Journal of Integrated System (JIS)
Vol. 7 No. 2 December 2024: 211-222
e-ISSN: 2621-7104

Received: 17 October 2024
Accepted: 29 December 2024
https://doi.org/10.28932/jis.v7i2.10152

The Ergonomic Risk Evaluation of Work Posture for Oil Palm Harvest Workers in Large Plantations in East Kalimantan using SNI 9011:2021

Theresia Amelia Pawitra*, Rivki Al Khairi, Dharma Widada
Program Studi Teknik Industri, Fakultas Teknik, Universitas Mulawarman, Samarinda, Indonesia
*Corresponding author, email: triciapawitra@gmail.com

Abstract

Indonesia, as the world's largest palm oil producer, relies on contributions from smallholder farms, state plantations, and private estates. Despite its scale, much of the harvesting process remains manual, posing risks of musculoskeletal disorders due to non-ergonomic work postures. This study evaluated work postures in two plantations: PT DSN (private) and PTP XIII (state-owned) in East Kalimantan, involving 96 workers: 47 harvesters, 12 transporters, and 37 loose fruit collectors. The findings revealed that 83% of harvesters experienced neck pain, 75% of transporters of fresh fruit bunches (FFB) reported knee pain, and 95% of loose fruit collectors faced neck pain. Ergonomic Risk Factor analysis showed FFB transportation as the most hazardous activity (score 74), followed by harvesting (62) and loose fruit collection (55). The key contributors to these risks included body posture and manual material handling, with body posture contributing 58% to scores in loose fruit collection and FFB unloading. Proposed ergonomic improvements include holistic safe care for harvesters, tractor scissor lifts for FFB transport, and modified nut pickers for loose fruit collection. While these interventions promise to increase efficiency, productivity, and safety, success hinges on addressing challenges such as initial costs, worker training, and equipment adaptation to field conditions.

Keywords: ergonomic, palm oil, musculoskeletal disorder, SNI 9011:2021

1. Introduction

According to BPS (2020), the area of palm oil plantations in East Kalimantan covers 1,228,238 hectares, consisting of smallholder plantations, state-owned plantations, and private plantations. Some companies involved in the palm oil sector include PT Perkebunan XIII Kebun Tabara and PT Dharma Satya Nusantara. Both plantations are large; however, PT DSN is privately owned, while PTP XIII is government-owned. PTP XIII Kebun Tabara is located in Paser, and PT DSN is situated in Muara Wahau. In both large plantations, the harvesting of palm oil is still carried out manually (Pawitra *et al*., 2023). Manual handling includes the harvesting of Fresh Fruit Bunches (TBS), which involves harvesting TBS, collecting loose fruit, and transporting TBS from collection points to trucks.

Palm oil plantation workers are at risk of experiencing musculoskeletal disorders (MSDs) due to improper work postures (Alisha *et al*., 2021; Arsi *et al*., 2020; Myzabela *et al*., 2019). Musculoskeletal disorders refer to injuries and diseases affecting the muscles, nerves, tendons, ligaments, joints, cartilage, and spine (Suryani *et al*., 2022). Dianat *et al.* (2020) stated that this risk arises from heavy and repetitive physical activities such as harvesting, collecting loose fruit, and transporting palm fruit, as well as awkward body postures while working, such as bending or twisting, the use of poorly designed tools, and long working hours with limited breaks.

Improving work posture is essential to reduce the risk of injuries and musculoskeletal disorders (MSDs), enhance comfort and work efficiency, maintain the long-term health of workers, and ultimately increase plantation productivity. Numerous studies have been conducted to evaluate work-related musculoskeletal disorders (WMSDs) among palm oil workers during four main harvesting activities. For instance, research in palm oil plantations in Indonesia (Teresia and Lestari, 2022; Priyambada and Suharyanto, 2019; Suryani *et al*., 2022; Surya *et al*. (2017); Arsi *et al*., 2020; Hendra and Rahardjo, 2009; Alisha *et al*., 2021; Prabawati and Lidiana, 2021; Syuaib *et al*., 2015), as well as studies in

How to Cite:
Pawitra, T.A., Khairi, R. Al and Widada, D. (2024) ‘The ergonomic risk evaluation of work posture for oil palm harvest workers in large plantations in East Kalimantan using SNI 9011:2021’, *Journal of Integrated System*, 7(2), pp. 211–222. Available at: https://doi.org/10.28932/jis.v7i2.10152.

Malaysian plantations (Ng *et al*., 2013; Deros *et al*., 2016; Nawi *et al*., 2016; Henry *et al*., 2015), and in various countries such as Papua New Guinea, Cameroon, Ghana, and Myanmar (Myzabella *et al*., 2019) have been published. However, among the reviewed literature, only Saputri *et al*. (2022) studied in Berau, Alisha *et al*. (2021) in West Kalimantan, and Pawitra *et al*. (2023) in East Kalimantan.

The reviewed literature underscores several emerging issues and notable differences in research on ergonomic risks and musculoskeletal disorders within palm oil plantations. A significant issue is the influence of environmental and climatic factors, such as extreme weather, on worker health and fatigue, which often indirectly but substantially contribute to ergonomic risks. Another critical focus is the integration of ergonomics with productivity objectives, as many studies highlight how optimizing worker postures and minimizing physical strain can improve efficiency in harvesting and material handling activities. A key distinction lies in the application of localized versus global ergonomic standards; for instance, research in Indonesia frequently utilizes national standards such as SNI 9011:2021 (Pawitra *et al*., 2023), while studies in Malaysia and other regions adopt internationally recognized frameworks, underscoring the challenges of achieving standardization across varied operational settings.

Furthermore, research gaps are evident in underrepresented regions, such as Berau in East Kalimantan (Saputri *et al*., 2022), and among worker groups beyond those engaged in harvesting tasks. Disparities in occupational health practices across countries are also apparent, as highlighted in the comparative study by Myzabella *et al*. (2019), which examines diverse regulatory and economic contexts in Papua New Guinea, Cameroon, Ghana, and Myanmar. Lastly, there is limited exploration of the long-term sustainability and effectiveness of ergonomic interventions, with few studies investigating their enduring impact on reducing musculoskeletal disorders and enhancing workplace health. These distinctions and emerging issues emphasize the need for more inclusive, comprehensive, and standardized research approaches to tackle the multifaceted challenges faced by workers in the palm oil industry. In 2010, the World Bank, also, highlighted that the safety and health of workers in palm oil plantations pose a challenge for the sustainability of the industry in the future (Myzabella *et al*., 2019). Improving worker safety and health will positively impact work performance, which, in turn, enhances palm oil plantation productivity. Therefore, this study aims to identify the ergonomic issues in the body postures of palm oil workers and provide suggestions for improvements, especially in large plantation in East Kalimantan.

2. Method

Data collection for this study was conducted from November to December 2023. The sampling method used involves total workers from a specific division (afdeling) chosen by the company. The total sample size for this study is 96 workers, consisting of 47 harvesters, 12 transporters, and 37 loose fruit collectors from PT Perkebunan XIII Kebun Tabara and PT Dharma Satya Nusantara. The sample size represents the total number of workers in the afdeling being studied. The afdeling studied was determined by the company. The palm oil harvesting process consists of several stages: cutting FFB from the tree using an *egrek* (harvester), transporting it to the fruit collection point (mover), loading the fruit from the collection point onto the truck (transporter), and collecting loose fruits (collector). The evaluation of the ergonomic appropriateness of workers' postures was conducted using the GOTRAK method and the Ergonomic Risk Factor (ERF) assessment. Both methods are based on SNI 9011:2021 (Badan Standardisasi Nasional, 2021). GOTRAK is used to assess whether there are any musculoskeletal disorder (MSD) complaints. The survey depends on the tasks performed by the respondents. Since a harvester not only uses the *egrek* but also transports FFB to the collection point, the GOTRAK survey combines the harvester and mover roles, as both tasks are performed by the same worker.

SNI 9011:2021 is divided into two parts: the identification of workers using the GOTRAK survey, which involves video recordings of work activities and filling out the GOTRAK survey forms. If the number of workers with a GOTRAK score ≥ 8 exceeds 30% of the total respondents, further analysis using the Ergonomic Risk Factor (ERF) method is necessary (Badan Standardisasi Nasional, 2021).

Table 1 illustrates how to determine the GOTRAK score, where red indicates high risk, yellow represents moderate risk, and green signifies low risk.

To determine GOTRAK score, respondents are asked about the severity and frequency of discomfort in each body segment (National Standardization Agency, 2021). The severity scale is as follows: (1) No Problem: no complaints and does not interfere with work, (2) Uncomfortable: there are complaints that begin to slightly interfere with work, (3) Pain: discomfort that interferes with work, (4) Severe Pain: very painful, making it impossible to work. The frequency scale is as follows: (1) Never: does not occur, (2) Sometimes: may occur 1–3 times a year, (3) Often: may occur 1–3 times a month, (4) Always: occurs almost daily.

For the calculation of the Ergonomic Risk Factor (ERF), the researcher recorded videos of each harvesting activity. From these videos, potential ergonomic hazards were identified, and the percentage of time workers were exposed to these hazards was calculated. The exposure level can be calculated using the formula below (Badan Standardisasi Nasional, 2021).

$$\text{exposure level percentage}=\frac{\text{Exposure duration to hazard(Hours)}}{\text{Duration of work in one shift(Hours)}}\times 100\% \quad (1)$$

The percentage exposure value is used to obtain the ERF score. If the total score for the activity is ≥ 7, it indicates a very severe potential for improper work posture, requiring immediate corrective action (Badan Standardisasi Nasional, 2021). From the same reference, if the result is low, the need for posture improvement can be reconsidered.

Table 1. Risk level of GOTRAK (Badan Standarisasi Nasional,2021)

Frequency	Severity			
	No Problem	Uncomfortable	Pain	Severe Pain
Never	1	2	3	4
Sometimes	2	4	6	8
Often	3	6	9	12
Always	4	8	12	16

3. Result and Discussion

3.1 GOTRAK Survey

GOTRAK survey was conducted on 96 palm oil harvesters from PT Perkebunan XIII Kebun Tabara and PT Dharma Satya Nusantara, comprising 47 harvesters, 37 collectors of loose fruit, and 12 transporters. The number of movers is the same as the number of palm oil harvesters because harvesters also serve as movers, transferring fresh fruit bunches (FFB) to the collection point from the trees that have been harvested. The average age of the harvesters is over 35 years, which increases the potential risk of musculoskeletal disorders (MSDs) (Alisha *et al.* (2021), Hendra and Rahardjo (2009)). Figure 1 shows GOTRAK results for each activity with scores ≥ 8.

Figure 1 shows activities in harvesting that have more than 30% of respondents with GOTRAK scores ≥ 8. Figure 1 shows more than 30% harvester experienced GOTRAKscore ≥ 8 in neck, elbow, shoulder and knee. This is because, when using an *egrek*, workers must tilt their heads upward to see the palm fronds or FFB that need to be cut (see Figure 2). They also must repeatedly thrust their arms to ensure the *egrek* can cut the fronds or FFB. Afterward, they load the FFB into a wheelbarrow to transport it to the fruit collection point. This repetitive activity causes more than 60% of harvest workers to experience neck and knee pain. This leads to muscle fatigue and stiffness (Walker-Bone and Palmer, 2002). Additionally, intensive use of muscles causes fatigue to develop quickly (Susihono and Adiatmika, 2021). The hip is also affected, as they continually move and twist to follow the angle of the fresh fruit bunches being lowered with the sickle.

More than 30% of transporters had a GOTRAK score ≥8 in all analyzed segments except for the neck and calves. This is because the loaders are responsible for lifting FFB from the collection point onto the truck, requiring workers to swing their arms upward to toss the FFB over the side of the truck. The higher the FFB stack on the truck, the higher the workers must swing their arms (see Figure 3). Given that each FFB weighs an average of 25 kg per bunch and this posture is repeated continuously over a long period (more than 6 hours per day), it is unsurprising that over 60% of transport workers experience pain in their elbows, hands, shoulders, and knees.

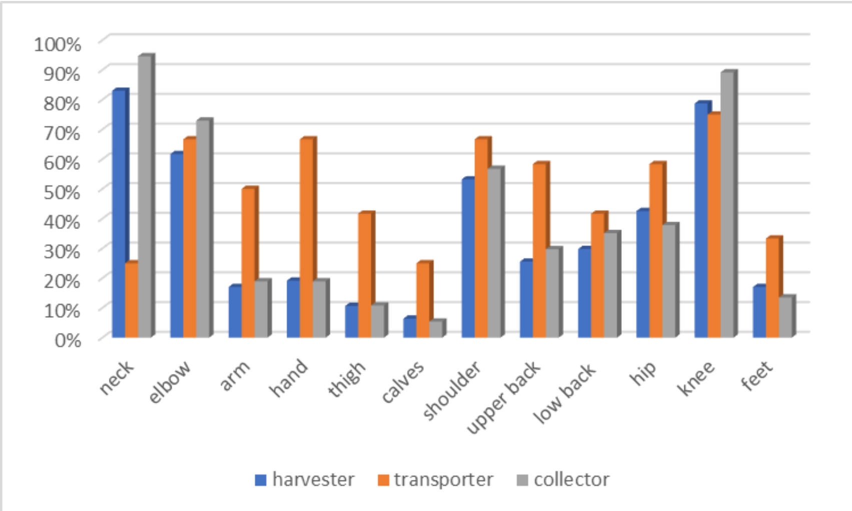

Figure 1. GOTRAK evaluation diagram

Figure 2. Harvester's workers

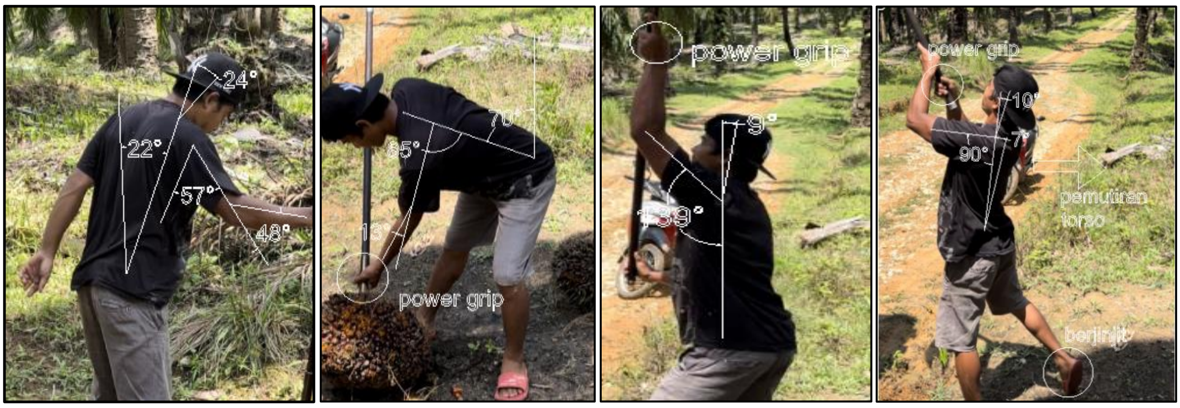

Figure 3. Transporter's workers

Similarly, more than 30% of loose fruit collectors also experienced a GOTRAK score ≥8 in almost all body segments, except for the arms, hands, thighs, calves, and feet. Loose fruit collectors must bend and squat or stoop to search for and pick up loose fruits from the ground and place them into a sack (see Figure 4). Afterward, they walk around to find more loose fruits on the ground. This activity is repeated continuously. Once the sack is full, workers carry it to the collection point, either by shouldering it or carrying it near their hip. This task is performed repeatedly over a long period (more than 6 hours per day). As a result, more than 80% of loose fruit collectors experience pain in their neck and knees.

Figure 4. Loose fruit collector's worker

3.2 ERF Survey

After conducting the work posture analysis using GOTRAK survey, it was found that all harvesting activities had GOTRAK scores of 8 or higher. Therefore, the posture analysis was continued using the Ergonomic Risk Factor (ERF) method. Table 2 presents a recap of the ERF scores. These scores were derived from the completion of a checklist outlined in SNI 9011:2021. In the checklist, the researcher marked ergonomic postures that occurred in each activity along with the percentage of time spent in those positions divided by the length of the work shift. The score for each position was determined based on these two factors. The values in Table 1 represent the average ERF scores from PT DSN and PTP XIII. The activities performed at both plantations are identical, as they are both large plantations with nearly the same area and similar terrain characteristics.

The differences between the two locations do not affect the GOTRAK results because workers in both companies engage in the same tasks: harvesting and transporting fruit to the collection site, picking up loose fruits, and loading FFB (Fresh Fruit Bunches) onto trucks. The equipment used is also the same, such as *egreks* (harvesting tools), loose fruit sacks, and wheelbarrows, resulting in no significant differences in the evaluated body postures. The key difference between large plantations and smallholder plantations lies in the transportation of FFB from the fruit collection point to the CPO (Crude Palm Oil) processing facility. Large plantations use trucks for transportation, while smallholder plantations typically use pickup trucks.

Based on the results of the work posture assessment using the ERF survey in Table 2, the classification of risk levels was obtained from the final score calculations for each activity of palm oil harvesters. The results of the assessment for each harvesting activity can be seen in Figure 5. Figure 5 shows that transporting fresh fruit bunches has the highest total score, followed by harvesting and collecting loose fruit. In the activity of transporting fresh fruit bunches to the truck, the lack of ergonomics is attributed to body posture (score 38) and manual material handling (MMH) (score 36). For collecting loose fruit and lowering fresh fruit bunches, MMH contributes more to the total score than body posture.

Table 2. ERF evaluation

Potential Hazard Number	Category	Score		
		Lowering FFB	Transporting FFB	Collecting Loose Fruit
1	Twisted Neck	4,5	5	5,5
2	Unsupported Arms	6,5	2	0
4	Bent Wrist	3	0	3
5	Moderate Hand Movement	0	4	0
6	Intensive Hand Movement	1	0	0
9	gripping with a power grip	4,5	6	0
10	Pressing Objects with Fingers >1 kg	0	3	3,5
11	Skin Compressed by Hard Objects	1	2	0
14	Control Factor	1	1	1
15	Lighting	1,5	1	1,5
16	temperature	1,5	1	1,5
17	Body Bent 20 – 45°	0	4	4,5
18	Body Bent >45°	0	0	4,5
19	Body Bent Back	2,5	0	0
20	Twisting Torso	0	1	0
22	Squatting Position	0	0	6,5
23	Ankle Bent Up	0	0	0
24	Ankle Activity	2,5	0	0
27	Body Pressed by Hard Objects	0	2	0
30	Moderate Load	0	0	0
31	Heavy Load	6,5	3	0
32	factor control	1	1	1
	Total Hazard Score	37	36	31,5
Potential Hazard Number	Manual Lifting Category	Score		
		Lowering FFB	Transporting FFB	Collecting Loose Fruit
33	Manual Lifting	12	18	9
34	Twisting Body While Lifting	0	1	0
35	Lifting with One Hand	0	2	4
36	Lifting Unexpected Loads	0	4	0
37	Lifting 1-5 Times Per Minute	1	0	1
38	Lifting More Than 5 Times Per Minute	3	5	0
39	Object Positioned Above Shoulder	2	4	0
40	Object Being Lifted Below Elbow Position	0	0	4
41	Carrying Objects Over Distances of 3-9 Meters	4	4	2
42	Carrying Objects Over Distances Greater Than 9 Meters	3	0	3
	Total Score of Manual Lifting	25	38	23
	Total Score	62	74	55,5

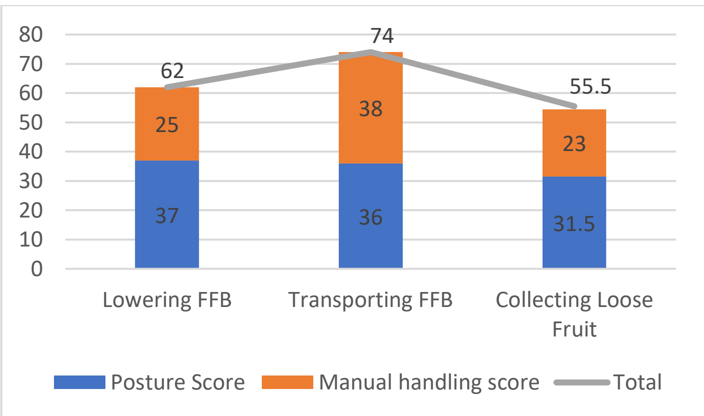

Figure 5. ERF evaluation diagram

3.3 Proposed Improvement

The following are recommendations for proposed improvements in the palm oil harvesting process. The ergonomic risk factor values after the improvements will be obtained from recalculating the ERF using the suggested tools. The use of these proposed assistive tools will eliminate several non-ergonomic positions, thereby reducing the previous scores.

3.3.1 FFB Harvesting Activities

Based on the data analysis of the harvesters, as seen in Table 2, issues include unsupported arms, bent wrists, and the weight of the sickle exceeding 5 kg (with the sickle weighing 6 kg). If harvesting continues to be done manually, the proposed improvement is an administrative control through Holistic Self Care, which combines stretching exercises and breathing techniques. According to Umairah (2020), Holistic Self Care, by integrating stretching exercises and breathing techniques, can address musculoskeletal disorders caused by work. Practicing these exercises five days a week for 4 to 6 weeks can improve workers' physical condition. Even patients with chronic pain can benefit from stretching exercises and breathing techniques to help alleviate their discomfort. By engaging in Holistic Self Care before harvesting, workers can reduce the load caused by forceful exertions when lifting the sickle throughout the harvesting process.

3.3.2 FFB Transporting Activities

The height of the truck used for transporting fresh fruit bunches from the ground to the truck is 3.5 meters, which requires significant effort to lift a weight of 20 kg repeatedly for 71.5 minutes each day. This can lead to rapid muscle fatigue and potentially result in musculoskeletal disorders (MSDs). One proposed improvement is to replace the current tractor with one equipped with a scissor lift in the bed (see Figure 6). This modification would facilitate the direct transfer of fresh fruit bunches from the ground to the truck bed without the need to first collect them at the collection point (TPH).

Using a scissor lift tractor for transporting fresh fruit bunches can reduce several non-ergonomic postures. For example, it eliminates the need to bend over when inserting the hook into the fruit bunches and the lifting and throwing of the bunches onto the truck. By reducing these postures, the transportation score decreases by 13 points, changing the final score from 74 to 61 for the transportation process (see Figure 7).

In addition to using a scissor lift, risk reduction can be achieved by using a conveyor, as shown in Figure 8 The use of this conveyor can lower the score from 35 to 22. This is because the neck no longer bends backward, the time spent supporting the arms is reduced from 33% to 16%, the exposure time for gripping decreases from 91% to 56%, the percentage of body bending drops from 58% to 40%, and there is no torso twisting involved.

Figure 6. Tractor scissor lift (Quick, 2017)

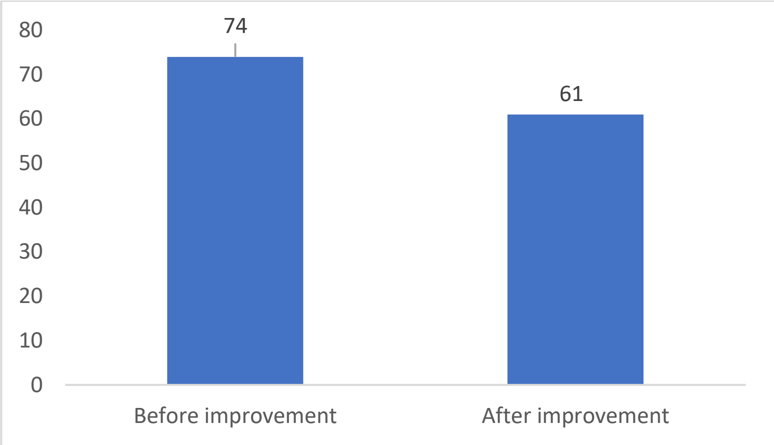

Figure 7. Comparison of transporter

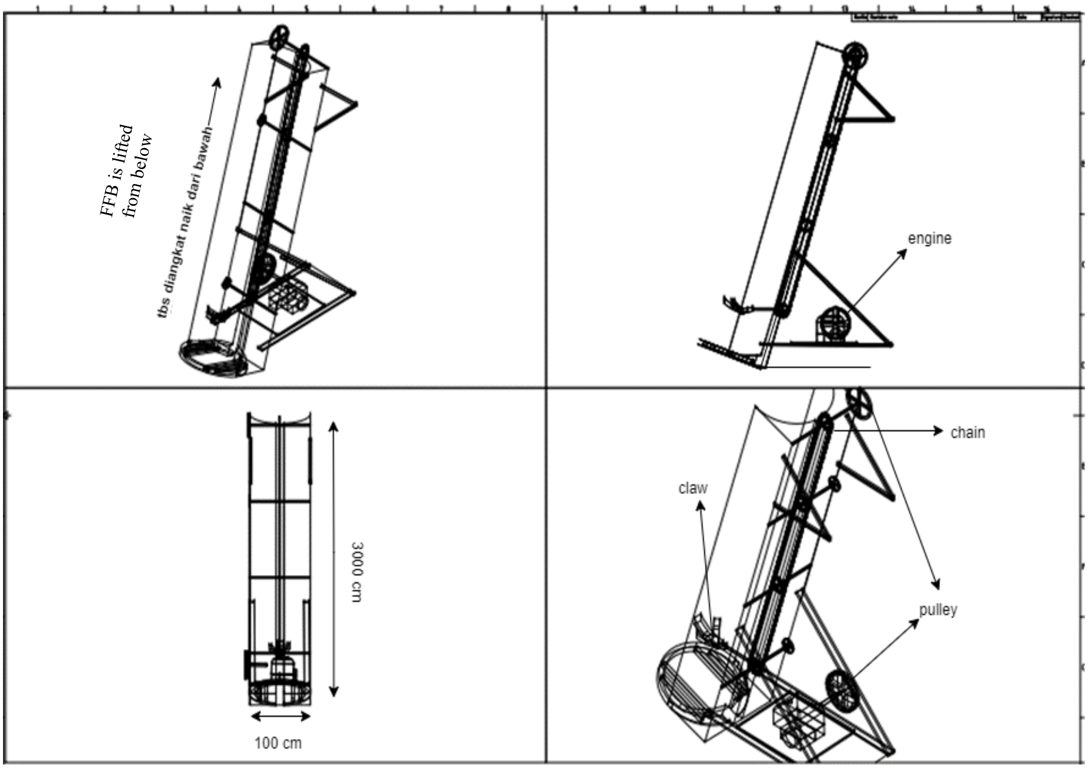

Figure 8. Conveyor design

3.3.3 Collecting Loose Fruit Activities

The proposed improvement for collecting loose fruit involves implementing an engineering control in the form of a tool: manual nut picker. There are two (2) types of nut picker, manual and motorize. Manual Nut Pickers (Mechanical) is a hand-operated tools featuring spiked rollers, rakes, or comb-like attachments that collect loose fruits as they are pushed across the ground (see Figure 9). Its advantages are affordable, lightweight, and simple to use. Its usage best for small to medium plantations or areas with uneven terrain. Motorized Nut Pickers is a powered by engines and equipped with rotating mechanisms, these self-propelled machines quickly gather loose fruits using suction, rollers, or brushes. Its advantages are highly efficient, speeds up collection, and reduces labour requirements. Its best for: large plantations requiring extensive loose fruit collection. By using a manual nut picker for loose fruit collection, workers no longer need to squat or bend over, so that it will reduce the ERF (Ergonomic Risk Factor) score 36% from 55.5 to 35.5 (see Figure 10).

Statistical testing (Wilcoxon sign rank test) was conducted to confirm whether there is a statistically significant difference in the ERF score before and after using the assistive tool. Figure 11 shows that there is a significant difference between the ERF scores before and after the use of scissor lift. This outcome is expected, as the score reduction is attributed to the elimination or decrease of non-ergonomic postures.

The score reduction occurred because the arms are no longer raised to waist height, the neck is not twisted, the percentage of body bending decreased from 58% to 45%, lifting is done close to the body, the TBS (Total Body Score) position is at waist level, and there is no need to lift loads weighing 1-9 kg thanks to the scissor lift that brings the load closer to the truck. The Wilcoxon sign test is conducted to determine whether there is a difference between before and after the implementation of the conveyor. Figure 12 shows a significant difference in the ERF score (p value ≤ 0.05). The results indicate that the use of assistive technologies, such as scissor lift tractors or nut pickers, can help prevent musculoskeletal disorders (MSDs) in palm oil workers, as mentioned in previous studies discussed above. The use of these technologies can reduce non-ergonomic or awkward working postures, such as bending, raising arms above the waist, or twisting. Additionally, the use of technology can also reduce the load that needs to be carried.

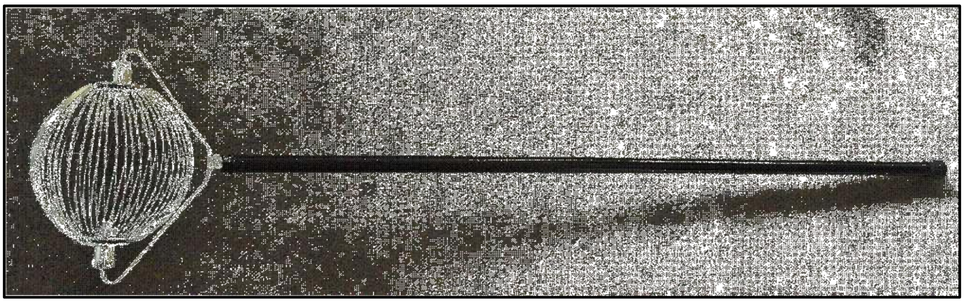

Figure 9. *Nut picker* (InfoSawit, 2024)

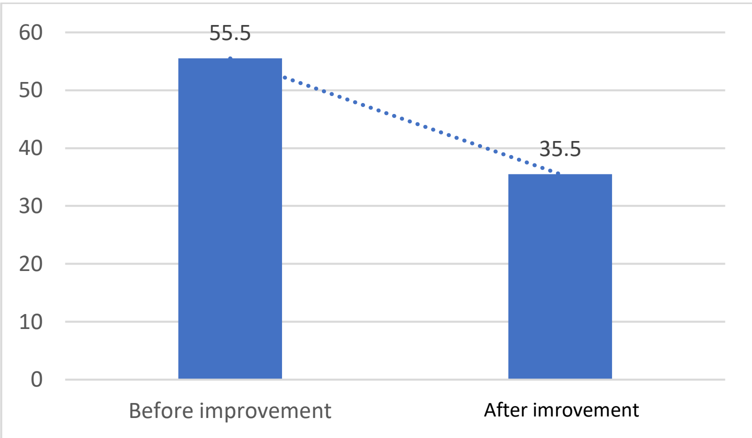

Figure 10. Comparison of loose fruit collector

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between Pre_lift_A and Post_lift_A equals 0.	Related-Samples Wilcoxon Signed Rank Test	.009	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Figure 11. Wilcoxon sign test result of before and after using the scissor lift

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between Pre_conv_B and Post_conv_B equals 0.	Related-Samples Wilcoxon Signed Rank Test	.023	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Figure 12. Wilcoxon sign test result of before and after using the conveyor

3.4 Managerial Implications

The integration of assistive technologies, such as scissor lift tractors, conveyors, and nut pickers, offers significant benefits for palm oil plantations by improving efficiency, reducing physical effort, and enhancing compliance with safety standards. Despite high initial investments, the long-term advantages include reduced labour costs, fewer workplace injuries, and improved operational sustainability, which also bolster the company's reputation and appeal to stakeholders.

For workers, these technologies provide safer and more ergonomic conditions, minimizing physical strain and reducing the risk of injuries. They also present opportunities for skill development and career growth, contributing to job satisfaction and morale. However, managers must address challenges such as training requirements, adaptation difficulties, and worker concerns about job security.

To ensure successful implementation, companies should start with pilot projects, establish maintenance schedules, and provide comprehensive training programs. Engaging workers in the transition process and monitoring the impact of these tools will facilitate acceptance and sustained efficiency. Strategically adopting assistive technologies can boost productivity, improve worker welfare, and support sustainable growth, ensuring a competitive edge in the industry.

The studies previously reviewed before in Introduction part, propose various methods to prevent or mitigate musculoskeletal disorders (MSDs) among plantation workers, focusing on ergonomic interventions, workplace modifications, and the adoption of assistive tools. Traditional ergonomic approaches emphasize redesigning tasks, adjusting workstations, and providing training on proper techniques for lifting and posture management. Holistic methods, including stretching exercises and relaxation techniques, are also recommended to enhance workers' physical resilience. Tools like RULA and ERF scores are frequently used to assess ergonomic risks and prioritize areas for improvement. While these studies often advocate for simple, cost-effective solutions such as nut pickers, sack carriers, and adjustable tools, others emphasize the benefits of advanced technologies like scissor lift tractors, conveyors, and mechanized tools to further reduce physical strain and enhance productivity.

Although both traditional and advanced approaches aim to improve workplace conditions and reduce ergonomic risks, they differ significantly in scope and impact. Traditional methods focus on immediate, low-cost solutions that primarily improve worker health, making them more accessible for plantations with limited resources. Advanced technologies, on the other hand, offer broader, systemic improvements, including higher productivity and operational efficiency. However, these technologies often require significant financial investment, infrastructure development, and worker training, which may not be feasible for smaller plantations.

Another key distinction lies in the consideration of psychosocial factors. Traditional ergonomic interventions often address broader worker well-being, including stress and fatigue, while studies promoting advanced technologies tend to focus more narrowly on physical ergonomic risks. To address these gaps, a balanced strategy is recommended—one that implements affordable ergonomic tools for immediate improvements while planning for the gradual adoption of advanced technologies as resources and infrastructure allow. Future research should examine the combined impact of these approaches on worker well-being and operational efficiency, ensuring comprehensive and sustainable solutions for reducing MSDs in plantation work.

4. Conclusion

A survey of musculoskeletal disorders among 96 workers revealed that pain during fresh fruit bunch (FFB) harvesting was most felt in the neck, while transporting FFB caused pain primarily in the knees. Loose fruit collection also resulted in significant neck pain. The highest ergonomic risk factor (ERF) score was for transporting FFB (74), followed by harvesting (62) and loose fruit collection (55). To mitigate these risks, recommendations include using scissor lift tractors for transporting FFB, adopting Holistic Self Care practices (stretching and breathing techniques) for harvesting, and designing nut pickers for loose fruit collection. Simulations showed that scissor lift tractors could lower the ERF score for transporting by 13 points, while nut pickers could reduce the ERF score for loose fruit collection by 20 points by minimizing non-ergonomic postures.

The research highlights the importance of ergonomic interventions, such as assistive technologies, in reducing musculoskeletal disorders and improving workplace safety. However, limitations include the potential lack of generalizability, economic disparities affecting technology adoption, and insufficient focus on psychosocial factors. Despite these challenges, investing in these tools can enhance efficiency, reduce worker strain, and improve overall job satisfaction, leading to higher productivity and operational performance. The study also emphasizes the need for context-specific ergonomic solutions and further research on long-term impacts and cost-benefit analyses. While foundational, this research underscores the importance of innovation and policy advancements in agricultural ergonomics.

References

Alisha *et al.* (2021). ‘Determinants of musculoskeletal complaints in workers unloading and loading of palm oil fresh fruit bunches (FFB)’. *JIK (Jurnal Ilmu Kesehatan)*, 5(2), pp. 366–374.

Arsi, F., Zadry, H.R. and Afrinaldi, F. (2020). ‘Perbaikan postur kerja proses muat kelapa sawit berdasarkan metode Selang Alami Gerak (SAG)’. *Jurnal Inovasi Vokasional Dan Teknologi*, 20(1), pp. 1–12. Available at: https://doi.org/10.24036/invotek.v20i1.710

Deros, B.M. *et al.* (2016). ‘Ergonomic risk assessment on oil palm industry workers’. *Iranian Journal of Public Health*, 45(March), pp. 44–51.

Dianat, I. *et al.* (2020). ‘Work posture, working conditions, and musculoskeletal outcomes in agricultural workers’. *International Journal of Industrial Ergonomics*, 77, pp. 1–9. Available at: https://doi.org/10.1016/j.ergon.2020.102941

Hendra and Rahardjo, S. (2009). ‘Risiko ergonomi dan keluhan musculoskeletal disorders (MSDs) pada pekerja panen kelapa sawit’. *Prosiding Seminar Nasional Ergonomi IX*, November, pp. 978–979.

Henry, L.J. *et al.* (2015). ‘Patterns of work-related musculoskeletal disorders among workers in palm plantation occupation’. *Asia-Pacific Journal of Public Health*, 27(2), NP1785–NP1792. Available at: https://doi.org/10.1177/1010539513475657.

InfoSawit (2024). ‘Memungut berondolan sawit lebih efisien menggunakan APB’. Available at: https://www.infosawit.com/2024/06/29/memungut-berondolan-sawit-lebih-efisien-saat-gunakan-apb/ (Accessed: 25 December 2024).

Myzabella, N. *et al.* (2019). Occupational health and safety in the palm oil industry: A systematic review. *International Journal of Occupational and Environmental Medicine*, 10(4), pp. 159–173. Available at: https://doi.org/10.15171/ijoem.2019.1576

Nawi, N.S. *et al.* (2016). Malaysian oil palm workers are in pain: Hazards identification and ergonomics related problems. *Malaysian Journal of Public Health Medicine*, 16(May), pp. 50–57.

Ng, Y.G. *et al.* (2013). ‘Ergonomics observation: Harvesting tasks at oil palm plantation’. *Journal of Occupational Health*, 55(5), pp. 405–414. Available at: https://doi.org/10.1539/joh.13-0017-FS

National Standardization Agency (2021). *SNI 9011:2021 ‘Pengukuran Dan Evaluasi Potensi Bahaya Ergonomi Di Tempat Kerja’.* BSN, Jakarta.

Prabawati, R.K. and Lidiana, E. (2021). 'Profil pekerja pemanen kelapa sawit bagian cutting sickle'. *Herb-Medicine Journal*, 4(2), p. 23. Available at: https://doi.org/10.30595/hmj.v4i2.9931

Pawitra, T.A. *et al.* (2023). Assessment of musculoskeletal disorders among palm oil farmers with SNI 9011:2021 in Muara Wahau. *Operations Excellence: Journal of Applied Industrial Engineering*, 15(3), pp. 243–251.

Priyambada, G. and Suharyanto, S. (2019). 'Analisis risiko postur kerja di industri kelapa sawit menggunakan metode Ovako Working Analysis System dan Nordic Body Map'. *Jurnal Teknik Lingkungan*, 25(1), pp. 43–56. Available at: https://doi.org/10.5614/j.tl.2019.25.1.4

Tractor Angkut Quick Tractor QT-16 (2017). Available at: https://quick.co.id/qt-16-e-series (Accessed: 25 December 2024).

Surya, R.Z. (2017). 'Pemetaan potensi musculoskletal disorders (MSDS) pada aktivitas manual material handling (MMH) kelapa sawit'. *Journal of Industrial Engineering and Management Systems*, 10(1), pp. 25-33.

Suryani, E. *et al.* (2022). 'Assessment postur kerja pada pekerja panen kelapa sawi't. *Jurnal Teknik Industri – Universitas Bung Hatta*, 9(1), pp. 25–31.

Syuaib, M.F. and Dewi, N.S. (2015). 'Studi gerak kerja pemanenan kelapa sawit secara manual'. *Jurnal Keteknikan Pertanian*, 3(1), pp. 49–56.

Saputri, A.I., Ramdan, I.M. and Sultan, M. (2022). 'Postur kerja dan keluhan musculoskeletal disorders pada pemanen sawit di PT. Inti Energi Kaltim Kabupaten Berau'. *TROPHICO: Tropical Public Health Journal - Faculty of Public Health, USU*, pp.54-59.

Teresia, V. and Lestari, D.I. (2022). 'Analisis postur kerja terhadap keluhan gangguan muskuloskeletal pada pekerja pemanen kelapa sawit'. *Tarumanagara Medical Journal*, 4(2), pp. 352–359. Available at: https://doi.org/10.24912/tmj.v4i2.20767.

Umairah, S. *et al.* (2020). 'Efektifitas holistic self-care mengatasi gangguan otot tulang rangka akibat kerja pada pekerja dodos sawit Riau'. *Jurnal Universitas Islam Riau*, 1(69), pp. 5–24.

Walker-Bone, K., and Palmer, K.T. (2002). Musculoskeletal disorders in farmers and farm workers. *Occupational Medicine*, 52(8), pp. 441–450. Available at: https://doi.org/10.1093/occmed/52.8.441.