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Estimation of Physiological Cost of Female Agricultural Workers for Weeding Operation

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A B S T R A C T

Agriculture is the primary source of employment for women in most of the developing countries. In India 27 crore of women are engaged in agriculture in rural sector. The present study was conducted in UAS campus Raichur on a sample of 10 agricultural workers for estimation of physiological cost selected subject for three types of weeders. Anthropometric kit was used for measuring body dimensions and strength parameter, physiological cost estimation done by measuring heart rate, oxygen consumption rate and energy expenditure rate. The mean stature and weight of female subjects ranged 150.85 cm and 52.6 kg respectively. The mean work pulse (ΔHR) of all subject for khurpi, CIAE wheel hoe and CAE weeder were 39.59 beats/min, 32.04 beats/min and 23.45 beats/min, respectively. Mean working Oxygen consumption rate for khurpi, CIAE wheel hoe and CAE weeder were 0.664 l/min, 0.586 l/min and 0.525 l/min respectively. The energy expenditure rate was highest for khurpi (13.86 kJ/min) followed by CIAE wheel hoe (11.34 kJ/min) and CAE weeder (10.95 kJ/min). The HR, OCR and EER during weeding were more for khurpi and CIAE wheel hoe followed by CAE weeder. CAE weeder is ergonomical designed it reduces the fatigue and increases the efficiency.

Introduction

Female agricultural workers in India play dominant role in increasing production and productivity. About seventy per cent of the Indian women are engaged in agricultural work either in their own fields or as hired laborers. If eight hours of work is considered as one man-day, the Indian rural women work more than two man-day everyday both in home and farm together. Still women are considered as secondary workers in the economic scenario. The farm women perform almost each and every agricultural activity right from land preparation and sowing to the harvesting and storage of the agricultural produce.

Hand tools and manually operated equipments are extensively used for digging, weeding and harvesting operations in agriculture. Weeding is one of the most important farm operations in crop production system. The most commonly used hand tools and equipments by

the farmers for manual operations are spade, weeder, thresher, sprayer, plough, sickle, paddy puller, straw puller, hoe, hand power tiller *etc*., Manual weeding requires a huge labour force and accounts for about 25 per cent of the total labour requirement (Nag and Datt, 1979). So manually operated weeders are remained first priority of the researchers.

Weeding is one of the maximum drudgery involved activity performed for highest number of days in a year. These women do the back breaking agricultural activities without any protections from sun, soil or shower with the traditional tools. To increase the productivity of the women's work there is a greater need for the ergonomic analysis of the activities performed by women and to study the circulatory stress and the physiological cost of each agricultural activity (Hasalkar, 2004).

Ergonomical evaluation is necessary to assess the energy expenditure of agricultural workers their physiological cost and body discomfort suitable for female workers. How long they can work continuously without getting fatigue. Ergonomical evaluation along with mechanical evaluation helps us to make comparison between traditional method and improved methods. The method which gives better field capacity, less power consumption, low energy expenditure rate and more safety will be recommended for the agricultural operation.

When a person does any physical work, she uses her muscle power (energy) and skeletal tissues. During the muscular activity her physiological responses *i.e.,* energy expenditure rate, oxygen consumption rate and heart rate increases. This increase in physiological responses is related to the type, intensity and duration of work and thus sets limits to the performance of heavy work. In the present study oxygen consumption rate and heart rate was used for physiological cost estimation.

Materials and Methods

The study was carried out on farm women workers in age group 25-45 years were randomly chosen. Thirty body dimensions including strength parameters involved in manual weeding operations of 10 female (S_1 to S_{10}) of UAS Campus Raichur were measured by using anthropometric kit and mean values of body dimensions and strength parameters of the subjects were calculated. They were screened for normal health with medical investigations. These subjects were used in the field trials for manual weeding each subject was replicated three times. Physiological cost estimation of the selected subjects were carried out to evaluate the performance of the three types of manual weeder *viz.,* Khurpi (Traditional), Wheel hand hoe (CIAE model), Standing khurpi (CAE model) (Table 1).

Physiological cost of the selected subjects during weeding operation

Field experiments were carried out to assess heart rate and oxygen consumption rate response during weeding operation with three types of weeders. The operation was performed in linseed crop (variety VT NL 115) having a row to row spacing of 30 cm.

Heart rate (HR), measured by polar heart rate monitor. The polar coded transmitter which measures the heart's electrical activity was fitted around the subject's chest with an elastic strap. A receiver worn as a wrist watch recorded the heart rate responses at the field testing sessions. Before fixing heart rate monitor to subject, setting should be made that age, sex, weight should be added in a watch. Before the start of the operation the subject was asked to take rest for 10 minutes

and her resting heart rate was recorded. One of the subjects was asked to operate khrupi observations were taken for 15 minutes working and 10 minutes resting shown in Plate 1. Heart rate was recorded for each 4 second interval and 15 readings were averaged to get the mean heart rate. This gave the mean steady state HR. This procedure is repeated for CIAE wheel hoe to find heart rate shown in Plate 2, for CAE weeder the heart rate evaluated shown in Plate 3.

After recording heart rate, the oxygen consumption rate (OCR) was calculated by Astrand and Rhyming nomogram graph, for each heart rate readings oxygen consumption rate is calculated 15 reading were recorded and averaged to get mean oxygen consumption rate. Analysis will be made by the nomogram having scale of body weight which is based on the assumption that every person having the same weight, when carrying out a similar stepping exercise, will have identical mechanical efficiency. This allows reading horizontally from the body weight scale to the oxygen uptake scale and with this assumed VO2 value, to proceed as explained before this gives the mean steady state OCR.

The energy expenditure rate (EER) was estimated by multiplying the working OCR with the calorific value of oxygen taken as 20.88 kJ/l (Nag and Dutt, 1980). The increase in HR for an area covered (ΔHR) by the subject was calculated. Steps were repeated for next 9 female subjects and repeated with 3 implements *viz.*, khurpi, wheel hand hoe (CIAE wheel hoe) and Standing khurpi (CAE wheel).

Results and Discussion

Thirty body dimensions including strength parameters involved in manual weeding operations of 10 female (S_1 to S_{10}) of UAS Campus Raichur were measured. The consolidated data on selected body dimensions and strength parameters are presented in Table 2.

Experiments were carried out to assess the physiological cost of the subjects in terms of heart rate (HR), oxygen consumption rate (OCR) and energy expenditure rate (EER). The stature and weight of female subjects ranged from 138 cm to 161.00 cm (mean = 150.85 cm) and 44 kg to 66 kg (mean = 52.6 kg) respectively. The mean maximum atmospheric temperature, relative humidity and wind velocity varied between 24˚C to 27.5˚C, 35 to 50 per cent and 1.6 to 3.2 km/h respectively during the experiments.

The mean rest heart rate of subject during weeding operation ranged from 68.8 to 80 (beats/min), 71.3 to 75.4 (beats/min) and 67.6 to 79.3 (beats/min) for khurpi, CIAE wheel hoe and CAE weeder respectively. The mean rate of ten subject before operation of khurpi, CIAE wheel hoe and CAE weeder were 76.54 beats/min 74.14 (beats/min) and 74.19 beats/min respectively. Heart rate measured for ten female subjects while operating three types of weeder in field. The mean working heart rate of the subject during weeding operation ranged from 110.7 to 125.7 beats/min, 100.6 to 112.1 beats/min and 94.9 to 100.2 beats/min for khurpi, CIAE wheel hoe and CAE weeder respectively. The mean working heart rate for khurpi, CIAE wheel hoe and CAE weeder were 97.63 beats/min, 116.13 beats/min and 106.18 beats/min respectively were presented in Table 3. The work heart rate of CAE weeder was less than khurpi and CIAE wheel hoe.

Mean work pulse (ΔHR) for all subjects ranged from 32.3 to 47.8 beats/min, 25.8 to 38.6 beats/min and 16 to 32.6 beats/min for weeding with khurpi, CIAE wheel hoe and CAE weeder respectively. The mean work

pulse (ΔHR) of all subject for khurpi, CIAE wheel hoe and CAE weeder were 39.59 beats/min, 32.04 beats/min and 23.45 beats/min respectively. The increasing in heart rate during weeding was more for khurpi and CIAE wheel hoe followed by CAE weeder presented in Figure 1. The mean rest oxygen consumption rate of subject during weeding operation ranged from 0.139 to 0.167 l/min, 0.136 to 0.165 l/min and 0.141 to 0.163 l/min for khurpi, CIAE wheel hoe and CAE weeder respectively. The mean rest oxygen consumption rate of ten subjects before operation of khurpi, CIAE wheel hoe and CAE weeder were 0.151 l/min, 0.153 l/min and 0.152 l/min respectively. The mean working oxygen consumption rate of the subject during weeding operation ranged from, 0.618 to 0.723 l/min, 0.509 to 0.620 l/min and 0.497 to 0.553 l/min for khurpi, CIAE wheel hoe and CAE weeder respectively.

In Table 4 shows the mean working Oxygen consumption rate for khurpi, CIAE wheel hoe and CAE weeder were 0.664 l/min, 0.586 l/min and 0.525 l/min respectively. The work Oxygen consumption rate of CAE weeder was less than khurpi and CIAE wheel hoe. CIAE weeder and CAE weeder was lesser compared to other method. This may be due to application of more continuous push and pull force as compared to other methods.

Mean (ΔOCR) for all subjects ranged from, 0.469 to 0.568 l/min, 0.367 to 0.48 l/min and 0.356 to 0.392 l/min for weeding with khurpi, CIAE wheel hoe and CAE weeder respectively. The mean (ΔOCR) of all subject for khurpi, CIAE wheel hoe and CAE weeder were 0.512 l/min, 0.433 l/min and 0.373 l/min respectively. The increasing in Oxygen consumption rate during weeding was more for khurpi wheel hoe followed by CIAE wheel hoe and CAE weeder presented in Figure 2.

Mean Energy expenditure rate in weeding operation ranged from 12.90 to 15.10 kJ/min, 10.76 to 11.98 kJ/min and 10.38 to 11.55 kJ/min for weeding with khurpi, CIAE wheel hoe and CAE weeder respectively. The mean energy expenditure rate for all subjects is presented in Table 5. The energy expenditure rate was highest for khurpi (13.86 kJ/min) followed by CIAE wheel hoe (11.34 kJ/min) and CAE weeder (10.95 kJ/min) presented in Figure 3. The energy expenditure rate for weeding CIAE wheel hoe and CAE weeder was almost same which implies that work load for both the wheel hoes is nearly same.

Table.1 Specifications of selected weeders for experiments

Specification	Khurpi	Standing khurpi (CAE model)	Wheel hand hoe (CIAE model)
Height of handle from the ground level	18.5 cm	84 cm	169 cm
Handle width	-	42 cm	41 cm
Width of cut	11.5 cm	18 cm	20 cm
Diameter of hand grip	3 cm	2.5 cm	2.5 cm
Diameter of ground wheel	-	15.5 cm	20 cm
Type of blade	-	flat type	V type

Table.2 Anthropometric and strength measurements of 10 randomly selected female agricultural workers of age group of 25-45 years

Body Dimensions	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	Mean
A. Measurements in standing posture											
Weight (Kg)	58	60	50	44	57	47	45	66	54	45	**52.6**
Stature	161	138	152	157	148	151.5	142	151	149	159	**150.85**
Eye height	147	127	136	142	140	142	132	141	133	144	**138.4**
Shoulder height	137	116	126	131	122	129	119	125	122	132	**125.9**
Elbow height	102	87	96	97	90	97	86	91	91	98	**93.5**
Olecranon height	103	90	94	91	93	96	87	95	92	96	**93.7**
Waist height	105	86	93	94	95	98	90	93	90	100	**94.4**
Knee height	48	43	44	42	44	40	43	43	37	47	**43.1**
Arm reach from the wall	85	80	68	94	84	86	79	79	75	93	**82.3**
Forearm hand length	43.5	39	40	38	41	43	39	41	38	44	**40.65**
Span	163.5	144	153	148	153	156	149	151	137	161	**151.55**
Span akimbo	83	77	74	76	76	78	76	79	74	78	**77.1**
Thumb tip reach	68	61	62	65	61	67.5	68	71	62	75	**66.05**
Shoulder grip length	66	55	69	52	61	63	63	61	55	68	**61.3**
B. Measurements in sitting posture											
Sitting height	77	70	76	73	73	72	82	84	75	89	**77.1**
Eye height	68	60	64	66	66	64	68	70	69	69	**66.4**
Popliteal height	41	41	39	42	37	47	45	42	39	44	**41.7**
Elbow rest height	21	21	19	20	21	22	18	23	20	23	**20.8**
C. Miscellaneous measurements											
Hand length	17.5	17	16	17	16	17.5	16.5	17	16	17	**16.75**
Hand breadth	8	9	10	9	9	9	9	9	8.5	9	**8.95**
Palm length	10	10	8.5	9	9.5	10	9.5	10	9	10	**9.55**
Grip diameter (inside)	4.35	4.054	3.33	3.484	3.55	3.696	3.715	3.269	3.28	3.806	**3.33**
Grip span	8.5	10.5	13	11	9	11	8.5	13	12	10	**10.65**
Maximum grip length	12	10.3	12.5	13.4	14.5	14	14	13	12.5	13	**12.92**
D. Strength Measurements											

Hand grip strength (right) (N)	170.69	183.45	215.82	157.94	110.85	136.36	130.47	133.42	80.44	130.47	**144.99**
Hand grip strength (left)(N)	206.01	147.98	166.77	127.53	119.68	128.51	143.23	180.50	74.56	89.27	**138.42**
Push strength with both hands in standing posture (N)	348.26	241.33	313.92	225.63	185.41	180.50	271.74	271.74	157.94	137.34	**233.38**
Pull strength with both hands in standing posture (N)	315.88	193.26	255.06	206.01	185.41	70.63	258.00	258.00	114.78	185.41	**204.24**
Right hand pull strength in sitting posture (N)	187.37	120.66	138.32	138.32	157.94	98.1	138.32	184.43	93.20	140.28	**139.69**
Left hand pull strength in sitting posture (N)	**189.33**	**100.06**	**129.49**	**126.55**	**147.15**	**78.48**	**136.36**	**171.68**	**81.42**	**151.07**	**131.16**

All dimensions are in cm, unless specified.

Table.3 Mean HR and ΔHR response during manual weeding

Methods of weeding	Khurpi		CIAE wheel hoe		CAE weeder	
Subjects	**HR (beats/min)**	**Δ HR (beats/min)**	**HR (beats/min)**	**ΔHR (beats/min)**	**HR (beats/min)**	**ΔHR (beats/min)**
S_1	111.8	38.4	101.0	27.3	99.5	25.1
S_2	111.6	32.8	111.7	38.4	100.2	32.6
S_3	110.7	32.3	107.9	33.1	98.5	25.1
S_4	113.6	35	109.9	38.6	97.3	19.6
S_5	114.6	37.8	112.1	36.7	98.8	25.1
S_6	124.1	44.1	100.6	25.8	96.6	24
S_7	112.2	43.4	107.0	32.2	98.5	27.1
S_8	125.7	47.8	105.2	29.9	96.7	20.3
S_9	121.5	42.1	104.4	29.7	95.3	16
S_{10}	115.5	42.2	102.0	28.7	94.9	19.63
Mean	**116.13**	**39.59**	**106.18**	**32.04**	**97.63**	**23.45**

Table.4 Mean working oxygen consumption rate during manual weeding

Methods of weeding	Khurpi		CIAE Wheel hoe		CAE weeder	
Subjects	**OCR (l/min)**	**ΔOCR (l/min**	**OCR (l/min)**	**Δ OCR (l/min)**	**OCR (l/min)**	**Δ OCR (l/min)**
S_1	0.619	0.469	0.563	0.404	0.515	0.374
S_2	0.666	0.513	0.576	0.423	0.530	0.374
S_3	0.618	0.479	0.612	0.48	0.513	0.366
S_4	0.682	0.536	0.620	0.475	0.535	0.377
S_5	0.670	0.517	0.578	0.416	0.513	0.367
S_6	0.719	0.558	0.611	0.45	0.550	0.387
S_7	0.653	0.486	0.589	0.435	0.519	0.368
S_8	0.723	0.568	0.602	0.444	0.553	0.392
S_9	0.655	0.508	0.604	0.438	0.520	0.366
S_{10}	0.631	0.488	0.509	0.367	0.497	0.356
Mean	**0.664**	**0.512**	**0.586**	**0.433**	**0.525**	**0.373**

Table.5 Mean energy expenditure rate during manual weeding

Methods of weeding	Khurpi	CIAE model Wheel hoe	CAE Model
Subjects	**EER(kJ/min)**	**EER(kJ/min)**	**EER(kJ/min)**
S_1	12.92	10.95	10.75
S_2	13.91	11.00	11.07
S_3	12.90	11.65	10.71
S_4	14.24	10.87	11.17
S_5	13.99	11.98	10.71
S_6	15.01	10.76	11.48
S_7	13.63	11.65	10.84
S_8	15.10	11.77	11.55
S_9	13.68	11.43	10.86
S_{10}	13.18	11.32	10.38
Mean	**13.86**	**11.34**	**10.95**

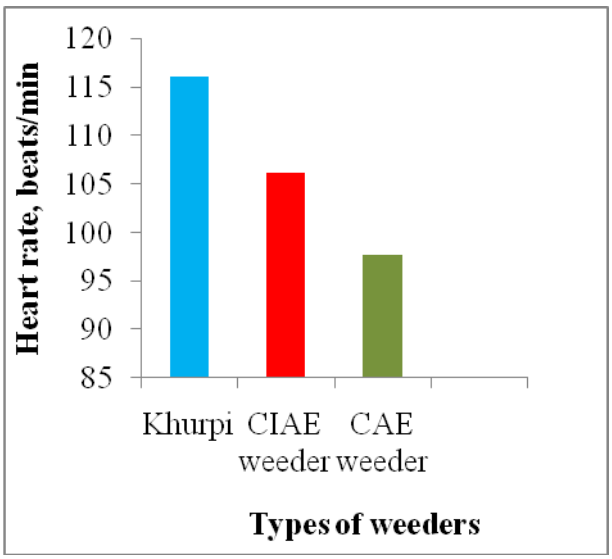

Fig.1 Heart rate in manual weeding operation

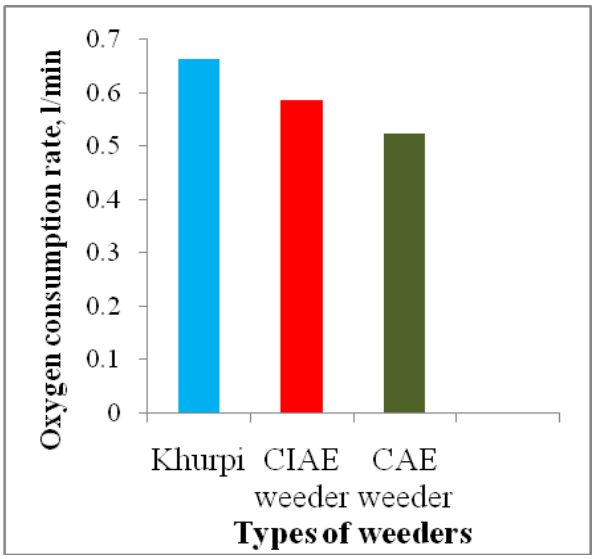

Fig. 2 Oxygen consumption rate during manual weeding operation

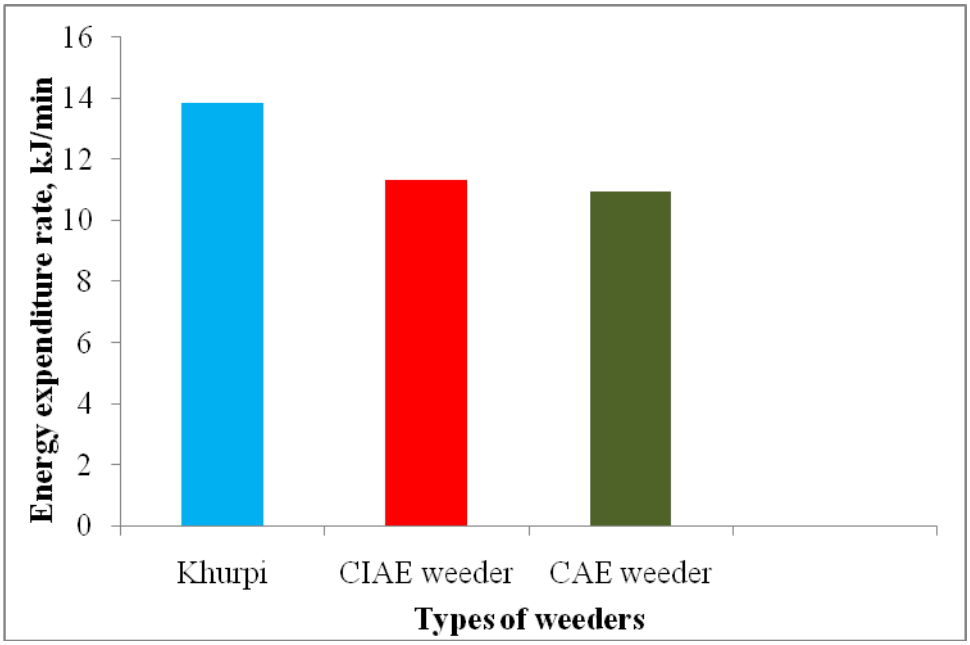

Fig.3 Energy expenditure rate in Manual Weeding operation

Plate.1 Physiological cost estimations for khurpi

Plate.2 Physiological cost estimations for CIAE wheel hoe

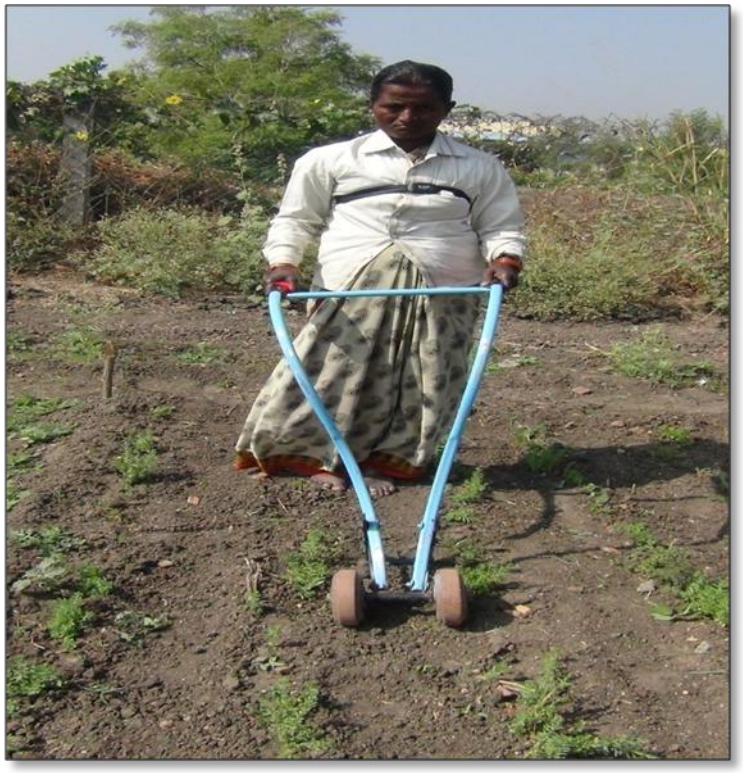

Plate.3 Physiological cost estimations for CAE weeder

In conclusion, CAE weeder CIAE weeder khurpi were evaluated with 10 subject to their physiological cost while weeding operation. The mean HR, OCR and EER during weeding with khurpi, CIAE wheel hoe and CAE weeder was 116.13 beats/min 106.18 beats/min, 97.63 beats/min, 0.664 l/min, 0.586 l/min, 0.525 l/min and 13.86 kJ/min, 11.34 kJ/min and 10.95 kJ/min, respectively. The minimum mean ΔHR and ΔOCR for subjects was observed during weeding with CAE weeder, followed by CIAE wheel hoe, whereas maximum value was observed for khurpi. Agricultural tools/implements are not designed ergonomically and this leads to increase in fatigue, health hazards and even accidents to agricultural workers. CAE weeder, which can increase their efficiency and work output and reduce the circulatory stress, physiological cost of work.

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