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Analysis of Physical Workload of Oil Palm Harvesters at Different Plant Ages Using the Cardiovascular Load Method di Afdeling X PT. XYZ Regional X

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ABSTRACT

Oil palm age influences harvesting tools, working postures, and activities, potentially affecting harvesters' physical workload. This study assessed physical workload and required rest time when harvesting 4- and 18-year-old palms using Cardiovascular Load (%CVL) and the Murrell equation. Seven harvesters from Afdeling X, PT XYZ Regional X, performed both harvesting tasks. This comparison used the same workers under both harvesting conditions. Resting and working pulse rates were measured using a pulse oximeter to estimate %CVL, energy expenditure, and rest requirements. Mean %CVL values were 37.76% for 4-year-old palms and 39.58% for 18-year-old palms; both indicated that improvements were needed. Energy expenditure averaged 5.59 and 5.90 kcal/min, respectively, while calculated rest times were 50.59 and 73.13 minutes. Harvesting older palms involved different tools and more demanding postures, resulting in greater physical workload. The findings suggest that rest schedules should reflect workers' physiological demands to reduce fatigue and support safer harvesting practices.

Keywords: %CVL, Energy Consumption, Load, Rest Time, Harvester.

1. Introduction

Oil palm is a plantation commodity that plays a vital role in supporting the Indonesian economy. The success of oil palm production is greatly influenced by the harvesting of fresh fruit bunches (FFB), as this process determines the quantity and quality of the harvest. Generally, harvesting is still done manually using dodos (hand-held) and egrek (hand-held) tools, requiring high physical strength. Activities such as cutting fronds, harvesting bunches, collecting the harvest, and transporting the bunches are performed repeatedly over long work periods. At the research site, harvesters work from 6:30 a.m. to 3:00 p.m. WIB (Western Indonesian Time) with a company-determined 30-minute break. This situation has the potential to increase physical workload and fatigue if the break time provided does not align with workers' physiological needs. Furthermore, the results of the questionnaire identification of the *Nordic Body Map* (NBM) show that harvesters at the age of 4 years and 18 years experience complaints in several parts of the body, so an evaluation of the physical workload during the harvesting process is needed [1] .

Physical workload is the magnitude of the work demands received by workers during work activities and can be evaluated through the body's physiological responses, one of which is based on

changes in heart rate [2], [3]. An increase in heart rate is the body's physiological response to the increased need for oxygen and energy during work activities. The higher the intensity of the work, the greater the need for metabolic energy that must be met so that the heart rate will increase in an effort to maintain body function. Therefore, the heart rate is widely used as an objective benchmark in assessing physical workload because it is able to describe the magnitude of work demands received by workers [4] . In addition to being influenced by work intensity, the magnitude of the physical workload is also influenced by work duration, work posture, use of tools, environmental conditions, and individual characteristics of workers [5] . One method that is widely used is *Cardiovascular Load* (CVL), which is a method that calculates the percentage of workload based on resting heart rate, working heart rate, and maximum heart rate [6] . The %CVL value is used to classify the level of workload so that it can be known whether a job is still in the safe category or requires corrective action. In addition to evaluation using the %CVL value, Energy consumption is also used to describe the amount of metabolic energy expended by workers when doing their work. The higher the energy consumption, the greater the need for rest time required to restore the worker's physiological condition. The Murrell equation is a method used to calculate the required rest time based on energy consumption so that the recommended rest time can be adjusted to the level of physical workload received by workers. In addition, the need for rest time can be determined using the Murrell equation based on the worker's energy consumption, so that the recommended rest time is more appropriate to the level of physical workload received by workers [7], [8] .

Method: *Cardiovascular Load* (CVL) has been applied in various studies to evaluate physical workload in various job sectors. Munte et al. [9] reported that some workers had %CVL values in the moderate to heavy category, so it was necessary to regulate rest periods and job rotation and improve work methods. Susanti and Pangesti [10] showed that 50% of workers were in the category requiring improvement, while the other 50% did not experience fatigue. Putri [11] combined the CVL method with energy consumption calculations and the Murrell equation and recommended adding rest periods of around 21 minutes. Research by Yasmin and Rizalmi [12] showed an average %CVL of 32.60%, which was included in the category requiring improvement, while Zacky and Bahri [13] proved that the use of trolley aids was able to reduce workers' %CVL values to a safe category. The results of these studies indicate that the CVL method is effective for evaluating physical workload as well as a basis for compiling recommendations for improving working conditions. Samosir [14] conducted a physical workload analysis using the *Cardiovascular Load* (CVL) in plantation sector workers and showed that manual work activities provide a fairly high workload, so that efforts are needed to improve working conditions to reduce worker fatigue. Zaini and Ernawati [15] reported that evaluating physical workload based on workers' physiological responses can be used as a basis for compiling recommendations for improving work systems and arranging rest periods to increase work safety and productivity.

However, previous research has been dominated by research subjects in the manufacturing industry, boiler operators, stevedoring workers, and small-scale industries. Research on physical workload in the plantation sector, particularly oil palm harvesters, is still limited [16] . Furthermore, previous research has not compared physical workload based on differences in plant age. Theoretically, differences in plant age affect tree height, the position of fresh fruit bunches (FFB), the harvesting tools used, work posture, and the characteristics of harvesting activities[17] . For 4-year-old plants, harvesters generally use a dodos (hand-held crane) with a relatively lower working position, while for 18-year-old plants, an egrek (hand-held crane) is used to reach bunches at a higher height. The use of an egrek involves repetitive lifting and pulling movements with the arms above the shoulders, increasing energy requirements and the body's physiological response, indicated by an increase in heart rate. Therefore, these differences in job characteristics have the potential to result in different physical workloads, requiring analysis using the method *Cardiovascular Load*(CVL).

Based on the description, this study aims to analyze the physical workload of oil palm harvesters at the ages of 4 years and 18 years using the Cardiovascular Load (CVL) method, which calculates

energy consumption and rest time requirements based on the Murrell equation, and provides rest time recommendations that are appropriate to the level of physical workload received by the harvester.

2. Method

2.1 Time and Place of Research

This research was conducted in Afdeling X, PT XYZ, Region X, North Sumatra, from January 2026 until completion. The research subjects were oil palm harvesters on 4-year-old and 18-year-old plants who carried out manual harvesting activities using dodos and egrek.

2.2 Sampling Techniques

The sampling technique in this study uses *purposive sampling* with a within-subject design (*repeated measures*), namely the same 7 respondents were measured in two work conditions, namely when harvesting 4-year-old plants and 18-year-old plants. The number of respondents was determined based on all harvesters who met the research criteria at the research location. Inclusion criteria included oil palm harvesters aged 20–50 years, male, in good health, willing to be respondents, and carrying out harvesting activities at both plant ages. Exclusion criteria included workers who experienced health problems during data collection and did not complete the entire series of measurements, or did not harvest at one of the plant ages. The use of the same respondents in both conditions aims to maintain the same individual characteristics so that the differences in physical workload obtained can be compared more objectively.

2.3 Data Collection Techniques

The study began with field observations to identify the work processes of oil palm harvesters on 4-year-old and 18-year-old plantations[18] . Respondents were then selected based on the research criteria. Primary data were collected through pulse oximeter measurements and questionnaires. *Nordic Body Map (NBM),* as well as recording the number of bunches harvested during the activity. Measurements were conducted on the same seven respondents during harvesting activities on 4-year-old and 18-year-old plants.

Pulse rate measurements included resting pulse rate (RI) and working pulse rate (BHR). BHR was measured twice, before work at 6:20–6:30 a.m. and during a break at 10:25–10:30 a.m., with the respondents sitting quietly and not engaging in any physical activity. BHR was measured eight times during harvesting activities, at 7:00, 8:00, 9:00, 10:00, 11:30, 12:30, 1:30 p.m., and 2:30 p.m. Each measurement was performed using a pulse oximeter attached to the respondent's finger until the pulse value was stable and readable. The BHR value was obtained from the average of two resting pulse measurements, while the BHR value was obtained from the average of eight working pulse measurements.

In addition to primary data, this study also utilized secondary data, including plant characteristics and other supporting data related to the study. All data obtained was then processed to calculate Cardiovascular Load (CVL), energy consumption, and rest time requirements using the Murrell equation.

2.4 Data Processing and Analysis Techniques

The data obtained in this study were processed and analyzed through several stages. The first stage was a recapitulation of the questionnaire results. *Nordic Body Map* (NBM) [19] was used to identify the body parts most frequently complained about by respondents during oil palm harvesting activities. The identification results were used as supporting data to describe musculoskeletal complaints before

conducting a physical workload analysis using the method. *Cardiovascular Load* (CVL) based on respondents' pulse data.

The next step is to process the measurement data to obtain resting heart rate (RHR), working heart rate (DNR), and maximum heart rate (MRR). The RHR was measured before the respondents started work and after a rest period, while the RHR was measured at several intervals during the harvesting process. The RHR and RHR values were obtained from the average of all measurements. The RHR was then determined based on the age of each respondent using the following equation [3] :

$$\text{DNM (Male)} = 220 - \text{Age} \quad (1)$$

$$\text{DNM (Female)} = 200 - \text{Age} \quad (2)$$

Information:
DNM = Maximum heart rate (beats/minute); this formula is used for male respondents.
After obtaining the DNI, DNK, and DNM values, the percentage calculation is carried out. *Cardiovascular Load* (%CVL) is calculated using the following equation [3] :

$$\%CVL = \frac{100 \times (Working\ Heart\ rate - Resting\ Pulse\ rate)}{(Maximum\ Heart\ rate - Resting\ Pulse\ rate)} \quad (3)$$

The %CVL value obtained is then classified based on the workload category as presented in Table 1. If the %CVL value is greater than 30%, further analysis is carried out in the form of calculating energy consumption based on the work pulse rate using the following equation [7] :

$$E = 1{,}80411 - 0{,}0229038\ X + 4{,}71733.10^{-4}X^2 \quad (4)$$

Keterangan:
X = Heart rate/working pulse (beats/minute)
E = Energy (Kcal/minute)
Next, the rest time requirement is calculated using the Murrell equation as shown in the following equation[20] :

$$R = \frac{T(K-S)}{K-1{,}5} \quad (5)$$

Information:
R = Break Time (minutes)
K = Energy Consumption (kcal/minute)
S = Standard Energy Expended (men = 5 kcal/minute, women = 4 kcal/minute)
T = Effective Working Time Duration (minutes)
The results of the rest time calculation are then compared with the rest time implemented by the company. If the calculated rest time is greater than the rest time implemented in the field, recommendations are made to adjust the rest time according to the level of physical workload experienced by the worker.

Table 1. Workload Classification Based on %CVL

Range	Classification
< 30%	No Fatigue Occurs
30% to < 60%	Improvement Required
60% to < 80%	Work in a Short Time
80% to < 100%	Immediate Action Required
%CVL>100%	Not Allowed to Do Activities

3. Results and Discussion

3.1 Respondent Characteristics

This study involved seven oil palm harvesters working in areas with 4-year-old and 18-year-old plantations. All respondents were male, aged 25–46 years, and had worked for 4–13 years. Respondent characteristics are presented in Table 2.

Table 2. Respondent Characteristics

No	Respondent	Age (Years)	Gender	Length of Service (Years)
1	R1	25	Man	5
2	R2	44	Man	12
3	R3	32	Man	4
4	R4	46	Man	11
5	R5	37	Man	13
6	R6	33	Man	5
7	R7	45	Man	12

3.2 Musculoskeletal Complaints Based on *Nordic Body Map*

Identification results using a questionnaire and the *Nordic Body Map (NBM)* showed that harvesters at the age of 4 years experienced complaints predominantly in the waist, right hand, and left and right calves. Meanwhile, at the age of 18 years, the dominant complaints occurred in the right forearm, right shoulder, back, waist, right wrist, and both calves. In general, the number of musculoskeletal complaints in harvesters at the age of 18 years was higher than in harvesters at the age of 4 years. This condition indicates that harvesting activities on taller plants require more energy and work postures, thus increasing the risk of musculoskeletal disorders. The results of the identification of musculoskeletal complaints using the Nordic Body Map (NBM) questionnaire in oil palm harvesters at the age of 4 years and 18 years are presented in Table 3.

Table 3. Musculoskeletal Complaints Based on Questionnaire *Nordic Body Map* (NBM)

Harvesting Group	Dominant Body Part Experiencing Complaints
Plant age 4 years	Waist, right hand, left calf, and right calf
Plant age 18 years	Right forearm, right shoulder, back, waist, right wrist, left calf, and right calf

Based on Table 3, harvesters with 18-year-old plants experienced musculoskeletal complaints in more body parts than harvesters with 4-year-old plants. This indicates that harvesting activities on taller plants place greater physical demands, particularly due to the use of egrek, the overhead working posture, and the heavier bunch weight.

3.3 Physical Workload Analysis Using the Method *Cardiovascular Load* (%CVL)

The results of the analysis using the Cardiovascular Load (CVL) method indicate that all respondents in both plant age groups were in the category requiring improvement. For 4-year-old plants, the %CVL value ranged from 33.68 to 40.72%, with an average of 37.76%. Meanwhile, for 18-year-old plants, the %CVL value ranged from 35.98 to 43.78%, with an average of 39.58%. This range of values indicates variations in physical workload among respondents, but all Respondents remained in the same category. The average %CVL value for harvesters of 18-year-old plants (39.58%) was higher than that of 4-year-old plants (37.76%). Based on the results of this study, harvesting activities on 18-year-old plants tend to have a higher physical workload. A summary of the calculation results is presented in Table 4.

Table 4. Summary of %CVL Calculation Results

Harvesting Group	Rate-rate %CVL	Classification
Plant age 4 years	37,76	Improvement Required
Plant age 18 years	39,58	Improvement Required

This difference is thought to be related to different work characteristics, such as the use of harvesting tools adapted to the age of the plant and the activity of reaching bunches at higher heights. However, this study did not directly measure working posture, plant height, or bunch weight, so these factors are interpreted rather than measured findings in the study.

3.4 Analysis of Energy Consumption and Rest Time Needs

The results of energy consumption calculations show that in 4-year-old plants, energy consumption ranges from 5.47 to 5.71 kcal/minute, with an average of 5.59 kcal/minute. In 18-year-old plants, energy consumption ranges from 5.67 to 6.14 kcal/minute, with an average of 5.90 kcal/minute.

Calculation of rest time requirements using the Murrell equation shows that in 4-year-old plants, the need for rest time ranges from 41.53 to 60.03 minutes with an average of 50.59 minutes/day, while in 18-year-old plants, it ranges from 56.74 to 88.88 minutes with an average of 73.13 minutes/day. These results indicate that the variation in rest time requirements between respondents is greater in 18-year-old plant harvesters.

These results indicate that the greater the energy expenditure of workers, the longer the rest period required to restore the body's physiological condition. Therefore, the rest period required for 18-year-old crop harvesters is higher than for 4-year-old crop harvesters.

Table 5. Comparison of Analysis Results

Rate-rate Indicator	Plant age 4 years	Plant age 18 years
%CVL	37,76	39,58
Energy consumption (Kcal/minute)	5,59	5,90
The need for rest time	50,59	73,13

The company's 30-minute break time is lower than the results calculated using the Murrell equation for both plant age groups. Four-year-old plants still have a break time gap of approximately 20.59 minutes, while 18-year-old plants still have a break time gap of 43.13 minutes. Therefore, the company needs to evaluate the break time arrangement to align with workers' physical workloads, thus optimizing recovery and reducing the risk of work fatigue.

The results of this study indicate that rest periods need to be adjusted to the level of physical workload of workers. Providing adequate rest periods can facilitate physiological recovery, reduce the risk of fatigue, and support smooth harvesting activities. Therefore, evaluating rest periods can be one way companies can improve the health and productivity of oil palm harvesters.

4. Conclusion

Based on the results of research on the analysis of the physical workload of oil palm harvesters using the Cardiovascular Load (%CVL) method, it can be concluded that:

1. Analisis menggunakan metode *Cardiovascular Load* (CVL) menunjukkan bahwa rata-rata Analysis using the Cardiovascular Load (CVL) method showed that the average physical workload of harvesters on 4-year-old plants was 37.76%, while on 18-year-old plants it was 39.58%. Both groups fell into the category of requiring improvement, with the physical workload on 18-year-old plants tending to be higher.

2. Calculations using the Murrell equation show that the average rest time requirement for 4-year-old plants is 50.59 minutes and for 18-year-old plants 73.13 minutes, higher than the company's current 30-minute rest time. Therefore, the company needs to adjust rest time settings based on the level of physical workload, especially for harvesting 18-year-old plants, to optimize worker recovery and reduce the risk of work fatigue.

Declaration of AI Use

The author states that ChatGPT was used to a limited extent to assist with language editing and grammar checking during the preparation of the manuscript. The author bears full responsibility for all scientific content, data analysis, interpretation of results, and conclusions. All editing assisted by ChatGPT has been reviewed and verified by the author.

Author Contributions

Conceptualization, Dwi Nirmalasari Manurung and Fatimah; methodology, Dwi Nirmalasari Manurung; formal analysis, Dwi Nirmalasari Manurung and Syarifuddin; investigation, Dwi Nirmalasari Manurung; data curation, Dwi Nirmalasari Manurung and Fatimah; writing—original draft preparation, Dwi Nirmalasari Manurung; writing— review and editing, Syarifuddin. All authors have read and agreed to the published version of the manuscript.

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