Ergonomic risk identification for rice harvesting worker

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Abstract. This paper studies important factors that influence the physical workload of rice harvesters. Rice harvesting in Java, Indonesia, mostly uses manual and semi-mechanical methods that require significant physical energy. These harvesting methods have potential Ergonomic Risk Factors (ERFs) that are skeletal, muscle, and peripheral nerve disorders called Musculoskeletal Disorders (MSDs). Surveys and observations of 7 workers of manual and 9 workers of semi-mechanical rice harvesting practices were done in Bantul Regency, Yogyakarta Province. The dependent variable of Cardio-vascular Load (CVL) was formulated in multiple linear regression equations by some independent variables, that were age, smoking habits, heart rate, and ambient temperature. The results showed that age and ambient temperature variables correlate strongly with CVL manual worker. CVL semi-mechanical worker was strongly correlated with age and heart rate. By F test, manual worker workload, 94.5% was significantly influenced by variables of age, smoking habits, heart rate and ambient temperature. CVL semi-mechanical workers were only 91.1%. To avoid high CVL, the age factor of workers is a major consideration. MSDs occur in the upper and lower back for manual workers, while semi-mechanical workers occur on the lower back and both hands. From the assessment of work posture in 4 elements of harvesting, transporting element was the activity with the worst posture. Ergonomic interventions are needed to reduce ergonomic risks in transportation.

1. Introduction

Ergonomics research of farmers is more developed to rice processing farmers because of the presence of tractors. Tractors have large vibrations that have a negative impact on operators [1]. Tractors are used to repair hoes that have negatives when used to treat soil [2]. The use of ani-ani is replaced by a sickle that speeds up the harvest. The Ministry of Agriculture recommends using jagged sickle that can increase crop productivity.

Many studies related to the increase in yields, reduction of losses, increase in productivity due to the use of combine machines [3,4]. The government's efforts to increase crop productivity using a combine harvester machine. According to the Central Bureau of Statistics from the 2013 agricultural census land ownership in Daerah Istimewa Yogyakarta province averaged only 700 m² / farmer families [6]. Such
small land is difficult to harvest using combine machines, as a result, the manual and semi-mechanical harvesting processes are still practiced, especially if the land is in a sloping location.

The development of farmer ergonomics research in Indonesia some of them in around 2015 had survey research on farmer anthropometry [5], hand tool design [6], injury to farmers [7], farmers' health problems [8] and many other research. Farmers who are on average over 40 years old, which means greater ergonomic risk. Ergonomics risk factors (ERFs) are the worker's risk that is closely related to musculoskeletal disorders (MSDs) that occur due to continuous, repetitive work on bad postures [9], repetitive joint work is not much variation in posture and movement, the body must bend to half squat to reach the rice stem, requiring a large work capacity, over a long period of time from morning to evening days during the rice harvest season. Risk factors occur because of heavy work such as lifting, carrying, pushing, pulling and everything is done in the field without adequate protection from extreme weather. The purpose of this study is to determine the important factors that influence the physical workload of the worker and find work elements that need immediate improvement. The results of this study are preliminary information to develop alternative solutions that can reduce the risk of economic harvesters.

2. Methodology

2.1. Respondents
Respondents who are carrying out harvesting and threshing of rice in the fields. For manual and semi-mechanical rice harvesting, respondents are peasants from outside the region that offer their energy to harvest rice until it becomes clean grain in sacks. Harvesters are not differentiated between male and female harvesters because at the same time their rights and obligations are the same. Data collection is done by interview and direct observation.

2.2. Dependent and Independent Variable
The dependent variable in this study is the cardiovascular load which is calculated based on the work pulse data of at work, at rest and maximum heart rate which is calculated using the 220-age formula for men and 200-age for women. From the calculation of % CVL, the value or index of the physical workload will be obtained by the workers. The load is calculated using the formula:

$$CVL = \frac{100 \times (HR_{work} - HR_{rest})}{HR_{max} - HR_{rest}}$$  

Independent Variable demography including age variables, Body Mass Index, work experience, smoking and drinking coffee habits, body temperature, environmental factors represented by temperature and environmental humidity. One method of measuring heart rate is to measure the pulse for 1 minute which can be done in the wrist or fingers [10]. Measurements were made using a wrist pulse meter which measures heart rate on the workers’ wrist. Every data on the heart rate, body temperature, temperature and humidity of the environment is measured every hour starting when the workers starts working until it’s finished.

2.3. Ergonomics risk
Ergonomics risk in rice harvesting is caused by (a) improper work postures, (b) repetitive work, (3) more than 8 hours of work every day, and (4) working every day during the harvest season. The effects of which are bodily pain due to work called work-related musculoskeletal disorders. The effect is a symptom of pain such as discomfort in the neck, pain in the shoulders, elbows, hands, fingers, thighs knees, all of which will be recorded on the Standard Nordic Questionnaire [11] whose assessment is carried out subjectively. The posture is assessed using the OWAS method.
2.4. Data Analysis

Data analysis was performed using IBM SPSS Statistics version 19. The survey data calculated means and standard deviations, while the relationship between dependent and independent variables was analyzed using multiple linear regression models, with Y being CVL, and X being age, smoking habit, heart rate, environmental temperature (Table 1). The hypothesis tested is the presence or absence of correlation X variable to Y with the hypothesis:

| No. | Hypothesis                                                                 | Decision at 5% significance level | Meaning of decision                      |
|-----|-----------------------------------------------------------------------------|-----------------------------------|------------------------------------------|
| 1.  | \( H_0 \): there is no significant relationship between variable X and variable Y  | \( H_0 \) is rejected if the significance is <0.05 | There is a significant relationship between X and Y |
|     | \( H_1 \): there is a significant relationship between variable X and variable Y |                                   |                                          |
| 2.  | \( H_0 \): Variable X together does not significantly influence the variable Y | F test                            | together X significantly influences the variable Y with an effect equal to adj R2 |
|     | \( H_1 \): Variable X jointly affects significantly the variable Y            | \( F \) count > F table df1: n-1  |                                          |
|     |                                                                               | df2: n-k-1                        |                                          |
| 3.  | \( H_0 \): Variable X itself does not significantly influence the variable Y  | t test                            | X alone has a significant effect on variable Y |
|     | \( H_1 \): Variable X itself has a significant effect on variable Y          | \( H_0 \) is rejected if the significance is <0.05 |                                          |

To see the variable X which has a significant effect on Y, it is necessary to do a classic assumption test which includes normality test, heteroscedasticity test, multicollinearity test and autocorrelation test.

3. Results and Discussion

3.1. Harvesting process

Harvesting consists of cutting rice stalks and threshing grain from rice stems [13]. Harvesting technology from rice is divided into 2 namely manual technology using simple sickle and pressure devices called gepyok and semi-mechanical technology using a small engine called mini thresher. The left-hand holds the rice stem in the middle, the right-hand holds the sickle and directs the sickle to the bottom of the worker left hand and cuts it. Worker will shift while bending or squatting to hold the rice stem again. While the left-hand holds the cut rice stem, the left hand will try to hold the rice stem again and the right hand will cut in the same way. After the left hand is unable to hold the rice stem again, the pieces of rice stalks are placed and stacked in one place. Four elements of harvesting were cutting rice stems, transferring rice stacks to the threshing process, threshing process, packaging and transporting the rice. All workers carry out all activities, there is no definite division of tasks to woman.

3.2. Worker characteristics

The workers in the harvesting activities discussed are called peasants, namely sharecrops who depend on landowners and do not have the freedom to develop their innovations in agricultural activities. Small farmers are those who have less than 0.5 hectares of agricultural land and they belong to the peasant category. While those with more than 0.5 hectares of land are included in the modern farmer [12]. Table 2 the worker characteristics used as the study sample. The numbers in the table show the percentage of workers grouped according to the level of existing technology. The Body Mass Index shows that the body weight is rated less (14% for manual, 11% for semi-mechanical), 72% of manual worker have an ideal BMI, 78% semi-mechanical. 14% and 11% have excessive weight.
Table 2. Worker characteristics

| Level of Tech | BMI  | Age (year) | Education | Experience | Habit |
|---------------|------|------------|-----------|------------|-------|
|               | Weight | ≤40 | 40-50 | >50 | elemen| Junior HS | Senior HS | <10 | >10 | smoke | Drink coffee |
| Manual        | less   | 14  | 14    | 14  | 43    | 0        | 0        | 100 | 0   | 71    | 43     |
| Semi-mechanical | ideal  | 11  | 0     | 33  | 67    | 11       | 0        | 0   | 0   | 44    | 22,2   |

3.3. Physical workload
Workers for these two harvest technologies more than 70% have ideal body weight, over 40 years of age with more than 10 years of work experience. Judging from age data, 86% of manual harvesters are workers who are aged 40-50 years, and the workload is moderate (Table 3). Whereas workers who are older, prefer to work with semi-mechanical methods who have a slightly lower workload (low-moderate category). Judging from one's work ability, according [14] the peak of one's work capacity occurs at the age of 25 years. After that there will be a decrease in muscle strength by 25% and a decrease in sensory-motoric ability by 60% from the age of 25 to 60 years. Manual harvest workers, age variable correlated strongly and significantly with CVL workload ($r = 0.792$), while work experience correlated strongly but not significantly with CVL with a value of $r = 0.715$. Semi-mechanical harvest workers are only age factors that correlate with CVL even though the correlation is strong but not significant ($r$ value 0.659). Physical work capacity is the body's ability to produce energy and is a function of the availability of nutrients and the body's ability to obtain oxygen. The amount of energy needed by the body, the energy needed just for life, and the energy needed to move [14].

Table 3. Heart Rate as Cardiovascular Load of Worker (in percent)

| Level Tech      | CVL (%)                     |
|-----------------|-----------------------------|
|                 | no fatigue occurs ≤30% | required repairs 30-60% | work in a short time 60-80 | immediate action is required |
| Manual          | -                          | 100                       | -                          | -                           |
| Semi-mechanical | 11.1                       | 89                        | -                          | -                           |

Despite having an ideal body weight and long experience, the work capacity of workers around 50 years has experienced a lot of decline, so that the physical workload declared as CVL in these two groups of workers almost all requires improvement (Table 3). Improvements to reduce physical workload can be done in work methods, work tools, work scheduling, and so on.

About 50% of workers have the habit of smoking and drinking coffee. Smoking is a recommended thing to avoid, statistically this smoking habit correlates low with semi-mechanical harvesting workloads, and correlates moderately with manual harvesting workloads. This shows that the work capacity of manual harvesters is a little disturbed due to the smoking habit of workers.

The cardiovascular system drains blood to all parts of the body and flows back to the heart [13]. The work physiology is mainly indicated by the cardiovascular system response. The proportion of work capacity is 50% for those who are trained and 33% for those who are not trained [15]. Work activities are quite high and the presence of static muscle loading can affect the cardiovascular system with increasing heart rate (cardiovascular load).
3.4. Factors related to Ergonomics Risk Factors

Ergonomic posture is work posture that uses a little static muscle, hands can be used easily and naturally, work posture changes, the muscle effort is small enough to be able to maintain one posture. Work on shedding rice includes hard work of farmers because it works in a static position, the posture bends, works for a long time, which can cause pain in the musculoskeletal system (work-related Musculoskeletal Disorders). The musculoskeletal system is a system of skeletal muscles or muscles that are attached to bones consisting of latitude fibers which can be regulated, which function as organizers of body movements, walking, maintaining attitudes or doing certain jobs such as standing, sitting, and producing heat [13].

In the process of cutting rice stalks, workers bend and slightly squat. Work posture bent, head inclination forward, squatting is a forced posture. In this posture there are several body parts such as waist, neck, back, legs, static loads for a long time. Muscles that experience static contraction for a long time will experience a shortage of blood flow which causes reduced energy, exchange and accumulation of metabolic waste in active muscles, will tired, pain will arise, contraction strength will decrease, so that the work results are reduced [14]. To identify the pain that arises, Standard Nordic Questionnaire, known as the Nordic Body Map, is used to identify pain or discomfort in the body of a worker due to work. Questionnaires were given to workers before and after work. The results of the Nordic Body Map assessment conducted subjectively by workers in Figure 1, with the X axis showing 15 parts of the body being assessed, the Y axis is the respondent.

![Nordic Body Map](image)

**Figure 1.** Results of assessment of Nordic Body Map after working for workers

a. Manual Harvest, b. Semi-Mechanical Harvest

Figure 1 indicated a difference in pain between manual and semi-mechanical workers. In harvesting, the upper and lower backs are felt pain, whereas in the semi-mechanical process, besides the lower back, the right and left hands are painful. This is due to the semi-technical process, workers must hold the rice stem on top of the thresher device, so that the one working is static muscle.

Work posture can be assessed using various methods, namely Rapid Upper Limb Assessment (RULA) [15], REBA (Rapid Entire Body Assessment) and OWAS (Ovako Working Assessment System). In this study the OWAS method was used to assess workers’ body postures when carrying out various harvesting activities, such as cutting rice stalks bent and squatting, transferring rice stalks with carrying loads, threshing, packaging carried out while standing and bending. The differences in activities between manual and semi-mechanical harvesting only occurred in the threshing process, Table 4 shows the results of posture assessment using the OWAS method.
Table 4. Results of Posture Assessment in Threshing Process

| Work Element          | Posture                                                                 | OWAS Score | Recommendation          |
|-----------------------|-------------------------------------------------------------------------|------------|-------------------------|
| A. Cutting rice stalks|                                                                         |            |                         |
| B. Transfer to threshing|                                                                        |            |                         |
| C. Threshing          |                                                                         |            |                         |
| C1. Manual threshing  | Picking the rice stem. The body bends 60-90°, head up, feet bent, hands under shoulders, light weight | 2141 Score 3 | Work is rather difficult repairs as soon as possible |
|                       | Slam the rice stem. The body bends 40-90°, head up, hands under-shoulder, legs up, light weight | 4141 Score 4 | Very heavy work repairs right away |
| C2. Semi-mechanical threshing | The body stands tall, hands hold the rice stem at the height of the elbow, held while being turned back and forth bending <20°, walk slightly, swing the rice stem and throw it with the right hand, walk back to its original location | 3121 Score 1 | Light work No need repairs |
| D. Packing and Transporting |                                                                         | 1171 Score 1 | Light work no need repairs |

The manual and semi-mechanical harvesting postures are only different in the process of threshing. Variations in posture from score 1 that are harmless to score 4 are very dangerous. Manual threshing is very dangerous for musculoskeletal workers, but not by threshing semi-mechanical methods. The impact of this posture is the pain felt by workers in the upper back and lower back (Fig 2.a). Besides the most dangerous manual threshing process is the process of cutting rice stems and collecting rice stems if done by bending.

Work posture is the main cause of skeletal muscle problems which should be reduced by modification of the tool [13]. In the process of cutting rice stalks, worker bend and slightly squat. Work posture bent, head inclination forward, squatting is a forced posture. In this posture there are several muscles of the body such as the waist, neck, back, legs, getting static loads for a long time. Muscles that experience static contraction for a long time will experience a shortage of blood flow which causes reduced energy, exchange and accumulation of metabolic waste in active muscles as a result of which muscles will get tired quickly, pain will arise, contraction strength will decrease, so that the work results are reduced [10]. For this reason, posture changes are expected to increase production, such as designing tools or working methods for the process of cutting rice stems, arrangements when working and at rest, reducing exposure to sunlight to harvesters' bodies and so on. In transporting rice stems, posture is not good. worker stands up from squatting with a load of 25-50 kg. Transportation from threshing, carrying a load of 40-50 kg with a longer distance. Ergonomics interventions need to be done to reduce risk.

3.5. Equation of Multiple Linear Regression
After testing the classical assumptions that overshadow the normality test, heteroscedasticity test, multicollinearity test and autocorrelation, all the variables in the equation in table 5 have passed the classic assumption test for multiple linear regression equations.
Table 5. Results of Regression Analysis, the Dependent Variable is CVL

| Harvesting technology | Variable Independent | Multiple Linear Regression Equation | Adj R² |
|-----------------------|----------------------|-------------------------------------|--------|
| Manual:               | X₁ age, X₂ smoking habits, X₃ heart rate, X₄ environmental temperature | Y = 112,268 + 0.296 X₁ + 1.962 X₂ + 0.375 X₃ - 3.741 X₄ | 0.945  |
| Semi mechanical       |                       | Y = 177,175 + 0.472 X₁ - 6.554 X₂ + 1.237 X₃ - 1.025 X₄ | 0.911  |

The coefficient of the difference between the independent variable and the dependent variable on manual harvesting, shows that only the age variable is strongly correlated with CVL (r = 0.792), while in the semi-mechanical, the age and heart rate variables (r=0.659 dan r=0.698). Independent variables in the form of age, smoking habits, heart rate and ambient temperature have a significant role in the workload of workers. 95% of manual workload problems are caused by these four independent variables, with the environment temperature variable having the greatest one. When the ambient temperature increases, the workload decreases. For manual harvesting, increases of age, smoking habits and increasing heart rate, the workload also increases. In semi-mechanical harvesting, increasing age and heart rate will increase physical workload. Conversely, the existence of smoking habits and increasing environmental temperature, workload decrease.

Judging from the ergonomics risk factor, and the physical workload of harvesters, it is necessary to ergonomics interventions to reduce the risk of workers by regulating work schedules, giving short breaks, using more ergonomic equipment, improving work methods and so on.

4. Conclusion
The results showed variable age, smoking habits, heart rate, and ambient temperature were variables that significantly affected workers' workload. Ergonomics interventions to reduce ergonomic risks in manual workers are by designing tools that more ergonomics and work methods, arrangements when working and at rest, arranging more frequent short break schedule.

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