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Ergonomic Evaluation of Paddy Harvester and Thresher with Farm Women

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Abstract: ***In India, nearly 50-60 per cent of women work force is engaged in agriculture. Systematic efforts to evaluate the energy expenditure of female labourers are generally non-existent in this region. The physiological response of women labourers while performing the rice farming operations such as harvesting with sickle, harvesting with self propelled harvester, threshing by hand and threshing with mini thresher at different time intervals i.e., before 9 am and after 11 am in a day were investigated. Psychophysical measurement technique was used to quantify the overall discomfort as well as body part discomfort. Nine subjects conforming to the statistical requirements of anthropometric dimensions were selected for the study. The maximum energy cost was observed to be 20.58 kJ min^{-1} for harvesting with sickle, whereas for harvesting with self propelled harvester, this value was observed to be 17.93 kJ min^{-1}. Harvesting after 11 am resulted in 18% more energy expenditure than harvesting before 9 am. The energy cost was observed to be 15.53 kJ min^{-1} for threshing with Mini Thresher, whereas for manual threshing this value was 21.55 kJ min^{-1}. All the operations were generally graded as "Moderately Heavy". The oxygen uptake in terms of VO_2 max was above the acceptable work load for all selected operations. Mean overall discomfort rating on a 10 point visual analogue discomfort scale (0- no discomfort, 10- extreme discomfort) was 6.6 and scaled as "moderate discomfort" for harvesting with self propelled harvester whereas the rating was 8 and scaled as "more than moderate discomfort" for manual harvesting. Similarly, the rating was 6.3 and scaled as "moderate discomfort" for threshing with Mini Thresher while the rating was 8.5 and scaled as "more than moderate discomfort" for manual threshing. Arms and shoulder regions were concerned areas of discomfort for machine operation, whereas for manual operation, back, buttocks, thighs and legs were the concerned regions of discomfort.***

Keywords: physiological response; women labourers; energy cost, oxygen uptake in terms of VO_2 max; overall discomfort; body part discomfort

1. Introduction

Rice is the staple food of Keralites and its cultivation had been the main occupation for generations. At present the rice situation in Kerala is dismal. It is reported that the area under paddy has declined by 38% within the last decade. The drudgery involved in cultivating rice is too intense and it calls for a decent compensation. Studies have shown that the human body consumes 2 Kcal/min additionally if a man/woman takes a tedious bending posture like in transplanting and harvesting; his/her heart also beats 35% faster. And it is very common that such labourers suffer from a lot of ailments, as they grow old. If the young, more literate generation is reluctant to spare their flesh and blood for the farm, we cannot blame them. It is reported that human labour accounts for over 60% of rice production cost. Reduction in labour cost by adoption of cost effective locally adoptable farm mechanization is need of the hour.

The performance of any machine especially manually operated ones could be considerably improved if ergonomic aspects are given due consideration (Gite, 1993). Hence, there is an urgent need to study the ergonomic aspects in detail to quantify the drudgery involved in agricultural operations. Human energy measurements are important because whenever the physical capacity of a person is exceeded, it is bound to cause considerable fatigue and reduction in the efficiency of operation. Thus, investigations on ergonomic evaluation of farm equipment can provide a rational basis for recommendation of methods and improvement in equipment design for more output and safety.

Most of the operations in rice cultivation are being done by the female labourers such as sowing the seeds, transplanting, weeding, harvesting, threshing and winnowing. Here, we analyze the human energy expenditure and discomfort experienced by the female labourers during operation of a self propelled harvester and mini thresher to reduce the workload/drudgery of women labourers in rice farming operations and enhancing their opportunities for remunerative employment and income using women friendly equipments.

2. Materials and Methods

2.1 Subjects

Nine subjects were selected having anthropometric dimensions conforming to statistical requirements from the anthropometric data base of the study region. The physiological characteristics of selected subjects are given in Table 1.

Table 1: Physiological characteristics of subjects

Variable	Subjects								
	1	II	III	IV	V	VI	VII	VIII	IX
Age, years	40	49	42	41	49	46	40	35	48
Body weight, kg	60	60	70	62	55	65	75	60	51
Height, m	157	156	159	160	150	157	160	152	152
Resting heart rate, beats min^{-1}	74	72	73	67	68	66	74	72	69
Resting oxygen consumption, l min^{-1}	0.239	0.196	0.245	0.136	0.166	0.232	0.149	0.259	0.196

2.2 Activities

The subjects were required to do the rice farming operations namely, harvesting with sickle (activity 1), harvesting with self propelled harvester (activity 2), manual threshing by beating on the stone (activity 3) and threshing with mini thresher (activity 4). The trials were conducted two times a day, at different time intervals i.e., before 9 am and after 11 am in order to find out the changes in energy expended and heart rate due to environmental condition. The self propelled harvester is a front mounted unit and consists of a cutter bar, three numbers of gathering header assembly with star wheels, two numbers of conveyor belt with GI lugs on the periphery, a gear box and a pair of wheels. The unit can harvest both line and random planted crops. A randomized field layout design was considered. The field was dry and without any lodging of crop. The mini thresher consists of a threshing cylinder, driving mechanism and supporting frame. The grains are separated by the combing as well as by hammering action of the threshing teeth.

2.3 Establishing relationship between Oxygen uptake and Heart Rate

On a separate day and before performing activities, the relationship between heart rate and oxygen uptake for each subject was determined. This relationship is used to indirectly evaluate physiological workload. Both heart rate and oxygen uptake have to be measured simultaneously in the laboratory at a number of different submaximal workloads (Maritz et al., 1961). This process is known as calibrating the heart rate-VO_2 relationship for a subject. Since the relationship between the two variables is linear during a typical submaximal workload, a subject's heart rate measured in the field can be converted into an estimate of oxygen uptake by referring to the laboratory data. The selected nine subjects were calibrated in the laboratory by measuring oxygen consumption and heart rate simultaneously while pedalling a standard bicycle ergometer to arrive at the relationship between heart rate and oxygen consumption.

2.4 Data Collection

All the nine subjects were equally trained in the operation of the self propelled harvester and mini thresher before the actual experiment. After 30 minutes of resting, the subject was asked to operate the harvester (already started by another person and engine throttle position set at required engine speed and change lever in the required position) at the recommended speed of 2.5 km h^{-1} (Vidhu,2001). The heart rate was measured and recorded using computerized heart rate monitor for the entire work period. Each trial was carried out for 15 minutes of duration and same procedure was repeated to replicate the trials for all the selected subjects.

The physiological response of the subjects while harvesting with sickle and manual threshing by beating on the stone were also assessed to compare the energy expenditure in manual and mechanized operation.

2.5 Data Analysis

From the mean values of heart rate (HR) observed during the trials, the corresponding values of oxygen consumption rate (VO_2) of the subjects were predicted from the calibration curves of the subjects. The energy costs of the operations were computed by multiplying the value of oxygen consumption (mean of the values of nine subjects) by the calorific value of oxygen as 20.88 kJ lit^{-1} (Nag et al., 1980). The energy costs for all selected operations were graded as per the tentative classification of strains in different types of jobs given in ICMR report as shown in **Table 2**. (Sen, 1969 and Vidhu, 2001).

Table 2: Tentative classification of strains (ICMR) in different types of jobs

Grading	*Physiological response*		
	Heart rate beats min^{-1}	Oxygen uptake lit min^{-1}	Energy expenditure kcal min^{-1}
Very light	<75	< 0.35	<1.75
Light	75-100	0.35 - 0.70	1.75-3.5
Moderately heavy	100-125	0.70 - 1.05	3.5-5.25
Heavy	125-150	1.05 - 1.40	5.25-7.00
Very heavy	150-175	1.40- 1.75	7.00-8.75
Extremely heavy	>175	> 1.75	>8.75

The results were statistically analyzed using an analysis of variance technique (ANOVA) by following completely randomized design (CRD) to assess the effect of mode of operation and time of operation on energy cost for harvesting and threshing operations.

2.6 Assessment of Postural Discomfort

Assessment of postural discomfort included overall discomfort rating (ODR) and body part discomfort score (BPDS). After 30 minutes of resting, the subject was asked to do the operations for duration of two hours.

2.6.1 Overall discomfort rating (ODR)

For the assessment of ODR**,** a 10 - point psychophysical rating scale (0 – no discomfort, 10 - extreme discomfort) was used which is an adoption of Corlett and Bishop (1976) technique (**Fig.1**). The overall discomfort ratings given by each of the nine subjects were added and averaged to get the mean rating.

2.6.2 Body part discomfort score (BPDS)

To measure localized discomfort, Corlett and Bishop (1976) technique was used. In this technique the subject's body is divided into 27 regions as shown in **Fig.2**.

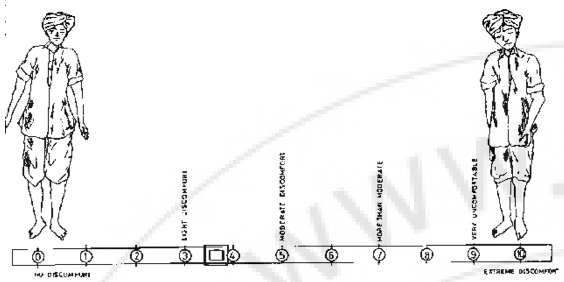

Figure 1: Visual analogue discomfort scale for assessment of overall body discomfort

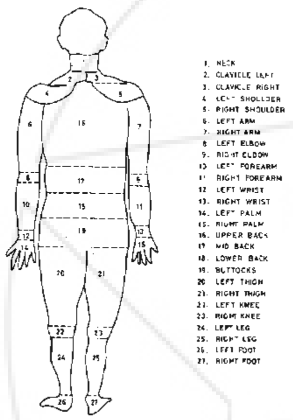

Figure 2: Regions for evaluating body part discomfort score

A body mapping similar to that of **Fig.2** was made to have a real and meaningful rating of the perceived exertion of the subject. The subject was asked to mention all body parts with discomfort, starting with the worst and the second worst and so on until all parts have been mentioned. The body part discomfort score of each subject was the rating multiplied by the number of body parts corresponding to each category. The total body part score for a subject was the sum of all individual scores of the body parts assigned by the subject.

3. Results and Discussion

3.1 Calibration process

By using the data on heart rate and oxygen consumption rate, calibration chart was prepared with heart rate as the abscissa and the oxygen uptake as the ordinate for the selected nine subjects (**Fig.3**). It is observed that the relationship between the heart rate and oxygen consumption of the subjects was found to be linear for all the subjects. This linear relationship defers from one individual to another due to physiological differences of individuals.

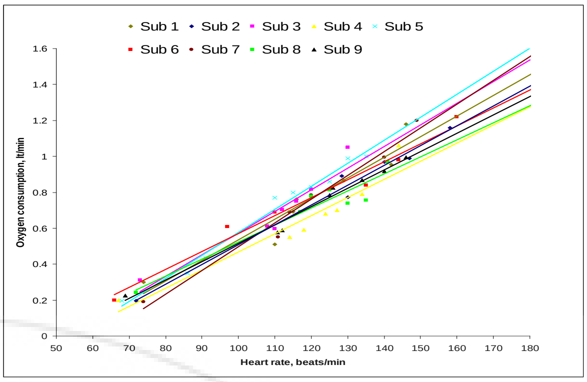

Figure 3: Relationship between oxygen uptake and heart rate

3.2 Energy cost in harvesting operation

The results showed that mode of operation and time of operation significantly influenced the energy cost as presented in **Table 3**.

It is noticed that the average energy expenditure was 17.93 kJ min^{-1} during operation of self propelled harvester while it was increased to 20.58 kJ min^{-1} during manual harvesting, the increase being 15%. Here the subjects harvesting the crops with sickle in bending posture.

Working in a bending posture increased the lordative curve of the spine, thus put more strain on the back muscles and result in increased energy expenditure. It is further noticed that the mean energy expenditure before 9 am was 17.64 kJ min^{-1} while after 11 am it was increased to 20.87 kJ min^{-1}. The variation may be attributed to the effect of environment on the subject since the heart rate integrates the total stress on the body and responds more quickly to changes in work demand and indicates more readily the quick changes in body function due to changes in work environment.

Table 3: Energy cost as influenced by mode of operation and time of operation during harvesting

Treatments	*Energy cost, (kJ min^{-1})*
Mode of operation	
Harvesting with self propelled harvester	17.93
Harvesting with sickle	20.58
F (32,1)	21.79**
CD (P=0.05)	1.16
Time of operation	
Before 9 am	17.64
After 11 am	20.87
F (32,1)	32.27**
CD (P=0.05)	1.16

** Significant at 1 % level of probability, F, variance ratio; CD, critical difference; P, probability

Based on the mean energy cost of nine subjects, the operation was graded as “moderately heavy”.

3.3 Energy cost in threshing operation

The results of the study show that there was significant difference in physiological cost between the mini thresher operation and manual threshing. Energy cost was recorded significantly higher in manual threshing than mini thresher operation. The maximum energy cost observed to be 21.55 kJ min^{-1} in manual threshing, whereas with the mini thresher this value was 15.53 kJ min^{-1} (**Table 4**). In manual threshing, the subjects were bending over work surfaces for targets which are too low. It may be suggested that pain rather than capacity may often be the limiting factor in such task situations. In mini thresher, the subjects can comfortably do the threshing in a standing posture. The energy expenditure after 11 am was increased by 23 % in compared to energy expenditure before 9 am. Threshing operations are graded as " moderately heavy " as per the classification of strains

3.4 Acceptable Workload (AWL)

Saha et al. (1979) reported that 35% of maximum oxygen uptake (also called maximum Aerobic capacity or VO_2 max)

Table 4: Energy cost as influenced by mode of operation and time of operation during threshing

Treatments	*Energy cost, (kJ min^{-1})*
Mode of operation	
Threshing with Mini Thresher	15.53
Manual Threshing	21.55
F (32,1)	95.52**
CD (P=0.05)	1.25
Time of operation	
Before 9 am	16.66
After 11 am	20.42
F (32,1)	37.23**
CD (P=0.05)	1.25

** Significant at 1 % level of probability, F, variance ratio; CD, critical difference; P, probability

can be taken as the acceptable work load (AWL) for Indian workers which is endorsed by Nag et al, 1980 and Nag and Chatterjee, 1981. To ascertain whether the operations selected for the trails were within the acceptable workload AWL) , the oxygen uptake in terms of VO_2 max (%) for each treatment was computed.

Each subject's maximum heart rate was estimated by the following relationship (Bridger, 1995).

Maximum heart rate (beats min^{-1}) $= 200 - 0.65 \times$ Age in years

The oxygen uptake corresponding to the computed maximum heart rate in the calibration chart gives the maximum aerobic capacity (VO_2 max) (**Fig.3**).

The maximum aerobic capacity of the selected nine subjects varied from 1.21 to 1.51 l min^{-1}**.** For harvesting with self propelled harvester, the oxygen uptake in terms of VO_2 max was 64.56 % while it was 74.12% for manual harvesting. Similarly oxygen uptake in terms of VO_2 max was 55.91% for threshing with mini thresher where as it was 77.58% for manual threshing. All the values were higher than that of the AWL limits of 35 % indicating that the above operations could not be operated continuously for 8 hours without frequent rest-pauses.

3.5 Overall Discomfort Rating (ODR)

The mean overall discomfort scores rated by nine subjects during harvesting and threshing operations are furnished in **Table 5**.

Table 5: Overall discomfort rating of subjects during selected operations

Sl.No.	*Selected operations*	*ODR (Mean Value)*	*Scale*
1	Harvesting with self propelled harvester	6.6	Moderate discomfort
2	Harvesting with sickle	8.0	More than moderate discomfort
3	Threshing with Mini Thresher	6.3	Moderate discomfort
4	Manual Threshing	8.5	More than moderate discomfort

The overall discomfort rating was 6.6 for harvesting with self propelled harvester and scaled as "moderate discomfort" where as it was 8.0 for harvesting with sickle and scaled as "more than moderate discomfort". Similarly ODR was 6.3 and scaled as "moderate discomfort" for threshing with mini thresher while it was 8.5 in threshing manually and scaled as "more than moderate discomfort", In general the ODR values were lower for machine operation than hand operation.

3.6 Body part discomfort score (BPDS)

The body discomfort score of selected operations are shown in **Table 6**.

Table 6: Body part discomfort score (BPDS) of the subjects for selected operations

Sl.No.	Selected operations	BPDS (Mean value)
1	Harvesting with self propelled harvester	30.90
2	Harvesting with sickle	31.95
3	Threshing with Mini Thresher	28.50
4	Manual Threshing	33.90

It is observed that the pattern of regional discomfort varied with different operating conditions. The majority of discomfort was experienced in the mid back, lower back, buttocks, left thigh, right thigh, left leg and right leg region for all the subjects during manual operation. However the majority of discomfort was experienced in left shoulder, right shoulder, left forearm and right forearm for all the subjects during machine operation.

Results showed that the intensity of pain experienced by the subjects was more in manual operation compared to machine operation. The BPDS value was maximum in harvesting with sickle, where as it was minimum in threshing with mini thresher.

4. Conclusion

There was significant difference in energy costs in machine and manual operation. The energy cost was 20.58 kJ min^{-1} for harvesting with sickle, whereas for harvesting with self propelled harvester, this value was observed to be 17.93 kJ min^{-1}. Harvesting after 11 am resulted in 18% more energy expenditure than harvesting before 9 am. The average energy expenditure energy cost was 15.53 kJ min^{-1} for threshing with Mini Thresher; while for manual threshing this value was 21.55 kJ min^{-1}. All the operations were generally graded as "Moderately Heavy". The oxygen uptake in terms of VO_2 max was above the acceptable work load for all selected operations. Mean overall discomfort rating on a 10 point visual analogue discomfort scale (0- no discomfort, 10- extreme discomfort) scaled as "moderate discomfort" for machine operations whereas it was scaled as "more than moderate discomfort" for manual operations . Arms and shoulder regions were concerned areas of discomfort for machine operation, whereas for manual operation, back, buttocks, thighs and legs were the concerned regions of discomfort. The intensity of pain experienced by the subjects was more in manual operation compared to machine operation. The BPDS value was maximum in harvesting with sickle, where as it was minimum in threshing with mini thresher.

References

[1] Bridger, R. S.1995. Introduction to Ergonomics, 3rd Edn., Mc Graw-HIll, Inc, New york
[2] Corlett, E.N. and R.P.Bishop.1976. A technique for assessing postural discomfort. Ergonomics, 19:175-182.
[3] Gite, L.P. 1993. Ergonomics in Indian Agriculture – A review, Paper presented in the International workshop on human and draught animal powered crop protection held at Harare, Jan. 19-22.
[4] Maritz,J. S., J. F.Morrison, J.Peters, N. B.Strydon, and C.H.Wyndham.1961. A practical method of estimating an individual's maximum oxygen uptake, Ergonomics, 4 (2):120-125.
[5] Nag, P.K., Sebastian, N.C. and M.G. Malvankar.1980. Occupational workload of Indian agricultural workers, Ergonomics, 23, 91–102.
[6] Nag, P. K. and S.K. Chatterjee.1981. Physiological reactions of female workers in Indian agricultural work, Human Factors, 23, 607–14.
[7] Saha, P. N., Datta, S. R., Banergee, P. K. and G. G. Narayanee. 1979. An acceptable work-load for Indian workers, Ergonomics, 22(9), 1059-1071.
[8] Sen, R.N. 1969.Tentative classification of strains in different types of jobs according to the physiological responses of young Indian workers in comfortable climates, ICMR report, Indian Council of Medical Research, New Delhi.
[9] Vidhu, K. P. 2001. An investigation on ergonomic evaluation of selected rice farming equipment, Unpublished M.E. (Ag.) Thesis, Department of Farm Machinery, Tamil Nadu Agricultural University, Coimbatore, India