Analysis of workload and long rest periods on mobile rice grain milling operator at Sidolelono Pleret Community Bantul

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Abstract. Noise and vibration are the hallmarks of mobile rice grain milling. The difference in working time between operators, the number of grains milled in one day, and looking for customers activity can be a factors that affect the operator’s workload. This study aims to determine the workload experienced, identify the factors that affects the workload, and determine the long rest periods required by the mobile rice grain milling operator. The workload experienced by operators measured by the cardiovascular load (CVL), the level of caloric needs, and NASA-TLX questionnaire. Factors considered in determining operator workload are age, body mass index (BMI), body temperature, noise, ambient temperature, humidity, and vibration. The long rest periods are calculated based on the operator’s heart rate converted into energy consumption. Based on CVL, operators experience no fatigue while from the level of caloric needs and mental workload, operators experience a moderate workload. The partial t-test for one operator group indicates that there is an effect of BMI and ambient temperature on the level of caloric needs. The regression test for two operators group showed that body temperature had an effect of 63.9% on CVL. The long rest periods applied by the operator is sufficient.

1. Introduction
The postharvest process of paddy consists of harvesting, grain threshing, recovery, transportation, drying, packaging, storage, milling, processing, and standardizing the quality of rice [1]. Rice grain milling is removing or separating husks and bran to obtain rice for consumption [2]. The milling process can be done with mobile rice grain milling. Mobile rice grain milling is a modification between rice polisher with transportation which can be seen in figure 1. They are found in many parts of Indonesia which are rice-producing areas including Yogyakarta Special Province and Jember. Sidolelono Pleret Community in Bantul Regency, Yogyakarta Special Province consists of twenty-four mobile rice grain milling units. Based on the author's observations, the duration of the work of each operator is different because there is no time limit for operators to start and complete their work and the amount of rice grain milled by the operator in one day does not have a fixed amount. The amount of rice grain depends on the order received by the operator before starting its work through cellular telephone and the amount of rice grain milled by the consumer who calls the operator when passing the consumer's house. If the operator before work does not have an order, then the operator needs to go around first to get a consumer who wants to mill his rice grain. The difference in working time, the amount of rice grain that is milled in one day, and the activity of traveling around looking for rice grain that needs to be milled can be a factor that affects the operator’s workload. The workload
experienced by the operator can be influenced by age, and body mass index (BMI), noise, ambient
temperature, humidity, and vibration [3]. The activity of moving from one place to another can affect
the level of noise, ambient temperature, and humidity that is felt by the operator. The workload is an
effort that needs to be issued by someone to fulfill the "request" of the work [4]. The workload can be
divided into two, namely mental and physical workload. Nevertheless, the physical and mental
workload are two interrelated things. The workload assessment can be done by various methods, in
this study workload assessed by cardiovascular load (CVL) method, the level of caloric needs, and
mental load subjectively using NASA-TLX (NASA Task Load Index).

![Figure 1](image.png)

**Figure 1.** Process of transporting rice grain from the consumer’s storage area.

Resting time is useful to prevent fatigue which can reduce physical and mental abilities and loss of
work efficiency, recovery or refresh the body, and provide opportunities for socializing [5]. Reference
[6] states that heavy physical activity can cause a physical load beyond the physiological capacity of
the operator. It means energy produced through the body's metabolism is lower than the energy needed
to move. In the long term, this can cause excessive fatigue that is dangerous such as a heart attack or
failure of bodily functions. This impact is the reason for determining the long rest periods owned by
the operator is now sufficient or the need for an additional duration. The purpose of this study is to
determine the workload experienced by the mobile rice grain milling operator, to identify the factors
that affect the workload of the mobile rice grain milling operator and determine the long rest periods
required by the mobile rice grain milling operator.

2. Methods

2.1. Participants

The study was carried out on 24 mobile rice grain milling units at Sidolelono Pleret Community which
consisted of 19 male operators in one operator group and 7 male operators and 3 female operators in
two operators group. Participant characteristics can be seen in table 1.

| Characteristics | Classification         | Percentage (%) |
|-----------------|------------------------|----------------|
|                 | One operator group     | Two operators group |
| Age (years)     | <40                    | 21             | 40            |
|                 | 40-60                  | 74             | 60            |
|                 | >60                    | 5              | 0             |
| Body Mass Index | Underweight (15 - 19.9)| 5              | 10            |
| (kg/m²)         | Normal (20 - 24.9)     | 64             | 50            |
|                 | Overweight (25 - 29.9) | 26             | 30            |
|                 | Obesity class I (30 - 34.9) | 5        | 10            |

Table 1. Participant characteristics based on groups.
2.2. Measurement of factors affecting workload
The factors used in this study are limited to the physical aspects of humans, such as age, BMI, and body temperature and human external factors such as noise, ambient temperature, humidity, and vibration. The participant's body weight is measured using a body scale. The participant's height is measured by measuring height. The body temperature measured by forehead temperature. Measurement of noise, ambient temperature, and humidity are carried out with environment meter. Noise measurement is carried out every time the participant receives consumers. The body temperature of the participant, ambient temperature, and humidity are measuring every hour. Body temperature measurement using forehead temperature because measurement on the forehead is one way to find out body temperature without disturbing the participant doing his work. Whole body vibration is measured every time the operator is moving from one location to another with a vibration meter.

2.3. Nordic Body Map (NBM)
Ebonyi State Milling Industry operators in Nigeria feel back pain as a result of task performance requiring repetitive movements and carrying sacks of rice [7]. Driving discomfort can cause musculoskeletal disorders (MSDs), injuries, low back pain, and fatigue. Reference [8] showed 77% of participants agreed that driving posture could affect their discomfort during driving. The level of pain experienced by participants before and after work is measured by the NBM questionnaire.

2.4. Measure of workload
The CVL value is obtained by equation 1 where HR is the heart rate. The heart rate before work is used as the participant's resting heart rate. The maximum heart rate depends on the participant’s age and gender. The participant's heart rate when they are working is calculated once an hour and then averaged to obtain the participant's heart rate. The workload based on the level of caloric needs is measured by the participant's weight, the elements of work carried out by the participant, and caloric requirements based on energy expenditure according to the workload calculation table stated in Indonesian National Standards (SNI) 7269-2009-1. The participant's mental workload is measured subjectively with the NASA-TLX questionnaire.

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

2.5. Test differences between groups and identify factors that affect workload
To determine the difference in the average value of the factors affecting workload and workload between the two groups, an independent sample t-test was performed. Statistical tests used IBM SPSS Statistics 22 software. Besides, to the magnitude of the influence of factors that have been measured against workload, multiple linear regression tests. Independent variables in statistical tests are age, BMI, body temperature, noise, ambient temperature, humidity, and whole-body vibration. The dependent variable is CVL, the level of caloric needs, and NASA-TLX as mental workload subjective.

2.6. Calculation of long rest periods
Reference [9] states that the value of energy consumption is obtained by converting the heart rate to energy and measuring the difference in energy expenditure while working and resting which can be seen in equation (2), (3), and (4). The relationship between heart rate and energy can be seen in equation (2) where E is the energy in units of kcal/minute and X is the heart rate in units of beat/minute. Energy consumption is obtained by applying equation (3) and (4) where K is energy consumption in units of kcal/minute, Et is energy expenditure at certain times in units of kcal/minute, Ei is energy expenditure at rest in units of kcal/minute, R is long rest periods in units of minutes, T is total work time in units of minutes, and S is standard energy expenditure in units of kcal/minute. Standard energy expenditure for men is set at 5.4 kcal/minute while woman is 3.4 kcal/minute.
\[ E = 1.80411 - 0.0229038 X + 4.71733.10^{-4}X^2 \]  
\[ K = E_t - E_i \]  
\[ R = T(K - S) / (K - 1.5) \]

3. Results and Discussion

3.1. Production process

The process of milling the rice grain includes husking, polishing, packaging, and storing. When operating the mobile rice grain milling, the activities carried out by the participant are going around in residential areas or consumer searches, preparation of tools, take the rice grain at the consumer's home, milling process, delivery of mills, storage of tools and by-products, and receiving money wages if the owner takes the bran. The mobile rice grain milling in the Sidolelono Pleret Community consists of only one polisher. Therefore, husking and polishing are carried out with the same machine. In general, the polishing is carried out as much as two to three times depending on the quality of the rice grain being milled and the degree of rice saturation that consumers want.

3.2. Measurement of factors affecting workload

| Factors               | One operator group | Two operators group | Independent sample t-test          |
|-----------------------|--------------------|---------------------|-----------------------------------|
| Ages (years)          | 46.95±8.52         | 43.40±7.59          | No significantly different        |
| Body Mass Index (kg/m²) | 23.57±3.34       | 24.24±4.47          | No significantly different        |
| Body Temperature (°C) | 35.43±0.38        | 35.70±0.41          | No significantly different        |
| Noise (dB)            | 82.56±2.55        | 84.24±1.66          | No significantly different        |
| Ambient Temperature (°C) | 33.49±0.97       | 32.41±1.66          | Significantly different           |
| Humidity (%)          | 58.56±5.11        | 62.68±4.95          | No significantly different        |
| Vibration (m/s²)      | 0.53±0.17         | 0.48±0.22           | No significantly different        |

The results of measurements of the factors affecting workload and the result of the independent sample t-test on the average value of the two groups can be seen in table 2. The greater the age of a person, the maximum the heart rate decreases. Heart rate is also affected by weight. Bodyweight is part of the BMI. The greater the person's weight, the greater the body weight and BMI of the person. Body temperature can be affected by environmental temperature and humidity because it releases of body heat through the surface of the person's skin [10].

Based on the regulation of the Indonesian Ministry of Health Number 1405/menkes/SK/XI/2002 concerning Health Requirements of Office and Industry Work Environment determines that the threshold value of the temperature of the industrial work environment is 30 °C and humidity is between 40% to 60%. Noise measured is noise that arises when the milling process is carried out. Noise exposure thresholds based on The Health Standards and Requirements for the Industrial Work Environment 70 of 2016 for the duration of 8 hours working time which is 85 dB. It is known that the participant does not mill of rice grain more than 8 hours a day so that the noise received by the participant is still within safe limits. Based on the same rules that are used to determine noise threshold values, the average daily vibration exposure value perceived by the participant is still safe.

3.3. Nordic Body Map (NBM)

Before work, some operators experience MSDs on certain parts of the body. It can be seen in figure 2 for one operator group and figure 3 for two operators group. Participants who experience MSDs before work can be caused by a night’s rest that is unable to recover the fatigue that is felt after work and other activities carried out before carrying out milling work. MSDs after working in group one operator are shown in figure 4 and group two operators in figure 5.
Figure 2. Pain complaints before working in one operator group.

Figure 3. Pain complaints before working in two operators group.

Figure 4. Pain complaints after working in one operator group.

Figure 5. Pain complaints after working in two operators group.

After work, many participants in one operator group has complaints in waist, buttock, and right shoulder with the level of pain complaints and two operators in waist and buttock with the level of pain complaints. MSDs felt by participants can be caused by the activity of lifting loads in the form of grain, rice, and bran repeatedly by the participant. Research conducted by reference [11] of permanent rice polishing operator shows that before improving the posture of operators, the operator experienced MSDs in 20 parts of the body excluding waist and buttocks and after improvement in 4 parts of the body.

3.4. Determination of workload

Table 3. The result of workload assessment, different tests, and multiple linear regression tests.

| Workload          | Group | Average value | Category of Workload | Adjusted R² | F test | t-test | Independent sample t-test |
|-------------------|-------|---------------|---------------------|-------------|-------|--------|--------------------------|
| CVL               | One   | (27.01±7.30)% | No fatigue          | Negative and 0 | Rejected |         | CVL is affected by body temperature by 63.9% | No significantly different |
|                   | Two   | (26.79±10.87)%| No fatigue          | 0.639       | Accepted |        |                           |                          |
| The level of caloric needs | One   | (212.81±17.94) kcal/hour | Moderate | 0.692 | Accepted |         | Calorie workload is affected by BMI by 15.04% and by humidity by 19.31% | No significantly different |
|                   | Two   | (202.29±32.91) kcal/hour | Moderate | Negative and 0 | Rejected |         |                           |                          |
| NASA-TLX          | One   | 76.60±8.85    | Moderate            | Negative and 0 | Rejected |        |                           | -                        |
|                   | Two   | 75.67±6.84    | Moderate            | Negative and 0 | Rejected |        |                           | -                        |
Based on the results of the assessment of the three workload methods and independent-sample t-test, the results obtained can be seen in table 3. The CVL value is obtained from equation 1 and because the value is less than 30% included in no fatigue category. Based on Indonesian National Standards (SNI) 7269-2009-1, it is known that workload based on caloric needs is classified as moderate if it has a value of more than 200 to 350 kcal/hour. The load based on the level of caloric needs takes into account the time each participant performs each operating process, the estimated workload according to the energy requirements, weight, and gender of the participant.

The mental workload of NASA-TLX is moderate when it has a score of 50 to 80. Participants' mental workload can be caused by several factors, such as the quality of the rice grain being milled and the time available. Poor rice grain quality results in participants needing more physical energy and thoughts to mill the rice grain. Rice grain which is still mixed with impurities as a result of the rice grain threshing process causes the milling process to last longer because the impurities prevent the rice grain from entering the part of the waste chamber.

3.5. Identification of factors that influence workload

Identification of factors that influence workload using multiple linear regression test and the result of a test can be seen in table 3. Before the multiple linear regression test, these variables are tested classic assumptions first. The classic assumption test consists of linearity, normality, multicollinearity, and heteroscedasticity. The hypothesis on the F test and the partial t-test are accepted if p-value <0.05. The F test serves to determine the factors that have a simultaneous influence on workloads while the t-test serves to determine the effect of each factor on workload. The F test results that are not accepted and t-test without the influence of independent variables on the dependent can be caused by the participant has not reached the peak point of fatigue while working or the workload experienced is relatively light.

3.6. Determination of long rest periods

Based on calculations with equation 3, it is obtained that the K value is smaller than S. Therefore, equation 4 cannot be done and the current rest applied by participants is sufficient. The same thing happened in reference [12] where a K value is (2.66-3.26) kcal/minute indicates that Kricak Noodle workers have a small level of fatigue and sufficient rest periods. The work activities of one operator group in one day can be seen in figure 6 and figure 7 for two operators group. Black block in figure 3 and 4 mean they are serving consumers, the white block means the activity of traveling around looking for consumers, and the gray block indicates the resting activity. The difference in the distance between serving consumers and the duration of rest periods can be a factor that causes the participant’s workload to be low and the duration of the participant’s long rest periods to be sufficient.

Reference [13] states that several short breaks (3:5 minutes) will give better results in output produced and the effects on the physical body than given while resting in the period of rest. The rest is better done when the participants before reached its maximum heart rate at work. The heart rate of operators every hour can be seen in figure 8. Based on the figure, it is known that short breaks can be done in the second, fourth, sixth, and ninth working hours for one operator group, and second and sixth for two operators group.
4. Conclusions

The cardiovascular workload of milling rice operators is classified as no fatigue and workload based on the level of calorie needs and mental load of NASA-TLX including moderate workload. F test results for one operator group showed BMI and humidity have a simultaneous influence on calorie workload. T-test results of two operators group obtained that there is an effect of body temperature of 63.9% on CVL. The long rest periods applied by operators is sufficient.

Recommendations that can be given are first is the existence of research on improvements to the design of mobile rice milling by considering ergonomic aspects to reduce MSDs experienced by operators. Second, the short breaks are done when operators have not reached its maximum heart rate at work. Third, the use of other equations to calculate the long rest periods due to the calculation of rest duration taking into account the energy consumption of the heart rate conversion results unable to calculate the rest duration required for work with normal loads.

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