



Participatory Ergonomic Approaches for the Prevention of Musculoskeletal Disorders among Informal Workers: A Scoping Review

Cita Fitria Putri^{1*}, Ekawati¹

¹Universitas Diponegoro

*Corresponding Author: citafitria@gmail.com

Abstract

Musculoskeletal disorders (MSDs) are a significant global health concern, particularly impacting informal workers who lack organized occupational health services. Participatory ergonomic approaches present a solution by engaging workers in recognizing hazards and improving their work settings. This scoping review outlines evidence on participatory ergonomic interventions for preventing MSDs in informal work environments. A search was performed across PubMed, Scopus, ProQuest, EBSCO, ScienceDirect, and Google Scholar for studies published up to 2025. Qualified studies focused on informal workers, used participatory ergonomic approaches, and documented MSD prevention outcomes. Ten studies were selected for analysis. Interventions primarily focused on modifying tools, workstations, and facilities based on workers' body measurements and job requirements. Other approaches included ergonomic aids, stretching programs, and workplace layout reorganization. Workers participated through interviews, focus groups, observations, and risk assessments. Results showed reduced musculoskeletal complaints by up to 47.9%, improved posture, reduced workload, and increased productivity. Implementation barriers included limited finances, traditional work practices, lack of ergonomic awareness, and resistance to change. These findings highlight the need to customize interventions for specific socio-economic and cultural contexts. Future studies should examine methods for ensuring long-term viability and cultural adaptation of these interventions.

Keywords: informal workers, musculoskeletal disorders, participatory ergonomic

Pendekatan Ergonomi Partisipatif untuk Pencegahan Gangguan Muskuloskeletal pada Pekerja Sektor Informal

Abstrak

Gangguan muskuloskeletal (Musculoskeletal Disorders/MSDs) merupakan masalah kesehatan global yang signifikan, terutama pada pekerja informal yang tidak memiliki layanan kesehatan kerja yang terorganisir. Pendekatan ergonomi partisipatif menawarkan solusi dengan melibatkan pekerja dalam mengidentifikasi bahaya dan memperbaiki lingkungan kerja. Tinjauan ini memaparkan bukti terkait intervensi ergonomi partisipatif untuk pencegahan MSDs pada lingkungan kerja informal. Pencarian dilakukan di PubMed, Scopus, ProQuest, EBSCO, ScienceDirect, dan Google Scholar untuk studi yang diterbitkan hingga tahun 2025. Studi memenuhi syarat jika berfokus pada pekerja informal, menggunakan pendekatan ergonomi partisipatif, dan mendokumentasikan hasil pencegahan MSDs. Terdapat sepuluh studi yang terpilih untuk dianalisis. Intervensi terutama difokuskan pada modifikasi alat, stasiun kerja, dan fasilitas berdasarkan ukuran tubuh pekerja serta tuntutan pekerjaan. Pendekatan lain mencakup alat bantu ergonomi, program peregangan, dan reorganisasi tata letak tempat kerja. Pekerja berpartisipasi melalui wawancara, diskusi kelompok terfokus, observasi, dan penilaian risiko. Hasil menunjukkan penurunan keluhan muskuloskeletal hingga 47,9%, perbaikan postur, penurunan beban kerja, dan peningkatan produktivitas. Hambatan pelaksanaan meliputi keterbatasan keuangan, praktik kerja tradisional, kurangnya kesadaran ergonomi, dan resistensi terhadap perubahan. Temuan ini menyoroti perlunya penyesuaian intervensi dengan konteks sosial ekonomi dan budaya tertentu. Penelitian selanjutnya perlu mengkaji metode untuk memastikan keberlanjutan jangka panjang dan adaptasi budaya dari intervensi ini.

Kata Kunci: ergonomi partisipatif, gangguan muskuloskeletal, pekerja informal

Introduction

Musculoskeletal disorders (MSDs) represent one of the most prevalent occupational health conditions globally, contributing to long-term pain, disability, and reduced functional capacity among workers. MSDs affect over 1.71 billion people worldwide, substantially impacting quality of life and imposing a considerable economic burden through healthcare costs and productivity losses (Malliaropoulos & Daoukas, 2025). The global prevalence and burden of MSDs are exceptionally high, accounting for 21.3% of total years lived with disability globally and 6.7% of total global disability-adjusted life years (DALYs). This makes MSDs the second highest cause of disability worldwide, after mental and behavioral problems (Woolf, 2015). Interestingly, while communicable diseases were the focus of global health priorities in the past century, the increasing average age and decreased death rates have led to a rise in non-communicable diseases like MSDs (Woolf, 2015).

Work-related musculoskeletal disorders are particularly burdensome, associated with high rates of disability, absenteeism, presenteeism, loss of productivity, longer recovery timeframes, and workers' compensation costs (Hutting et al., 2020). The healthcare costs associated with MSDs are substantial, emphasizing the economic strain they impose. For instance, In Belgium, MSDs cost an average of 3 billion € in medical expenses and 2 billion € in indirect costs per year, with low back pain being the most costly (Gorasso et al., 2023). In Ontario, Canada, the total costs for MSD-related care were \$1.6 billion in 2013-2014, with an additional \$169 million for MSD-related imaging, bringing the total cost estimate to \$1.8 billion (Power et al., 2022). MSDs not only affect individuals' quality of life and economic independence but also impose significant costs on society due to health and social care expenses and work loss (Woolf, 2015).

Despite the growing global burden, musculoskeletal health remains a low priority in public health policy, underscoring the need for greater attention—particularly in informal work settings, where MSDs are a major occupational health concern. Informal workers often exposed to physical risk factors, such as repetitive movements, forceful exertions, awkward postures, and prolonged static positions (Matsuzaki et al., 2025; Soares et al., 2019). These factors are compounded

by the lack of ergonomic considerations and proper equipment in informal workplaces. For instance, manual-working farmers, who often operate in informal settings, show high occurrence rates of MSDs, particularly in the lower back (71.4%), fingers (62.1%), and shoulders (56.4%) (Jain, Meena, Dangayach, & Bhardwaj, 2018). The high prevalence of MSDs among manual-working farmers underscores their heightened occupational health risks and the urgent need for targeted interventions and better policies.

The informal nature of the work environment makes it challenging to implement standardized ergonomic interventions or enforce safety regulations. In such settings, there is often a lack of structured organizational hierarchy, clear job roles, or established protocols, making it difficult to introduce and maintain consistent safety measures (Capodaglio, 2022). Additionally, many informal workers have limited access to healthcare and may continue working despite pain or injury, exacerbating their conditions. This condition may result in long-term health problems and decreased productivity over time (Oladosu, Khai, & Asaduzzaman, 2023). The absence of formal training programs or safety education further compounds the issue, leaving workers unaware of proper ergonomic practices and potential risks. Moreover, the financial constraints often associated with informal work environments may limit the availability of ergonomic equipment or resources necessary for implementing safety measures (Ahmed, Shaukat, Usman, Nawaz, & Nazir, 2018; Chen, 2016).

Consequently, addressing MSDs in informal work requires innovative, low-cost solutions and community-based approaches that consider the unique constraints and cultural contexts of these work settings. Participatory ergonomic (PE) approaches, which actively involve workers in identifying risks and developing practical solutions, shows promise as an effective strategy for preventing MSDs among informal workers. These approaches can empower workers to take ownership of their health and safety, leading to more sustainable improvements in workplace practices (Capodaglio, 2022). However, the extent and effectiveness of such interventions in the informal sector remain underexplored. This scoping review aims to map the existing evidence on participatory ergonomic approaches for the

prevention of MSDs among informal workers and identify gaps to inform future research and practice.

Methods

In light of the limited research data, the scoping review approach was chosen as the most appropriate strategy. The primary objective was to review existing literature on the topic, identify key concepts, recognize gaps in knowledge, and highlight areas requiring further research. This review followed the methodological framework proposed by Arksey and O'Malley, as well as enhancements recommended by the Joanna Briggs Institute (JBI) (Westphal et al., 2021). The stages of the scoping review included:

Identifying the Research Question

The research question was developed using the Population, Concept, and Context (PCC) framework recommended by JBI. The Population of interest was informal workers; the Concept was participatory ergonomic interventions; and the Context was the prevention of musculoskeletal disorders (MSDs). The guiding research questions were:

- What types of participatory ergonomic interventions have been implemented among informal workers?*
- How are informal workers involved in the participatory ergonomic intervention process?*
- What are the reported outcomes of these interventions?*
- What barriers or challenges are encountered in implementing participatory ergonomic interventions in informal work settings?*

Identifying Relevant Studies

A comprehensive interdisciplinary search was conducted in the following databases: PubMed, Scopus, ProQuest, EBSCO, ScienceDirect, and Google Scholar. The search aimed to identify empirical studies reporting participatory ergonomic interventions for the prevention of MSDs among informal workers. A combination of keywords, synonyms, and subject headings related to the core concepts were used, including: "*participatory ergonomics*", "*ergonomic intervention*", "*musculoskeletal disorders*", "*MSDs*", "*informal workers*", "*informal employment*", "*occupational health*",

and "*work-related musculoskeletal symptoms*". Boolean operators (*AND*, *OR*) were applied to combine terms. The search was conducted in both English and Bahasa Indonesia. To ensure inclusion of the most recent evidence, the search was limited to articles published between 2015 and 2025.

Selecting Studies for Analysis

All identified records were imported into reference management software such as Mendeley, where duplicates were removed. The titles and abstracts of the remaining studies were subsequently assessed for relevance according to the inclusion and exclusion criteria. This screening was conducted independently by two reviewers. When differences in judgments occurred, the reviewers discussed the discrepancies and agreed on a final decision by reaching consensus. The complete selection process is illustrated in Figure 1.

The inclusion criteria encompassed empirical studies that reported on participatory ergonomic interventions, specifically targeting informal workers or those engaged in informal employment, with the aim of preventing or reducing musculoskeletal disorders. The exclusion criteria included reviews, theoretical articles, book chapters, editorials, and conference proceedings without full texts, as well as studies that did not utilize participatory ergonomic methods or were solely conducted in formal or strictly regulated work settings. The screened records were then assessed for eligibility through full-text review to determine final inclusion based on the predefined criteria. As this review synthesizes previously published studies, all included primary research was assumed to have obtained ethical approval in accordance with the guidelines of their respective institutions.

Data Charting and Analysis

A standardized data extraction form was created to systematically record pertinent details from the chosen studies. The data gathered included the study's title, author(s), publication year, country where the study was conducted, the population targeted, types of ergonomic interventions, methods of participation, tools or instruments used to assess MSDs outcomes and risk factors, outcomes measured (such as a decrease in MSDs, enhanced work posture, or increased productivity), and any challenges or

limitations reported. The extracted data were synthesized descriptively, focusing on patterns, themes, and variations across studies. Findings were then grouped under key domains such as types of participatory ergonomics, worker participation strategies, outcomes, and implementation barriers.

Results and Discussion

This scoping review analyzed a total of ten studies conducted in various countries, including Indonesia, South Korea, Iran, and Malaysia. The study populations comprised informal workers from a range of sectors, such as home-based industries (e.g., tofu pressing, batik, laundry), agriculture (e.g., fruit farmers, pistachio farm workers, pineapple plantation workers), informal construction (e.g., brick makers) and dairy farming as detailed in Table 1. To better understand how ergonomic risks were addressed in these diverse settings, this review categorized the types of participatory ergonomic interventions implemented across the included studies.

Types of Participatory Ergonomic Interventions

Across the reviewed studies, participatory ergonomic (PE) interventions were diverse, with the most common approach involving the redesign of work tools and facilities to align with workers' anthropometric data and job tasks. These included the development of ergonomic flour dough mixers, powered carts, modified workstations, and low-cost assistive devices such as feed bag holders and vacuum pumps. Other interventions encompassed the provision of personal protective equipment (PPE) and ergonomic tools, posture correction, implementation of stretching exercises, ergonomics training such as *Kiken Yochi Training (KYT)* to enhance hazard awareness, and improvements in workplace layout and environmental conditions.

Redesigning tools and equipment was a frequently employed strategy. Research focused on creating ergonomic flour dough mixers, motorized carts, and affordable assistive devices—like feed bag holders and vacuum pumps—aimed to lessen manual handling burdens and better match workers' body measurements. Although these interventions were applied in various settings, they consistently led to enhanced postural comfort and a decrease in musculoskeletal risks.

Another set of research concentrated on modifying workstations, which involved altering the height of work surfaces, optimizing layouts, and enhancing the environment. These studies aimed to reduce awkward postures and repetitive movements, with several showing decreases in task cycle time and ergonomic risk scores.

Additionally, a different group of studies introduced stretching or micro-break exercise programs, all designed to lessen fatigue and musculoskeletal discomfort. Although the specific exercises varied, these interventions consistently reported short-term reductions in perceived discomfort, highlighting a similar mechanism of benefit. Additional PE interventions included the provision of personal protective equipment (PPE), ergonomic tools, posture correction strategies, and ergonomics training such as *Kiken Yochi Training (KYT)* to enhance hazard awareness. Although diverse, these interventions shared a common emphasis on increasing worker participation and awareness in identifying and mitigating ergonomic risks.

Methods of Participation

All interventions incorporated active worker participation, although the extent and nature of involvement varied across studies. Methods of participation included direct observation, structured interviews, focus group discussions (FGDs), collaborative risk assessments, and active involvement in the design, selection, and evaluation of ergonomic solutions. In most instances, workers provided essential input regarding perceived discomfort, equipment usability, and job demands, which significantly informed the intervention design. Several studies also emphasized collaboration among informal workers, business owners, researchers, ergonomists, and other stakeholders, with some forming participatory ergonomics teams to ensure a more inclusive and context-specific approach.

Assesment Tools

The studies employed various ergonomic and health assessment tools to evaluate risk and outcomes. Frequently used tools included the Nordic Body Map, Nordic Musculoskeletal Questionnaire, REBA, RULA, OWAS, and Modified Oswestry Questionnaire. Additional measures included pulse meters, fatigue

questionnaires, and modified scales for low back pain intensity and subjective satisfaction ratings.

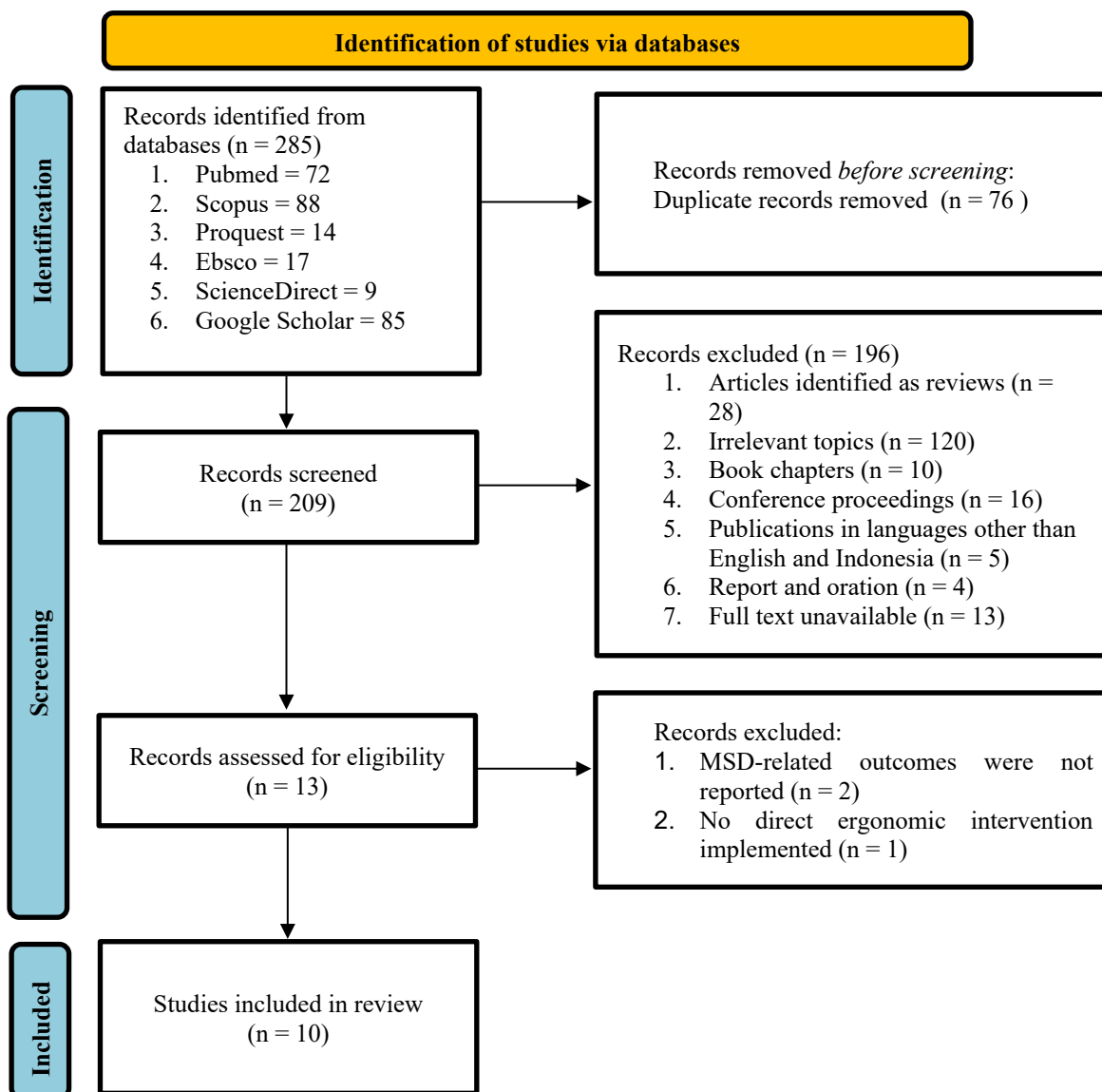


Figure 1. PRISMA Flow Diagram

Table 1. Data Extraction

Title and Author	Author, Year	Location	Population	Ergonomic Interventions	Methods of Participation	Tools	Outcomes	Barriers
Redesign of work facilities at the tofu pressing station with a participatory ergonomic approach	Erliana et al, 2024	North Aceh, Indonesia	Workers at a tofu pressing station	Redesign of work facilities according to anthropometry	Direct observation and interviews; Workers provided input and improvement ideas.	REBA	Reduction of MSD's risk; Use of more ergonomic technology; Improved production workflow; Safer work	Simple/traditional production technology; Limited resources in micro-enterprises; Small number of workers;

Title and Author	Author, Year	Location	Population	Ergonomic Interventions	Methods of Participation	Tools	Outcomes	Barriers
(Erliana, Sayuti, Abdullah, Asral, & Siagian, 2024)							environment	Dependence on old work habits
Design of Ergonomic Flour Dough Mixer with Participatory Approach to Increase Work Productivity MSME Employees (Sudana & Yusuf, 2024)	Sudana et al, 2024	Tabanan Regency, Indonesia	MSME Workers Processing Flour Dough	Design and implementation of an ergonomic flour dough mixer	Direct input from workers regarding design needs; Design based on users' anthropometric data; Adjustment of tool height, hand reach, and grip size to match workers' body dimensions.	Nordic Body Map; Pulse meter; General fatigue questionnaire	Workload decreases; Musculoskeletal complaints decrease; Work fatigue decreases; Productivity increases.	Design and manufacturing costs of the tool; 220 V electricity access is required; Initial adjustment to the new tool.
Participatory Ergonomic Interventions for Improving Agricultural Work Environment: A Case Study in a Farming Organization of Korea (Kee, 2022)	Kee et al, 2022	South Korea	Peach farmers	Engineering controls: powered cart, automatic fruit sorter, adjustable chair, protective gear, seasonal clothing. Administrative controls: education/physiotherapy, work-rest schedule, PPE and machine training.	Farmers involved in risk identification, tool selection, and intervention evaluation; Stakeholder consultation: ergonomists, farmers, and Rural Development Agency; Joint risk assessment with farmers for each work phase.	RULA; 5-item Likert scale questionnaire; RULA assessment; Average farmer satisfaction score on all aspects of the intervention was > 4.1 out of 5.	Significant reduction in musculoskeletal load related to powered equipment; Potential reduction of manual labor; Lack of ergonomic awareness; Small sample size.	Budget constraints; Environmental concerns related to powered equipment; Potential reduction of manual labor; Lack of ergonomic awareness; Small sample size.
Improvement of Working System in Mr. Wash Laundry Using Ergonomic Participatory Method (Rini & Prakoso, 2021)	Rini et al, 2021	Yogyakarta, Indonesia	Laundry workers	Redesign of the workplace and work system	Interviews and Focus Group Discussions (FGDs); Identification of complaints; Proposed design improvements; Pre- and post-intervention evaluation.	Nordic Body Map	Reduction in musculoskeletal complaints; Improved work comfort and productivity; Ergonomic design specifications	Limited number of workers; No days off; Disorganized work environment; Reliance on non-ergonomic tools; Low initial awareness of ergonomics.
Work Safety Aspects	Restuputri et al, 2021	Tuban, Indonesia	Workers in Batik Center	Improvement of physical work ergonomics	Formation of an OWAS		Reduction in musculoskel	Low worker awareness of

Title and Author	Author, Year	Location	Population	Ergonomic Interventions	Methods of Participation	Tools	Outcomes	Barriers
Using Participatory Ergonomic Approach (Restuputri, Huda, & Mubin, 2021)				environment, workspace layout, and working posture; Use of PPE; Ergonomic workplace layout design.	team consisting of researchers, business owners, workers, and supervisors; Focus Group Discussion; Work comfort questionnaires.	Nordic Body Map	etal disorder (MSD) complaints; Improvement in physical work environment; Increased productivity.	occupational safety; Deeply rooted poor posture habits; Substandard and difficult-to-modify physical environment; High workload and no days off; Potential resistance to change.
Prevalence of musculoskeletal disorders, ergonomics risk assessment and implementation of participatory ergonomics program for pistachio farm workers (Hasheminejad, Choobineh, Mostafavi, Tahernejad, & Rostami, 2021)	Hasheminejad et al, 2021	Rafsanjan county, Iran	Pistachio farmers	Improvement of tools; and facilities Modification of work systems; Ergonomics training and education.	Ergonomics training sessions; Discussion of high-risk tasks; Collection of worker suggestions; Discussion of feasibility and selection of interventions.	Nordic Musculoskeletal Questionnaire (NMQ); Manual worker Tasks Risk Assessment (ManTRA)	Decreased ManTRA risk scores (reduced exposure to ergonomic risk factors); Increased worker satisfaction.	Limited intervention time; Small sample size; Incomplete monitoring of compliance; Influence of individual factors and secondary jobs; Evaluation based only on self-reported symptoms; Lack of prior ergonomics training.
Posture Improvement and Stretching Treatment Based on Participatory Ergonomic Decrease Risk of Work Posture and Low Back Pain Intensity on	Ratu, 2020	Kupang, Indonesia	Brick workers	Improvement of working posture; Stretching (William Flexion Exercise) performed before and after work.	Involvement of workers, researchers, and business owners in intervention design; Observation and video recording; Group-based education and exercise sessions.	REBA; Modified Oswestry Questionnaire	Reduction in postural risk; Decreased intensity of low back pain.	Poor postural habits already established; Lack of knowledge about ergonomics and LBP; Low attention to occupational health and safety; Work facilities not

Title and Author	Author, Year	Location	Population	Ergonomic Interventions	Methods of Participation	Tools	Outcomes	Barriers
Brick Workers in Kupang, NTT (Ratu, 2020)								suited to workers' anthropometry ; Unstructured rest habits.
Prevalence of work-related musculoskeletal disorders in agriculture workers in Korea and preventative interventions (Kee & Haslam, 2019)	Kee et al, 2019	South Korea	Farmers	Provision of ergonomic agricultural tools; Safety control interventions tailored to crop types and specific agricultural risks.	Multi-stakeholder involvement; Village-level consultation and coordination; Farmer participation in tool design revision; Intervention adjustments based on crop type and specific tasks; Evaluation conducted by farmers.	Nordic Musculoskeletal Questionnaire	Improved work efficiency and safety; High farmer satisfaction; Moderate fatigue reduction; Adjusted tools provided better comfort and safety.	Low level of agricultural mechanization ; Aging farming population; Predominantly female workforce; Cost of tool procurement and adaptation.
Low-cost ergonomic interventions to reduce risk factors for work related musculoskeletal disorders during dairy farming (Mokarami et al., 2019)	Mokarami et al, 2019	Yasuj, Iran	Dairy farm workers	Use of automatic milk transmission system; Use of vacuum pump for corn feed; Development of feed bag holder; Modification of manure shovel into ergonomic design	Training on anatomy and ergonomics; Formation of a working group (workers, managers, ergonomist); Workers proposed and selected simple ergonomic interventions	REBA	Elimination of high-risk tasks; Reduced postural risks; Improved working posture.	Poor farm economic conditions; Intervention implemented in only one farm; Limited funding; Risk evaluation conducted only using REBA; No pre- and post-intervention symptom assessment.
Reducing work-related musculoskeletal symptoms through implementation of Kiken Yochi training intervention	Ya'acob et al, 2017	Johor, Malaysia	Pineapple plantation workers	General ergonomics training; Kiken Yochi Training (KYT)	Identification of posture-related hazards; Group discussions; Corrective actions determined by participants;	Standardized Nordic Questionnaire; RULA	Reduced prevalence of musculoskeletal symptoms in ankle/feet region in the intervention group	High physical job demands remained; Worker resistance to change; KYT not implemented regularly; Lack of involvement



Title and Author	Author, Year	Location	Population	Ergonomic Interventions	Methods of Participation	Tools	Outcomes	Barriers
approach (Ya'acob, Abidin, Rasdi, Rahman, & Ismail, 2018)					Practice of "point and call" method; Active participation in selecting ergonomic solutions and practices			from supervisors or management; Reliance on traditional manual tools

Outcomes of Interventions

The majority of studies reported positive outcomes following participatory ergonomic interventions, including substantial reductions in musculoskeletal complaints—some by as much as 47.9%—lower ergonomic risk scores, decreased physical workload, improved posture, enhanced work comfort, and increased productivity. Notably, one study documented a 501.1% increase in productivity among micro, small, and medium enterprises (MSME) workers after implementing a redesigned dough mixer. Workers also expressed high levels of satisfaction with the ergonomic improvements, often scoring above 4 out of 5 on Likert-type scales.

These positive outcomes demonstrate the potential of participatory ergonomic interventions to significantly improve workplace conditions and employee well-being in MSMEs. The substantial reductions in musculoskeletal complaints and ergonomic risk scores suggest that such interventions can effectively address common health issues in small-scale industrial settings. Furthermore, the notable increases in productivity and worker satisfaction highlight the dual benefits of ergonomic improvements, benefiting both employees and employers.

Comparative analysis across studies shows that tool and equipment redesign was the most consistently effective participatory mechanism, particularly in informal and small-scale settings where manual handling tasks are physically demanding. These interventions succeeded because workers were directly involved in identifying tool-related problems and testing prototypes, which improved acceptance and usability. Workstation modifications were similarly effective in settings where constrained spaces or awkward postures were prominent concerns, while stretching or micro-break programs showed benefits primarily in contexts

involving repetitive tasks. Across these categories, interventions that actively engaged workers in problem identification and decision-making tended to yield the greatest improvements in both ergonomic outcomes and worker satisfaction.

Barriers and Challenges

Although there were positive results, several obstacles were noted. Common challenges included limited financial resources in small businesses, dependence on traditional methods, low initial awareness of ergonomics, and brief intervention periods. In informal environments, interventions sometimes encountered resistance due to ingrained work habits, a lack of prior ergonomics training, and difficulties in altering non-ergonomic tools or physical settings that were not originally designed to be adjustable. These issues clarify why some interventions were highly successful while others had less impact, highlighting the need for context-sensitive design and ongoing worker involvement.

This scoping review highlights the efficacy of participatory ergonomic (PE) interventions in improving working conditions and the well-being of workers within the informal sector. The most commonly implemented strategies involved the redesign of tools and workstations, taking into account workers' anthropometric measurements and job requirements. These interventions led to substantial reductions in musculoskeletal complaints—up to 47.9% in certain studies—enhanced ergonomic risk assessments, increased comfort, and significant productivity improvements. In the contexts of MSME, agriculture, and home-based manufacturing, PE methods proved particularly effective, as they offered context-specific solutions to local challenges.

One of the key advantages of PE is its ability to be inclusive and sensitive to context. By directly

engaging workers in pinpointing issues and crafting solutions, PE encourages a sense of ownership and acceptance of the interventions (Hignett, Wilson, & Morris, 2005; Laing et al., 2007). Additionally, it is both cost-effective and practical in settings with limited resources (Mokarami et al., 2019). Nonetheless, the approach has its drawbacks, such as requiring more time, relying heavily on the motivation and involvement of workers, and potentially encountering resistance to change, particularly in traditional work environments (Mani & Mishra, 2020).

In contrast to the formal sector, implementing PE in informal environments poses distinct challenges, such as scarce financial resources, a lack of initial understanding of ergonomics, and dependence on conventional tools (Kee, 2022). Consequently, PE strategies in the informal sector often need to be adjusted to be more adaptable and attuned to local requirements. This might involve using affordable technologies and engaging local stakeholders, like community leaders or small business proprietors, in the process of designing interventions (Laing et al., 2007; Rasmussen et al., 2016).

The results provide valuable insights for occupational health professionals, NGOs, and policymakers. To enhance the adoption of participatory ergonomics in the informal sector, it may be necessary to offer ergonomics training tailored to specific contexts, create practical guidelines using illustrations or case studies, and encourage community-driven ergonomic initiatives. Additionally, government agencies and pertinent organizations can contribute by incorporating PE into the development strategies for micro, small, and medium enterprises (MSMEs) or into local health and safety programs (Sudana & Yusuf, 2024).

The studies reviewed revealed several limitations. A significant number were observational and depended largely on self-reported tools, like pain or satisfaction surveys, which could lead to perception bias. Additionally, most research focused on short-term effects, leaving the long-term sustainability unclear. There is also a lack of geographic diversity, with insufficient data from certain areas, especially Africa and Latin America, potentially impacting the global relevance of the results.

To expand on this, the dominance of short-term evaluation studies hinders the understanding of whether the advantages of participatory ergonomic interventions persist over time. The use of self-reported tools can introduce bias, as workers' perceptions might not accurately represent objective changes in ergonomics or health outcomes. The limited geographic diversity of these studies restricts the generalizability of the results, as workplace conditions, cultural factors, and resources can differ greatly across regions. Lastly, the absence of longitudinal evidence makes it challenging to evaluate the long-term effectiveness and sustainability of PE interventions, underscoring the need for more extended and geographically varied studies to enhance the evidence base.

To evaluate the long-term effects of PE interventions, future research should employ longitudinal studies and investigate how these interventions can be integrated with suitable low-cost technologies. Additionally, it is crucial to study how participatory ergonomic methods can be culturally tailored to enhance their acceptance and relevance in local work environments. Conducting further research across various geographic and occupational settings will contribute to a more thorough understanding of the significance of PE in the informal sector.

To improve the practical use of participatory ergonomic interventions, we suggest guidelines for NGOs, policymakers, and small businesses. These guidelines involve involving workers in spotting ergonomic hazards, focusing on interventions for the most physically challenging tasks, and offering basic ergonomics training to boost awareness and implementation. In low-resource environments, cost-effective adaptation strategies can be applied, such as altering existing tools or workstations, utilizing locally sourced materials for assistive devices, and promoting simple behavioral changes like taking micro-breaks and doing stretching exercises. These practical suggestions are designed to support the adoption of PE interventions in informal work settings while ensuring they are feasible and sustainable.

Conclusion

This scoping review underscores the effectiveness of participatory ergonomic strategies in preventing musculoskeletal disorders among informal workers. By actively engaging workers in

identifying hazards and crafting solutions, these interventions have resulted in lower ergonomic risk scores, a decrease in musculoskeletal complaints, and enhanced job satisfaction and productivity.

Due to their affordability and ability to adapt to specific contexts, participatory ergonomics are particularly suitable for informal sectors like agriculture, home-based industries, and small enterprises. To maximize their effectiveness, it is essential to provide broader support through specialized training, practical guidelines, and community involvement. Future studies should investigate the long-term success and cultural adaptation of these methods in various informal environments. This includes conducting longitudinal studies to evaluate the lasting effects of PE interventions. This includes creating ergonomic models that are culturally specific, establishing community-led ergonomics frameworks, and incorporating technology, such as mobile apps for posture tracking, into PE interventions. Exploring these aspects in various informal work settings will yield essential insights to improve the effectiveness, acceptance, and enduring impact of PE interventions.

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