs) among construction workers. For example, Seo et al. (2023, Developments in the Built Environment) reported that posture-focused interventions reduced disc compression and joint loading by more than 30%, demonstrating measurable benefits for spinal health. Similarly, Antwi-Afari et al. (2021, Safety Science) showed that the application of a passive exoskeleton decreased lumbar erector spinae activity by 33% and reduced discomfort scores by 42% during heavy material handling. In another context, Cruz et al. (2021, International Journal of Industrial Ergonomics) highlighted that powered cargo systems lowered low-back compression forces and shoulder flexor moments compared with manual lifting, proving the advantage of integrating ergonomic technology in construction tasks.

Administrative and organizational approaches have also shown impact. Wurzelbacher et al. (2020, Applied Ergonomics) found that ergonomic interventions in material handling operations reduced reports of low-back and upper extremity pain among high-exposure workers. Similarly, Ryu et al. (2020, Automation in Construction) observed that semi-automated systems reduced joint loading by 40% while improving productivity by 10%. Zhang and Lin (2023, Automation in Construction) demonstrated through simulation modeling that applying ergonomic design principles can balance productivity demands with worker fatigue, supporting the integration of ergonomics into planning.

Nevertheless, limitations are evident. Gonsalves et al. (2023, Engineering, Construction and Architectural Management) reported that while passive back-support exoskeletons alleviated lumbar strain, they caused discomfort in the chest and thighs. Similarly, Garosi et al. (2022, Applied Ergonomics) found that a neck-supporting device reduced sternocleidomastoid activity but simultaneously increased trapezius load, transferring strain from one region to another. Maciukiewicz et al. (2021, Applied Ergonomics) identified mixed outcomes when evaluating pallet-wrapping tasks, as muscle demand varied depending on wrapping technique and height. These findings indicate that although participatory ergonomics can reduce MSDs, their success depends on task type, equipment design, and compatibility with work systems

Usage of Technology in Participatory Ergonomics to Assess and Reduce Ergonomic Risks in Construction Work

Technological applications have increasingly enhanced participatory ergonomics by providing objective, data-driven methods for assessing and reducing ergonomic risks. Seo and Lee (2021, Automation in Construction) achieved 89% accuracy in automated classification of construction postures using vision-based posture recognition, demonstrating reduced reliance on subjective observational assessments. Similarly, Antwi-Afari et al. (2022, Automation in Construction) applied wearable insole pressure sensors combined with recurrent neural networks, achieving 99% accuracy in identifying awkward postures, showing the potential of sensor-based monitoring for MSD prevention. Li et al. (2024, Automation in Construction) further demonstrated that multi-sensor data fusion with deep learning achieved more than 98% accuracy in recognizing sitting behaviors among excavator operators, providing reliable insights into operator ergonomics.

In terms of training and feedback, Akanmu et al. (2020, Automation in Construction) developed a cyber-physical postural training system that combined wearable sensors with real-time feedback, which was positively received by construction workers for improving posture awareness. Beyond construction, Kumar et al. (2021, International Journal of Industrial Ergonomics) designed ergonomic load-carrying systems for agricultural workers, showing that participatory and culturally adapted designs could reduce spinal strain, a lesson transferable to construction tasks.

Despite these advances, challenges remain. Okunola et al. (2024, Advanced Engineering Informatics) found that while active back-support exoskeletons reduced spinal loading, they increased plantar pressure by 7–51%, raising potential fall risks during movement-intensive tasks. Acceptance of interventions has been shown to increase when accompanied by economic benefits; for instance, Adeyemi et al. (2020, Scientific African) demonstrated that ergonomic lifting programs in block-making industries reduced absenteeism by 66.7% and medical costs by 98.3%, proving both health and financial benefits. Organizational support is also critical. Cuny-Guerrier et al. (2019, Applied Ergonomics) emphasized that management commitment, steering committees, and alignment with organizational goals were essential for sustaining participatory ergonomics programs. Similarly, Zhang and Lin (2024, Applied Ergonomics) applied implementation science to participatory ergonomics, achieving reductions in MSD injuries, improved worker knowledge, and a positive return on investment.

These findings collectively demonstrate that technology enhances the effectiveness of participatory ergonomics in construction by improving assessment precision, supporting worker training, and providing real-time monitoring. However, their long-term success depends on design improvements, financial justification, and continuous organizational commitment

DISCUSSION AND CONCLUSION

Research evidence highlights that ergonomic interventions substantially reduce biomechanical strain and improve musculoskeletal outcomes in construction activities. Seo et al. (2023) observed that posture-oriented interventions lowered disc compression and joint moments by over 30%, indicating positive effects across multiple body regions. Antwi-Afari et al. (2021) similarly found that a passive exoskeleton reduced lumbar erector spinae activity by up to 33% and discomfort scores by 42% under heavy lifting, while Cruz et al. (2021) demonstrated that powered cargo systems significantly decreased low-back compression forces and shoulder flexor moments compared with manual handling. Positive impacts were also reported in studies applying systemic and administrative approaches; Wurzelbacher et al. (2020) confirmed reductions in reported upper extremity and low-back pain among highly exposed employees using ergonomic interventions in material handling, and Ryu et al. (2020) showed that semi-automated systems cut joint loads by 40% and improved productivity by 10%. Moreover, Zhang and Lin (2023) applied simulation modeling to demonstrate that incorporating ergonomic principles into planning can balance worker fatigue with productivity. Collectively, these studies underline that interventions whether exoskeletons, semi-automation, or improved planning offer strong potential to mitigate musculoskeletal disorders in construction work.

However, results also reveal limitations, trade-offs, and the need for iterative design improvements. Gonsalves et al. (2023) found that while back-support exoskeletons reduced lumbar strain, they caused discomfort in the chest and thighs, whereas Garosi et al. (2022) noted that neck-supporting devices alleviated sternocleidomastoid activity but increased trapezius load, highlighting the issue of risk transfer across body parts. Maciukiewicz et al. (2021) identified similar mixed effects, showing that wrapping devices altered muscle demands differently depending on height, reducing postural risks in some cases while increasing muscular activation in others. Meanwhile, Motabar and Nimbarte (2021) showed that specific task rotation sequences could lower shoulder muscle fatigue, although the effects varied by exertion level. Carlan et al. (2023) also reported that the adoption of new pipe-joining methods has potential to reduce risks but is limited by barriers such as cost and tool design. These findings demonstrate that while ergonomic interventions are broadly effective in reducing exposure to musculoskeletal risks, their success is highly dependent on task type, posture requirements, and device compatibility with existing work systems, stressing the importance of context-specific design and implementation strategies.

Studies assessing musculoskeletal disorders (MSDs) in construction consistently reveal that both physical and psychosocial exposures contribute significantly to workers' health outcomes. Kusmasari et al. (2024) showed that workers exposed to high physical and psychosocial demands were over twelve times more likely to develop neck pain, while e Silva Nascimento et al. (2024) confirmed that maintaining awkward lower limb positions increased the risk of MSDs in the thigh, leg, and foot, with psychosocial stressors indirectly moderating these effects. De Souza et al. (2021) similarly found that back disorders in Brazilian workers were influenced by curved spine postures, uncomfortable lower limb positions, long working hours, and job insecurity, with psychosocial stress acting as an indirect factor. Supporting these findings, Ogedengbe et al. (2023) emphasized that prolonged sitting, heavy lifting, and twisting are common postures leading to elevated ergonomic risks, while Ijaz et al. (2020) documented that brick kiln workers faced very high risk levels in tasks such as mixing and molding, reporting widespread pain across multiple body regions. Das (2021) added that although brick manufacturing in India exposed workers to high-risk postures under the OWAS method, reorganization of tasks improved productivity by 32% and reduced biomechanical strain. Together, these findings underline that MSDs in construction emerge from a complex interaction of biomechanical demands, psychosocial pressures, and workplace conditions, requiring holistic risk assessment.

Technological and data-driven approaches have emerged as valuable tools to enhance risk evaluation and management. Seo and Lee (2021) achieved nearly 89% accuracy in automated classification of construction workers' postures through vision-based methods, reducing reliance on traditional observational analysis and minimizing observer bias. González Fuentes et al. (2022) demonstrated the predictive power of machine learning in analyzing overexertion injuries in the cleaning industry, showing that absence duration could be forecast using factors such as injury type and employment conditions, offering applications for construction safety. Umer (2022) advanced this approach by demonstrating that physical and mental stress can be simultaneously monitored with 94.7% accuracy using physiological measures and machine learning, paving the way for comprehensive real-time monitoring of workload. Collectively, these results illustrate that alongside traditional ergonomic assessments, advanced computational techniques and organizational interventions provide promising pathways to predict, prevent, and mitigate the risks of MSDs in construction work.

Technological innovations such as exoskeletons, wearable sensors, and cyber-physical systems are increasingly applied in construction to prevent musculoskeletal disorders (MSDs), with evidence highlighting both effectiveness and limitations. Kim et al. (2023) identified fatigue reduction, performance gains, and standardization as key drivers influencing exoskeleton adoption, although actual use remains low due to variable perceptions among workers. Li et al. (2024) demonstrated that multi-sensor data fusion and deep learning achieved over 98% accuracy in recognizing excavator operators' sitting postures, offering reliable insights into operator behavior. Similarly, Antwi-Afari et al. (2022) achieved 99% accuracy in classifying awkward postures using wearable insole pressure data with recurrent neural network models, confirming the potential of sensor-based systems for proactive MSD prevention. Supporting this direction, Akanmu et al. (2020) introduced a cyber-physical training system integrating sensors, virtual reality, and real-time feedback, which was positively perceived by workers for learning safe postures without disrupting tasks. Kumar et al. (2021) further contributed by designing ergonomic load-carrying harnesses for agricultural workers, redistributing spinal loads and demonstrating that cultural practices can be retained while reducing biomechanical strain. Collectively, these findings suggest that sensor-driven, AI-enabled systems can significantly enhance ergonomic monitoring, training, and intervention in construction environments.

Nonetheless, emerging evidence also reveals challenges and unintended risks that must be considered for sustainable adoption. Okunola et al. (2024) found that active back-support exoskeletons increased plantar pressure in carpentry tasks by 7–51%, raising fall risks particularly during movement-intensive subtasks, emphasizing the need for improved design to prevent secondary hazards. Adeyemi et al. (2020) showed that ergonomic lifting programs not only reduced fatigue and musculoskeletal pain in block-making industries but also delivered economic benefits, reducing absenteeism by 66.7% and medical costs by 98.3%, reinforcing that acceptance is higher when interventions provide measurable financial gains. Cuny-Guerrier et al. (2019) highlighted that senior management commitment is critical for participatory ergonomics programs, with strategies such as steering committees, knowledge transfer, and aligning interventions with shared organizational goals fostering stronger engagement. Zhang and Lin (2024) also demonstrated that applying implementation science frameworks to participatory ergonomics facilitated continuous improvements, achieving reductions in MSD injuries, enhanced worker knowledge, and positive return on investment. Finally, Virmani and Salve (2021) underscored that systemic and organizational barriers, including costs, perceptions, and cultural resistance, often hinder the smooth implementation of ergonomic programs. Taken together, these studies illustrate that while technological and participatory innovations show high potential in reducing MSDs, their effectiveness depends on careful integration of safety design, organizational strategies, and economic justification.

In conclusion, the reviewed evidence highlights the considerable promise of ergonomic strategies such as exoskeletons and digital monitoring tools in reducing musculoskeletal disorders within construction activities. The success of these interventions, however, depends greatly on designs tailored to specific work contexts, sustained organizational support, and attention to both biomechanical and psychosocial risk factors. These findings emphasize the importance of adopting a comprehensive approach to promoting health and safety among construction workers.

Conflicts of Interest

The authors declare that they have no conflicts of interest to report regarding the present study

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