ISSN 2985-5667 (Online) | 2985-6353 (Print) | Vol. 4, No. 3, August (2026), pp. 209-217

Published by: IARN Institute

International Journal on Health and Medical Sciences

Journal homepage: https://journals.iarn.or.id/index.php/HealMed/index

Effect of ergonomic seat redesign for a gingga machine on musculoskeletal disorder complaints among oil palm

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Article Info

Article history:

Received Aug 1, 2026
Revised Aug 11, 2026
Accepted Aug 18, 2026

Keywords:

Ergonomic Intervention;
Musculoskeletal Disorders;
Nordic Body Map;
Oil Palm Workers;
Seat Redesign.

ABSTRACT

Oil palm fertilization exposes workers to manual handling, repetitive movements, and non neutral postures, yet evidence is limited on ergonomic seating integrated into gingga machines used for fertilizer application. This study evaluated whether a redesigned gingga seat was associated with reduced musculoskeletal disorder complaints among oil palm fertilization workers. A quasi-experimental pretest posttest control-group study was conducted at an oil palm plantation in North Sumatra, Indonesia, from October to December 2025. Using purposive sampling, 84 eligible workers were allocated equally to an intervention group using gingga machines with redesigned seats (n = 42) and a control group continuing usual work (n = 42). Musculoskeletal complaints were measured using the Nordic Body Map and analyzed separately within each group using paired samples t-tests. The control group mean decreased from 61.45 to 60.80, a nonsignificant reduction of 0.65 points ($p = 0.231$). The intervention group mean decreased from 62.10 to 54.35, a significant reduction of 7.75 points or 12.5% ($p < 0.001$), with the group mean shifting from the painful to the slight-pain category. These findings suggest a potentially meaningful practical improvement following seat redesign. However, groups were not randomly assigned, baseline characteristics differed, and change scores were not compared directly between groups; therefore, a comparative intervention effect cannot be confirmed. The redesigned seats provide preliminary evidence for adapting gingga machines to workers' physical support needs. Randomized or matched studies using anthropometric design, objective ergonomic measures, direct between group analysis, and longer follow-up are needed to confirm effectiveness and sustainability.

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1. INTRODUCTION

Musculoskeletal disorders (MSDs) constitute a major public health and occupational health problem because they can cause pain, restricted movement, reduced work capacity, and long-term disability. Approximately 1.71 billion people worldwide live with musculoskeletal conditions, with low back pain remaining the leading contributor to disability in many countries (WHO, 2022). In occupational settings, MSDs may develop or worsen when workers are repeatedly exposed to heavy physical work, awkward postures, forceful exertion, repetitive movements, and manual material handling (Da Costa & Vieira, 2010). These ergonomic risk factors are particularly common in labor intensive agricultural activities, where work is often performed manually under variable field conditions (Dev et al., 2025).

Workers in the palm oil industry are exposed to multiple occupational hazards, including injuries, chemical exposure, and musculoskeletal problems (Myzabella et al., 2019). Oil palm plantation activities require workers to lift and carry heavy loads, walk over uneven terrain, maintain non-neutral postures, and perform repetitive upper and lower body movements. Previous research among oil palm workers found that MSD complaints were associated with productivity loss, demonstrating that musculoskeletal problems affect not only workers' health but also their ability to complete physically demanding tasks (Ng et al., 2014). Back, shoulder, and neck complaints are among the symptoms most frequently reported by palm plantation workers (Henry et al., 2015).

The high occurrence of MSDs among oil palm workers is closely related to the biomechanical demands of their tasks. Heavy lifting, repetitive movements, task type, and awkward working postures have been identified as important risk factors (Bhuanantanondh et al., 2021; Ng et al., 2015). Research on oil palm harvesting tools also showed that tool design and operating technique influence workers' posture, muscle activity, and exposure to upper body MSDs (Mohamaddan et al., 2021). Field measurements further demonstrated that several oil palm harvesting tasks produced very high ergonomic risk scores, excessive forces at the L5–S1 spinal segment, and high muscle activation (Abdullah et al., 2023). Although these studies were primarily conducted among harvesters, their findings indicate the broader importance of adapting plantation equipment to workers' physical capacities. Oil palm fertilization also involves considerable physical demands. Preliminary observations at the study site indicated that workers previously carried fertilizer loads of approximately 25 kg while walking repeatedly across plantation areas. A gingga machine was subsequently used to support the fertilization process, but its existing configuration did not provide ergonomically designed seats for workers positioned on both sides of the machine (Rakpongsiri et al., 2025). Inadequate seating may require workers to maintain unsupported or non neutral postures during equipment operation. Prolonged exposure to such conditions can increase mechanical stress on the back, shoulders, waist, and lower extremities (O. Odebiyi & Arinze Chris Okafor, 2023). Therefore, modifying the machine based on ergonomic and anthropometric principles may provide better postural support and reduce musculoskeletal strain.

Ergonomic interventions aim to adapt work equipment, tasks, and working conditions to workers' capabilities. Evidence from participatory ergonomics suggests that workplace modifications can reduce musculoskeletal symptoms, occupational injuries, compensation claims, and work absence, although the effectiveness of an intervention depends on its design and implementation (Rivilis et al., 2008). A recent systematic review and meta-analysis also found that ergonomic interventions significantly reduced work related musculoskeletal pain, particularly in the lower back, upper back, wrists, ankles, and neck (Santos et al., 2025). In oil palm plantations, participatory ergonomic training has shown potential to improve working practices and reduce workers' exposure to ergonomic risks (Ng et al., 2014). However, intervention studies focusing specifically on ergonomic seating for machines used in oil palm fertilization remain limited.

Previous ergonomic studies in oil palm plantations and agricultural work have primarily examined harvesting postures, manual material handling, hand tool design, and ergonomic training (Abdullah et al., 2023; Mohamaddan et al., 2021; Ng et al., 2014; Widyanti, 2018). Although these studies demonstrate that equipment design and working posture influence musculoskeletal loading, evidence remains limited regarding seats integrated into gingga machines for fertilizer application. Unlike stationary seating, workers positioned on both sides of a moving gingga machine must maintain stability while exposed to uneven terrain, vibration, and lateral body movement. No previous controlled study was identified that evaluated whether redesigning this seating arrangement could reduce musculoskeletal complaints or how the design should accommodate fertilizer workers' physical dimensions. This study addresses this gap by evaluating a direct machine modification within actual oil palm fertilization activities. This study contributes to the development of fertilization equipment by providing preliminary evidence for adapting gingga machines to workers' physical support requirements. Rather than focusing only on training or behavioral change, the intervention modified the equipment used during routine fertilization by adding bilateral seating and body support. The findings can inform the development of a more human centered gingga machine in which seating dimensions, support components, and machine stability are progressively adjusted to workers' anthropometric characteristics. However, the current prototype represents an initial design rather than a finalized anthropometric standard.

To address this gap, an ergonomic seat was added to the left and right sides of the gingga machine using a welded metal structure designed to provide stable support during fertilization activities. Unlike previous studies that primarily examined harvesting postures, hand tools, or ergonomic training, this study evaluated a direct modification of equipment used in the fertilization process. Therefore, this study aimed to analyze the effect of ergonomic seat redesign for a gingga machine on musculoskeletal disorder complaints among oil palm fertilization workers.

2. RESEARCH METHOD

Study Design and Setting

This study employed a quasi-experimental design with a pretest–posttest control group (Siregar et al., 2022). The study was conducted at an oil palm plantation company in North Sumatra Province, Indonesia, from October to December 2025. The intervention group performed fertilization activities using a gingga machine equipped with redesigned seats, while the control group continued using the existing fertilization method without the redesigned seats. Musculoskeletal disorder complaints were measured before and after the intervention in both groups.

Population and participants

The study population comprised 275 oil palm fertilization workers. Of these, 84 workers met the eligibility criteria and were available to participate without disrupting routine operations, all 84 were included. The sample was therefore determined by the number of eligible workers rather than by a formal statistical power calculation. The workers were allocated equally to the intervention and control groups, with 42 participants in each group, to maintain balanced group sizes and comparable precision for the pretest posttest estimates. Because purposive sampling and non random group allocation were used, the sample may not represent all fertilization workers, and residual differences between groups should be considered when interpreting the findings.

Ergonomic seat intervention

The intervention involved modifying the gingga machine by adding seats to its left and right sides. The seats were constructed from metal and attached to the machine using a welding process to provide stable seating for workers during fertilization activities. The modification was intended to improve body support and reduce the need to maintain unsupported or awkward working postures. Before the intervention, workers in both groups completed the baseline assessment. Workers in the intervention group then carried out their usual fertilization activities using the gingga machine equipped with the redesigned seats. Meanwhile, workers in the control group continued their regular fertilization activities without using the redesigned seats. After the intervention period, musculoskeletal complaints were reassessed in both groups using the same instrument. The gingga machine was equipped with two fixed seating assemblies positioned symmetrically on its left and right sides. Based on the technical drawing, each lateral seating support frame measured 50 cm in length and 18 cm in width and was positioned 20 cm above the lower machine frame. Each assembly incorporated a padded seat and backrest, a lateral hand and body support measuring 24 cm in width and 18 cm in height, and a foot-support platform measuring 33 × 23 cm. The supporting structure was constructed from 1-inch steel pipes and 3-mm steel plates and was attached to the machine by welding. These components were intended to support the pelvis, back, upper extremities, and feet while reducing the muscular effort required to maintain stability during machine movement. The seats were fixed and non adjustable and had not been individualized to variations in workers' anthropometric dimensions.

Measurement of musculoskeletal complaints

Musculoskeletal complaints were measured using the Nordic Body Map (NBM), which was adapted from the standardized Nordic musculoskeletal questionnaire developed by Kuorinka et al. (1987; Tarwaka, 2015). Participants rated discomfort in 28 body regions using four response categories: no pain, slight pain, pain, and severe pain. Each response was scored from 1 to 4, resulting in a total score ranging from 28 to 112. Higher scores indicated more severe and extensive musculoskeletal complaints. For descriptive analysis, total NBM scores were categorized as follows 28: no pain; 29–57: slight pain; 58–86: pain; and ≥87: severe pain. The total NBM score was treated as a continuous variable in the pretest–posttest analysis.

Data collection

Data collection was performed in three main stages. First, participants in the intervention and control groups completed the pretest assessment before the redesigned seats were introduced. Second, the intervention group used the gingga machine fitted with the redesigned seats during fertilization activities, while the control group continued its usual work procedures. Third, both groups completed the posttest assessment after the intervention period. The participants' demographic and occupational characteristics were collected using a structured questionnaire. Musculoskeletal complaints were assessed directly using the NBM at the pretest and posttest stages. The same measurement procedures were applied to both groups.

Data Analysis

Participant characteristics and musculoskeletal complaints were summarized using frequencies, percentages, means, and mean differences. The distribution of the NBM scores was examined using the Kolmogorov–Smirnov test. Homogeneity of variance between the intervention and control groups was assessed using Levene's test. Because the NBM scores were normally distributed, paired-samples t-tests were used to compare the pretest and posttest scores separately within the control and intervention groups. All tests were two-tailed, and a p-value of less than 0.05 was considered statistically significant. The analysis focused on within-group changes in NBM scores.

3. RESULTS AND DISCUSSIONS

A total of 84 oil palm fertilization workers participated in this study. The participants were divided equally into a control group and an intervention group, with 42 workers in each group. The characteristics of the participants are presented in Table 1.

Table 1. Characteristics of participants in the control and intervention groups

Characteristics	Control group, n (%)	Intervention group, n (%)
Age (years)		
<22	7 (17)	6 (14)
23–35	13 (31)	23 (55)
36–38	14 (33)	11 (26)
39–40	8 (19)	2 (5)
Sex		
Male	23 (55)	31 (74)
Female	19 (45)	11 (26)
Educational level		
Elementary school	0 (0)	0 (0)
Junior high school	24 (57)	17 (40)
Senior high school	18 (43)	25 (60)
Work experience		
<2 years	2 (5)	7 (17)
3–5 years	13 (31)	21 (50)

Characteristics	Control group, n (%)	Intervention group, n (%)
5–8 years	23 (55)	8 (19)
>9 years	4 (9)	6 (14)

The control group was predominantly composed of workers aged 36–38 years, whereas more than half of the intervention group was aged 23–35 years. Male workers represented 55% of the control group and 74% of the intervention group. Differences were also observed in educational level and work experience. Most participants in the control group had completed junior high school and had worked for 5–8 years, while most participants in the intervention group had completed senior high school and had worked for 3–5 years. These differences indicate that the groups were not completely comparable in terms of demographic and occupational characteristics. Age, sex, and length of employment may influence the occurrence and severity of work-related musculoskeletal complaints. Longer exposure to repetitive movements, awkward postures, and manual handling may increase cumulative biomechanical stress (Da Costa & Vieira, 2010; Greggi et al., 2024). Therefore, the observed differences between the groups should be considered when interpreting the intervention results. Before the intervention, musculoskeletal complaints were common in both groups. In the control group, 18 workers (43%) were categorized as having painful complaints, 17 (40%) had slight pain, and only 7 (17%) reported no pain. A similar distribution was observed in the intervention group, in which 19 workers (45%) were categorized as having painful complaints, 15 (36%) had slight pain, and 8 (19%) reported no pain. No workers in either group were categorized as having severely painful complaints.

The high proportion of workers reporting musculoskeletal complaints is consistent with previous studies in oil palm plantations. Myzabella et al. identified musculoskeletal conditions as one of the main occupational health problems faced by workers in the palm oil industry (Myzabella et al., 2019). Ng et al. found that musculoskeletal complaints among oil palm harvesters were associated with decreased productivity (Ng et al., 2015). Studies in Malaysia and Thailand also reported a high prevalence of complaints involving the lower back, shoulders, and neck among oil palm workers (Bhuanantanondh et al., 2021; Henry et al., 2015; Ng et al., 2014). Although the work processes of harvesters and fertilizer applicators differ, both groups are exposed to physically demanding activities, including heavy load handling, repetitive movements, awkward postures, and work on uneven terrain. Widyanti reported that Indonesian agricultural workers experienced considerable ergonomic risks, particularly during manual land preparation and fertilization activities, with the shoulders and lower back among the most frequently affected body regions (Widyanti, 2018). These findings support the need for equipment modifications that reduce workers' biomechanical exposure.

The reduction in musculoskeletal complaints is consistent with previous ergonomic research in agricultural and physically demanding work. Studies among oil palm harvesters have shown that tool design and operating technique influence working posture, muscle activity, and biomechanical loading, particularly in the back and upper extremities (Abdullah et al., 2023; Mohamaddan et al., 2021). Widyanti (2018) similarly identified substantial ergonomic risks among Indonesian agricultural workers during manual preparation and fertilization activities. The present findings extend this evidence from hand tools and harvesting tasks to a machine mounted seating intervention used during fertilization. The redesigned seats may have reduced unsupported postures and the muscular effort required to stabilize the body. Nevertheless, comparisons with previous studies should be interpreted cautiously because the tasks, interventions, measurement instruments, and follow-up periods differed.

The mean NBM scores before and after the intervention are presented in Table 2. This table includes the posttest score of the control group so that changes in both groups can be evaluated.

Table 2. Differences in Nordic Body Map scores before and after the intervention

Group	n	Pretest mean	Posttest mean	Mean reduction	t	p-value	Interpretation
Control	42	61.45	60.8	0.65	1.214	0.231	Not significant
Intervention	42	62.1	54.35	7.75	5.872	<0.001	Significant

The mean pretest NBM scores were relatively close between the control and intervention groups, at 61.45 and 62.10, respectively. Based on the NBM classification used in this study, both mean scores were within the painful category. This finding indicates that workers in both groups had a substantial level of musculoskeletal discomfort before the redesigned seats were introduced. In the control group, the mean NBM score decreased slightly from 61.45 to 60.80, representing a reduction of only 0.65 points. The change was not statistically significant ($t = 1.214$; $p = 0.231$). Therefore, the musculoskeletal complaints experienced by control-group workers remained relatively unchanged between the two measurement periods. In contrast, the intervention group showed a reduction in the mean NBM score from 62.10 to 54.35. The mean reduction of 7.75 points was statistically significant ($t = 5.872$; $p < 0.001$). The posttest mean was within the slight-pain category, indicating that the average severity of musculoskeletal complaints shifted from painful to slight pain after the redesigned seats were used.

The 7.75-point reduction represented a 12.5% decrease from the intervention group's baseline mean. Its practical relevance is also indicated by the shift in the group mean from the painful category at pretest to the slight-pain category at posttest. Furthermore, the proportion of intervention workers classified as having painful complaints decreased from 45% to 0%, while those reporting no pain increased from 19% to 74%. These changes suggest improved comfort during routine fertilization activities. However, a validated minimal clinically important difference has not been established for the total NBM score. Therefore, the reduction should be interpreted as a potentially meaningful practical improvement rather than definitive evidence of clinical effectiveness. This interpretation is further limited by the absence of a direct statistical comparison of changes between groups.

The categorical findings further supported this change. In the intervention group, the proportion of workers reporting no pain increased from 19% before the intervention to 74% after the intervention. The proportion reporting slight pain changed from 36% to 26%, while the proportion categorized as having painful complaints decreased from 45% to 0%. However, categorical posttest frequencies for the control group were not reported in the thesis; therefore, they were not presented or estimated in this manuscript. The reduction in NBM scores suggests that the redesigned seats may have provided more stable physical support for workers during fertilization activities. By providing designated seating on both sides of the gingga machine, the modification may have reduced unsupported working positions and excessive muscular effort required to maintain body stability. This may have decreased mechanical loading on the back, shoulders, waist, hips, and lower extremities.

Previous studies support the relationship between equipment design and musculoskeletal loading. Mohamaddan et al. demonstrated that the design and operating technique of oil palm harvesting tools affected workers' upper-body posture and muscle activity (Mohamaddan et al., 2021). Abdullah et al. found that oil palm harvesting tasks were associated with very high ergonomic risk scores, excessive compression at the L5–S1 spinal region, and high muscular activation (Abdullah et al., 2023). These findings suggest that physical modifications to plantation equipment may reduce exposure to biomechanical factors contributing to MSD complaints.

The findings are also consistent with ergonomic intervention studies in other physically demanding occupations. Susihono and Adiatmika reported a reduction in musculoskeletal complaints following an ergonomic intervention among traditional metal casting workers (Susihono & Adiatmika, 2021). Wurzelbacher et al. found that workers who regularly used ergonomic equipment during heavy material handling reported fewer lower back and upper extremity symptoms (Wurzelbacher et al., 2020). A systematic review of participatory ergonomic interventions also identified partial to moderate evidence that workplace modifications can reduce musculoskeletal symptoms, occupational injuries, and lost workdays (Rivilis et al., 2008). A recent systematic review and meta-analysis found that ergonomic interventions significantly reduced work related musculoskeletal pain, particularly in the lower back, upper back, wrists, ankles, and neck

(Santos et al., 2025). These body regions may benefit when workplace modifications reduce awkward postures and excessive mechanical loading. Nevertheless, the effectiveness of ergonomic interventions depends on the compatibility of the equipment with the worker, the nature of the task, intervention duration, and consistency of use.

Evidence regarding chair based interventions remains mixed. Van Niekerk et al. found a consistent trend toward reduced musculoskeletal symptoms following workplace chair interventions, although the overall quality of evidence was moderate (Van Niekerk et al., 2012). In contrast, Channak et al. reported conflicting and generally low certainty evidence regarding the effects of chair interventions on lower back pain, discomfort, and trunk muscle activation (Channak et al., 2022). These findings indicate that adding a seat alone may not be sufficient unless its dimensions, position, structural stability, and supporting components are appropriate for the users and the work environment.

The findings indicate that seating should be treated as an integrated component of gingga machine design rather than an additional platform alone. Further development should incorporate anthropometric adjustability, adequate seat depth and width, back and lateral support, foot support, vibration attenuation, safe handholds, and stability on uneven terrain. The additional structure should not adversely affect the machine's center of gravity, maneuverability, fuel consumption, fertilizer distribution, or operator safety. Sustainable implementation also requires durable and corrosion resistant materials, replaceable components, routine inspection, local repairability, and worker involvement in prototype evaluation. These improvements may extend the useful life of the intervention while ensuring that ergonomic benefits are maintained under plantation conditions.

The redesigned gingga seats in this study were constructed from metal and installed on the left and right sides of the machine. However, the design had not been fully individualized according to variations in workers' anthropometric dimensions. Future modifications should consider seat height, width, depth, back support, foot support, clearance, vibration exposure, and worker stability when the machine is operated on uneven plantation terrain. Ergonomic training should also accompany equipment modification because workers need to understand how to maintain safer postures and use the redesigned equipment correctly (Pillastrini et al., 2010; Robertson et al., 2009; Van Niekerk et al., 2012). The lack of a significant change in the control group and the significant reduction in the intervention group provide preliminary support for the potential benefit of the redesigned seats. However, the statistical tests were conducted separately within each group. A significant pretest–posttest result in the intervention group and a nonsignificant result in the control group do not automatically demonstrate that the magnitude of change differed significantly between the groups. A direct comparison of change scores or an analysis of covariance controlling for baseline scores would be required to confirm the comparative effect of the intervention.

Several limitations should be considered. Participants were selected using purposive sampling and were not randomly allocated to the groups. Differences in age, sex, educational level, and length of employment may have influenced the findings. Musculoskeletal complaints were measured using a self-reported instrument without objective assessment of working posture, muscle activity, vibration, or biomechanical load. Although Nordic instruments are widely used and the Indonesian version has demonstrated acceptable validity and reliability (Ramdan et al., 2019), self-reported data remain susceptible to recall and response bias. Future studies should include anthropometric measurements during the design process, direct postural assessments such as the Rapid Entire Body Assessment, objective measurements of vibration and biomechanical loading, and longer follow-up periods. Randomized or matched comparison groups and direct statistical comparisons of score changes should also be used to provide stronger evidence of intervention effectiveness.

4. CONCLUSION

The redesigned seats added to the gingga machine were associated with reduced musculoskeletal complaints among oil palm fertilization workers. In the intervention group, the mean Nordic Body

Map score decreased from 62.10 to 54.35, with a mean reduction of 7.75 points ($p < 0.001$). In contrast, the control group showed only a small and nonsignificant reduction from 61.45 to 60.80 ($p = 0.231$). These findings provide preliminary evidence that modifying the gingga machine may improve workers' physical support and reduce musculoskeletal complaints during fertilization activities.

Further research should use randomized or matched groups, direct between group analysis of score changes, and longer follow up to determine whether the improvement is maintained. Future prototypes should be developed using workers' anthropometric measurements and evaluated through objective postural, biomechanical, and vibration assessments. Studies should also examine safety on different terrain, user acceptance, productivity, durability, maintenance requirements, and cost-effectiveness to ensure the intervention's effectiveness and sustainability. For practical implementation, plantation management may introduce the redesigned seats through a controlled pilot program accompanied by worker fit assessment, training in safe posture and machine use, pre-operational safety checks, and routine maintenance. Workers' musculoskeletal complaints, equipment stability, and field safety should be monitored periodically before wider adoption. Because the prototype was fixed and not fully individualized, implementation should include progressive anthropometric adjustment rather than applying one seat configuration to all workers.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the management and oil palm fertilization workers who participated in this study. The authors also thank Universitas Islam Negeri Alauddin Makassar for its academic support and Denarya Education Center for assistance with manuscript preparation and academic editing.

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