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Ergonomic Evaluation of Different Paddy Threshing Methods in Meghalaya

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ABSTRACT

Paddy threshing is an essential part of harvesting in paddy production in which farm machinery plays a crucial role for efficient threshing, reduced threshing losses and improved threshing capacity. Traditionally, farmers often thresh paddy by hand beating using a stick, or hitting a punch of harvested paddy on a wooden log followed by hand beating with a locally evolved hand tool. In this study, three different paddy threshing methods, including conventional hand beating, cycle-type pedal-operated thresher, and foot-type pedal-operated thresher, were subjected to ergonomic measures such heart rate (HR), energy expenditure rate and overall discomfort rating (ODR). It was observed that energy demand and ODR are significantly high (P<0.05) in farmers in the case of conventional hand-beating paddy threshing method than in paddy threshing by cycle-type pedal-operated thresher, and foot-type pedal-operated thresher. It was noticed that mean working EER, mean energy expenditure, and mean working ODR decreased by 19.69 and 15.15 percent, by 38.72 percent and 26.66 percent, and by 50 and 34.37 percent in case of paddy threshing by cycle-type and foot-type paddy thresher respectively as compared to hand-beating paddy threshing method with a significance level of P<0.05. The results suggested that cycle-type and foot-type paddy thresher gave better performance from ergonomics perspective as compared to traditional hand-beating method.

Key Words*:* Energy expenditure, Ergonomics, Heart rate, Paddy, Threshing.

INTRODUCTION

Rice crop production costs are rising drastically due to higher daily wages and greater demand for labour in paddy cultivation and post-harvesting (Devi *et al,* 2020). Moreover, modern agriculture is heavily dependent on farm mechanization. The availability of farm electricity and effective farming equipment, as well as their economic use, determine farm productivity. Agricultural mechanization makes it possible to use various inputs like seeds, fertilizer, plant protection measures, and effective irrigation systems efficiently. It also aids in improving agricultural production, which boosts agricultural output and boosts the economy of many farmers by making farming a lucrative business (Kanta and Devi, 2017). However, the level of farm mechanization is extremely low in northeast India. Factors such as hilly terrain, high transportation costs, lack of governmental funding, various financial restrictions brought on by socioeconomic conditions, and lack of agricultural machinery manufacturing businesses have prevented these states' economies from growing in the farm equipment industry (Rajkhowa *et al,* 2020). Moreover, the bulk of the tribal population in northeast India are prone to excessive drudgery in farm operations. The dominance of traditional farming practices and a low level of mechanization are two major factors in the region's inferior agricultural productivity. Local artisans and small-scale manufacturers produce tools and equipment without using

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ergonomic principles, which have a low level of operating effectiveness and frequently fail to lessen the arduousness of operation in hills. While introducing enhanced machinery for adoption, difficulties have been encountered in various regions of the nation.

Paddy threshing is the separation of the paddy kernels from the panicle of the rice plant. The impact and stripping rubbing motion cause the grains to separate from the panicle (Perumal *et al,* 2013). The traditional method of threshing rice by hand involves beating bundles of panicles with a flail or against a hard object (such as a bamboo bar, bar stone, bamboo table). Depending on the kind of rice, the production per man-hour ranges from 10 to 30 kg of grain. When threshing is done too late, this procedure results in grain losses of between 1% and 4% (Paulsen *et al,* 2015); some unthreshed grains might also be lost over the threshing area. Trampling with persons and animals while threshing traditionally results in significant losses (Belay *et al*, 2013; Lad, 2020). Most of the paddy threshing in Meghalaya is generally done by hand beating by farmers.

For the design of manual material handling jobs, ergonomic studies on operator capabilities are crucial. Threshing operations, according to (Kathrivel and Shivkumar, 2003), use 25% of the total energy used in rice production. The most laborious process, traditional threshing involves thrashing the grain bundle on stones or a wooden platform while bending over. Bending over while working adds to the tedium that has to be eradicated with the right technology (Kathrivel and Sivakumar, 2003; Khadatkar *et al*, 2017). Therefore, the mechanization of these processes should be emphasized to reduce labour needs in rice threshing. Human energy is mainly used in agriculture for seedling raising, weeding, harvesting, and cleaning. In order to improve the efficiency of human work, simple, adequate, and efficient machines or tools must be available to increase agricultural production in Meghalaya (Devi *et al*, 2020). Economic situations, tiny and dispersed land holdings, a lack of/uncertainty in electricity, etc. are some of the obstacles that prevent small-holding farmers from using power threshers. For them, employing human force to do the threshing is the finest option. To lessen the labour-intensive nature of threshing, it was imperative to conduct ergonomic studies of small machine such as pedal-operated paddy thresher for popularization and adoption among the farmers. Therefore, research on the ergonomics of farmers engaged in paddy threshing is essential (Khadatkar *et al*, 2017). Hence, considering the above issue, an ergonomic study was conducted for performance evaluation of different paddy threshing methods in Meghalaya.

MATERIALS AND METHODS

Pedal Thresher

For the ergonomic experiment, two types of pedal threshers from ICAR (NEH, Meghalaya) were selected. The selected thresher were cycle-type pedal threshers with seating arrangements and another one is a foot-type pedal-operated, both threshers attach with a wire loop-type cylinder. The selected threshers were also facilitated with power transmission systems, foot and cycle-type pedals, and mild steel sheet bodies. Specifications of both threshers are given in Table 1.

Selected area for experiment

Umeit and Pynthor are two villages of Ri - bhoi district of Meghalaya that was selected for the experiments. The latitude and longitude of the selected villages are 25.7176° N & 25.9363° N, and 92.0191° E & 91.7666° E respectively. Both villages are situated nearby ICAR for the NEH complex of Meghalaya, India. People of those villages follow traditional hand-beating for the paddy threshing process.

The ergonomic experiment was carried out on ten male farmers (N=10) based on anthropometric characteristics between the 5^{th} and 95^{th} percentile, and these ten workers handled all of the study's operations. The chosen ten farmers were in the age range of 20 to 39 years. The experiments were carried out between 8 am to 1 pm in the month of December 2022. The anthropometric dimensions like stature (cm), age (years), weight (kg), and heart rate (HR) (bpm) were recorded. Additionally, the subject's height and weight were divided to calculate the subject's body mass index (BMI) (m^2). Hume's formula (1966) and DuBois and DuBois's formula were

Table 1. Specifications of selected threshers

Sr. No.	Specifications	Cycle -type pedal - operated thresher	Foot -type pedal - operated thresher
1	Diameter of Drum (mm)	300	300
2	Width (mm)	500	600
3	Height (mm)	890	800
4	Length (mm)	780	700
5	Power Source	One person	One Person
6	Transmission System	Cycle -type pedal with 1:4 gear ratio	Crank mechanism with 1:4 gear ratio
7	Weight , kg	43	37

used to computing each subject's body surface area (m^2) and lean body mass (kg) (Shuter and Aslani, 2000). Hume's formula (2.1) was used to calculate the lean body mass (LBM) weight (Hume, 1966).

LBM=[(body weight× 0.29569)+(body height × 0.41873) - 43.29]...... (2.1)

Each participant's Body Surface Area (BSA) was calculated using the DuBois and DuBois formula based on their weight and height as specified in eq. 2.2.

$BSA = Weight^{0.425} \times Height^{0.725} \times 0.007184$ …… (2.2)

By dividing each subject's weight in kilograms by the square of their height in meters square, the body mass index, or BMI, was also calculated. The World Health Organization (BMI) gave the body mass index the following category. BMIs of 18.5 or below is considered underweight, whereas those between 18.5 and 24.9 are regarded as medium weight. People that are overweight have a BMI of 25 or above. By utilizing the formula of Robergs and Landwehr ($HR_{max} = 205.8 - 0.685 \times Age$), the maximum HR was determined (Robergs and Landwehr, 2002).

The study was conducted in an open rice field on male agricultural workers of Meghalaya. Three distinct paddy threshing procedures, including conventional hand beating, cycle-type pedal-operated thresher, and foot-type pedal-operated thresher, were subjected to ergonomic measures (HR, ODR and energy expenditure rate) for a period of 30 minutes each. Major instruments used for conducting the field experiments are a tachometer, Polar HR monitor M10, measuring tape, weighing machine, etc. (Fig 1). Before beginning the experiments, the subjects were given enough time to rest in order to calculate their resting heart rates (HR rest).

Circulatory stress was evaluated using the cardiac cost of labour and the cardiac cost of recovery. The cardiac cost of recovery is the sum of all heartbeats above the resting rate between ending work and returning to sleep (Saha, 1976). The heart rate was determined using a Polar heart rate monitor using the formula HR=beat/min.

Heart rate

Heart rate is one of the primary physiological indicators connected to increasing physical strain and energy requirements. Three different types of heart rates were considered for the evaluation of the physiological responses. In this investigation, a Polar heart rate monitor was used to assess heart rate. Resting heart rate (Rhr), average working heart rate (Rw), peak heart rate (Phr), and other cardiovascular characteristics are taken into account throughout the field trial. The following definitions include some particular words associated with heart rate.

Maximum heart rate (HR_{max})

The maximum heart rate (HR_{max}), which decreases with age, is the greatest heart rate a person may achieve without exhausting themselves excessively. The most accurate

a. Measurement of cylinder speed by tachometer

b. Meghalaya traditional hand beater for paddy threshing

c. Polar M10 HR Monitor

d. Attaching Polar M10 on the chest

Figure 1. Instrumentation for carrying out the field experiment

method for determining HR_{max} is a cardiac stress test because HR_{max} varies from person to person. For determining the HRmax, the formula from Robergs and Landwehr (2002) was used (HR_{max} = 205.8 - 0.685 Age) (Robergs and Landwehr, 2002).

Resting heart rate (R_{hr})

The resting heart rate, measured in beats per minute (bpm), is the typical pulse rate while at rest. The basal or resting heart rate (Rhr) is the heart rate of an individual while they are awake, in a temperature-neutral environment, with no recent activity or stimulus, such as stress or surprise. A substantial amount of data indicates that the typical range is 60–100 bpm. Mortality is commonly correlated with resting heart rate. The remaining farmers were given 5 minutes to relax while the resting heart rate was monitored under field circumstances.

Working heart rate (R_w)

Working heart rate is the typical HR that participants have while they are working (R_w). In order to determine the effects of heat stress on R_w during labour, it evaluated the working heart rate under three distinct WBGT circumstances.

Table 2. Discomfort in body parts (adopted from Kwatra *et al,* 2010)

Sr. No.	Particulars	Intensity of pain
1	Very severe	4
2	Severe	3
3	Moderate	2
4	Mild	1
6	very Mild	1

Table 3. Physical characteristics of selected farmers

Sr. No.	Particulars	Statistic of Subjects
1	Height (cm)	161.6±1.42
2	Age (yr)	30.10 ±5.13
3	Weight (kg)	60.4±4.08
4	BSA (m^2)	1.63±0.05
5	BMI (kg/m^2)	23.12±1.48
6	LBM (kg)	46.10±1.82
7	HR_{max} (bpm)	185.19±3.6

Peak heart rate (P_{hr})

Peak heart rate is the maximum heart rate that can be reached without running any danger of cardiovascular disease or the highest heart rate that can be measured while working (P_{hr}).

Recovery heart rate (HR_r)

Recovery heart rate is the decrease in heart rate that occurs one minute after a peak effort. While a heart rate of 50 to 60 bpm is considered exceptional, a recovery heart rate of 25 to 30 bpm is considered good. By allowing the farmer to rest for five to ten minutes, recovery heart rate (HR_r) may be very helpful for detecting the cardiovascular strain under heat stress and monitoring the resting heart rate in field situations. Work strain is determined by adding values for the recovery heart rate (SRHR) throughout the 5 to 10-minute recovery interval (Dey *et al*, 2007).

Energy Expenditure Rate

In addition, it was generally accepted that there was a connection between heart rate and energy expenditure. Based on the empirical equation, the energy expenditure rate (EER) (2.3) was estimated with the aid of heart rate (Saha *et al.*, 1979; Yadav *et al.*, 2007).

$$EER=(HR-66)/2.4 \quad \ldots\ldots(2.3)$$

Measurement of Pain Intensity

The occurrences of discomfort the individuals reported during the performance of the activity indicated by different locations on a body map were used to calculate the muscular strains. On the five-point scale shown below (Table 2), the degree of discomfort in the bodily parts mentioned above was scored:

RESULTS AND DISCUSSION

The demographic information of the selected farmers is detailed in Table 3. Most farmers reported that they rely on traditional methods for threshing due to the ease of use and low cost, despite the advent of modern mechanical methods. The physiological parameters during paddy threshing in three different methods is shown in Table 4. Fig. 2 showed the experiment for ergonomic evaluation carried out at Umeit and Pynthor villages of Ri -bhoi district of Meghalaya by adopting three different methods of paddy threshing i.e. traditional hand beating (Fig 2a), cycle-type pedal-operated thresher (Fig. 2b) and foot-type pedal-operated thresher (Fig. 2c) for 30 minutes.

The variation in heart rate of selected farmers at different paddy threshing processes was presented in Fig. 3. The heart rate of each farmer was measured with the help of polar H10 by

a. Paddy threshing by traditional hand beating process | b. Paddy threshing by cycle-type pedal-operated thresher | c. Paddy threshing foot-type pedal-operated thresher

Figure 2. Ergonomic evaluation of paddy threshing using different methods

Table 4. Physiological parameters during paddy threshing in three different methods

Sr. No	Parameters	Hand heating Paddy threshing	Cycle-type pedal-operated thresher	Foot-type pedal-operated thresher
1	Mean Working HR, bpm	132	106	112
2	Mean Resting HR, bpm	90	85	87
3	Mean Recovery HR, bpm	109	95	99
5	Energy Expenditure Rate, KJ/min	27	17	19

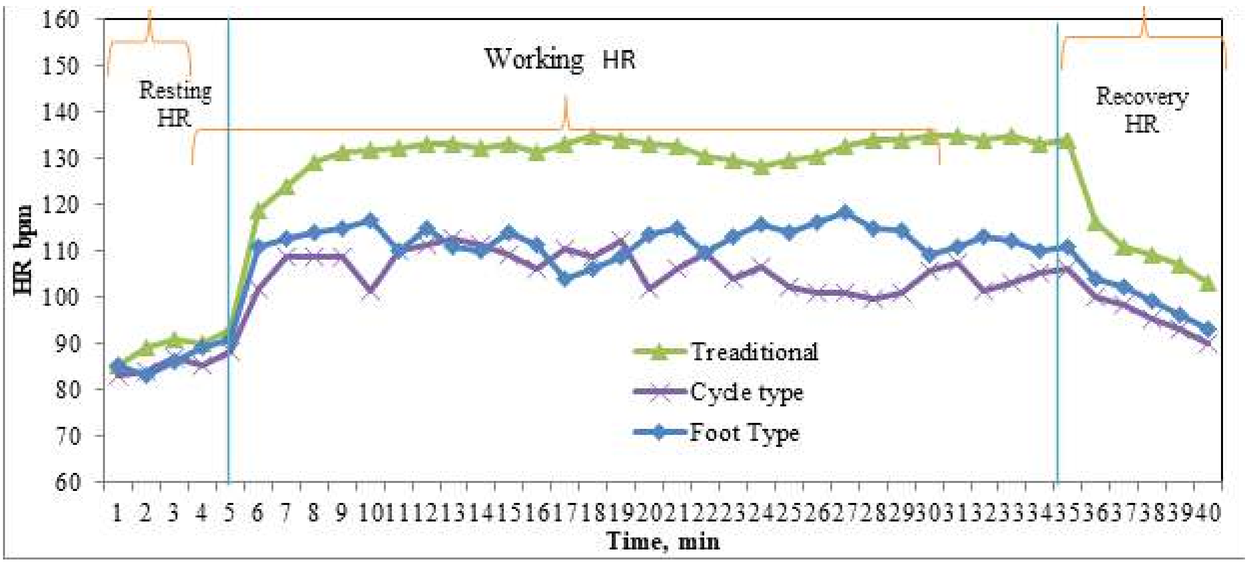

Figure 3. Mean heart rate of selected farmers using different paddy threshing methods

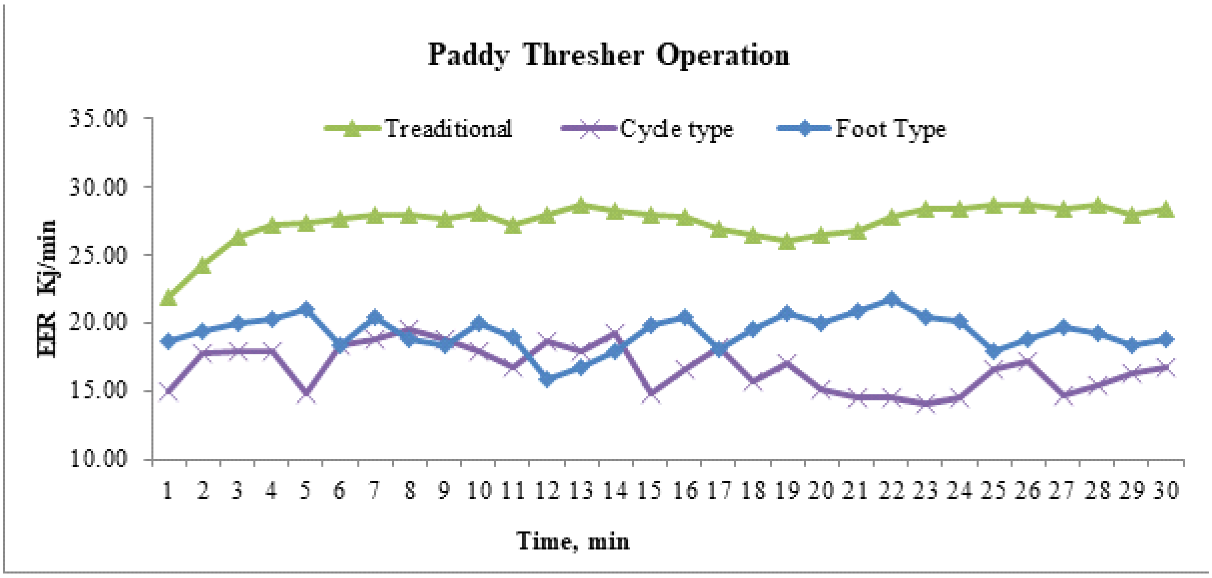

Figure 4. Variation in energy consumption during paddy threshing

Table 5. Recommended work category with the rate of energy expenditure

Sr.No.	Work category	EER, kJ/min
1	Light	<9.10
2	Moderate	9.11-18.15
3	Heavy	18.16-27.22
4	Extremely heavy	>27.22

attaching it to the chest of a farmer with a suitable belt arrangement. The mean heart rate for 30 minutes duration of selected farmers varied from 118 to 135 bpm during paddy threshing by hand beating, 101 to 113 bpm during paddy threshing by cycle-type pedal-operated thresher, and 104 to 116 bpm during paddy threshing by foot-type pedal-operated thresher respectively. The mean working HR, mean resting HR, and mean recovery HR is presented in Table 4. The mean resting HR and mean recovery HR for 5 min duration. It was observed that mean working HR decreased by 19.69 and 15.15 percent in the case of paddy threshing by cycle-type and foot-type paddy thresher compared to hand-beating paddy threshing. It was also noticed that the recovery HR has not come to normal after threshing performed by hand beating for a duration of 5 min. However, more rest may be required to recover the HR after the hand-beating paddy threshing for the duration of 30 min. It was observed that HR was significantly increased ($P<0.05$) in the case of hand-beating paddy threshing compared to paddy threshing by cycle-type and foot-type paddy thresher with the help of paired *t*-test.

Energy Expenditure Rate

The graphical presentation in Fig. 4 showed the variation in energy consumption under working conditions at various processes of rice threshing. The mean energy expenditure varied between 21.86 to 28.70 KJ/min during paddy threshing by hand beating 14.78 to 19.44 KJ/min during paddy threshing by cycle-type pedal-operated thresher and 15.78 to 21.69 KJ/min during paddy threshing by foot-type pedal-operated thresher respectively. The mean±SD energy expenditure was 27.37±1.50 KJ/min, 16.77±1.63 KJ/min, and 19.30±1.29 KJ/min respectively for three different paddy threshing processes. The classification of agricultural work according to energy expenditure values was carried out by Nag *et al*. (1980) (Table 5). It represented that paddy threshing by hand beating is extremely heavy and, paddy threshing by cycle-type pedal-operated thresher and foot-type pedal l-operated thresher are under the heavy category. It

Table 6. Comparison of ODR between traditional paddy threshing and cycle-type pedal-operated thresher for the duration of 30 minutes

Condition	Sample	Mean	SD	df	*t*-value	*P*-value
Traditional paddy threshing	10	3.20	0.92	9	25.92	0.0002
Cycle-type pedal-operated thresher	10	1.60	0.84	-	-	-

Table 7. Comparison of ODR between traditional paddy threshing and foot-type pedal-operated thresher for the duration of 30 minutes

Condition	Sample	Mean	SD	df	*t*-value	*P*-value
Traditional paddy threshing	10	3.20	0.92	9	22.52	0.0115
Foot-type pedal-operated thresher	10	2.10	0.99	-	-	-

was observed that EER decreased significantly by 38.72 percent and 26.66 percent respectively in the case of paddy threshing by cycle-type and foot-type paddy thresher compared to hand-beating paddy threshing. It was also observed that EER is significantly increased ($P<0.05$) in the case of hand-beating paddy threshing compared to paddy threshing by cycle-type and foot-type paddy thresher with the help of paired t-test.

Overall Discomfort Rating (ODR)

The farmers' overall discomfort rating (ODR) was found to be 3.2±0.91 when paddy was threshed manually by hand pounding, as opposed to 1.6±0.84 & 2.1±0.99 while utilizing cycle-type and foot-type paddy threshers. When compared to hand-beating paddy threshing, it was shown that ODR dramatically lowered for cycle-type and foot-type paddy threshers by 50 and 34.37 percent, respectively. When pounding rice crop bundles by hand, the discomfort was mostly caused by the standing posture used. However, when using a foot-type paddy thresher, the discomfort was mostly caused by pedalling while standing. The same findings were reported by Dewangan (2007). The seating configuration of the cycle-type paddy thresher also makes it less uncomfortable. It was also observed that ODR is significantly increased ($P<0.05$) in the case of hand-beating paddy threshing compared to paddy threshing by cycle-type and foot-type paddy thresher with the help of paired *t*-test (Tables 6 and 7).

CONCLUSION

This ergonomic study was carried out to know the workload of Meghalaya farmers working in different types of paddy threshing systems. It was observed that mean working EER, mean energy expenditure, and mean working ODR decreased by 19.69 & 15.15 percent, by 38.72 percent & 26.66 percent, and by 50 and 34.37 percent in case of paddy threshing by cycle-type and foot-type paddy thresher respectively as compared to hand-beating paddy threshing method with a significance level of $P<0.05$. Therefore, the results suggest that cycle-type and foot-type paddy thresher gives better performance from ergonomics perspective as compared to traditional hand-beating method.

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