The effects of the muddy surface environment on heart rate and pain perception in the lower extremity during the paddy planting activity

by Agung Kristanto

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Abstract

The agricultural industry of many Southeast Asian countries, including Indonesia, is highly reliant on human labor, with minimal use of modern equipment. Preliminary studies on the paddy planting activity revealed a significant occurrence of musculoskeletal disorders (MSDs) and structure malalignments in the lower extremities. This is because these farmers usually execute paddy planting activities on heavy and muddy terrain with bare feet using more significant lower extremity muscle. Therefore, this research examines the effect of muddy terrain on the lower extremity of 30 experienced rice farmers through simulated rice planting activities in terms of heart rate response and perceived pain. The Suunto wristband and the modified Standardized Nordic Questionnaire (SNQ) – visual analog scales (VAS) for perceived pain questionnaire were used to collect the data of heart rate response and pain perception on the lower extremity,which were compared between muddy (mud force) and flat rigid (no force) terrain, respectively. The Repeated Measure ANOVA test revealed that muddy work terrain had a significant effect on heart rate (100.58±1.91 beat per minute) compared to flat rigid terrain (94.68±1.50 beat per minute). Meanwhile, the paired T-test results showed that muddy work terrain had a significant effect on the increase in pain in the farmer's lower extremity when performing rice planting activities compared to flat hard terrain. The results of this study can be used as a basis for the development of an assistive device capable of preventing injuries to the lower extremity caused by muddy work surface conditions.

Keywords: Heart rate response, Pain perception, Musculoskeletal disorders, Muddy work environment, Lower extremity

1. Introduction

Rice is the main source of carbohydrate in almost all Asian Countries, as opposed to American, Australia, and the European continent, where it is consumed in a lesser amount. According to Mundi Index, Indonesia is the 4th largest producer of milled rice globally in 2021 [1]. Based on data from the Indonesian Central Bureau of Statistics (BPS), there was an increase in rice production by 0.08 percent from 2019 to 2020, with a predetermined continuous future rise [2]. Therefore, due to this increase, there is a need for a safe and healthy working environment for rice farmers to ensure the availability of labor.

Preliminary research on paddy agricultural workers revealed that the prevalence of musculoskeletal disorders (MSDs) was relatively high within a year, with the possibility of rising to other areas of the body [3]. Approximately 99 percent of rice farmers have MSDs, with 95 percent suffering from lower extremity injuries and chronic pain [4]. Several studies reported a 1-year prevalence of lower extremity MSDs in farmers ranging from 10-41 percent [5]. Identical findings have been reported in other rice farmers, with 41, 35.4, and 10.3 percent complaining of hip, knee, as well as ankle, and foot discomfort, respectively [3]. Furthermore, rice farmers had a higher prevalence of lower extremity MSDs than other manual occupations. [6].

MSDs in farmers can be found at all stages of rice farming, including plowing, seeding, planting, nursing, and harvesting. The planting stage is usually associated with ergonomic risks and pain in the farmer's lower extremity [7]. This process is performed with the trunk and knee bent forward and twisted while the right arm is moved away from the body to plant rice sprouts. Furthermore, the left-hand holds a heavy bundle of rice sprouts while it is planted below the knee position. The trunk and lower limbs experience significant pains due to the uncomfortable position and force exerted [8-9], leading to harm in muscular tissue. Long-term exposure leads to discomfort thereby, reducing job productivity [10-11]. In addition, rice planting activities are usually carried out with bare feet in muddy terrain. This environmental condition increases the force loading on the lower extremity joints caused by the mud's viscosity [12] during the stepping phase.

When farmers walk in muds, their body and tool weights produce high viscosity, leading to higher muscle strength with the lower extremity. Therefore, this study investigates the muddy surface condition effects of farmers on the lower extremity loading in rice planting work. It compared heart rate response and pain perception in each lower extremity when performing on a flat and hard surface (rigid terrain) and actual rice field surface environments (muddy terrain).

2. Material and Methods

2.1. Participants

A total of 30 experienced rice farmers consisting of males and females aged 38 to 70 working on a rice farmer in the Sewon subdistrict, Bantul, Yogyakarta, Indonesia, were involved in this research. Participants had a minimum of a year working experience in the rice planting process and were required to have no current injury to the lower extremity or any previous history of surgery or fracture.

2.2. Description of the activity

The farmers were instructed to complete the rice planting simulation activity under 2 different conditions (figure 1), namely on rigid and muddy terrains. In this study, the rice planting activity was performed on a rice field. In both experimental settings, the farmers were instructed to hold a rice sprout with an average weight of 1.5 kg in the left hand and 0.15 kilograms (one-tenth of a bundle's weight force) in the right. Throughout the planting performance simulation, a video camera was used to capture a high-angle side view of all movements. The sequence of the experimental conditions was randomly drawn at the beginning of the study. After being allocated to certain conditions, the farmers were instructed to execute simulated planting activities by pushing a small bundle of rice seedlings into the ground using their right hands. Before proceeding to the next planting row, the participants were instructed to take 6 steps backward, turn counterclockwise, and repeat the procedure with a 60 beats/minute tempo and step length of 35 – 40 cm, as shown in Figure 1. The metronome was used to control the speed of lower body movement and steps during planting tasks. Furthermore, participants were instructed to complete a total of 4 replications for each condition by rehearsing the movement pace and stepped length before starting the experiment to minimize re-dos or errors. They were also asked to score their pain perception of each lower extremity part due to task performance at the end of each condition. Based on recommendations from preliminary studies, the break interval between conditions was set to 5 minutes to help relieve the fatigue of the muscle[13].

(a) (b) (c)

Fig. 1: Simulated planting task performance: (a) rigid terrain; (b) muddy terrain; (c) direction of movement.

2.3. Response measures

2.3.1. Heart rate response

The Suunto 9 Black wrist band (Suunto Oy, Finland) was attached to the subjects' wrists to measure their heart rate responses. A set of personal data, including gender, weight, height, and maximum heart rate, were inputted into the Suunto smartwatch for the participants. The maximum heart rate was calculated using the standard equation by subtracting 220 bpm from participants age. For optimal performance of the wrist heart rate sensor, the watch needs to be worn higher above the wrist because the sensor reads blood flow through tissue. The skin at the heart rate sensor location was cleaned with alcohol to minimize impedance.

2.3.2. Pain perception

The pain perception questionnaire was used to collect the self-report of pain for each joint of the lower extremities (Indonesian version). The Standardized Nordic Questionnaire (SNQ), consisting of a body part map, was used to create the questionnaire [14]. The pain was assessed using 10-cm visual analog scales (VAS) sensitive to treatment effects [15]. The pain rating VAS scales ranged from 0 to 10 points, where 0 represented no pain, and 10 denotes intolerable pain. The questions included participants' perceived pain on both sides of each lower extremity part, such as the left and right sides of their hip, knee, and ankle. Figure 2 depicts an excerpt from the questionnaire used in the current investigation, which had been demonstrated in prior studies for adequate reliability[16].

2.4. Hypotheses

Based on the literature review, this study predicted an increase in heart rate response when farmers plant rice in muddy terrain, compared with the rigid terrain (Hypothesis 1). The additional effort exerted due to mud viscosity may overburden the lower limb muscles and tendons [17] therefore, it is expected to increase the lower extremity pain perception [8][18-19] (Hypothesis 2). The lower extremities experience an increased risk of injury due to the most significant effects of muddy terrain.

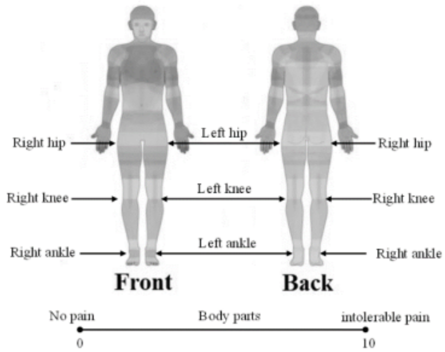

Figure 2: The Modified SNQ – VAS for perceived pain questionnaire

2.5. Statistical analyses

A physiology-based heart rate response analysis was performed during the simulated rice planting process to identify the potential effects of work surface conditions against rice farmers' heart rates. The independent variable in this part of the study is the working surface conditions for rice cultivation, namely (1) rigid (baseline) and (2) muddy terrains for both heart rate response and perceived pain. Heart rate during rice farming on rigid and muddy terrains is used as the dependent variable. Since the farmers were assigned to a certain order of conditions at random measurements, a Repeated Measure ANOVA was used to compare the heart rate between performing on flat rigid terrain and muddy terrain. Furthermore, a paired T-test was used to compare perceived pain on the lower extremity of farmers when they performed the planting task on both surfaces. Meanwhile, the pain perception responses rated by the Modified SNQ - VAS, including pain at the left and right sides of the hip, knee, and ankle, were taken as the dependent variable. The Shapiro-Wilk test was used for the normal distribution confirmation test for heart rate response and perceived pain since the data set in this study was smaller than 2000. The SPSS version 26.0 software (IBM Corporation) with a significance level of 0.05 was used for all analyses.

3. Results

3.1. Participants

The participant's demographic characteristics and descriptive statistics are shown in table 1, where 80 percent had a normal body mass index.

Table 1: The demographic characteristics and descriptive statistics of participants (n = 30)

Characteristics	N (%)	Mean ± SD
Sex		
Male	11(36.67)	
Female	19(63.33)	
Age (years)		56.33 ± 8.87
Height (cm)		158.23 ± 6.97
Weight (kg)		54.58 ± 10.29
BMI (kg/m^2)		21.55 ± 3.77
Working experience (years)		21.93 ± 13.42

SD = standard deviation

3.2. Heart rate response analysis

The repeated measure ANOVA illustrated in Table 2 showed that the heart rate during simulated rice planting significantly differed during experimental conditions ($p < 0.05$). In contrast, the heart rate during simulated rice planting did not differ significantly through experimental repetitions ($p > 0.05$). Furthermore, the combination in terms of conditions and repetitions was also insignificant.

Table 2: The repeated measure ANOVA results for heart rate during simulated rice planting

	Heart rate response

Condition	F(1 ; 29) = 24.982 p < 0.001*
Repetition	F(2.343 ; 67.951) = 1.541 p = 0.219
Conditon x Repetition	F (2.336 ; 67.757) = 2.007 p = 0.135

The pairwise comparisons test for heart rate data on working surface conditions was performed due to the significant effect of the working surface condition. The pairwise comparisons post hoc test results for average heart rate data for rice planting simulations on rigid and muddy terrain are depicted in figure 3.

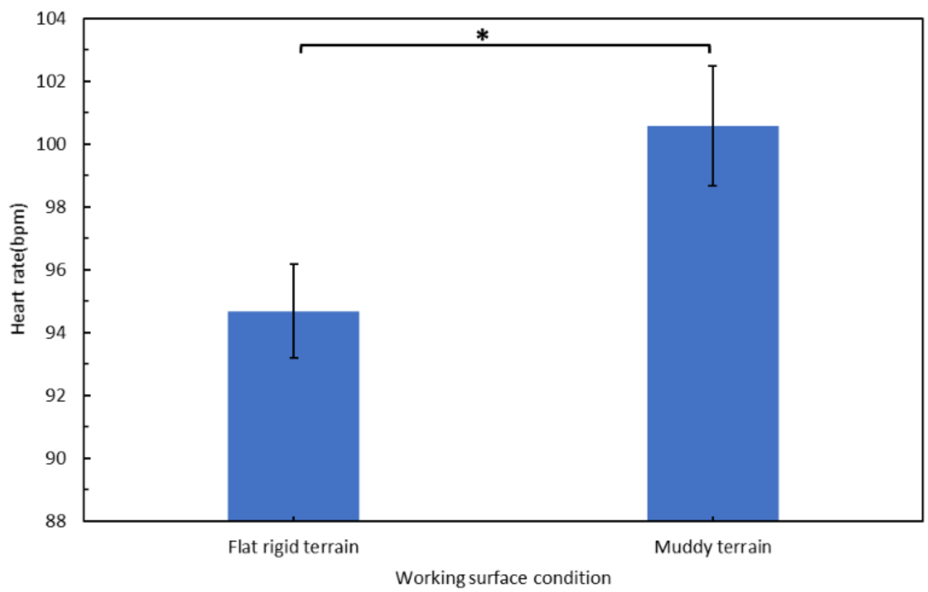

Figure 3: Comparison chart of mean heart rate between two working surface conditions. Asterisks represent significance (*p < 0.05)

The pairwise comparisons test results in figure 3 showed an increase in heart rate response on muddy terrain conditions (100.58 ± 1.91) beat per minute compared to a rigid surface (94.68 ± 1.50).

3.3. Pain perception analysis

The mean comparison chart of pain perception score between two working surface conditions is shown in figure 4.

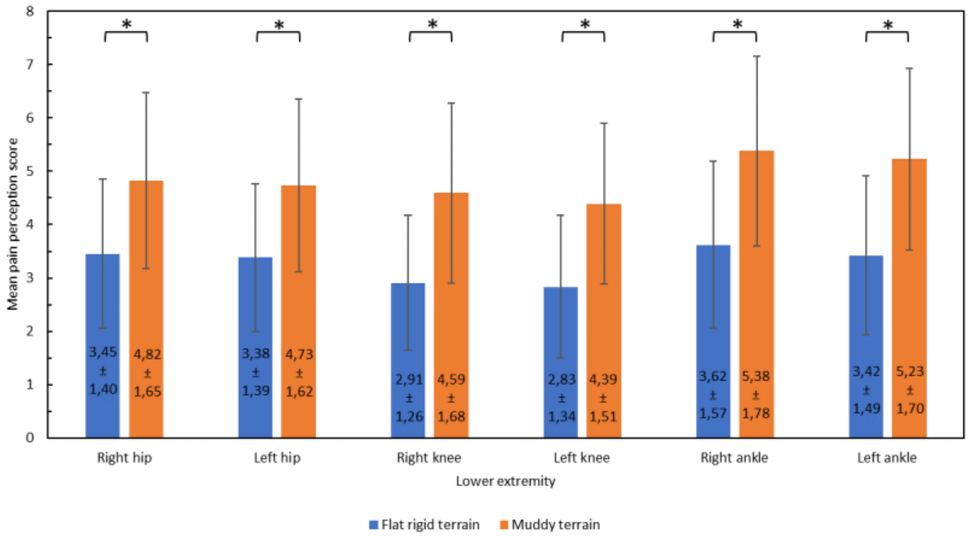

Figure 4: Comparison of mean pain perception score between two working surface conditions. Asterisks represent significance (*p < 0.05)

According to the Paired T-test results, there was a significant effect on the pain perceived by the rice farmers in all lower extremities when planting in muddy surface environment conditions compared to a flat hard surface (p-value<0.05). Figure 4 showed an increase in pain felt by the farmers in the right and left hips on muddy terrain by 4.82 ± 1.65 and 4.73 ± 1.62 compared to rigid terrain by 3.45 ± 1.40 and 3.38 ± 1.39. The perceived pain was also higher in the right and left knees on muddy terrain (4.59 ± 1.68 and 4.39 ± 1.51) compared to rigid terrain (2.91 ± 1.26 and 2.83 ± 1.34). Furthermore, there is an increase in perceived pain in the right and left ankles on muddy terrain (5.38 ± 1.78 and 5.23 ± 1.70) compared to rigid terrain (3.62 ± 1.57 and 3.42 ± 1.49). The most pain was reported on the right ankle (5.38) on the muddy terrain, followed by the left (5.23).

4. Discussion

An increasing trend in heart rate value occurred in muddy activities for simulated rice planting compared to rigid terrain. Furthermore, a linear relationship between the increased heart rate and energy expenditure [20] showed that simulated planting activity required more energy when performing in muddy terrain than on rigid. According to research carried out by Nag et al [21], the increase in heart rate caused by the bending posture during the simulated rice planting activity is 18% more than the sitting posture. This is because a greater amount of energy is needed to compensate for mud viscosity. It was confirmed by prior research [22] that revealed muddy work surroundings led to considerably higher muscle activation and pain perception of the knee and ankle. An increase in lower extremity muscular force led to a rise in heart rate value.

This study observed that the participants' heart rate were enhanced due to physiological stress generated due to the workload in different activities in rice farming. According to Kroemer & Grandjean [23], it increased linearly with the work performed. From the physiological study, it has been revealed that different activities in rice cultivation caused a significant increase in heart rate, which is an indicator of physiological stress. Furthermore, the increase in heart rate was due to the continuous rise in strenuous work until either the work was interrupted or the workers were forced to stop due to exhaustion. Other studies also explained that the increase in heart rate is linear to the rise in the rate of activities [24]. Similarly, the contracting and stretching of the muscles during different activities required energy [25-26]; therefore, the heart has to beat faster to supply more blood. Subsequently, an increase in heart rate leads to a rise in the mean arterial pressure, which in turn affects the heart's output and the blood vessels' resistance.

Muddy terrain surfaces significantly affect the increase the pain in the farmer's lower extremity, including the right and left hips, knees, and ankles when conducting rice planting activities compared to flat, hard terrain. Meanwhile, they experience increased pain in the lower extremity when planting on muddy terrain, which increases the force acting on the stance phase of gait [12].

Exposure to planting tasks that include repetitive motions and uncomfortable postures such as bending back and knee and lifting heavy loads is closely linked to knee discomfort due to high load on the joint, which eventually leads to fatigue and pain. According to Swangnetr et al [27], farmers have difficulty stabilizing their bodies when walking on wet and muddy soil. This study also reports that strong and extensive lower limb movements are needed to walk backward on muddy terrain. Therefore, high exertion of the legs and feet muscles can cause rapid fatigue and pain in the joints.

This study is partially in line with the analysis on the prevalence of pain in Thai rice farmers [3], which indicated 41%, 35.4%, and 10.3% for hip, knee, and ankle and foot pain. For the specific planting stage of rice cultivation, Karukunchit [28] indicated farmers perceived high hip and knee pain, with limited ankle pain with rating of 6.08, 3.55, and 0.52, during planting tasks. However, this study showed high pain perceived in the right and left sides of the ankles due to differences in the depth of farmers' feet submerged in the mud. In this study, the average depth of farmers' feet submerged in mud was 20 cm, while it was 18 cm in preliminary studies. The investigation of lower extremity malalignment [29] also revealed knee valgus and foot pronation with the highest prevalence of 18.49% and 20.89%. The recommendations that need to be made to improve a safe and healthy working environment to avoid the impact of MSDs that are more severe for farmers are to reduce the frequently conducted workload and adjust the ergonomic principles. Furthermore, it is necessary to pay attention to posture in a balanced state to avoid being at risk of MSDs. According to a previous study [22], preventing injuries to the lower extremities on the knees and feet of farmers during the completion of rice cultivation tasks may be done by self-protection programs development, personal protective equipment (PPE), and assistive devices development. Additionally, designing footwear covered with materials that lower resistive effort while removing feet from mud can help to prevent MSDs. Future research needs to focus on backward walking and other phases of mobility, with the ultimate objective of inventing assistive devices for farmers' knees and feet to reduce or eliminate the ergonomic risks associated with rice farming.

This study is associated with some shortcomings regarding the time conducted and the scope of analysis. First, it only took about 12 minutes to complete 2 conditions with 4 replications for each participant, while in the actual situation, it takes farmers 3 - 10 hours to complete [7]. Prolonged performing such high exertion of legs and body stability control in muddy terrain [30], thereby leading to muscle overload, fatigue, and more leg pain [8-9] [18-19]. Second, the current study focused only on the analysis of the heart rate response of farmers and the identification of pain perception in the lower extremity due to the effect of muddy work environments during the rice planting process. It also failed to design an assistive device to reduce MSDs.

5. Conclusion

The condition of the work surface has a significant effect on the heart rate of rice farmers. Furthermore, based on the analysis of pain perception in the lower extremity perceived by farmers during the rice planting process on flat hard, and muddy surfaces conditions. Therefore, the muddy work surface significantly affects farmers' lower extremities, including the hips, knees, and ankles, when carrying out rice planting activities compared to flat hard surfaces.

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