

Circulo - respiratory efficiency of agricultural workers in Odisha

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ABSTRACT : The cardio respiratory performance of male and female subjects was studied in relation to manual types of agricultural work in Odisha. Operations like land preparation with spade, manual transplanting and seeding methods, weeding, harvesting with local sickle and reaper were evaluated. The working heart rate and oxygen consumption rate recorded 136.3 beats/min, 0.98 l min⁻¹ for male and 138.4, 0.92 l min⁻¹ in spading operation. Manual random transplanting required working heart rate of 118.6 beats/min and 114.7 beats/min for male and female workers and higher heart rate of 128.7 beats/min, 133.7 beats/min was recorded in 2 row and 4 row paddy transplanter operated by male workers, and it was 130.4 beats/min and 134.8 beats/min in 2 row and 4 row paddy transplanter for female workers. The 2 row and 4 row transplanter required 9.3 and 20.3 man day / ha for male and female workers, respectively. Weeding in squatting posture required less working heart rate and oxygen consumption rate of 98.3 beats/min, 0.45 l min⁻¹ for male and 100.2 beats/min, 0.4 l min⁻¹ for female workers. Four row pre germinated paddy seeder required the working heart rate, oxygen consumption rate and relative cost of work load of 126.4 beats/min, 0.80 l min⁻¹ and 41 per cent against 140.2 beats/min, 1.08 l min⁻¹ and 55.4 per cent in case of 8 row paddy seeder operated by male workers. The female workers could not operate the 6 and 8 row pre germinated paddy seeders due to higher pulling force in puddled field. Operation of locally available sickle in squatting posture required, 23.2 and 33.3 per cent lower energy expenditure rate against paddy reaper for both male and female workers. Pedal thresher was about 70 per cent more efficient than manual threshing. The working heart rate, oxygen consumption rate required in pedal thresher was 126.5 beats/min, 0.79 l min⁻¹ for male and 124.3 beats/min, 0.68 l min⁻¹ for female workers. The relative cost of workload of pedal thresher was 23.9 and 18.5 per cent lower than that of manual threshing by male and female workers. Proper training and modification of existing tools and equipments will reduce drudgery and fatigue of workers.

KEY WORDS : Working heart rate, Oxygen consumption rate, Relative cost of work load

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INTRODUCTION

In rice cultivation system, different cultural operations are mostly done by male and female workers. Human labourers contribute about 60 per cent of total cost of cultivation in paddy crop. Therefore, it is of prime need to evaluate the ergonomic aspects of quantum of drudgery involved in agricultural

activities in paddy cultivation. Ergonomical cost of work consists of the anthropometry, body size, health of the worker, basal metabolic rate, energy expenditure rate, oxygen consumption rate and type of working posture. Many ergonomical studies have been conducted on some selected implements but study on the complete set of operations in rice cultivation system with male and female agricultural workers need to be studied. The strength and efficiency of the female agricultural workers is 70 per cent of male workers (Astrand and Rodahl, 1986). Some implements and operations are best suited to female workers. Thus, studies on human energy measurements in agricultural operations of both male and female workers can provide a rational basis for recommending methods and implements for performing the agricultural operations most efficiently and safely (Gite and Singh, 1997). Therefore, ergonomical study was conducted for different

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operations in rice farming system by using various farm implements and machines with both male and female workers.

EXPERIMENTAL PROCEDURE

Selection of the subjects :

Twelve subjects from both the sex in the age group of 18 to 45 were selected for this study. The subjects selected were closely to the 5th, mean and 95th percentile value of stature taken from the anthropometric observations collected from all the agro-climatic zones of Odisha (Mohanty, 2004). They were calibrated in the laboratory to assess their physiological parameters. Before calibration, the subjects were screened on the basis of their normal health and physical fitness which was decided from their blood pressure and electro cardiograph (ECG) test. The heart rate and oxygen consumption rate of twelve short listed subjects were measured in the laboratory and the maximum aerobic power was measured with indirect calorimetric method on treadmill. At each walking speed, heart rate was measured with the help of a polar heart rate monitor. The corresponding oxygen consumption rates were also measured by Metamax II (Fig. A). For assessment of maximal oxygen uptake of the subjects, the heart rate of the subject during their exercise on a treadmill and the corresponding oxygen uptake were measured. Each trial was replicated thrice for every subject. Prior to the test, their resting heart rate, oxygen consumption rate and blood pressure were measured. As per the previous study by Astrand and Rodal (1977), five sub maximal loads (varying walking speed of 1.0, 1.5, 2.0, 2.25 and 2.5km/h on treadmill) and 5 per cent slope were applied by means of speed regulator in the treadmill. The experiment was conducted at natural environmental condition ($29.4 \pm 2.4^{\circ}\text{C}$ and $74 \pm 8.3\text{ R.H}$) in the ergonomics laboratory in CAET, Bhubaneswar, Odisha during the month of July to October, 2006. The subjects walked with each speed for 5 minutes. A rest period that is sufficient to bring the heart rate down to the resting level was allowed between the successive rides.



Fig. A : Measurement of VO_2 on treadmill

The subjects selected for this study were engaged to perform different farm operations in rice cultivation in OUAT farm during *Kharif* 2006. During this period the mean dry bulb temperature, relative humidity, air velocity were $29.3 \pm 3.1^{\circ}\text{C}$, 75.3 ± 8.5 per cent and 3.4 to 5.5 m/sec, respectively. The selected subjects had previous experience of using agricultural implements and machines as they are working in OUAT farm for many years. Everyday the experiment was conducted from 9.00 AM to 1.00 PM. The duration of each trial was kept 20 min continuously for recording of heart rate and oxygen consumption rate of subject. The heart rate, oxygen consumption rate during 6th to 20th min of work for each subject was measured as one's heart rate and oxygen consumption rate get stable after 3 to 5th minute of continuous operation (Vidhu, 2001 and Mohanty, 2004). The energy expenditure rate was computed by multiplying 28.86 kJ/ min with VO_2 for Indian workers (Nag and Dutta, 1980).

Cultural operations :

In rice cultivation system, the main operations include land preparation, sowing or broad casting, transplanting, weeding, spraying, harvesting, threshing and winnowing. For the present study, land preparation was done by both wooden plough and iron plough using local bullocks with only male workers as ploughman. Leveling was done by using local leveler made up of bamboo. Hand tools such as trench hoe and spade were used for further leveling the field. For effective work, the spading rate of 18 to 21 scoops / min, throw distance of 1.0 m and throw height of 0.8 to 1.0 m were adopted for both male and female agricultural workers (Pradhan *et al.*, 1980). For sowing in puddled field, 4 row, 6 row and 8 row pre-germinated seeders were used and these were drawn by both male and female workers. Transplanting was done by using 2-row and 4-row manually operated rice transplanter and the physiological responses of workers with that of traditional manual transplanting were compared. Hand weeding was done in squatting or bending posture in traditional transplanted rice field where as push pull type low land weeders were used for weeding in mechanically transplanted rice field. Fertilizer broadcasting was done manually where as spraying was done by using knapsack sprayer with safety kits and without safety kits. Harvesting was done by using local sickles as well as by power reaper. Transporting of harvested crop to threshing yard was done manually on overhead and by using yoke. Threshing was performed conventionally by beating over stone as well as by using pedal thresher and power thresher. Winnowing was done by using Kulah and also by using hand operated winnower.

Classification of work load :

During physical activities the heart rate and oxygen consumption rate increase and the maximum values of these in

normal healthy individuals are about 190 beats/min and 2.0 lit/min (*i.e.* up to $VO_{2\max}$), respectively. However, at this extreme workload a person can work only for few seconds. The acceptable work load (AWL) represents that level of physical activity which can be sustained by an individual in an 8 hours of working period in a physiologically steady state that does not cause fatigue or discomfort. It is generally expressed in terms of percentage of maximum aerobic power ($VO_{2\max}$) (Muller, 1953). AWL was recommended to be 33 per cent of $VO_{2\max}$ (Lehmann, 1962 and Blink, 1962). Based on investigations on a large number of industrial workers, a ratio of 3:1 between $VO_{2\max}$ and the acceptable average oxygen uptake (VO_2) over 8.5 hours was suggested (Bonjar, 1968). Saha (1979) has suggested the acceptable work load (AWL) as 35 per cent of $VO_{2\max}$ for Indian workers.

EXPERIMENTAL FINDINGS AND ANALYSIS

The experimental findings of the present study have been presented in the following sub heads:

Physical characteristics and health status of farm workers :

The mean height, weight and body surface area (BSA) of selected subjects were found to be 164.8 cm, 57.4 kg and 1.69

m^2 for male and 152.0 cm, 51.7 kg and 1.52 m^2 for female workers, respectively. The $VO_{2\max}$ of male workers was found to be in the range of 1.8 to 2.12 l/min while that of 1.56 to 1.81 l/min for female workers (Table 1). Earlier studies reported similar results for the $VO_{2\max}$ of Indian male and female subjects (Nag, 1981; Nag *et al.*, 1988; Gite, 1996; Singh *et al.*, 2001; Bimala *et al.*, 2001, Vidhu, 2001; Mohanty, 2004).

Thirty five types of different agricultural operations starting from land preparation to harvesting and transportation of harvested material are mostly done in paddy cultivation system in Odisha has been evaluated. Although most of the operations are done by male and female workers, some operations like use of bullock drawn implements, spraying with knapsack sprayers, broadcasting of seeds and fertilizer, tractor and power tiller operations are not generally done by female workers. However, after proper training during the study period, female workers could be able to operate self propelled rice transplanter, power thresher and winnower. Some of these activities have been presented in Table 2.

Circulo-respiratory efficiency of agricultural workers :

Hand tools such as trench hoe and spade are used for leveling the field. The average working heart rate, oxygen consumption rate and the energy expenditure rate were found

Table 1: Physical characteristic of the selected subjects

Physical characteristics	Male (6 Nos)			Female (6 Nos)		
	Mean	\pm S.D.	Range	Mean	\pm S.D.	Range
Age, yrs	31.3	8.46	19 – 45	31.1	8.06	18 – 44
Weight, kg	57.4	10.57	42 – 73	51.7	4.91	53 – 59
Height, cm	164.8	9.62	152.9 – 178.2	152.0	7.61	142.1 – 162.2
BSA, m^2	1.69	0.20	1.45 – 1.96	1.52	0.12	1.38 – 1.69
HR _{rest} , bpm	73.5	3.89	69 – 79	70.3	3.2	65 – 76
OCR _{rest} , l/min	0.22	0.03	0.16 – 0.26	0.19	0.02	0.16 – 0.23
$VO_{2\max}$, l/min	1.95	0.09	1.825 – 2.12	1.70	0.08	1.56 – 1.81
BMI, kg/m^2	21.7	1.66	17.87 – 23.03	22.32	0.82	20.5 – 23.3

Table 2: Physiological parameters of selected subjects during paddy cultivation

Sr. No.	Operation	Male			Female		
		WHR beats/min	OCR l/min	EER kJ /min	WHR beats/min	OCR l/min	EER kJ /min
1.	Spade	136.3	0.98	20.5	138.4	0.92	19.3
2.	Manual transplanting	118.6	0.76	15.9	114.7	0.65	13.6
3.	2-row transplanter	128.7	0.92	19.3	130.4	0.82	17.2
4.	4-row transplanter	133.7	1.13	23.7	134.8	1.19	24.9
5.	4-row paddy seeder	126.4	0.80	19.9	130.2	1.02	21.4
5.	8-row paddy seeder	140.2	1.08	25.5	-	-	-
6.	Manual weeding	98.3	0.45	11.7	100.2	0.41	12.1
7.	Local sickle	110.5	0.68	14.2	100.2	0.62	13.0
8.	Pedal thresher	126.5	0.89	18.6	124.3	0.76	15.9
9.	Reaper	126.4	0.91	19.1	120.3	0.86	18.0

to be 123.3 beats/min, 0.82 l/min and 17.2 kJ/min for male and 124.3 beats/min, 0.78 l/min and 16.3 kJ/min for female agricultural workers operating with trench hoe (2.5 kg, handle height 65 to 70 cm). While working with spade (3.5 kg) with handle length of 70 to 75 cm, a higher working heart rate, oxygen consumption rate and energy expenditure rate of 136.6 beats/min, 1.101 l/min and 23.0 kJ/min for male and 138.4 beats/min, 1.121 l/min and 23.5 kJ/min for female workers, respectively were observed and this may be due to the higher weight of spade. The relative cost of work load was noticed to be 42.1 and 45.9 per cent for male and female workers operating with trench hoe while that of 56.4 and 65.9 per cent during operation with spade for leveling in the puddled field. The relative cost of work load of the workers operating the spade was found to be above the recommended acceptable work load limit of 35 per cent of their $VO_{2\max}$. However, at this work load, a person can work only for few minutes (Saha *et al.*, 1979).

Broadcasting of paddy by male workers required lower working heart rate, oxygen consumption rate and energy expenditure rate of 114.4 beats/min, 0.65 l/min and 13.6 kJ/min, respectively. In case of conventional manual transplanting, the working heart rate, oxygen consumption rate and energy expenditure rate were recorded to be 118.6 beats/min, 0.76 l/min and 15.9 kJ/min for male and a lower value of 114.7 beats/min, 0.65 l/min and 13.6 kJ/min for female workers. Higher working heart rate in manual transplanting operation may be due to working in bending posture. Similar results were observed by Nag *et al.* (1980). Although manually operated rice transplanter and seeders have higher field capacity, these machines required a higher working heart rate, oxygen consumption rate, energy expenditure rate due to the fact that the workers had to walk in puddled field and simultaneously drag the transplanter at a dragging force of 80.8 N for 2 row and 111.6 N for four row rice transplanter. It was also observed that manual transportation of seedlings required a working heart rate of 115.3 beats/min for male and 112.7 beats/min for female workers.

During operation of six row pre-germinated paddy seeder, the male workers required higher working heart rate (132.2

beats/min), oxygen consumption rate (1.03 l/min), energy expenditure rate (21.6 kJ/min) and relative cost of work load (52.8%) as against a lower working heart rate (128.8 beats/min), oxygen consumption rate (0.95 l/min), energy expenditure rate (19.9 kJ/min) and relative cost of work load (48.7%) for four row pre germinated paddy seeder. This may be due to the reason that more effort is required to operate the six row seeder against four row paddy seeder because of its more contact area. Similarly, oxygen consumption rate and working heart rate were observed by Nag and Dutt (1980) during test of pre-germinated paddy seeders. It was also observed that operation of 8-row paddy seeder required 28.1 per cent more energy expenditure rate over four row and 18.5 per cent over six row paddy seeder and that is why female workers could not operate the eight row paddy seeder.

Women typically comprised a large portion of the work force engaged in weeding. In case of upland rice, the women workers squatted on the ground with one or two legs flexed at the knee and removed the weeds by pulling out with their hands and sometimes using a worn out sickle which required energy expenditure rate of 12.1 kJ/min against that of 11.7 kJ/min for male workers.

Local sickles are mostly used by the farmers for harvesting of paddy crop in Odisha. While harvesting with sickles, the working heart rate was observed to be 110.5 and 100.2 beats/min where as the energy expenditure rate was found to be 14.2 and 13.0 kJ/min for male and female agricultural workers, respectively. Studies conducted by Nag *et al.* (1980) for harvesting with sickle observed similar results. During harvesting with self propelled reapers higher working heart rate, oxygen consumption rate, energy expenditure rate and relative cost of work load 126.4 beats/min, 0.91 l/min, 19.1 kJ/min and 46.7 per cent for male and 120.3 beats/min, 0.86 l/min, 18.6 kJ/min and 50.6 per cent for female workers were observed. This may be due to the reason that operator had to walk behind the reaper at higher speed and he had to apply force for turning and changing gears.

Higher working heart rate and oxygen consumption rate of 142.3 beats/min and 1.28 l/min for male and comparatively a

Table 3: Work rest scheduling of selected subjects during paddy cultivation

Sr. No.	Operation	Maximum working time, min	Resting time required, min	Work:rest, %
1.	Spade	28	12	25.0
2.	Manual transplanting	56	11	16.4
3.	2-row transplanter	23	13	36.1
4.	4-row transplanter	21	13	29.6
5.	4-row paddy seeder	28	12	30.0
6.	8-row paddy seeder	22	14	38.8
7.	Manual weeding	75	10	11.8
8.	Local sickle	60	9	13.1
9.	Pedal thresher	31	10	24.4

lower value of 132.5 beats/min and 1.19 l/min for female were observed during conventional threshing *i.e.* beating of paddy bundles on stone or wooden surface. The relative costs of workload of the workers were found to be 65.6 per cent and 70.0 per cent for male and female workers during conventional threshing operation. Frequent rest was required in this method after every 10-12 minutes of continuous operation. It was observed that workers had to beat the paddy bundles for 82500 times to harvest the crop of one hectare. While operating with pedal thresher the energy expenditure rate was found to be 16.5 kJ/min for male and 13.5 kJ/min for female workers. The relative cost of workload for male and female workers observed to be 45.6 per cent and 44.7 per cent during operation of a pedal thresher which is slightly more than the recommended acceptable work load of 35 per cent of $VO_{2\max}$.

Conclusion :

Design improvement in the existing tools, equipment and methods of work has significant effects in minimizing human strain, fatigue and increasing farm productivity. Extensive ergonomic research on farm operations and practices may generate a great deal of knowledge for the betterment of health, safety and productivity of billions of agricultural workers. In the present study the maximum oxygen consumption rate was recorded in pre-germinated paddy seeder (6- row), followed by operation in tenda, rice threshing on stone surface, for both male and female agricultural workers. Relative cost of work load was observed to be higher in weeding, transplanting, sowing seeds with seeders and threshing operations for both male and female workers. Suitable work rest cycle may be followed to reduce the fatigue and drudgery involved in rice cultivation system in this region.

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