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Reducing Ergonomic Risk and Musculoskeletal Complaints through Participatory Ergonomics in an Informal MSME Food-Processing Enterprise: A Quasi-Experimental Case Study

Nana Rahdiana[1]*, Afif Hakim[1], Suryadi Suryadi[1], Bambang Suhardi[2], Jafri Mohd Rohani[3], Falahal Majid[4], Nindya Fatharani Shafa[5]

[1]Faculty of Engineering, Universitas Buana Perjuangan Karawang, West Java, Indonesia
[2]Faculty of Engineering, Universitas Sebelas Maret, Surakarta, Central Java, Indonesia
[3]Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, Johor Bahru, Malaysia
[4]Faculty of Industrial Technology, Telkom University, Bandung, West Java, Indonesia
[5]Faculty of Psychology, Universitas Islam Indonesia, Yogyakarta, Indonesia

***Corresponding Author**: E-mail: nana.rahdiana@ubpkarawang.ac.id

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ABSTRACT

Introduction: Informal micro and small-scale enterprises in developing countries frequently operate under suboptimal occupational safety and health conditions, exposing workers to significant ergonomic risks and musculoskeletal disorders (MSDs). This study examined whether a participatory ergonomics (PE) intervention was associated with reductions in ergonomic risk and musculoskeletal complaints in small-scale milkfish processing enterprises in Indonesia.

Methods: A quasi-experimental, one-group, pretest-posttest design was implemented over three months, involving 12 workers. Ergonomic risk was assessed using the Rapid Entire Body Assessment (REBA), musculoskeletal complaints were evaluated using the Nordic Musculoskeletal Questionnaire (NMQ), and workplace hazards were identified using the ILO-PATRIS checklist with Delphi-based prioritization.

Results: Following the intervention, the mean REBA score decreased from 9.25 (high risk) to 4.75 (moderate-low risk), representing a 48.6% reduction. The prevalence of lower back complaints declined from 91% to 46%, shoulder complaints from 78% to 35%, and wrist complaints from 63% to 28% after the intervention. Perceived work comfort increased by 46.4 percentage points. These changes suggest meaningful ergonomic improvements associated with participatory interventions and low-cost workstation modifications.

Conclusion: The findings indicate that participatory ergonomics may offer a feasible and contextually adaptable strategy for mitigating ergonomic risks and promoting worker well-being in informal MSME food-processing environments.

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INTRODUCTION

Micro, Small, and Medium Enterprises (MSMEs) constitute a crucial pillar of Indonesia's economic structure, contributing substantially to national Gross Domestic Product (GDP) while simultaneously absorbing a large share of the workforce (1) (2). In many developing economies, MSMEs also function as an essential source of livelihood for local communities, which explains why they are frequently described as the backbone of economic activity (3). Despite their important economic role, many MSMEs operate under labor-intensive conditions with limited technological support and constrained financial resources. Such structural limitations often increase their vulnerability to occupational safety and health (OSH) risks.

These challenges are particularly visible in informal sectors such as small-scale fish-processing industries, where most production activities rely heavily on manual labor. Workers commonly perform tasks in awkward postures, bending, squatting, sitting on the floor, or standing for prolonged periods, while using basic or non-ergonomic work tools. In addition, environmental conditions such as high temperatures, humidity, and poor ventilation frequently characterize these workplaces. When combined with suboptimal workspace layouts, these factors can substantially increase the risk of musculoskeletal disorders (MSDs) while simultaneously reducing work efficiency.

Another important contributing factor is the relatively low level of awareness regarding occupational hazards and the limited integration of ergonomic principles into everyday work practices (4). As a result, workers frequently experience musculoskeletal discomfort, physical fatigue, and decreased levels of work comfort, conditions that may gradually influence productivity and long-term occupational health outcomes (5)(6)(7). Taken together, these circumstances highlight the need for practical and context-sensitive OSH interventions that are not only affordable but also compatible with the operational realities of small-scale fish-processing enterprises. In this context, participatory approaches may offer a promising pathway for improving workplace safety while maintaining operational feasibility.

One approach that has received growing attention in occupational ergonomics is Participatory Ergonomics (PE), which emphasizes collaborative problem solving by directly involving workers in identifying workplace issues, developing solutions, and implementing improvements (8). Ergonomic interventions more broadly have long been recognized as effective strategies for improving worker safety and health (9)(10). What distinguishes PE from conventional ergonomics is its emphasis on worker participation and shared ownership in the process of workplace change (11). Through this collaborative process, workers' experiential knowledge and local practices can be incorporated into the design of ergonomic solutions, thereby increasing both contextual relevance and implementation feasibility.

Evidence from previous studies supports the effectiveness of this approach. A systematic review conducted by Rivilis et al. (2008), for example, reported that participatory ergonomic interventions were associated with reductions in musculoskeletal symptoms and lost workdays, although the magnitude of these effects varied across different intervention designs and organizational contexts (12). More recent empirical studies have also demonstrated that PE implementation can reduce MSD risks, improve work comfort, and contribute to productivity improvements across several sectors, including small manufacturing and home-based industries (13)(14)(15).

Nevertheless, the success of participatory ergonomics interventions is often influenced by organizational and contextual factors. Elements such as management support, internal communication processes, ergonomic training, and the degree of worker involvement can shape how effectively participatory mechanisms function in practice (16). Furthermore, the outcomes of PE programs may vary depending on the specific design of the intervention, its implementation duration, and the characteristics of the industrial environment in which it is applied (17). For instance, a study conducted in China involving 138 dentists across five hospitals reported that PE implementation significantly reduced ergonomic exposure and the prevalence of neck and wrist musculoskeletal disorders (OR = 2.93; 95% CI: 1.25–4.03) (18).

Despite this growing body of evidence, most participatory ergonomics studies have been conducted in formal industrial settings or large-scale organizations (19). In contrast, empirical applications within MSMEs, particularly in traditional food-processing sectors such as fish processing, remain relatively limited. This imbalance suggests an important research gap, especially in countries such as Indonesia where informal enterprises constitute a substantial

portion of the workforce and where working conditions often involve manual labor, minimal mechanization, and family-based organizational structures.

Although the literature on participatory ergonomics continues to expand, several conceptual and empirical gaps remain. Much of the existing research has been carried out in organizations with relatively formalized safety management systems, whereas empirical evidence from informal MSMEs, where regulatory enforcement, capital investment, and technical expertise are often limited, remains comparatively scarce. In addition, many previous studies report ergonomic improvements following participatory interventions; however, relatively few investigations integrate systematic hazard identification, consensus-based prioritization, and pre–post ergonomic risk evaluation within a single analytical framework. From a theoretical standpoint, the positioning of participatory ergonomics as a strategy for occupational health promotion in informal production systems has also received limited scholarly attention.

To address these gaps, the present study investigates the implementation of a structured participatory ergonomics intervention in an informal MSME food-processing enterprise using a quasi-experimental case study design. The intervention integrates several complementary components, including hazard identification using ILO-PATRIS, consensus-based prioritization through the Delphi method, ergonomic risk assessment using the Rapid Entire Body Assessment (REBA), and pre–post evaluation of musculoskeletal symptoms using the Nordic Musculoskeletal Questionnaire (NMQ). By combining these approaches, the study seeks to provide empirical insight into how participatory ergonomics can be operationalized in resource-constrained environments commonly found in informal economies.

The study was conducted at Israfood, a small-scale milkfish-processing enterprise located in Cicinde Village, Karawang Regency, which represents a traditional fish-processing operation with considerable ergonomic risk exposure. The main objective of this study was to evaluate the effects of participatory ergonomic interventions on reducing ergonomic risks, decreasing musculoskeletal complaints, and improving workers' perceived comfort. From an academic perspective, the findings contribute to expanding the application of participatory ergonomics within Indonesia's MSME context. From a practical standpoint, the results are expected to provide useful insights for business owners and MSME development agencies in designing worker-centered occupational health promotion strategies and implementing sustainable ergonomic improvements in small enterprises.

METHOD

This study employed a quasi-experimental one-group pre-test–post-test design (20) to examine intervention-associated changes in ergonomic risk, musculoskeletal complaints, and perceived comfort within a small-scale MSME milkfish processing enterprise. The design enabled a structured comparison of working conditions before and after the implementation of a participatory ergonomics intervention within a naturally bounded workforce.

This approach is particularly relevant for field-based research in MSMEs, where establishing a control group is often impractical due to limited workforce size and relatively homogeneous job characteristics (21). Nevertheless, the one-group pretest–posttest design may pose certain limitations in terms of internal validity, including potential maturation effects, regression to the mean, secular trends, and participant reactivity. To reduce these potential threats, several procedural controls were applied. Measurement procedures were standardized across both assessment periods, identical instruments were used at pre- and post-intervention stages, and no organizational or structural changes occurred during the three-month intervention period. Despite these precautions, causal interpretations should be made with caution, and the findings should be interpreted primarily as evidence of intervention-associated changes within the observed setting.

The intervention was conducted over three months (May–July 2025) in a traditional milkfish processing enterprise in Cicinde Village, Karawang Regency, West Java, Indonesia. A participatory ergonomics (PE) approach was adopted to actively involve workers in identifying workplace problems, developing practical solutions, and implementing context-specific ergonomic improvements. All twelve production workers in the enterprise participated in the study. This reflects a total enumeration of the operational workforce rather than sampling intended for statistical generalization (22). Given the naturally bounded and relatively homogeneous workforce, the study is therefore positioned as a single-site intervention evaluation aimed at examining within-group changes under real-world field conditions.

The participatory ergonomics intervention followed four main stages adapted from Wilson, Haines, and Morris (2005) and was guided by the principles of participatory action research (23). This framework emphasizes the active involvement of workers throughout the entire process, from initial diagnosis to the evaluation of implemented changes, thereby supporting contextual relevance and practical sustainability.

Stages of Participatory Ergonomics Intervention

Problem identification

Field observations and semi-structured interviews were conducted to identify the primary sources of discomfort and potential ergonomic risk factors in daily production activities. Data collection included the administration of the Nordic Musculoskeletal Questionnaire (NMQ) and systematic observation of work postures during processing tasks.

Solution design

Participatory workshops involving both workers and the business owner were organized to collaboratively develop ergonomic improvement strategies. The agreed solutions included modifications of work aids, rearrangement of workstations, posture awareness training, and the introduction of active rest practices. In this study, active rest refers to short micro-breaks combined with light activities such as simple stretching, posture changes, or brief walking between work areas.

Implementation

The agreed ergonomic improvements were implemented over a three-month period. During this phase, weekly monitoring was conducted by the research team to observe implementation progress, ensure adherence to the intervention plan, and document worker participation.

Evaluation

Evaluation focused on three primary indicators: changes in ergonomic risk levels, variations in musculoskeletal complaints, and workers' perceived comfort following the intervention.

Instruments

Work posture analysis

The Rapid Entire Body Assessment (REBA) method was used to assess posture-related ergonomic risk before and after the intervention (24).

Musculoskeletal complaints

The Nordic Musculoskeletal Questionnaire (NMQ) was adapted to the Indonesian context based on SNI 9011:2021 (25)(26).

Work condition assessment

The ILO-PATRIS checklist was used to identify workplace conditions, hazards, and potential corrective actions (13)(27).

Work comfort scale

A 10-item self-developed Likert scale (1 = very uncomfortable to 5 = very comfortable) was used to assess seating posture, table height, lighting, and subjective fatigue.

Hazard Prioritization

To determine improvement priorities, the Delphi method was employed to reach a consensus among participants with relevant experience (13)(28). A Likert-type questionnaire was distributed to assess the perceived importance of each sub-aspect identified using the ILO-PATRIS checklist.

Twelve respondents participated in the two Delphi rounds. Consensus was achieved when the standard deviation (SD) was < 1.5 and the interquartile range (IQR) was < 2.5 (29). The improvement recommendations

focused on the sub-aspects with the highest mean scores, indicating a greater urgency and ergonomic risk. Throughout this process, an ergonomic expert served as a consultant and provided technical input and scientific justification for each proposed intervention (13).

Ethical Considerations

This study complied with the occupational health research ethics guidelines. All participants provided written informed consent, participation was voluntary, and confidentiality was ensured. The authors declare no conflicts of interest.

RESULT

Participant Characteristics

A total of 12 workers participated in this study, with a mean age of 38.2 ± 7.4 years, indicating that most participants were within the productive age group. The average length of employment was 6.8 ± 3.1 years, suggesting a relatively high level of experience in fish processing. Of the total participants, nine (75%) were female and primarily engaged in sorting, cleaning, seasoning, and packaging tasks. Most workers performed 6–8 working hours per day, predominantly in prolonged standing postures, which potentially contributed to muscle fatigue and musculoskeletal discomfort in the lower back and limbs of the workers. Figure 1 illustrates the main production stages: (a) raw material arrival, (b) storage, (c) sorting, (d) filleting, (e) washing, (f) seasoning, (g) arrangement, (h) steaming, (i) packaging, and (j) distribution of the final product.

Figure 1. Sequence of milkfish production activities

Workplace Observation and Condition Assessment

Field observations revealed that most production processes were performed manually, involving awkward postures such as prolonged bending, squatting, or static standing. The production environment was characterized by high heat and humidity, with an average temperature of 34.5°C and relative humidity of 72%, exceeding the

recommended comfort threshold. These environmental conditions increase the likelihood of worker fatigue and musculoskeletal disorders (MSDs).

Workplace conditions were evaluated using the ILO-PATRIS checklist through direct observation, visual documentation, and discussions with workers and business owners. Each sub-aspect was scored as follows: 0 = requires major improvement, 1 = requires minor improvement, and 2 = satisfactory or no improvement needed. The results were used to identify work areas with the highest potential hazards and establish priorities for ergonomic interventions. Table 1 presents a structured summary of the workplace condition assessment across eight domains using the ILO-PATRIS checklist. The distribution of scores allows for the identification of domains with the greatest deficiencies and highest ergonomic risk exposure.

Table 1. Summary of workplace condition assessment based on the ILO-PATRIS check sheet

Monitoring Item	Maximum Number of Scores (Number of Sub-Aspects × 2)	Total Score	Percentage of Accomplishment
Physical Environment	10	2	20%
Premises	16	6	38%
Welfare Facilities	8	7	88%
Ergonomics	8	4	50%
Equipment	2	1	50%
Work Organization	6	6	100%
Personal Protective Equipment	2	0	0%
Daily Management	6	4	67%
Total	**58**	**30**	**52% (Average)**

The total score obtained was 30 out of 58 (52%), indicating that nearly half of the assessed dimensions of the workplace required improvement. As shown in Table 1, the most critical deficiencies were observed in the Physical Environment (20%) and Personal Protective Equipment (0%) domains, suggesting substantial gaps in environmental control and safety behavior. In contrast, Work Organization (100%) and Welfare Facilities (88%) demonstrated relatively adequate performance, indicating that the organizational structure was not the primary source of ergonomic risk. These findings provide a structured basis for prioritizing targeted interventions.

Hazard and Improvement Prioritization

Using the two-round Delphi procedure described in the Methods section, consensus was achieved after the second round (SD < 1.5, IQR < 2.5). Five sub-aspects were identified as top priorities, with mean scores above 4.0, indicating high urgency for improvement. These priorities were predominantly associated with the physical environment, workplace cleanliness, and PPE use, reflecting workers' shared perception of immediate safety needs. Table 2 summarizes the consensus-based ranking of ergonomic and safety improvement actions. The ranking reflects the collective perception of urgency among the participants and highlights the areas requiring immediate corrective action.

Table 2. Results of the second round of Delphi and priorities for improving working conditions

No.	Sub-Aspects That Need Improvements	Average (Round 2)	SD	IQR	Priority Level	Recommended Improvement Actions
1	Noise	4.67	0.52	1	High	Sound-absorbing materials should be installed, and hearing protection should be provided.
2	Dust	4.50	0.63	1	High	Improve workplace cleanliness and ventilation
3	Housekeeping/general order cleanliness	4.50	0.75	1	High	Apply the 5S principles (sort, set in order, shine, standardize, sustain) for better workplace organization
4	Shoes, gloves, masks, and glasses	4.50	0.58	1	High	Provide ergonomically designed personal protective equipment (PPE) and conduct proper training

5	Delegation of safety responsibilities to workers	4.33	0.83	2	High	Establish safety champions among workers to promote occupational safety behavior
6	Floor/stairs	3.83	1.00	2	Medium	Add anti-slip surfaces and repair damaged stairs
7	Chemicals	3.67	1.20	2	Medium	Use closed containers and appropriate PPE during material mixing
8	Material storage and handling	3.50	1.10	2	Medium	Rearrange storage areas to improve accessibility and ergonomics
9	Waste disposal	3.33	1.22	2	Medium	Separate organic and non-organic waste properly
10	Working tools or machines	3.33	1.15	2	Medium	Conduct regular maintenance of work equipment
11	Hazardous postures	3.17	1.00	2	Medium	Redesign worktables and adjust working postures
12	First aid	3.17	1.20	2	Low	Provide first-aid kits (FAK) within the work area
13	Lighting	3.00	1.30	2	Low	Add artificial lighting in dimly lit areas
14	Work surfaces	3.00	1.25	2	Low	Adjust worktable height according to worker anthropometric dimensions
15	Temperature	2.83	1.33	2	Low	Install additional fans and cross ventilation to improve air circulation
16	Fire prevention	2.83	1.40	2	Low	Provide fire extinguishers (APAR) in strategic locations
17	Drinking water	2.83	1.10	2	Low	Install a drinking water dispenser in the work area
18	Walls	2.50	1.35	2	Low	Repaint workplace surfaces to enhance cleanliness and visual comfort

As shown in Table 2, the highest-priority items were predominantly related to environmental hazards and safety behavior, particularly noise control, dust management, housekeeping practices, and PPE provision. This pattern indicates that workers perceive physical exposure and protective measures as more urgent than structural or organizational factors. The high level of consensus (SD < 1.5; IQR < 2.5) further strengthens the reliability of the prioritization process and underscores the effectiveness of participatory decision-making in identifying context-specific risks.

Ergonomic Improvements

Based on prioritization outcomes and participatory discussions, ergonomic interventions focused on three main domains.

Physical work environment improvement

The limited production area was reorganized to improve worker safety and comfort. The steam boilers were relocated to an open area to reduce the ambient temperature and minimize the explosion risk. An exhaust fan was installed to enhance air circulation, lower humidity, and reduce heat and odor.

Enhancement of personal protective equipment (PPE) use

Prior to the intervention, workers rarely used PPE (e.g., gloves, masks, and goggles) because of discomfort and limited awareness. After training and participatory discussions on occupational safety, PPE compliance increased substantially, leading to greater comfort and hygiene and reduced injury risk.

Implementation of a locally designed sit–stand support chair

A low-cost "local wisdom–based exoskeleton" was developed using lightweight iron and coated wood materials to support workers during prolonged standing tasks. This simple device effectively reduced the static postural load on the back and legs, significantly lowering the REBA scores and increasing comfort levels.

In addition to physical and equipment improvements, active rest has been introduced as a complementary strategy for preventing fatigue. Workers performed 2–3 min micro-breaks every 60–90 min, including light stretching and short walks between the work areas. Observations and worker feedback indicate that active rest effectively reduces muscle tension in the back, shoulders, and legs, resulting in greater perceived freshness and reduced discomfort. This finding supports the role of active rest as a simple and low-cost recovery mechanism that does not compromise productivity of workers.

All interventions were implemented over one month, followed by field evaluations to assess acceptance and effectiveness. Observations and interviews confirmed improvements in comfort, body posture, and task efficiency compared with pre-intervention conditions.

Effectiveness of the Participatory Ergonomics Intervention

Participatory ergonomic intervention effectively reduced ergonomic risks, decreased musculoskeletal complaints, and improved overall work comfort. The REBA score decreased from 9.25 to 4.75, indicating a shift in risk level from high to medium–low. Based on the Nordic Musculoskeletal Questionnaire (NMQ), the prevalence of musculoskeletal discomfort showed a marked reduction across several major body regions: the lower back (from 91% to 46%), shoulders (from 78% to 35%), and wrists (from 63% to 28%) (Figure 2). Correspondingly, the Comfort Score increased from 2.80 to 4.10, reflecting a 46.4% improvement in perceived work comfort after the implementation of the ergonomic improvements. These findings suggest that the integrated intervention, particularly the enhancement of working posture through locally designed sit–stand support, the introduction of active rest, and the consistent use of personal protective equipment, substantially reduced static load and improved worker comfort. Overall, the results align with previous studies, confirming that participatory ergonomic approaches are effective in mitigating work-related musculoskeletal disorders (WMSDs), especially in manual and static work environments.

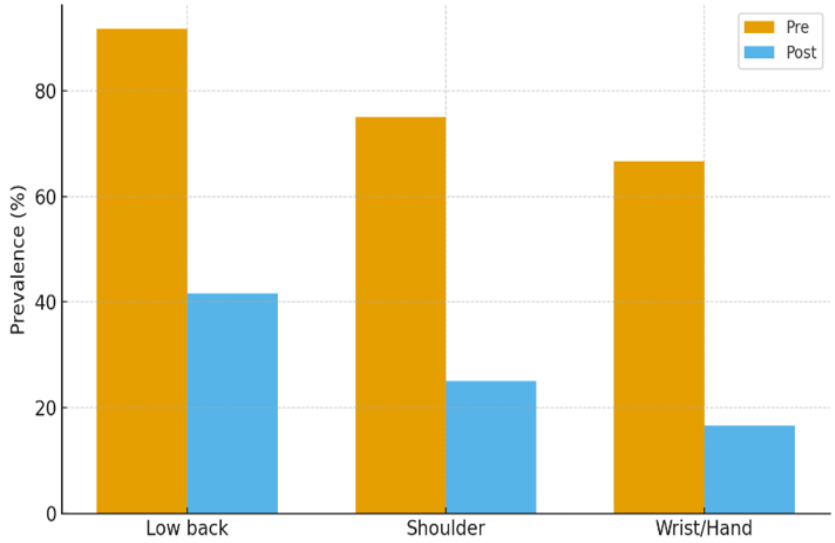

Figure 2. Comparison of the prevalence of musculoskeletal complaints before and after ergonomic intervention

Collectively, these findings demonstrate that a combination of low-cost, contextually tailored participatory ergonomic interventions can significantly enhance worker health, safety, and comfort in small-scale fish-processing industries. To provide a consolidated overview of intervention-related changes across primary ergonomic indicators, Table 3 summarizes pre–post differences in REBA scores, musculoskeletal complaint prevalence, and perceived comfort levels.

Table 3. Recapitulation of REBA, NMQ, and comfort score measurement results

Evaluation Parameters	Before Intervention	After Intervention	Change (%)	Outcome Category
REBA score	9.25 ± 1.50	4.75 ± 1.20	↓ 48.6%	Risk level: Decreased (High → Medium–Low)
NMQ Complaints (average of three main sections)	77%	36%	↓ 53.2%	Musculoskeletal complaints: Significantly reduced
Comfort Score	2.80 ± 0.65	4.10 ± 0.55	↑ 46.4%	Work comfort: Increased

As shown in Table 3, consistent improvements were observed across all three indicators. The reduction in REBA scores indicates a meaningful decrease in postural risk exposure, while the substantial decline in musculoskeletal complaint prevalence suggests improved physical well-being. The increase in comfort scores further reflects subjective acceptance of the implemented ergonomic modifications. Collectively, these converging trends strengthen the internal coherence of our findings.

DISCUSSION

Interpretation of Key Findings

This study contributes to the participatory ergonomics literature by demonstrating how a structured participatory ergonomics (PE) framework can be adapted to an informal MSME environment characterized by limited resources and loosely structured organizational arrangements. Most classical participatory ergonomics models have been developed and tested in formal organizational environments where safety management systems, managerial hierarchies, and regulatory mechanisms are already well established. In contrast, the present findings indicate that structured participatory mechanisms, such as Delphi-based hazard prioritization combined with systematic ergonomic assessment, can be applied within loosely structured, family oriented enterprises in real-world fields.

These findings are consistent with the participatory ergonomics framework proposed by Vink, Imada, and Zink (2008), which emphasizes the importance of worker involvement in intervention processes (30). Within the observed MSME setting, workers participation was associated with observable improvements in ergonomic risk indicators and perceived comfort. The findings indicate that the success of the intervention was not primarily determined by organizational formality. Instead, contextual alignment, the use of simplified participatory tools, and worker-driven prioritization processes appeared to facilitate the implementation of ergonomic improvements in this informal production setting. In this respect, this study positions participatory ergonomics as a potentially viable occupational health promotion strategy within informal economies.

Comparison with Previous Studies

The reductions observed in musculoskeletal complaints and ergonomic risk indicators in this study are broadly consistent with international findings reporting positive outcomes from participatory ergonomic interventions. Lin et al. (2022) reported reductions in neck and wrist musculoskeletal symptoms among healthcare workers after participatory ergonomic training (18). Similarly, Rasmussen et al. (2020) observed decreased work absenteeism related to musculoskeletal pain following participatory ergonomic initiatives (31).

In the national context, Candra et al. (2023) indicated that participatory ergonomics in small enterprises can be implemented using simplified macroergonomic approaches that involve workers as change agents (19). The present findings suggest that similarly structured participation mechanisms may also be applicable in small-scale food processing enterprises characterized by manual and repetitive work patterns.

Recent evidence also suggests that multicomponent participatory ergonomic interventions tend to produce stronger improvements in musculoskeletal outcomes than single-component strategies, as reported in a systematic review by Krishnanmoorthy et al. (2025) (17). The integrated approach adopted in this study, which combined workstation modification, posture training, and work area reorganization, reflects this multicomponent orientation and may explain the favorable trends observed across multiple indicators.

Theoretical and Practical Implications

From a conceptual perspective, the present findings extend the discussion of participatory ergonomics beyond formal industrial environments to informal MSMEs operating under resource limitations. The findings suggest that structured participation, consensus-based prioritization, and systematic risk assessment can be operationalized even in enterprises that lack formal safety management systems.

Rather than organizational maturity, the results indicate that adaptability, contextual alignment, and active worker engagement may influence the observed intervention-related improvements. This perspective refines participatory ergonomics assumptions by emphasizing flexibility and contextual tailoring in small enterprise environments.

Practically, this study provides context-specific insights for small-scale enterprises seeking to improve workplace safety. Low-cost measures, such as workstation redesign, posture awareness training, and scheduled active rest, were feasible within the observed MSME setting and were associated with positive changes in ergonomic indicators and perceived comfort.

The strong consensus achieved through the Delphi process further illustrates how participatory decision-making can enhance contextual relevance and shared commitment. Conceptually, this study proposes a simplified participatory architecture that integrates risk assessment, consensus-based prioritization, and incremental ergonomic redesign suitable for informal production systems.

Limitations and Cautions

Several methodological limitations must be acknowledged. First, the one-group pretest–posttest design without a control group limits the ability to establish causal inferences. Second, the small sample size (n = 12) and single-site setting restrict external generalizability of the results. Third, the three-month evaluation period does not capture the long-term sustainability of the observed changes. Additionally, some indicators, including comfort levels, were self-reported and, therefore, subject to perception bias.

Therefore, the results should be interpreted as contextual evidence of intervention-associated improvements within the observed MSME setting rather than as definitive proof of intervention effectiveness. Despite these constraints, consistent directional changes across multiple ergonomic indicators suggest the potential benefits of structured participatory engagement in similar small-enterprise environments.

Recommendations for Future Research

Future research should employ designs that incorporate comparison groups and larger multisite samples to strengthen internal validity and generalizability. Mixed-methods approaches integrating quantitative and qualitative analyses would help elucidate the social and cultural dynamics influencing participatory ergonomic improvement and its possible association with productivity and broader occupational health outcomes. Economic evaluations may also clarify the feasibility and cost implications of adopting PE in MSMEs.

CONCLUSION

This study examined the implementation of participatory ergonomics as a workplace health promotion approach within a milkfish processing MSME in Cicinde Village, Karawang, Indonesia. The intervention period was associated with observed reductions in REBA scores and ergonomic risk levels, accompanied by improvements in perceived work comfort.

Within the constraints of a single-site quasi-experimental design, the findings suggest that participatory ergonomics may contribute to positive ergonomic changes in informal enterprise contexts when structured participation and context-sensitive adaptation are implemented. This study contributes to the Indonesian ergonomics literature by illustrating how worker involvement in hazard identification and solution prioritization can be operationalized in resource-limited settings.

While limitations related to design, sample size, and duration restrict generalizability, the results provide contextual evidence supporting the potential relevance of participatory ergonomics in MSMEs. Further research across diverse sectors and longer timeframes is required to clarify the strength, sustainability, and broader implications of intervention-related improvements in occupational health promotion.

AUTHOR CONTRIBUTION STATEMENT

All authors contributed equally to the conception and design of the study and the data collection, analysis, interpretation, and preparation of the manuscript. Each author reviewed and approved the final version of the paper and agreed to be accountable for all aspects of the work, ensuring its accuracy and integrity.

CONFLICTS OF INTEREST

The authors declare no conflict of interest regarding the publication of this article. They have no financial, personal, or institutional relationships that could be perceived as influencing the impartiality of this study.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

Generative AI tools, specifically ChatGPT (OpenAI), were used to improve language clarity, organization, and readability during the preparation of this manuscript. The authors confirm that all intellectual content, data interpretation, and final conclusions are their own.

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