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ERGONOMIC INTERVENTIONS FOR REDUCING MUSCULOSKELETAL DISORDERS IN SMALL AND MEDIUM-SIZED ENTERPRISES: A SYSTEMATIC REVIEW

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ABSTRACT

Background: Musculoskeletal disorders (MSDs) remain a significant occupational health concern in small and medium-sized enterprises (SMEs) particularly in labour-intensive sectors where workers are exposed to awkward postures, repetitive movements, manual handling and poor workstation design.

Aim: This systematic review aimed to synthesize evidence on ergonomic interventions for reducing MSD risks among SME workers.

Methods: The review was conducted in accordance with PRISMA 2020 guidelines. Four databases from PubMed, Scopus, IEEE Xplore and Google Scholar were searched for English-language studies published between 2020 and 2024. Studies were included if they focused on workplace ergonomic interventions, reported MSD or ergonomic risk-related outcomes and involved SME worker populations. Due to heterogeneity in intervention types, study designs and outcome measures, a narrative and descriptive synthesis was performed. Thirty-four studies were included in the final review.

Results: The findings showed that MSD prevalence among SME workers remained high, with common complaints involving the lower back, neck, shoulders, wrists/hands and knees. Effective interventions included workstation modifications, tool redesign, ergonomic training, participatory ergonomics, active breaks, job rotation and work-rest scheduling. These interventions were associated with reduced ergonomic risk scores, improved posture, lower discomfort and fatigue, and better worker health, efficiency and satisfaction. However, implementation was limited by low awareness, financial constraints, poor infrastructure and lack of occupational health support.

Conclusion: Overall, ergonomic interventions, particularly multi-component approaches combining training with workstation or tool redesign, can help reduce MSD risks in SMEs. Future studies should assess long-term effectiveness, cost-effectiveness and scalability across different SME sectors.

Keywords: Ergonomic Interventions; Musculoskeletal Disorders; Small and Medium-Sized Enterprises; Workplace Ergonomics; Occupational Health; Systematic Review

1 INTRODUCTION

Musculoskeletal disorders (MSDs) remain a major occupational health concern worldwide, particularly in low- and middle-income countries (LMICs) across Asia. Small and medium-sized enterprises (SMEs), which form the economic backbone of countries such as India, Malaysia, Indonesia, and Vietnam, often operate in ergonomically hazardous conditions. Workers in these sectors are commonly exposed to repetitive tasks, awkward postures and poorly designed workstations[1,2].

The informal and under-regulated nature of many SME workplaces contributes to poor enforcement of safety standards and limited ergonomic awareness. For example, nearly 60% of traditional handloom weavers in India reported lumbar spine pain related to poor postural practices and lack of ergonomic equipment[3]. In Malaysia, high rates of MSDs have been observed among warehouse and factory workers, particularly due to prolonged standing and manual handling[4].MSDs in SME settings are strongly associated with reduced productivity, absenteeism, and presenteeism. Estimates indicate that presenteeism alone accounts for more than 50% of productivity losses among affected workers[5.] The economic impact is further compounded in LMICs where many SMEs lack the financial or technical capacity to implement effective ergonomic solutions[6,7].

Beyond physical symptoms, poor ergonomics can negatively impact mental health. Chronic pain, job insecurity, and limited access to care contribute to psychological stress and a diminished quality of life[8,9]. Workers in informal sectors such as food processing, metal casting, and textile production often remain underserved in occupational health planning. There is, however, growing evidence that ergonomic interventions such as workstation redesign, participatory ergonomics, training, and tool modifications can significantly reduce MSD risks and improve worker outcomes[10,11]. Studies across Asia have demonstrated the effectiveness of low-cost, contextually adapted strategies in enhancing posture, reducing pain, and improving job satisfaction[12,13].

Despite these advances, many SMEs continue to underprioritize ergonomics due to inadequate knowledge, limited training, and weak policy enforcement[2,14.] Considering the significant share of the workforce employed in SMEs across Asia, there is a pressing need for scalable and cost-effective ergonomic solutions tailored to these environments. This systematic review aims to synthesize empirical evidence from studies conducted between 2020 and 2024 on ergonomic interventions implemented in SMEs across Asia and other LMICs. It identifies key intervention types, evaluates health outcomes, and highlights implementation challenges to guide future workplace health strategies.

2 METHODOLOGY

2.1 Protocol and Reporting Standards

This systematic review was conducted following the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines[15] which provide a standardized framework to enhance methodological transparency and reproducibility in health-related literature reviews. A four-phase flow diagram and 27-item checklist were used to guide reporting, study selection, and data synthesis[16,17,18].

2.2 Search Strategy

A comprehensive search was performed across four electronic databases: PubMed, Scopus, IEEE Xplore, and Google Scholar, covering studies published from January 2019 to April 2024. The search strategy included combinations of Medical Subject Headings (MeSH) and free-text keywords related to "ergonomic interventions," "musculoskeletal disorders (MSDs)," "occupational exposure," and "small and medium enterprises (SMEs)." Boolean operators (AND/OR) and database-specific syntax were applied to optimize the sensitivity and specificity of the search. All retrieved records were imported into a reference manager, and duplicate entries were removed. The detailed search terms and strings used in each database are presented in Table 1.

Table 1: Search process information from databases.

Search Database	Search Term	Search Number
PubMed	("Ergonomics"[Mesh] OR "Ergonomics"[All Fields]) AND ("Musculoskeletal Pain"[Mesh] OR "Musculoskeletal Diseases"[Mesh]) AND (training [All Fields] OR education [All Fields] OR guidelines [All Fields])	1
IEEE Xplore	("Ergonomic Interventions" OR "Ergonomic Solutions" OR "Ergonomic Practices" OR "Ergonomic Techniques") AND ("Musculoskeletal Disorders" OR "Musculoskeletal Discomfort" OR "Muscle Pain" OR "Muscle Strain" OR "Muscle Fatigue" OR "Muscle Soreness")	2
Google Scholar	"Ergonomic Interventions" AND ("Musculoskeletal Discomfort" OR "Muscle Pain" OR "Muscle Strain") ("Ergonomic Interventions" AND Musculoskeletal Discomfort AND small medium industries)	3
Scopus	TITLE-ABS-KEY ("Ergonomic Interventions" OR "Ergonomic Solutions") AND TITLE-ABS-KEY ("Musculoskeletal Discomfort" OR "Muscle Pain") TITLE-ABS-KEY ("Ergonomic Interventions at small, medium industry")	4

2.2.1 Selecting the Studies (Eligibility and Screening)

Titles and abstracts were independently screened by two reviewers. Full texts of potentially relevant studies were retrieved and assessed based on predefined inclusion and exclusion criteria (see Table 2).

Studies were included if they:

- Focused on workplace ergonomic interventions.
- Reported quantitative outcomes related to MSDs or ergonomic risk.
- Involved worker populations in SMEs.
- Were peer-reviewed empirical studies in English.

Excluded studies included review papers, grey literature, editorials, conference abstracts, and those lacking intervention data. All discrepancies in selection were resolved by discussion between reviewers

Table 2: Inclusion and exclusion criteria for the relevant literature search.

Inclusion Criteria	Exclusion Criteria
Addressed the research question on ergonomic interventions and MSDs	Did not directly address the research question
Peer-reviewed academic publications	Non-academic or grey literature
Focused on workplace ergonomics or ergonomic interventions	Focused on unrelated workplace factors or lacked intervention scope
Investigated musculoskeletal pain or muscle fatigue as primary outcomes	Studied pain/fatigue not related to MSDs
Reported empirical findings with a clearly defined methodology	Lacked empirical results or methodological transparency

2.3 Study Selection Process

All titles and abstracts retrieved were screened independently by two reviewers. Studies that met the eligibility criteria were reviewed in full text. Disagreements between reviewers were resolved through consensus. The number of records at each screening phase is depicted in the PRISMA 2020 Flow Diagram (Figure 1).

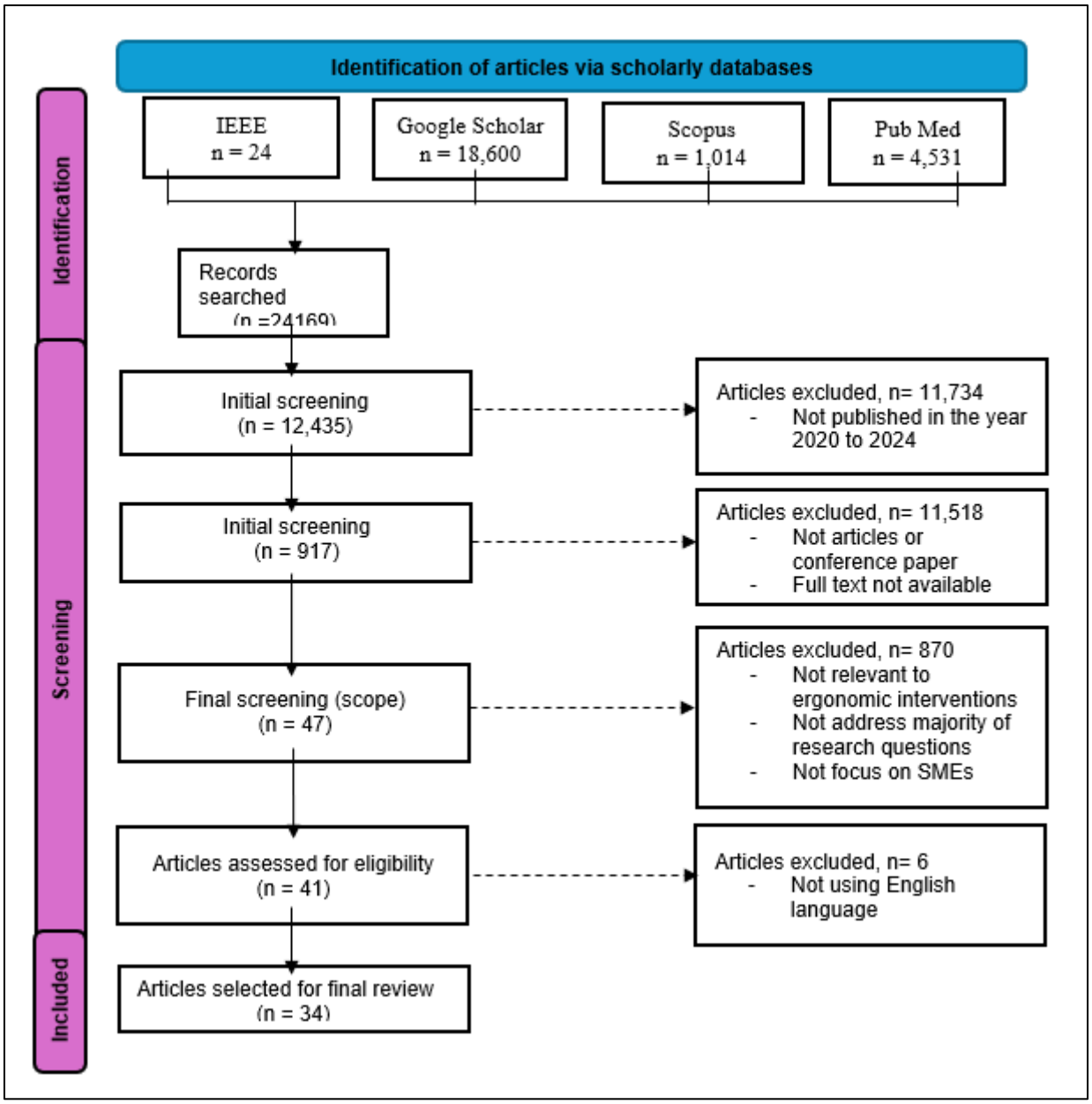

Figure 1: Study selection process for this systematic review (Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Flowchart

2.4 Extracting the Data

Data extraction was performed independently by two reviewers using a standardized extraction template designed to ensure consistency, completeness, and transparency. For each included study, key information was systematically recorded, including: the name of the first author, year of publication, country of study, the specific SME industry or sector examined, the ergonomic intervention applied, the assessment tools used, and the main findings. The outcomes of interest included changes in musculoskeletal disorder (MSD) symptoms, ergonomic risk levels, and health or productivity improvements post-intervention. This process ensured that extracted data could be meaningfully compared and synthesized despite the diversity in methods and outcomes reported across studies. Any discrepancies between reviewers were resolved through discussion to ensure reliability in the final dataset.

2.5 Synthesizing the Data

Given the heterogeneity in study designs, intervention modalities, outcome measures, and ergonomic evaluation tools, a meta-analysis was not appropriate. As such, a narrative and descriptive synthesis was undertaken, following the PRISMA 2020 framework. This approach enabled structured comparison across diverse settings while preserving the contextual nuances of each study.

The synthesis categorized studies according to four main analytical dimensions:

Type of ergonomic intervention: Training-based interventions (e.g., posture education, lifting techniques), workstation redesigns (e.g., tool and seating modifications), and multi-component approaches combining both physical and educational strategies.

Industry or sector: Studies were grouped into manufacturing (e.g., textiles, garments, metal casting), agriculture, administrative and clerical services, and informal/traditional sectors (e.g., weaving, transport, handicrafts).

Assessment tools used: A mix of observational tools (RULA, REBA, QEC, OWAS, NIOSH Lifting Equation), self-reported questionnaires (NMQ, CMDQ, VAS), and biomechanical assessments (sEMG, grip strength, motion capture) were employed.

Health and ergonomic outcomes: These included reported reductions in musculoskeletal symptoms, improved posture scores, enhanced safety practices, increased worker satisfaction, and reductions in absenteeism.

Table 3 presents the characteristics of the 30 included studies. Most of the studies were conducted in Asia, particularly in India, Indonesia, Iran, and Malaysia, with a few studies originating from Africa (Uganda, Ethiopia) and Latin America (Peru, Brazil). The most frequently addressed sectors were manufacturing (especially metal casting, textile, and food production), followed by informal craft industries such as weaving and pottery, and administrative or agricultural sectors. The interventions applied varied but often included posture training, participatory ergonomics, workstation modifications, and ergonomic tool redesign. A wide range of ergonomic tools was used across the studies, with RULA, REBA, QEC, and NMQ being the most applied. All included studies reported measurable improvements in ergonomic risks or MSD-related symptoms. For instance, several studies observed significant improvements in posture scores, reductions in reported musculoskeletal pain, and increased ergonomic awareness following intervention.

Table 3: Full Characteristics of Included Studies

Author (Year)	Country	Industry/Sector	Intervention Focus	Tool Used	Key Outcome
Tamale et al. (2024)[19]	Uganda	Desludging	Equipment provision, lifting training, posture awareness, job rotation	NMQ	WMSDs significantly linked to equipment access and perceived effort
Chandra & Arora (2024)[20]	India	Welding	Posture training, adjustable benches, ergonomic guidelines	RULA	Improved posture, reduced discomfort in upper body
Ahmad et al. (2021)[21]	Pakistan	Textile	Workplace redesign, seating, protective equipment	REBA	Lowered ergonomic posture risk
Aquino-Rojas et al. (2022)[11]	Peru	Clothing accessories	Lean + ergonomic redesign, simulation	RULA, REBA, NIOSH	Reduced MSD risk and absenteeism
Soewardi et al. (2020)[22]	Indonesia	Handicraft	Participatory ergonomics, stakeholder engagement	Nordic Body Map	Primary MSD prevention through ergonomic aids
Widodo et al. (2020)[13]	Indonesia	Bag production	Tool redesign for gluing/sticking	REBA, WERA, NBM	Improved posture scores, reduced discomfort
Susihono & Adiatmika (2021)[23]	Indonesia	Metal casting	SHIP model, ergonomic ladles, follow-ups	Weekly assessments	Decreased fatigue and MSD symptoms

Susana & Putra (2023)[24]	Indonesia	Pottery	Tool redesign using anthropometry	NBM	Physical workload reduction via custom tools
Karuppiah et al. (2020)[25]	India	Leather garments	SME awareness, ergonomic factor assessment	FAHP, Likert	Highlighted ergonomic design priorities
Randrianarivelo et al. (2022)[26]	Canada	Manufacturing SMEs	OHS management evaluation, risk control	Survey	Identified gaps in SME OHS practices
Humaizi & Hamid (2023)[27]	India	Farming	Workstation redesign, exoskeletons, monitoring	REBA, RULA	Reduced physical demands via high-tech ergonomics
Bashtani et al. (2021)[28]	Iran	Workshops	Training, tool/work height adjustments	REBA	Improved posture, efficiency
Khalaji et al. (2020)[29]	Iran	Food factory	8-week intervention, satisfaction improvement	NMQ, QEC, VAS	Pain alleviation and improved job satisfaction
Babatunde (2022)[30]	Uganda	Sugar factory	Organizational and workstation redesign	QEC	Reduced MSD prevalence after intervention
Ruslan et al. (2024)[29]	Malaysia	Warehouse	Risk assessment, wellness program, training	REBA, ERA	Improved ergonomic compliance and reduced risk
Suherdin et al. (2024)[30]	Indonesia	Welding	PPE, posture training, photokeratitis prevention	NBM	Reduced MSD and eye strain
Gayathri Devi (2019)[31]	India	Weaving	Low-cost tool redesign, exercises	Interviews, grip strength	Raised ergonomic awareness, improved safety
Widodo et al. (2022)[32]	Indonesia	Tofu cutting	Tool prototyping, posture simulation	REBA, Catia	Improved posture and workstation design
Hailu Tesfaye et al. (2023)[33]	Ethiopia	Small business cashiers	Physical activity promotion, posture maintenance, alcohol use guidance	NMQ	Health behavior changes linked to reduced MSD symptoms
Andriani et al. (2021)[34]	Indonesia	Metal fabrication	Lifting tools, posture improvement, machine training	REBA, NMQ	Improved safety and posture awareness
Lee et al. (2020)[35]	Brazil	Administrative	Workstation adjustments,	NMQ, pain scale	Primary MSD prevention via

			supervision, ergonomic modification		posture improvement
Shakerian et al. (2023)[36]	Iran	Craft industry	Posture correction, workload management, education	QEC, CMDQ	Improved comfort, reduced strain in seated work
Kataria et al. (2022)[37]	India	Metal casting	Sit-stand stools, work-rest schedule, job rotation	REBA, DHM	Reduced exposure to physical strain and fatigue
Kataria et al. (2022)[38]	India	Foundry	Tool redesign, manual handling training, awareness programs	NMQ, RULA, BSAA	Workplace ergonomics improved using low-cost tools
Esmaeili et al. (2023)[39]	Iran	Foundry	Training, height adjustment, workstation modifications	CMDQ, QEC	Discomfort scores improved after 6–12 month intervention
Araujo et al. (2024)[40]	Peru	Garment manufacturing	Posture training, active breaks, ergonomic redesign	RULA, OCRA	Active breaks and redesign lowered WMSD risk
Estember & Espinosa (2020)[41]	Philippines	Transport drivers	CMDQ/RULA evaluation, driver-focused ergonomics	CMDQ, RULA	Prevention of discomfort through tiered interventions
Sharma & Ramkumar (2023)[42]	India	Machinery foot-pedal use	Foot-pedal design, sEMG fatigue analysis	sEMG, strain gauges	Muscle fatigue reduced via ergonomic pedal design
Jafarian et al. (2023)[43]	Iran	Automobile manufacturing	Team lifting, roller adjustments, job rotation	QEC, motion capture, force plates	Improved material handling safety
Chithrananda & Jothirathna (2024)[44]	India	Apparel	Training, participatory approach, posture & lighting changes	REBA, OWAS	Posture optimization and ergonomic awareness improved

2.6 Risk of Bias, Limitations and Registration

This systematic review adopted a narrative and descriptive synthesis approach, as a meta-analysis was not feasible due to the substantial heterogeneity in study designs, intervention types, outcome measures, and ergonomic assessment tools. While no formal risk-of-bias tools such as RoB 2 or ROBINS-I were employed, all included studies were qualitatively assessed for methodological quality, with attention to reporting clarity, internal consistency, and transparency of intervention reporting. Likewise, the certainty of evidence (e.g., using GRADE) and publication bias were not formally evaluated, reflecting the exploratory and descriptive scope of this synthesis. This review was not registered in PROSPERO, and no pre-specified protocol was made publicly available. However, the review process followed the PRISMA 2020 guidelines for transparency and completeness. The study selection process is depicted in the PRISMA 2020 flow diagram (refer to Figure 1), and Table 4 showed the summary checklist of PRISMA items is presented to demonstrate compliance with internationally accepted standards for systematic reviews.

Table 4: PRISMA 2020 Checklist Summary

Section and Topic	Checklist Item	Reported (Yes/No)
Title	Identify the report as a systematic review.	Yes
Abstract	Structured summary of review.	Yes
Rationale	Describe the rationale for the review.	Yes
Objectives	Provide explicit review objectives.	Yes
Eligibility criteria	Specify inclusion and exclusion criteria.	Yes
Information sources	Specify all databases searched.	Yes
Search strategy	Present full search strategy.	Yes
Selection process	Describe the study selection process.	Yes
Data collection process	Describe how data were extracted.	Yes
Data items	List all variables and outcomes extracted.	Yes
Study risk of bias assessment	Describe methods used to assess risk of bias.	No (qualitative only)
Effect measures	Specify effect measures for outcomes.	Not applicable
Synthesis methods	Describe synthesis methods.	Yes
Reporting bias assessment	Describe methods to assess reporting bias.	No
Certainty assessment	Describe methods to assess certainty of evidence.	No
Study selection	Provide numbers of studies screened and included.	Yes
Study characteristics	Present characteristics of included studies.	Yes
Risk of bias in studies	Present assessments of risk of bias.	No
Results of individual studies	Present summary data for each study.	Yes
Results of syntheses	Summarize synthesis results.	Yes
Discussion	Interpret results and implications.	Yes
Limitations of evidence	Discuss limitations in evidence included.	Partially
Limitations of review processes	Discuss review process limitations.	Partially
Conclusions	Provide general interpretation of results.	Yes
Registration and protocol	Provide registration information.	No
Support	Describe sources of funding.	Pending
Competing interests	Declare conflicts of interest.	Pending
Availability of data, code, materials	State availability of materials.	No

3 RESULT

3.1 Study Selection and Publication Trends

A total of 30 empirical studies published between 2019 and 2024 met the eligibility criteria and were included in this systematic review. As illustrated in Figure 2, the highest number of included studies was published in 2023 and 2024 (n = 6 each), indicating a recent surge in research interest on ergonomic interventions in small and medium-sized enterprises (SMEs). This was followed by 2020 (n = 5), 2022 (n = 4), 2021 (n = 3), and 2019 (n = 1). The steady increase in scholarly output, especially in the post-pandemic years, reflects growing recognition of workplace ergonomics as a critical dimension of occupational health and safety in SMEs.

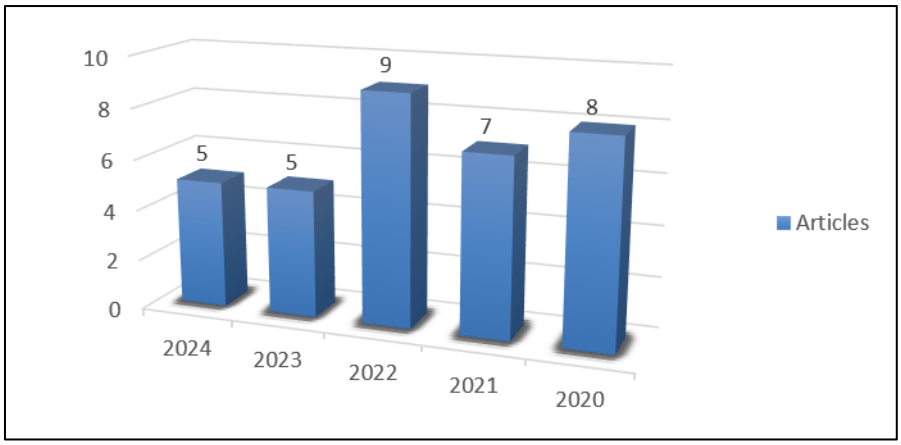

Figure 2: Number of included studies by publication year (2019-2024)

3.2 Geographic Distribution of Studies

The country-wise distribution of the 30 included studies is shown in Figure 3. The highest number of studies originated from India and Indonesia, with seven publications each, followed by Iran (n = 6). Countries such as Uganda, Peru, and Malaysia contributed two studies each, while Pakistan, Canada, Ethiopia, Brazil, and the Philippines each contributed one study.

This distribution highlights a strong regional representation from South and Southeast Asia, reflecting a focused research agenda on occupational ergonomics in developing economies. It also emphasizes that MSDs and ergonomic concerns in SMEs are not only widespread but disproportionately examined in low- and middle-income countries, where resource constraints pose unique challenges for implementing occupational safety measures.

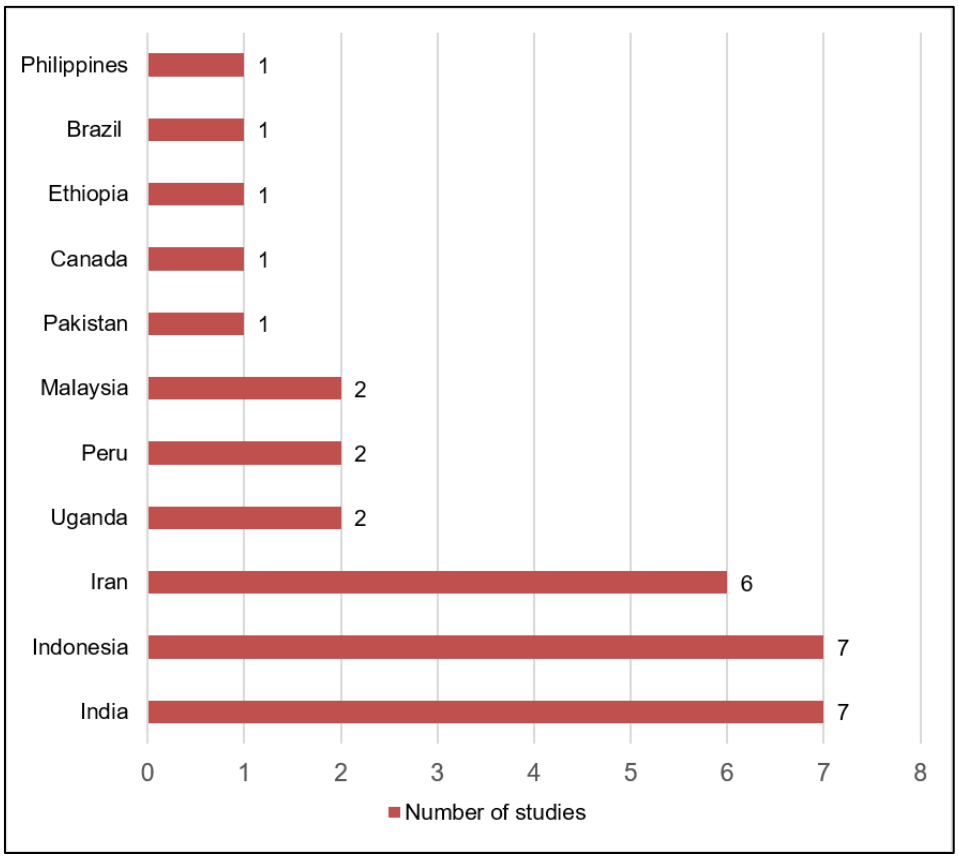

Figure 3: Distribution of included studies by country

3.3 Prevalence and Impact of Musculoskeletal Disorders (MSDs)

Across the reviewed studies, the prevalence of work-related musculoskeletal disorders (MSDs) ranged from 29.7% among desludging operators to 75.4% among cashiers. Frequently affected anatomical regions included the lower back, neck, shoulders, wrists/hands, and knees, consistent across sectors such as manufacturing, agriculture, administrative services, and informal labor.Beyond physical discomfort, MSDs were also linked to decreased work ability, increased absenteeism, and lower job satisfaction. For instance, in one cross-national study, 63% of SMEs identified MSDs as a major contributor to productivity loss. Evidence from Iran, Indonesia, and India confirmed similar trends, underscoring the pervasive burden of MSDs in labor-intensive SMEs.

3.4 Effectiveness of Interventions

Several types of ergonomic interventions were implemented across the studies, demonstrating statistically significant improvements in both worker health and performance. Interventions included:

- Workstation redesign (e.g., adjustable benches, ergonomic toolkits)
- Task rotation and active breaks
- Postural training and awareness programs
- Ergonomic equipment modifications

Outcomes reported included reductions in MSD symptoms, improvements in posture scores (REBA, RULA), and increased worker satisfaction and productivity. For example:

- A study in India reported a reduction in RULA scores from 5.91 to 2.93 post-intervention.
- Another study observed an 81.8% improvement in REBA risk levels following ergonomic simulation.

These findings collectively demonstrate the positive impact of targeted ergonomic strategies on reducing biomechanical stress and enhancing workplace safety in SMEs.

Assessment Tools and Ergonomic Risk Evaluation

- Various validated ergonomic assessment tools were employed across the reviewed studies. These included:
- Observational tools: REBA, RULA, QEC, OWAS, OCRA, NIOSH Lifting Equation
- Self-report questionnaires: Nordic Musculoskeletal Questionnaire (NMQ), CMDQ, VAS
- Physiological/biomechanical methods: sEMG, grip strength, motion capture

These tools enabled identification of high-risk postures, awkward movements, and prolonged static workloads, with over 60% of postures classified as “high” or “very high risk” in tasks involving manual material handling or repetitive actions.

3.5 Implementation Challenges and Recommendations

Despite their effectiveness, implementation of ergonomic interventions faced several challenges:

- Low ergonomic awareness among workers and supervisors
- Outdated or inflexible equipment and tools
- Limited financial and managerial commitment
- Resistance to behavioral and operational change

Several studies recommended participatory ergonomics, combining top-down and bottom-up engagement, and highlighted the importance of context-appropriate, low-cost ergonomic redesigns, particularly in traditional crafts and informal sectors.

4 DISCUSSION

This systematic review synthesizes evidence from 30 empirical studies exploring the effectiveness of ergonomic interventions in mitigating work-related musculoskeletal disorders (WMSDs) among workers in small and medium-sized enterprises (SMEs). The findings reveal a high prevalence of MSDs across diverse occupational groups and sectors—ranging from desludging operators (29.7%) to cashiers (75.4%) highlighting the pervasive nature of ergonomic risks in resource-constrained workplaces.

4.1 WRMSD Prevalence and Ergonomic Risk Factors in SMEs

Consistent with earlier studies, the most affected anatomical regions include the lower back, neck, shoulders, wrists/hands, and knees—regions typically associated with static postures, repetitive tasks, and manual material handling. These risks were particularly elevated in labor-intensive occupations such as welding, manufacturing, and craft-based trades[20,32]. Evidence from Iran, Indonesia, and India countries with large SME labor forces further supports the assertion that ergonomic hazards contribute substantially to lost productivity and diminished worker well-being[36,46].Notably, multiple studies reported declines in work ability, increased absenteeism, and low job satisfaction as direct consequences of MSDs,affirming the need for structural ergonomic interventions within occupational health policy frameworks, especially for SMEs which often lack formalized health and safety systems.

4.2 Effectiveness of Ergonomic Interventions

The reviewed literature offers strong support for the efficacy of targeted ergonomic interventions. Workstation redesigns, ergonomic tool modification, posture education, and participatory training were among the most impactful strategies. Post-intervention improvements included statistically significant reductions in ergonomic risk scores such as the decrease in RULA scores from 5.91 to 2.93[20] and an 81.8% improvement in REBA scores following simulation-based training[11]. These improvements were not only clinically relevant but also practical, with several studies noting enhancements in worker efficiency, reduced fatigue, and improved satisfaction[46,47].

The case of tofu-cutting tool redesign[32] offers a particularly compelling example of low-cost engineering modifications that reduced REBA scores from 12 to 4. Similarly, posture training integrated with task rotation in metal fabrication and apparel sectors contributed to tangible reductions in musculoskeletal discomfort[38,48].

4.3 Application of Ergonomic Assessment Tools

A variety of validated tools were used to evaluate pre- and post-intervention outcomes. Observational methods like REBA, RULA, QEC, and OCRA were frequently applied and demonstrated consistent sensitivity in detecting posture-related risks. Self-reported tools such as the Nordic Musculoskeletal Questionnaire (NMQ) and CMDQ enabled nuanced evaluation of discomfort and symptom localization, while biomechanical tools for example sEMG, motion capture provided objective data on muscular strain and fatigue. Importantly, over 60% of postures were classified as “high” or “very high risk” before intervention, suggesting that routine ergonomic evaluations using these tools are crucial in SMEs. These findings underscore the value of integrating ergonomic risk assessments into occupational safety protocols and emphasize the role of evidence-based interventions in reducing physical burden among workers.

4.4 Challenges in Implementation

Despite the demonstrated benefits of ergonomic interventions, several barriers to effective implementation were identified. These included low awareness of ergonomic principles, lack of managerial commitment, outdated infrastructure, financial constraints, and resistance from both workers and supervisors[25]. This barrier should overcome by participatory ergonomics that emerged as a key recommendation. This approach involves engaging workers directly in the redesign of work processes and tools, thus promoting both ownership and sustainability of ergonomic practices[49.] Additionally, face-to-face training, sector-specific toolkits, and integration of ergonomic education into routine workflows were suggested as cost-effective and scalable strategies.

5 CONCLUSION

This systematic review underscores the high burden of work-related musculoskeletal disorders (WMSDs) among workers in small and medium-sized enterprises (SMEs), particularly in resource-constrained settings. The findings demonstrate that ergonomic interventions—such as workstation redesign, postural training, participatory ergonomics, and tool modification—are effective in reducing ergonomic risks, alleviating musculoskeletal symptoms, and improving worker productivity and well-being. Validated ergonomic assessment tools (e.g., REBA, RULA, QEC, NMQ) played a crucial role in identifying high-risk tasks and quantifying intervention outcomes. However, implementation challenges such as low ergonomic awareness, financial limitations, and infrastructural constraints remain significant barriers, especially in low- and middle-income countries. To ensure sustainable occupational health improvements in SMEs, future initiatives should emphasize low-cost, context-specific ergonomic solutions, integrate training and organizational support, and adopt participatory approaches that empower workers. Longitudinal and cost-effectiveness studies are needed to strengthen the evidence base and guide policy interventions. Investing in ergonomics is not only a health imperative but also a strategic move toward enhancing workplace efficiency and equity in developing economies.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

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