



ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(9): 1920-1926
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www.thepharmajournal.com
Received: 08-06-2022
Accepted: 19-07-2022

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Ergonomical assessment of pedal operated thresher for tribal women of bastar plateau zone of Chhattisgarh

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Abstract

Indian agriculture is heading towards precision farming with highly mechanized farm machinery in many parts of the country. But, still few parts of the country following the traditional ways which is tedious and time-consuming. Lack of knowledge and awareness, fragmented land holdings of tribal farmers forced them to practice traditional ways. Bastar region of Chhattisgarh state is one of the area where farmers still go along with traditional method of threshing i.e. hand beating. Therefore, introduction of pedal operated thresher has been thought to supersede the problem of threshing of paddy and wheat. In this research work, the physiological responses of 20 tribal farm women of Bastar has been investigated in view of their traditional way of threshing and pedal operated thresher with paddy and wheat crops. To assess the comfort and safety, physiological parameters like HR, delta HR, OCR and EER of selected subjects have been measured with selected methods of threshing.

The average value of working heart rate of selected subjects found to be 126 bpm and 112 bpm during hand beating and pedal operated threshing operation respectively. The average value of working delta HR, working oxygen uptake and working EER are to be calculated about 47 bpm, 0.75 l/min and 11.27kJ/min during hand beating of paddy crop. Similarly, delta heart rate was also observed while manual threshing wheat i.e.127 bpm whereas 112 bpm with pedal operated thresher. The output capacity while threshing with pedal operated thresher is 40% more than the threshed by hand beating. It is also learned there is a mismatch of body dimension which is responsible for back pain and other discomfort. Hence, it is signified that pedal operated thresher is ergonomically convenient for tribal women of Bastar plateau zone of CG.

Keywords: Ergonomics, heart rate, tribal, bastar, pedal thresher, women

Introduction

Agriculture engages about 50% of the workforce in India, and therefore, considered as backbone of the country (Madhusudhan, 2015) [6]. The agricultural workforce includes male and female workers both. The population of agricultural workers are expected to be about 230 million of which 45% will be the female workers till 2020 (Mehta, 2014) [7]. In Indian agriculture, rice, and wheat are the major crops, and paddy production is second largest in the world after China. The contribution of Chhattisgarh state in paddy production is high and state known as 'Rice bowl of India'. It produces high-yielding and drought tolerant varieties like Poornima, Vandana, Danteswari while MTU1010, Bambleswari, R1027, IR 64, Swarna and Indira Sona are popular as rain-fed varieties across the state. The state's cultivated area is about 4.78 million ha, constituting 35% of the total geographical area. Out of which, about 3.7 million ha is under rice cultivation with average productivity of about 1.3 tonnes/ha. Being a tribal dominated state, major constraints in production are low coverage under high-yielding varieties, drought in uplands and traditional practices of cultivation with conventional tools.

Bastar is one of the districts with immense yield potential, resources availability, diversity and favorable climatic conditions. Farm women play a vital role in farming practices and their participation observed majorly in rice crop (78.18%), followed by wheat (12.76%), field pea (3.22%) and black gram (2.41%) (Anonymous, 2012) [2]. Census suggests yield of such crops be very low i.e. 08.53 t/ha in Bastar plateau region of Chhattisgarh. The livelihood in such districts still continues to be on forest based produces. Moreover, many tribes do prefer agriculture but traditionally. This has lowered the production of agriculture. The tribals of Bastar follows, badi cultivation system and available with sufficient farm size but fragmented. Due to this, tribals bound to do cultivation on fragmented land which limit the use of machinery thereby reduces productivity. Further, small fragments do not allow machine harvesting and threshing by reaper and power thresher (Tiwari, *et al.*, 2020) [13].

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In such circumstances, clod breaking, ploughing, harvesting, and threshing operation are normally carried out manually (Tiwari, *et al.*, 2021) [14]. As shown in Fig.1 threshing

operation is performed either by hand beating or tapping under feet (Trampling).



Fig 1: Manual threshing of crops.

Both the ways of threshing are strenuous and labour-intensive, but preferably performed by women. Hand beating of crop could be performed using stick to avoid discomfort. However, taping of crop under feet expose feet to sharp edges of crop kernels and bundles thereby feet prone to pierce and injured along with the fall down of workers. Further, such methods often lead to grain loss due to shattering. Hand beating and bullock treading are common to thresh paddy and wheat crop in Bastar. It is observed that such methods causes grain losses till 4.5% (Satapathy, 2005) [11]. Such traditional methods in Bastar are still in practice though it has low output, higher grain damage and involve more drudgery. Due to poor economic condition tribals do not own power thresher. To overcome this, cost effective pedal and electrical operated threshers are available for limited requirement of small and marginal farmers. But due to erratic power supply in rural area makes ‘electrical power operated thresher’ in a controlled scope. However, pedal operated thresher becomes much popular and create huge potential for large scale adoption. But, adoption of pedal operated thresher left the possibility of ergonomically mismatch and increased drudgery for farm women. Further, literature suggests that limited work has been carried out to investigate the ergonomical parameter of farm women during threshing operation at Bastar plateau zone of Chhattisgarh. The energy expenditure rate (EER) estimated to be about 17.71 KJ/min during threshing of paddy using the power thresher whereas EER reported about 19.34 KJ/min during traditional threshing (Khadatkar *et al.*, 2017) [4]. The mean ΔHR found to be 155 beats/min during hand beating of paddy crop whereas it was 123 beats/min with the use of

pedal operated paddy thresher (Kwatra *et al.*, 2010) [5]. Thus, a significant reduction in HR of about 21 percent was observed due to use of pedal operated thresher. Agrawal *et al.*, (2013) [1] found the most promising design of pedal thresher with the lowest work pulse rate. Similarly, Sam (2012) [10] gave the energy cost for threshing with mini thresher is 15.53 KJ/min, whereas for manual threshing was 21.55 KJ/min. It is therefore an investigation has been planned to assess the suitability of pedal operated thresher for tribal women. The Bastar has crop intensity more than 100% and farmers used to take paddy crop primarily followed by wheat crop. Thus, both the crops have been considered for the study and measure performance of pedal operated thresher with paddy and wheat. Apart from this, anthropometric data bank of agricultural workers of Bastar is limited which could help researchers to design new farm tools and machinery specific to tribal population. Thus, anthropometric dimensions have also been recorded under this investigation. In nutshell, traditional way of threshing, has been evaluated and provided a solution for drudgery reduction with better comfort and safety.

2. Methodology

To investigate the level of drudgery and ergonomical parameters, 20 tribal women involved in agricultural operations were selected from Bastar plateau zone of CG. The selected women were asked to perform threshing of crops by hand beating and using pedal operated thresher. The experiments were conducted on paddy and wheat crops. HR and blood pressure was recorded by digital instruments.

Design of experiment

| Independent parameters | | |
|--|-------|---|
| Particular | Level | Details |
| Crop | 02 | Paddy, Wheat |
| Methods | 02 | Hand beating, Pedal Operated thresher |
| Subjects | 20 | S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14, S15, S16, S17, S18, S19, S20 |
| Dependent parameters | | |
| Machine Parameters: Yield, Shattering losses, Mechanical Damage, Field capacity. | | |
| Ergonomical Parameters: Heart rate, delta HR, blood pressure, energy expenditure rate (EER), oxygen consumption rate (OCR) | | |

2.1 Selection of operation

Agricultural practices in Bastar is lacking in view of improved farm tools and machinery. The tribals are still practicing traditional way of threshing like beating the crop on hard surface or treading with bullock. Such operations are

tedious, and time-consuming. Thus, introduction of pedal operated thresher thought to be introduced. But, there are possibilities of mismatch in the anthropometric dimension due to which machine may not fit ergonomically and may increase unnecessary burden and drudgery over the tribal population.

Therefore, the experiment has been conducted to assess the suitability of pedal operated thresher for the tribal population of Bastar plateau zone of CG. To conduct the experiment, pedal operated thresher (OUAT make) has been tested for its

safety and comfort at Bastar district of CG. The technical specifications of selected pedal operated thresher has been measured and given in Table 1.

Table 1: Salient Features of Pedal Thresher

| S. No. | Specifications | Dimensions(mm) |
|--------|--------------------------------|----------------|
| 1. | Overall dimensions (L × W × H) | 910×510×740 |
| 1. | Length of threshing drum | 450 |
| 2. | Diameter of threshing drum | 360 |
| 3. | Type of threshing drum | Wire loop type |
| 4. | Number of wire loop | 104 |
| 5. | Number of slats | 12 |
| 6. | Height of wire loop | 43 |
| 7. | Length of pedal | 480 |
| 8. | Gear ratio | 22:6 |
| 9. | Number of drum | 01 |
| 10. | Spacing of wire loops | 45 |
| 11. | Power source | 01 person |

2.2 Selection of subjects

The conduct the experiments, subjects (women) were selected from the age group of 20-45 years under self-farming category based on their origin. It was ensured that the selected subjects must be true representatives of their respective tribes. Total 20 farm women were selected randomly and their distributions among ethnic groups were based on the population in the village. Farm women were screened for normal health with general medical investigations like blood pressure and pulse rate, etc. It assured that nobody is handicapped, dwarf, giant, and musculoskeletal injury. The anthropometric dimensions of the subjects are given in the Table 2. All measured anthropometric dimensions were statistically analyzed for the value of maximum, minimum, mean, percentile value and coefficient of variance, etc.

2.3 Physiological parameters

Experiments were started at 07:30 hour and subjects were asked to report at field. Pre-checks for health conditions have been done and after satisfactorily report from medical personnel, women were allowed to perform threshing the operation. The environmental conditions like dry bulb and wet bulb temperature along with relative humidity were taken. Before starting the experiments, subjects were asked to take rest for 15 minutes, so that, resting heart rate could be measured. Experiments were performed for 30 minutes, and after that subjects are allowed to take rest until HR reduced to initial heart rate or near about. The experiments were replicated thrice and average working heart rate was calculated. Further, oxygen consumption rate (OCR) determined with the help of formula given by (Singh *et al.*, 2008)^[12].

■ Measuring of heart rate

To measure the heart rate of subjects, commercial heart rate monitor is used. The HR monitor is available with chest strap for taking heart rate of the selected subject. Monitor receives the signal from chest strap and indicates the heart rate in beats per minute (bpm). Further, Δ HR could be calculated;

$$\Delta\text{HR} = \text{HR}_{\text{work}} - \text{HR}_{\text{rest}} \text{ eq. (2.1)}$$

Where;

Δ HR = increase in Heart rate, bpm

HR_{work} = working Heart Rate, bpm

HR_{rest} = Resting Heart Rate, bpm

■ Determination of oxygen consumption rate

The oxygen consumption rate is the amount of oxygen inhaled by the women per unit time and computed from the heart rate of the subject. It represents an individual capacity to utilize oxygen. It states that a point is reached where increase at work rate is no longer accompanied by increase in oxygen uptake and the individual is assumed to have reached her maximum level of oxygen uptake and is given by the following equation (Singh *et al.*, 2008)^[12].

$$\text{OCR} = 0.0114 \times \text{HR} - 0.68 \text{ eq. (2.2)}$$

Where

OCR= oxygen consumption rate (l/min)

HR= heart rate (bpm)

■ Predication of energy expenditure rate

Energy expenditure is the amount of energy (or calories) that a person needs to carry out a physical activity such as breathing, blood circulation, food digestion, and body movement. The energy expenditure rate (EER) could be determined directly by multiplying the OCR with the calorific value of oxygen as 20.93 KJ/l (Nag *et al.*, 1980)^[8]. The energy expenditure (KJ/min) could also be estimated using formula proposed by Varghese *et al.* (1994)^[15] as follows;

$$\text{EER} = 0.159 \times \text{AHR} - 8.72 \text{ eq. (2.3)}$$

Where

EER = Energy Expenditure Rate (kJ/min)

AHR = Average Heart Rate (bpm)

3. Results and discussions

3.1 Anthropometric measurement of subjects

Anthropometric dimension of selected subjects have been measured with the help of standard instruments. The data has been recorded in pre-prepared templates designed by Gite *et al.*, 2003. The selected subjects were under the age group of 20-45 years. The average bodyweight found to be about 46.5 kg and mean stature found to be about 153.3 cm of selected subjects. Total 79 anthropometric dimensions has been measured and statistically analyzed. Some appropriate anthropometric dimensions which are relevant to pedal operated thresher has been presented in Table 2.

Table 2: Some selected anthropometric dimensions of tribal women (N= 20).

| S. No. | Parameters | Mean | Min | Max | 5 th | 95 th |
|--------|-------------------------|-------|------|------|-----------------|------------------|
| 1 | Weight, kg | 46.5 | 34 | 76 | 34.5 | 58.5 |
| 2 | Age, yr | 36.2 | 19 | 58 | 18.1 | 54.4 |
| 3 | Stature, cm | 153.3 | 140 | 187 | 139.0 | 165.5 |
| 4 | Elbow height, cm | 95.8 | 83 | 110 | 88.4 | 103.3 |
| 5 | Olecranon height, cm | 91.1 | 32.7 | 103 | 74.7 | 107.5 |
| 6 | Iliocrystale height, cm | 84.7 | 72 | 97.5 | 75.8 | 93.6 |
| 7 | Iliospinale height, cm | 79.0 | 60.1 | 96.6 | 68.4 | 89.6 |
| 8 | Knee height, cm | 43.1 | 31.5 | 50 | 36.8 | 49.5 |
| 9 | Arm reach from wall, cm | 73.6 | 39.5 | 85.7 | 61.3 | 85.8 |
| 10 | Foot length, cm | 22.6 | 20 | 27 | 20.5 | 24.7 |

3.2 Prediction of physiological parameters of subjects

▪ Calibration of subjects

Step test has been conducted for the calibration of subjects. All 20 subjects were tested for resting HR and Maximum HR. Maximum HR were calculated using thumb rule i.e. Max HR= 220 - age (yrs) / 2. To conduct the test, a stool of 16'' height has been used. Subjects were asked to step up and step down on stool continuously for 3 minute or until sub maximal loading (75% of max HR) reached.

The HR was measured and monitored continuously. Step test performed till 75% of max HR or maximum 3 minute duration. The test supposed to complete either at sub maximal loading (75% of max HR) or 3 minute duration. The resting heart rate of the selected subjects found to be ranged among 68-85 bpm with the average value of 78 bpm. The corresponding OCR value calculated to be 0.167 l/min. The mean value of maximum HR observed to be about 167 bpm of selected subjects which range between 165-174 bpm shown in Table 3. The mean value of blood pressure among the selected tribal women was observed 113 mm Hg / 86 mm Hg. The HR and blood pressure data of individual subjects suggest that health condition is normal. The body mass index has been calculated for each subject and ranged from 17.34-18.62 kg/m². The average value of BMI is found to be 19.86 kg/m². The BMI, HR and OCR value suggest that selected women have normal health condition as prescribed by WHO and suitable for agricultural operation.

3.3 Ergonomical assessment of subjects during paddy threshing

All subjects were asked to get involved in hand beating and pedal operated threshing one by one. Proper rest has been provided to each woman during shifting in operations. The

selected physiological parameter such as HR, OCR and energy expenditure rate of the selected subjects has been measured during threshing of paddy crop. The average resting HR of subjects found to be about 78 bpm which includes the HR of 77, 78, 78, 78, 82, 79, 75, 80, 82, 81, 75, 76 bpm of subjects S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11 and S12 respectively. Similarly, the working HR of subjects such as S1, S2..... S12 observed to be 134, 126, 133, 132, 130, 117, 132, 116, 116, 116, 129 and 128 bpm respectively. Graphs have been plotted against the duration (time) Fig.2. The average value of working heart rate of selected subjects found to be 126 bpm and 112 bpm during hand beating and pedal operated threshing operation respectively. Such workload has been rated under moderately heavy and heavy physiological workload (drudgery) suggested by Varghese *et al.*, 1994 [15]. With the use of HR data, the average value of working delta HR, working oxygen uptake and working EER are to be calculated about 47 bpm, 0.75 l/min and 11.27kJ/min during hand beating of paddy crop. The other calculated physiological parameters have been presented in Table 4.

Table 3: Physiological characteristics of subjects (N=20)

| Particulars | Range | Mean |
|-------------------------------------|---------------|--------|
| Age, years | 18-47 | 36.2 |
| Weight, kg | 34-65 | 46.5 |
| Stature, cm | 140-187 | 153.3 |
| HR _{rest} , bpm | 68-85 | 78 |
| HR _{max} , bpm | 165-174 | 167 |
| OCR _{rest} , l/min | 0.095-0.175 | 0.167 |
| OCR _{max} , l/min | 1.258-1.349 | 1.271 |
| Blood pressure (Sys/Dia), mmHg/mmHg | 100/72-122/86 | 113/86 |
| BMI, kg/m ² | 17.34-18.62 | 19.86 |

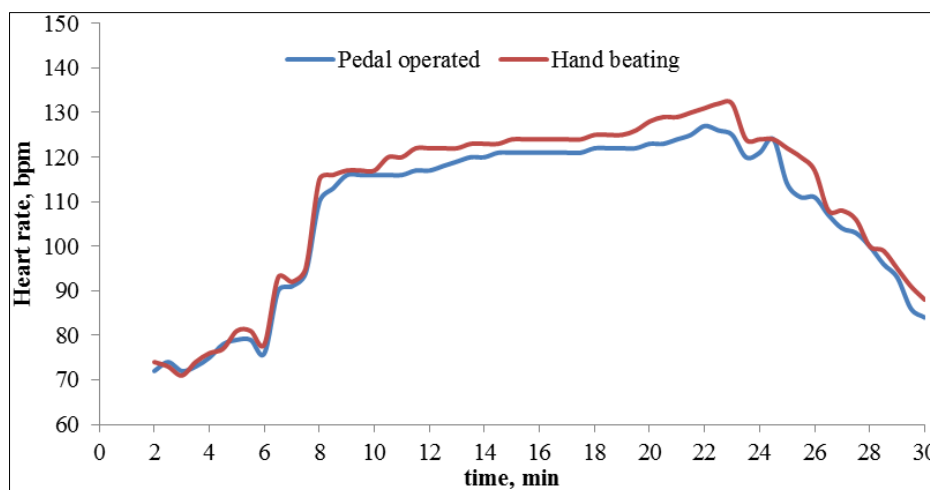


Fig 2: Calibration curve of a selected subject.

Table 4: Average value of physiological parameters during hand beating and pedal operated threshing of selected subjects with paddy crop.

| Parameters | Hand Beating | Rating | Pedal Thresher | Rating |
|---------------------|--------------|----------------|----------------|---------------------------|
| HR rest, bpm | 78 | Heavy workload | 78 | Moderately Heavy workload |
| HR working, bpm | 126 | | 112 | |
| Delta HR, bpm | 47 | | 34 | |
| OCR rest, l/min | 0.21 | | 0.21 | |
| OCR working, l/min | 0.75 | | 0.60 | |
| EER rest, kJ/min | 3.75 | | 3.75 | |
| EER working, kJ/min | 11.27 | | 9.09 | |

The OCR value during sub maximal loading found to be minimum 1.0 l/min and maximum 1.2 l/min among the subjects during hand beating operation of paddy crop respectively. It is estimated that OCR is varied about 20% among subjects during hand beating. Further, EER for hand beating is calculated to be about 11.27kJ/min and 9.09 KJ/min during pedal operated threshing. Hence, excess energy of about 2.18kJ/min is exhausted in case of hand beating. Similar reporting has also been reported by researchers like Khadatkar *et al.*, (2017) [4]. They observed there is a reduction in physiological responses of selected workers while using pedal operated thresher compared to manual operation. Furthermore, it was observed that the work rest cycle has also been improved by the use of pedal operated thresher. Earlier, it was observed there is a pause of about 7 minutes after 15 minutes of crop beating by hand or sticks. Addition to that, postural discomfort has also been reported due to seating posture for long duration. Whereas, pedal thresher is allows doing crop threshing in standing posture (Fig. 3) which improves work rest cycle. In this operation, women work for about 35 minute continuously without interruption. Ten minutes rest has been suggested to women due to standing posture. A little discomfort has been reported by the women during standing due to holding of crop. Such issue has been resolved by adjustment in height by keeping platform beneath the operator or so.

3.4 Ergonomical assessment of subjects during Wheat threshing

Table 5, shows the comparative performance of wheat threshed by hand beating and pedal operated thresher. It depicts that the average value of ΔHR found to be 49 bpm during hand beating, and about 36 bpm in case of pedal operated thresher. The working OCR is found to be 0.78 l/min for hand beating, and about 0.59 l/min for pedal thresher. It is determined that pedal operation reduces the oxygen demanded by 0.19 l/min compared with the hand beating. The EER in both the operations are found to be 11.43 KJ/min and 8.94 KJ/min respectively.



Fig 3: Tribal women during operation of pedal operated thresher with paddy

Table 5: Average value of physiological parameters of selected subjects during hand beating and pedal operated threshing of wheat crop.

| Sl. No | Parameters | Hand beating | Pedal thresher |
|--------|---------------------|--------------|----------------|
| 1. | HR rest, bpm | 78 | 73 |
| 2. | HR working, bpm | 127 | 111 |
| 3. | ΔHR, bpm | 49 | 36 |
| 4. | Resting OCR, l/min | 0.21 | 0.15 |
| 5. | Working OCR, l/min | 0.78 | 0.59 |
| 6. | EER resting, kJ/min | 3.67 | 2.91 |
| 7. | EER working, kJ/min | 11.43 | 8.94 |

The comparison of HR data suggests that wheat threshing involve more drudgery than the threshing of paddy. Further, the higher value of EER could be due to extreme weather condition at the time of wheat threshing in March and April. Also, anaerobic condition is not obtained as the energy cost of work have not exceeded 25 KJ/min suggested by Kathirvel (2005) [3]. Varghese *et al.*, (1994) [15] categorized such hand beating agricultural workload under ‘moderate heavy’ whereas pedal operated threshing of wheat comes under ‘heavy’ workload. The result reveals that the hand beating is more drudgery prone compared to pedal operated threshing in both crop. The statistical analysis suggests that both the operations were significantly different at 1% level of significance. It was observed that heart rate of subject were different in paddy threshing and wheat threshing. Shattering

losses has been recorded more in case of paddy crop while it was significantly less in wheat. Mechanical damage has been observed within 1%. There was significant increase in delta HR in paddy and wheat. Added to this, resting HR and working HR is found to be significantly different with both the crops. At 5% level of significance, pedal operated thresher found to be suitable for selected population with little adjustment in a machine.

3.5 Overall discomfort rating

The overall body part discomfort rating has also been taken with all selected subjects. About 65% of selected subjects reported for back pain after continuous operation. To reduce the same, work rest cycle has been enhanced. But, most of the subjects have opinion that machine height could be increased

little. It is due to the stature difference of tribal women of Bastar. In fact, selected pedal operated thresher is based on the anthropometric population of Odisha state. Due to this, there is a mismatch of body dimension which is responsible back pain and other discomfort. About 9% of the population is satisfied with performance of improved method. Similarly, 14 subjects have opinion that shattering losses are reduced compared to hand beating, and it could be further minimize by threshing the crop at proper moisture content.

3.6 Machine performance with the selected crops

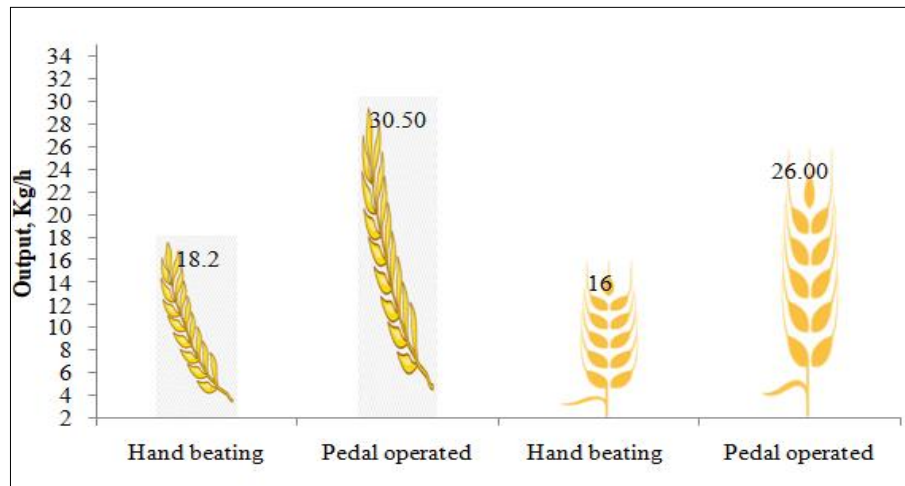


Fig 4: Output capacity during threshing of paddy and wheat crops.

4. Conclusion

The investigation on tribal women has been carried out which indicated that the physiological responses are reduced by preferring pedal operated thresher. The average HR of selected subjects significantly reduced from 126 bpm to 109 bpm. The delta HR has also observed to be reduced after shifting to pedal operated thresher for both the crops. The EER is reduced by 2.18 kJ/min during paddy crop whereas 2.84 kJ/min in wheat threshing. The study revealed that the pedal operated thresher is ergonomically fit with little adjustment for tribal women of Bastar. Therefore, pedal operated thresher must be introduced and recommended for tribal population of Bastar for a better comfort and safety with reduced drudgery. Redesign is required for the development of such population oriented machinery. But, meanwhile it is good option to perform threshing of crops in Bastar plateau zone of CG.

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