Vol. 14, No. 2 (2025): 594 - 603 http://dx.doi.org/10.23960/jtep-l.v14i2.594-603

JURNAL TEKNIK PERTANIAN LAMPUNG

ISSN 2302-559X (print) / 2549-0818 (online)
Journal homepage : https://jurnal.fp.unila.ac.id/index.php/JTP

Risk Assessment for Long-Term Injury of Oil Palm Harvester

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Article History:

Received : 13 December 2024
Revised : 26 January 2025
Accepted : 27 February 2025

Keywords:

Ergonomics,
Oil palm harvesters,
Rapid entire body assessment,
Risk level,
Workload.

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ABSTRACT

Fresh fruit bunches (FFB) are mostly harvested manually in large and small plantations. Ergonomically, this type of work has the potential to cause permanent muscle injuries over time. Based on these concerns, a study was conducted to assess the workload by monitoring heart rates using a Heart Rate Monitor for each task element of the oil palm fruit harvesters. The risk level of these harvesters was also assessed using the Rapid Entire Body Assessment (REBA) method. The risk levels were evaluated based on the weight and height of harvesters. The analysis of the harvesters' workload, based on heart rate measurements during different harvesting activities, shows that cutting bunches and fronds falls into the heavy workload category. Moving between locations is classified as a moderately heavy workload, while unloading and organizing bunches at the collection site (TPH) is considered a light workload. The results of the risk level analysis for the harvesters show that for the minimum weight variable, the risk is in the moderate risk category, while for the maximum weight variable, the risk is classified as high. In terms of height, both the minimum and maximum height variables fall into the moderate risk category.

1. INTRODUCTION

Oil palm is the main commodity in plantations in Indonesia. Currently, palm oil is one of the world's main sources of vegetable oil. The condition of the oil palm plantation area in Indonesia is also increasing. The expansion of oil palm land has increased since 2017 until now. The area of palm oil plantations in the country during 2017-2021 experienced an increasing trend. The Ministry of Agriculture (MOA) noted that the area of palm oil plantations will reach more than 16 million hectares (ha) in 2021. The plantation area increased by 1.5% compared to the previous year, which was 1.48 million ha. Of the 16 million ha, the majority is owned by Large Private Plantations (PBS) 55.8%, then People's Plantations (PR) 40.34% and Large State Plantations (PBN) 3.84%. The Ministry of Agriculture also noted that the national palm oil production amounted to 49.7 million tons in 2021. This figure increased by 2.9% from the previous year which amounted to 48.3 million tons (Direktorat Jenderal Perkebunan, 2020).

The results of Djamalus & Rahardjo (2009), research on Musculoskeletal Disorders (MSDs) injuries in oil palm harvesters stated that the risk of harvesting work has a high category (score 8-10) Attention to the plantation sector workforce, especially harvesting workers, needs special attention given the burden of workers at risk of permanent injury. This permanent injury has not been specifically recognized by all stakeholders. The weight of one palm fresh fruit bunch is between 16 kg and 32 kg. Until now the harvesters are still dominated by manual labor to harvest fresh fruit bunce weighing 15-30 kg/bunch, so that there is a potential of permanent injury for palm oil workers in the field.

Incorrect or unergonomic work positions practiced by workers at work will accelerate fatigue of workers and even risk 2.5 times greater spinal disorders than working with ergonomic work postures (Fibriansari, 2018). The area of oil palm plantations in Indonesia currently exceeds 16 million hectares, with annual palm oil production reaching 55.24

million tons in 2023 (Sipayung, 2024). Despite innovations in mechanical and robotic harvesting tools, the national palm oil plantation industry remains highly labor-intensive, particularly in harvesting activities. However, significant obstacles remain in the field. Various reasons have been cited for the low implementation of mechanical harvesting tools, one of which is comfort issues that impact harvesting work productivity.

The potential for long-term muscle damage can be ergonomically analyzed for harvesting workers in the oil palm plantation industry. One of the causes is that during harvesting operations, many harvesters are needed to pursue large harvest volumes. Body movements in the palm oil harvesting and transportation process include workers looking up when using an "egrek" to cut palm fruit bunches, and workers bending down to transport palm oil. Workers in the palm oil industry often report feeling pain due to these practices (Surya, 2017). According to the Ministry of Health, 41% of palm oil workers experience health problem due to work environments (Departemen Kesehatan, 2007). When lowering Fresh Fruit Bunches (FFB), palm oil harvesters often stand with an unsafe foot position and bent knees, leaning forward or hunched over, and the body tilted following the direction of the falling FFB. Action is needed to improve work postures because performing palm oil harvesting operations sequentially in a non-ergonomic manner can result in injury (Andriani *et al*., 2017). Ergonomic aspects are related to the size or body dimensions of workers, namely anthropometry. The purpose of the anthropometric approach is to create harmony between humans and the work system (man-machine system), enabling workers to work comfortably, well, and efficiently, and affecting work productivity, workload, work safety, and worker health.

Based on the above description, this study aims to determine the level of workload when performing a series of harvesting activities, measure the workload level of palm fruit harvesters, and measure the risk level and posture improvement of palm fruit harvesters. In addition, it is expected that this research will benefit oil palm stakeholders by increasing their awareness of the potential for occupational injuries during the harvesting process. This research is also expected to stimulate the development of better harvesting tools that can minimize the potential for injury during the harvesting process.

2. MATERIALS AND METHODS

Field research was carried out at the Koperasi Jasa Profesi Perkebunan Kelapa Sawit (KJP) Cipta Prima Sejahtera, located in Jilatan Village, Batu Ampar District, Tanah Laut regency. South Kalimantan. The study took place over seven months, from February to September 2023.

2.1. Research Design

This study employed a cross-sectional, descriptive-quantitative method. Participants from the KJP Cipta Prima Sejahtera were randomly selected for this study. This means each member of the population has an equal chance of being included in the sample (Arieska & Herdiani, 2018). The KJP Cipta Prima was chosen because it represents independent oil palm farmers who are managed in a structured and well-organized manner. The cooperative has a total of 120 employees, consisting of office staff and field workers, divided into monthly employees, daily employees, daily casual laborers, and all were supervised by a manager. The area of the KJP business unit covers a total of 606.38 ha, with the following details: producing plants covering 578.48 ha, factory area of 17 ha, infrastructure area of 2.8 ha, area potentially suitable for planting 8 ha, and area that cannot be planted covering 0.1 ha. The cooperative is owned by approximately 400 members from of the community.

Sampling was divided into 9 criteria groups according to the work elements of palm oil harvesters, with 30 workers selected as respondents with an age variable between 20-40 years. According to Hermawan (2013), workload of a person does not always decrease with increased work experience. Those aged 40 and above have more free time compared to those aged 20 to 40. Although all employees are expected to meet the goals and obligations set by the company, those over 40 tend to take a more relaxed approach to work. At age 25 and between ages 50 and 60, muscle strength decreases by 25 percent, as do sensory and motor abilities by 60 percent (Hermawan, 2013; Sedarmayanti, 2011). Stopwatch, tape measure, and heart rate monitor were used as experimental instruments.

The sample used for heart rate calculation is the same as the population because the number of harvesters at the study site is 30 personnel. While for REBA analysis using a sample of 4 people who represent the personnel who have the heaviest and lightest harvesters and the tallest and shortest harvesters. Furthermore, the results of heart rate analysis that represents the workload were statistically tested to see the validity of the data followed by REBA analysis to assess the risk of potential injury to harvesters. Analysis of these two approaches is then used to provide alternative solutions that may be done to reduce the potential for injury to oil palm harvesters.

The analyzed variables were conducted through direct involvement in the research site by the author, using calculations of working heart rate and resting heart rate with a total of 30 respondents. The repetitions were done three times to determine the workload levels across 9 elements of oil palm harvesting. The nine elements are described by Syuaib *et al*. (2015) including: (1) identifying FFB maturity; (2) preparing harvesting tools; (3) cutting bunches and fronds; (4) chopping and removing fronds; (5) discarding FFB waste; (6) picking up loose palm fruit (scattered fruit); (7) loading bunches into a cart or *angkong*; (8) moving bunches from one place to another; (9) unloading and tidying FFB at the collection point. However, for some considerations and conditions in the field, only three work elements of the harvesters can be used for workload analysis, including heart rate, namely: Element (3) cutting FFB and fronds (X1); Element (8) moving FFB from one place to another (X2); and Element (9) unloading and tidying FFB at the collection point or TPH (X3). Elements (1), (2), (4) and (5) were not carried out by KJP farmers, while element (6) is not always carried out and element (7) is included in the element (8).

The Rapid Entire Body Assessment (REBA) approach was employed to evaluate the sitting and standing positions of workers throughout the workday, resulting in several factors related to their body posture in the office. This was carried out through field research to capture samples in the form of photographs, then calculating the angle of inclination for each group of work postures and providing assessments for each group to determine the risk levels and necessary injury improvements for the 9 work elements of oil palm harvesters, with a total of 4 respondents. Each element utilized the maximum-minimum law based on respondent data with the variables of height and weight.

3. RESULTS AND DISCUSSION

3.1. Normality Test

The purpose of the normality test is to determine whether the residual values or the sample data taken are normally distributed or not, as normally distributed data will reduce the likelihood of bias occurring. X1 indicates the activity of cutting bunches and fronds, X2 indicates the activity of moving FFB from one place to another, and X3 indicates the activity of unloading and tidying bunches at the collection point (TPH). If the significance value > 0.05, the data comes from a population that has a homogeneous variance or is normally distributed. From the results of Shapiro-Wilk test presented in Table 1, it can be concluded that the three dependent variables X1, X2, and X3 are normally distributed. This can be observed from the significance values of the resulting regression equations which are >0.05, specifically 0.830 for X1, 0.233 for X2, and 0.105 for X3.

Table 1. Results of Kolmogorov-Smirnov and Shapiro-Wilk normality test

Variable	**Kolmogorov-Smirnov**[a]			**Shapiro-Wilk**		
Variable	**Statistic**	**DF**	**Sig.**	**Statistic R^2**	**DF**	**Sig.**
X1 (Cutting FFB and fronds)	0.144	30	0.113	0.980	30	0.830
X2 (Moving bunches from one place to another)	0.121	30	0.200*	0.955	30	0.233
X3 (Unloading and tidying FFB at the TPH)	0.140	30	0.137	0.942	30	0.105

a) Liliefors Significance Correction

3.2. Homogeneity Test

The data homogeneity test is used to determine whether the data collected from the same location contains extreme data that should be discarded and not included in the data sufficiency test calculations. Extreme data refers to data that is too large or too small and deviates from the norm. In the data homogeneity test, there are two parameters used: the Upper Control Limit (UCL) and the Lower Control Limit (LCL). Based on Table 2, it can be seen that all data passed the homogeneity test, so we do not need to discard anything that falls outside the normal limits.

Table 2. Results of homogeneity test

No	Data	N	AVG.	SD	UCL	LCL	Remarks
1	X1 (Cutting FFB and fronds)	30	138.89	3.38	149.85	127.91	Homogeny
2	X2 (Moving from one place to another)	30	113.12	4.58	129.86	96.37	Homogeny
3	X3 (Unloading and tidying FFB at the TPH)	30	93.83	2.10	100.76	86.89	Homogeny

Table 3. Results of data sufficiency test

Sample size	X1	X2	X3
Number of samples (*N*)	30	30	30
Minimum number of samples (*N'*)	1	3	1

3.3. Data Sufficiency Test

The purpose of the data sufficiency test is to check whether the collected data is adequate. This research's data sufficiency test, for example, uses an accuracy threshold of 95% with a tolerance of 5%. Based on the table above, it is known that the number of samples taken is greater than the minimum number of samples required. If $N' < N$, then the information collected so far is adequate.

3.4. Workload Data Analysis

The workload intensity of persons can be divided into the following categories (Table 4) based on their heart beats in one minute (Basri & Suseno, 2023). Figure 1 shows the graph of the data resulting from the analysis of workload according to the heart rate. It can be seen based on the result that X1 is in the range of 125–150 (heavy workload), the result X2 is in the range of 100–125 (moderate workload), and the result X3 is in the range of 60–100 (light workload). The overall results of the workload analysis can be seen in Table 5.

Table 4. Workload classification (Basri & Suseno, 2023)

Workload	Extremely light	Light	Moderately heavy	Heavy	Very heavy	Extremely heavy
Heart Rate (bpm)	< 60	60-100	100-125	125-150	150-175	>175

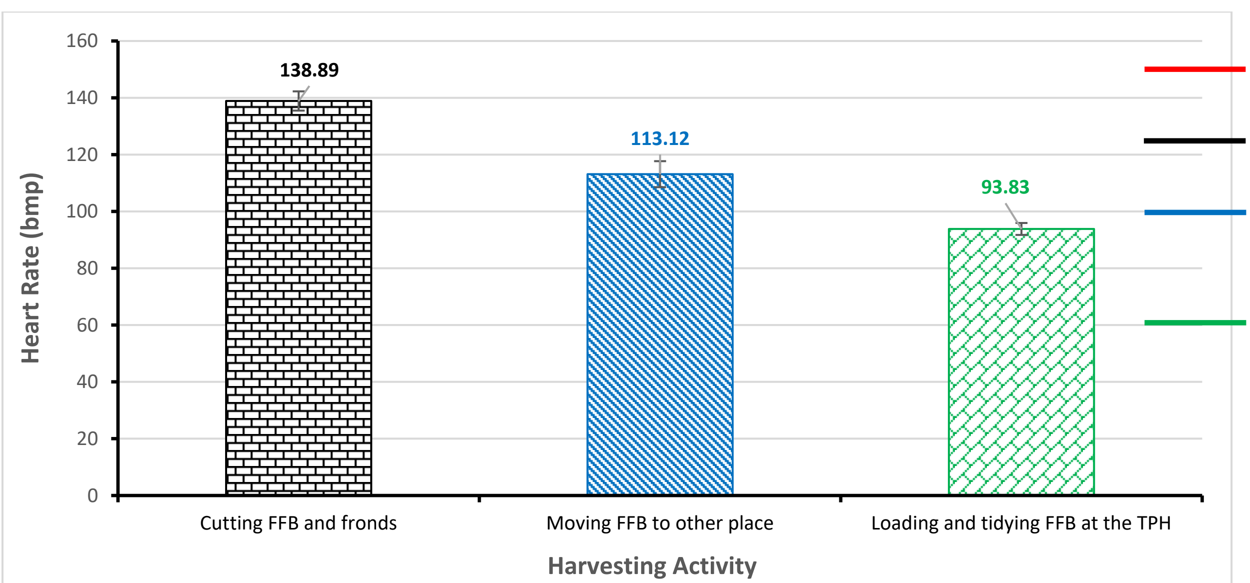

Figure 1. Effect of harvesting activity on the heart rate. [Bars are lower limit of heart rate for different workload: Red: very heavy (150), Black = heavy (125), Blue = moderate (100), Green = light (60)].

Table 5. Results of workload analysis

Code	Working Element	Heart rate	Workload
X1	Cutting FFB and fronds	125-150	Heavy
X2	Moving from One Place to Another	100-125	Moderately heavy
X3	Unloading and tidying bunches at the collection point (TPH)	60-100	Light

3.5. Analysis of Work Risk Levels Using the REBA Method

In the analysis of workload with heart rate, it was found that the heavy workload occurs in the work elements of oil palm harvesters, namely: cutting bunches and fronds, transporting from one area to another, deconstructing and cleaning bunches at the production site (TPH), as well as using the maximum and minimum principles of the Rapid Entire Body Assessment (REBA) approach as presented in Figure 2. Table 6 shows the results of the body posture analysis of the harvesters during FFB harvesting. The overall posture analysis of the workers was divided into two groups. Group A consists of the neck, trunk and legs. Group B consists of the upper arm, forearm and wrist. Table 7 is the result of the evaluation (score) of the posture analysis in relation to the body position in Table 6, and then the interpretation of the REBA score for each element that was examined, in order to then assess the level of risk and identify recommendations for action to be taken.

It can be seen in Table 8 that in the REBA method calculations, Group A and Group B at minimum weight are at a risk level (medium), at maximum weight the risk level is (high), at minimum height it is at a risk level (medium), and maximum height it is at a risk level (medium). Weight has a significant effect on the potential occurrence of MSDs. Based on the REBA analysis shows that the maximum load can change the risk to be high for harvesters. This activity needs and is highly recommended to be equipped with tools that can ease the workload for harvest workers.

Figure 2. Rapid Entire Body Assessment (REBA) for based on weight and height: (A) Minimum weight assessment, (B) Maximum weight assessment, (C) Minimum height assessment, and (D) Maximum height assessment

Table 6. Results of Rapid Entire Body Assessment (REBA)

Category	Group A			Group B		
	Trunk	Neck	Legs	Upper	Lower	Wrist
Minimum weight assessment	0° - 20° Flexion	20° extension	Knee (between) 30°- 60° +1	20°- 45° Flexion	>90° Flexion +2	< 15°
Maximum weight assessment	0° - 20° Flexion	20° extension +2	Knee (more) 30°- 60° +2	20°- 45° Flexion	60°- 100° Flexion +1	< 15°
Minimum height assessment	0° - 20° Flexion	0-20° extension	Knee (between) 30°- 60° +1	20°- 45° Flexion	>90° Flexion +2	< 15°
Maximum height assessment	0° - 20° Flexion	0° - 20°	Knee (between) 30°- 60° +1	20 ° Flexion	60°- 100° Flexion +1	< 15°

Table 7. Scoring for rapid entire body assessment result

Category	Activity	Group A			Result	Group B			Result
		Trunk	Neck	Legs		Upper	Lower	Wrist	
Minimum weight assessment		2	2	3+1	6	2	4+2	1	7
Maximum weight assessment		2	2+2	3+2	9	2	3+1	1	5
Minimum height assessment		2	2	3+1	6	2	4+2	1	7
Maximum height assessment		2	2	3+1	6	1	3+1	1	5

Table 8. Risk level and action recommendation for each REBA result

Category	Activity	Score		Action Level			
		A	B	Action Level	Score REBA	Risk Level	Action recommendations
Minimum weight assessment		6	7	2	4 - 7	Medium	Changes may be required
Maximum weight assessment		9	5	2	8 - 10	High	The condition is dangerous; it is necessary to check and change immediately
Minimum height assessment		6	7	3	4 - 7	Medium	Changes may be required
Maximum height assessment		6	5	2	4 - 7	Medium	Changes may be required

The results of the workload analysis indicate that the highest workload occurs in the work element of harvesting (cutting bunches and fronds), therefore the risk level measurement using the Rapid Entire Body Assessment (REBA) method is conducted on this element. The findings from the risk assessment show that the harvesting work element in question (cutting bunches and fronds) is not ergonomic, with a medium-risk level (requiring inspection and modification) and a high-risk level (hazardous condition, thus needing to be reviewed and changed immediately). According to findings by Andriani *et al*. (2017), the likelihood of injury among workers who adhere to ergonomic recommendations is higher. Oil palm harvesters perform work components in their tasks, namely cutting bunches and fronds, while standing in awkward positions with their backs bent forward or hunched, their bodies leaning in the direction of the falling FFB, and their feet often not in a strong yet flexible position. If a series of oil palm harvesting activities are performed with an ergonomic posture for an extended period, there is a possibility of injury.

In the risk level analysis, the variable of maximum body weight is at a risk level (high), with many factors influencing the high-risk level of maximum body weight; body weight and the contour or condition of the land at the harvesting site can affect the workload and risk level for the harvesters. Akbar (2005), explains that the greater the body weight of the harvester, the more it affects work productivity and heart rate, which is known that the higher the heart rate, the higher the workload and work risk level. Akbar & Herodian (2004), argues that issues of comfort, safety, and health of workers are caused by inadequate land conditions; this situation contributes to unnecessary physical and mental fatigue (physiological stress), which in turn affects work effectiveness and productivity. He argues that these issues are caused by unsuitable land conditions. Generally, an oil palm harvester performs the harvesting process in a hunched back position, a neck that looks up continuously, and a bent knee position, Pramadita *et al*. (2019) explains that these factors result in changes in bone shape, especially the vertebrae which will be related to posture, one of which is kyphosis posture change. Kyphosis is a form of abnormality that appears in the human spine that causes hunching (Rudi, 2019).

Workers share the same mentality when it comes to collecting palm fruit. During harvesting, an oil palm harvester often has a slumped back, a neck that is continuously stretched forward, and legs that are bent in front of them. According to research by Arsi *et al*. (2020), workers engaged in oil palm harvesting have a higher risk of developing musculoskeletal disorders (MSDs) due to the way they carry themselves while working. Pain in the lower back, right shoulder, waist, and calves are the most frequently reported types of MSDs among oil palm harvesters (Fiatno & Aliza, 2020). The future belongs to women. According to Utami *et al*. (2017), the most common cause of muscle strain in the workplace is when someone is asked to perform tasks excessively beyond their capabilities.

Kneeling, bending, and extending the neck forward are characteristics of the traditional working position of an oil palm harvester. Kyphosis is a result of the convergence of several factors that alter the geometry of the bones, particularly the spine, which impacts body posture. Kyphosis is a deformity that causes the spine to curve forward in humans and is referred to as kyphosis. Workers in improper or non-ergonomic working positions have a 2.5 times greater risk of developing spinal diseases compared to those in ergonomic positions.

A work system that successfully enhances productivity, safety, and user satisfaction takes ergonomics into account by designing around all human limitations and capabilities while emphasizing the relationship between employees and their environment. Ergonomics is a subfield of human factors engineering that focuses on the design of products and environments to optimize human performance. Ergonomics has the potential to improve public health within a system of activities, and human factors are also important. For the system as a whole to operate at maximum and effective capacity, all upstream and downstream processes need to be activated.

According to Pasaribu (2014), when implementing ergonomics, it is important to keep in mind several elements that need to be considered: (1) Human factors; (2) Anthropometric factors; (3) Body posture factors in work; (4) Work organization factors; (5) Human and machine (work equipment) factors; (6) Environmental control factors. With this, the KJP Cipta Prima Sejahtera should provide training or further understanding on the Standard Operating Procedures (SOP) for harvesting oil palm fruit, particularly regarding work posture, to minimize injury rates among harvesters.

By carefully considering the design of tools and workers, the occurrence of physical pain can be reduced or eliminated. Due to the repetitive and static nature of the activities, as well as the fact that harvest workers sometimes use tools that are too small for their bodies, common complaints among harvest workers include muscle stiffness, particularly in the arms, shoulders, waist, and neck (Lina *et al*., 2023; Fadhillah *et al*., 2024). The use of egrek has several technical shortcomings. Some of these technical shortcomings include the diameter of the egrek handle being larger than the grip of the hand, a slippery pole that always slips during use, and a rigid pole length. These design flaws indicate that the design of the egrek used is not tailored to the needs of the harvest workers. For instance, the designers did not consider the comfort of the workers by accounting for body size about the tools used. It is essential to develop appropriate equipment to reduce the likelihood of injury among harvesters and to create operating postures that are more beneficial for them. Their body posture is influenced by the size of the workers as well as the size of the tools and materials used in the task (Singleton, 1982).

Re-evaluating the working hours of harvesters in relation to the area worked is necessary, as the Cipta Prima Sejahtera Professional Services Cooperative (KJP) employs daily laborers for harvesting on a contract basis. According to findings from research conducted by Maharja (2015), there is a relationship between the weight of the load and the sense of fatigue. Statistics also show that increased effort results in increased fatigue. The level of physical activity required may impact the level of pain experienced due to MSDs. According to Suma'mur (2009), the duration of time required to complete a task is inversely proportional to the magnitude of the load carried.

To prevent fatigue, it is important to research on normal working days and weekly routines. Ergonomics is a multidisciplinary field that encompasses not only how to build a functional and pleasant work environment but also techniques, anthropometry, and design. According to the Center for Occupational Health and Safety of the Ministry of Health of the Republic of Indonesia, the discipline of ergonomics includes aspects from various other scientific subfields, including procedures or strategies for efficiently performing work to reduce the risk of injuries that may arise from improper ergonomics (Kementerian Kesehatan, 2016). At the physical level, when an individual's external appearance indicates that their physical resources align with the demands of their work. When task requirements exceed human physiological limits, several undesirable consequences can occur, including discomfort, fatigue, accidents, injuries, pain, illness, and decreased productivity.

The third topic is anatomy, which focuses on the range of motion and strength of the musculoskeletal system. Anthropometry is the field of study that examines human anatomy in numerical terms, enabling the built environment to be better adapted to a height, weight, and other physical characteristics of person. Physiology is the science that studies the body and its functions, which includes the study of issues such as core temperature, oxygen intake during exercise, muscle activity, and so on. Specifically, ensuring that workers are provided with everything they need to perform their tasks in a safe and comfortable environment.

4. CONCLUSION

The findings of this study are based on the analysis of the workload of harvesters in the activity of cutting bunches and fronds (X1) is classified into heavy workload category, the activity of moving FFB from one place to another (X2) is categorized as moderate workload, and the activity of unloading and organizing bunches at the collection point (X3) is categorized as light workload. The results of the risk analysis for harvesters show that the variable of minimum body weight of harvesters falls into the risk level category (moderate), the variable of maximum body weight of harvesters falls into the risk level category (high), the variable of minimum height of harvesters falls into the risk level category (moderate), and the variable of maximum height of harvesters falls into the risk level category (moderate). Moderate risk of joint injury due to muscle swelling. There is a low risk of physical fatigue for harvesters. Posture can be improved by redesigning harvesting equipment to reduce the workload on harvesters. Practical applications that can be done for cutting bunches and fronds, which are in the heavy workload category, and for moving activities from one place to another, which are in the medium workload category, are to add more ergonomic tools with extra motor/power, such as frond cutting/chopping tools, mini-loaders and mini-cranes. However, the choice of machines that are practical and easy to carry is actually an obstacle in the development of harvesting aids. As for the activities of unloading and tidying bunches at the collection point, which are in the light workload category, farmers can be encouraged to maintain correct posture while working. This can be done by educating farmers and increasing training so that farmers are more aware of potential work accidents. An analysis of the psychological impact and trauma to workers due to the workload of oil palm harvesters may be possible in future research. The development of a proper harvesting tool design for the three activities studied may provide a more feasible solution.

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