



An ergonomic evaluation of pedal operated paddy thresher for farm women

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ABSTRACT

Traditional paddy threshing is a labour intensive operation and mostly carried out by farm women in awkward posture. In this study, the performance of pedal operated paddy thresher was evaluated with 12 farm women and compared with traditional method, i.e. manual beating of paddy on wooden log. The mean working HR in pedal operated paddy thresher was found to be 134 beats/min, whereas it was 141 beats/min by traditional method. The corresponding work pulse (Δ HR) was 51 beats/min. The energy expenditure rate (EER) was 17.71 kJ/min with the use of paddy thresher whereas traditional method it was recorded as 19.34 kJ/min. It was observed that there was 20% increase in output with paddy thresher. The total cardiac cost of work (TCCW) and physiological cost of work (PCW) in paddy thresher was recorded as 1662 and 55, respectively. The reduction in drudgery was observed about 43% as compared to traditional method. The pedal operated paddy thresher is an improved and convenient technology developed for minimizing drudgery and grain losses occurring during traditional threshing operation.

Key words: Cardiac cost, Drudgery, Heart rate, Paddy thresher, Physiological cost, Traditional

Agriculture has an important place in Indian economy and the main work force in it is human power. The women work force in agriculture and allied sectors is estimated to be around 97 million which amounts to about 37% of the total agricultural workers in the country (Anonymous 2014). Table 1 gives the population dynamics of Indian agricultural worker and it was estimated that by 2020, the population of agricultural worker will be about 230 million of which 45% will be the female workers. India is one of the world's largest producers of white rice and brown rice, accounting for 20% of all world rice production. In India, paddy is the principal food crop and its production reached to a record high of 106.67 million tonnes in 2013-2014 crop years (Anonymous 2017). In paddy cultivation, women are the main power source as most of the operation like sowing, weeding, transplanting, harvesting and threshing is mainly done by them while men are engaged in other post-harvest activities. In Madhya Pradesh, participation of women in rice based cropping system was 40.51% and that of men was 59.49%. Also, the maximum participation of women was observed in rice crop (78.18%), followed by wheat (12.76%), field pea (3.22%) and blackgram (2.41%) (Anonymous 2012).

According to Kathrivel and Shivkumar (2003), threshing operation consumes 25% of the total energy

utilized in paddy cultivation. Traditional threshing is the most drudgery prone operation performed by farm women by beating the paddy bundle on stones or wooden platform in bending posture. Working in a bending posture causes more drudgery which needs to be eliminated with suitable technology. In paddy threshing, farm women have to bend over the work surface which is main cause of drudgery. This drudgery can be minimized by using improved technology, i.e. pedal operated paddy thresher.

Tiwari *et al.* (2011) in his study found that pedalling is the most efficient way of utilizing power from human

Table 1 Population dynamics of Indian agricultural workers (Banthia, 2004, Census of India 2002, Census of India 2006, Census of India, 2011) (No. in million)

Particular	1991	2001	2011	2020*
Country's population	846.3	1029	1211	1323
No. of workers as % of population	37.1	39.0	39.8	42.8
Total no. of workers	313.7	402	482	566
% of agricultural workers to total workers	67.1	58.2	54.6	40.6
No. of agricultural workers	210.5	234	263	230
No. of male agricultural workers	136.6	143	165.7	126.5
No. of female agricultural workers	73.9	91	97.3	103.5
% of females in agricultural workforce	35.1	39	37.2	45

* Estimated

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muscles. Pedal power enables a person to drive devices at the same or higher rate as that achieved by hand cranking, but with far less effort and fatigue. Kwatra *et al.* (2010) compared the ergonomic data of farm women by threshing the paddy bundles with traditional and improved method. In the study, they found that there was 20.71% reduction in heart rate with pedal operated paddy thresher as compared to local one of beating on wooden platform.

Mohanty *et al.* (2008) worked on paddy thresher with single and double operators and they found that there was noticeable reduction in heart rate with double operator, i.e. 10.82%. The total cardiac cost of work (TCCW) and physiological cost of work (PCW) reduced by 19.84 and 20% with double operators. They also suggest increasing the length of threshing drum to 75 cm, so that it can be operated by two operators comfortably.

The pedal thresher was found 50-70 % more efficient than manual threshing (Nag *et al.* 1980, Jena and Mohanty 2014). It was also observed from the study that the working heart rate and oxygen consumption rate of male worker required in pedal thresher was 126.5 beats/min and 0.79 l/min whereas for female worker it was 124.3 beats/min and 0.68 l/min. Also, the relative cost of workload of pedal thresher was 23.9 and 18.5% lower than that of manual threshing by male and female workers (Nag *et al.* 1980).

There are some constraints at small holding farming to do threshing by power thresher which includes economic condition, small and scattered land holding and unavailability/uncertainty in electricity etc. For them the best way is to do threshing by using human power. Pedal operated paddy thresher is a gender friendly technology developed to reduce drudgery involved in threshing. Therefore, there is necessity to study an ergonomic of farm women involved in threshing operation of paddy.

MATERIALS AND METHODS

The ergonomic evaluation of paddy threshing operation was carried out with twelve female agricultural workers (subjects) of Bhopal district of Central India (Singh 2016). In this study, two methods of paddy threshing were used viz., traditional method (manual beating on wooden log) and improved method (pedal operated paddy thresher). Both manual beating and pedal thresher was operated for 60 min duration. During threshing with pedal operated thresher, one person was engaged in supplying the paddy bundle to the operator and other person was engaged for manually moving the bundle over thresher and pedalling the thresher (Fig 1). At the beginning and at the end of each experiment, the subjects were given sufficient rest so that all the physiological parameters regained to their normal level. After achieving the resting heart rate, the subjects were asked to perform the threshing operation by beating paddy crop on wooden log for 60 min duration and then rest of 15 min was given to regain the physiological parameter to its resting level. Same procedure was followed with pedal operated paddy thresher with sufficient rest period between the two methods of operation. The data were recorded for



Fig 1 Paddy threshing with pedal operated paddy thresher

both the threshing methods. The detail specification of the thresher used in the study is given in Table 2.

The subjects selected were from the age group of 20-45 years as the highest strength level was obtained between this age group. All the subjects were right handed, physically fit and well-practiced with both the means of paddy threshing. The physiological responses of female subjects were measured while threshing with traditional method as well as improved method. The subjects were familiarized with experiment procedure and were screened for postural abnormalities or any occupational problems. Before conducting the experiments for measurement of physiological responses, each subject was checked for cardiovascular, neuromuscular and musculoskeletal disorders. The physical and physiological characteristics namely age, weight, stature and maximum heart rate of the selected subjects were also measured. A weighing balance (100 kg capacity, least count 0.1 kg) was used for the measurement of weight, stature was measured using anthropometer and maximum heart rate was determined by using the equation "220 - age (in years)".

Before starting the activity subjects were given sufficient rest to determine the resting heart rate (HR rest). The resting data was noted for 15 min prior to any experiment.

The HR was measured by heart rate monitor of Polar

Table 2 Salient specifications of the pedal operated paddy thresher

Specification	Dimension
Overall dimension (l × w × h), mm	670 × 750 × 990
Weight, kg	39
Number of slats	10
No. of wire loops/slat	8-9
Capacity, kg/h	35
Power source	one woman

make. The polar transmitter detects the HR and transmits it to the wrist receiver. It is generally considered that the heart rate gets stable after 3-5th minute of the work thereby HR work and the OCR was measured between 6th to 60th minute of work of each subject. The average HR and OCR were taken for computational work. The oxygen consumption rate (OCR) of subject on their measured heart rate was estimated based on general equation as given by Singh *et al.* (2008).

$$OCR = 0.0114 \times X - 0.68 \tag{1}$$

where, X = heart rate

The energy expenditure rate was measured by multiplying the OCR (l/min) with 20.93 kJ (1 litre = 20.93 kJ)

$$EER = OCR \times 20.93 \tag{2}$$

The increase in heart rate per kg of grain threshed (Δ HRKG) was determined by the following formula given by Solanki *et al.* (2006):

$$\Delta \text{ HRKG} = [\Delta \text{HR} / C] \cdot 60 \tag{3}$$

where, Δ HR = (Mean working HR – Resting HR), beats/min
C = Capacity of the thresher, kg/h

The total cardiac cost of the work can be obtained by adding cardiac cost of work and cardiac cost of recovery. When this total cardiac cost of work is divided by duration for which this activity carried out, it gives physiological cost of work. Following formulae were used to calculate the total cardiac cost of work (TCCW) and physiological cost of work (PCW) (Singh *et al.* 2007).

$$CCW = \Delta \text{HR} \cdot tA \tag{4}$$

$$CCR = (\text{AHR recovery} - \text{AHR rest}) \cdot tR \tag{5}$$

where, CCW = Cardiac cost of work

Δ HR = Mean working heart rate – Mean resting heart rate, tA = duration of activity, CCR = cardiac cost of recovery, AHR recovery = Average recovery HR, AHR rest = Average resting HR, tR = duration of recovery.

At the end of each experiment, the subjects were asked to indicate their Overall Discomfort Rating (ODR) on visual analogue discomfort scale from 0 to 10 (0-no discomfort, 10-extreme discomfort). To measure Body part discomfort score (BPDS), a score based technique was followed (Corlett and Bishop 1976). In this technique, the subject's body is divided into 12 regions and the subjects were asked to indicate and score the painful regions from 0-10 point scale. The subject was asked to mention all body parts with their discomfort score, starting with the most painful and the next painful and so on until all painful body parts have been mentioned.

The data on performance of paddy threshing with traditional as well as pedal operated paddy thresher, i.e. output capacity and physiological responses like work pulse (Δ HR), and subjective responses namely ODR and BPDS during threshing operation were statistically analysed using t-test. Analysis of variance (ANNOVA) was used for comparing the results.

RESULTS AND DISCUSSION

Ergonomic evaluation of paddy threshing

It was observed that with pedal operated paddy thresher the mean HR during work was 134 beats/min and corresponding work pulse (Δ HR) was 51 beats/min. The oxygen consumption rate (OCR) was 0.846 l/min and the energy expenditure rate (EER) was found to be 17.71 kJ/min. In traditional system, i.e. by manual beating on wooden log, the mean HR was found to be 141 beats/min and corresponding work pulse (Δ HR) was 51 beats/min. During manual beating the energy expenditure and oxygen consumption was high and it was recorded as 19.34 kJ/min and 0.924 l/min, respectively. According to categorization of the agricultural work given by Nag *et al.* 1980, pedal operated paddy thresher work can be put in the category of 'moderate' work but with the manual beating of paddy on wooden log it is a 'heavy' category work (Table 3).

Table 4 gives the comparison of physiological parameters with manual beating and pedal operated paddy thresher. The data on increase in heart rate per kg of grain threshed indicated that manual beating is more drudgery causing way of threshing as compared to improved method. In pedal operated paddy thresher this value was 78 beats/kg whereas it was 82 beats/kg in manual beating.

Physiological cost of work

The total cardiac cost of work (TCCW) and physiological cost of work (PCW) was 1662 and 55 with pedal operated paddy thresher and 1676 and 56 with traditional system as shown in Table 4. In manual beating, worker has to raise hand above the shoulder which is avoided in pedal thresher. In pedal thresher combination of hand movement over drum and leg are required. It is well known that human leg has more strength than the other body part and thus ensuring the pedalling the most efficient way of utilizing power from human muscles and accordingly improved technology have to developed.

Output capacity

The output capacity of the thresher was 39 kg/h as against 31 kg/h in manual beating of paddy. It was observed that there was 20% increase in output with paddy thresher. It is predicted that increase in output may be due to increased in number of strokes which resulted in more peripheral speed of the threshing drum and thus the output.

Overall discomfort rate and body part discomfort score

Table 3 Categorization of the agricultural work (Nag *et al.* 1980)

Variable	Light	Moderate	Heavy	Extremely heavy
O ₂ consumption (l/min)	0-0.435	0.436-0.870	0.871-1.305	>1.306
Energy cost (kJ/min)	<9.10	9.11-18.15	18.16-27.22	>27.23

Table 4 Comparison of physiological parameter of threshing operation

Parameter	Threshing operation	
	Manual beating on wooden log	Pedal operated paddy thresher
HR avg, (beats/min)	141	134
EE avg, (kJ/min)	19.34	17.71
OCR, (l/min)	0.924	0.846
Δ HRKG, (beats/kg)	82	78
TCCW	1676	1662
PCW	56	55
ODR	7.3	4.1
BPDS	77	54
Output, (kg/h)	31	39

The average ODR and BPDS of paddy threshing operation was higher with traditional method than pedal operated paddy thresher. The ODR and BPDS with traditional method was 7.3 and 77, respectively. Whereas, it was 4.1 and 54 with pedal operated paddy thresher. It was observed that there was 43% drudgery reduction in ODR and 30% reduction in drudgery with BPDS as compared to traditional system. All the subjects experienced discomfort mostly in lower leg and lower back. In pedal operated paddy thresher, continuous pedalling is required for undisturbed work which results in pain at lower leg whereas in manual beating of paddy crop, the body part discomfort was mainly in shoulder, in lower back due to bending working posture.

The ANOVA for threshing operation with pedal operated paddy thresher and traditional method were significantly different ($P < 0.05$) for Δ HR, output capacity, ODR and BPDS. The Δ HR, ODR and BPDS were significantly higher in traditional method of paddy threshing as compared to pedal operated paddy thresher. This indicated that the drudgery in paddy threshing operation with pedal operated paddy thresher was reduced. Similarly, the output capacity with pedal operated paddy thresher was significantly higher than the traditional method.

The mean HR in pedal operated paddy thresher was 134 beats/min whereas it was 141 beats/min in manual beating of paddy. The corresponding work pulse (Δ HR) was 51 beats/min. The data on energy expenditure showed that manual beating is heavy work and pedal threshing is moderate work carried out by farm women. Also, on small scale threshing is done by manual beating which leads to grain loss, which is addressed through the use of pedal operated paddy thresher. In our study on farm women we had higher output, i.e. 39 kg/h as against the 31 kg/h in manual beating. It was observed that there was 20% increase in output with pedal operated paddy thresher along with 30 and 43% drudgery reduction based on ODR and BPDS, respectively as compared to traditional method. Also, the postural analysis indicated that threshing with pedal operated paddy thresher had less bending and repetitive action of body parts.

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