Ergonomic evaluation of a power weeder for homestead gardens

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ABSTRACT : Weeding is an important agricultural unit operation. Delay and negligence in weeding operation affect the crop yield up to 30 to 60%. With regard this, the existing power weeder available in the market was tested in the farm to assess their performance. It works well in sandy loam soil. In lateritc soil, the performance of the machine was not satisfactory. Hence modification was done by attaching a rear wheel behind the weeder so as to improve the penetration in the soil and there by removing the weeds effectively. Additional wheels were also fabricated and fitted in the unit for easy transport of the machine. The cardiac cost involved in operation of power weeder was found out and the mean working heart rate value of the subject was 128 beats min^{-1} before modification. The corresponding value of energy expenditure was 22.44 kJ min$^{-1.}$ Based on the mean working heart rate, the operation was graded as " heavy". After modification, the average heart rate was reduced to 116 beats min^{-1}. The corresponding value of energy expenditure was 16.94 kJ min$^{-1.}$ The human energy expenditure was reduced to the tune of 25% and the operation was graded as " moderately heavy". Mean overall discomfort rating on a 10 point visual analogue discomfort scale (0- no discomfort, 10-extreme discomfort) was 5.0 and scaled as "moderate discomfort" before modification where as ODR was 4.0 and scaled as "more than light discomfort" during operation of modified power weeder. Shoulder and arm wrist regions are concerned areas of discomfort for operating power weeder.

KEY WORDS : Power weeder, Heart rate, Energy expenditure, Overall discomfort, Body part discomfort

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Homesteads farms of Kerala are peculiar in that they are very small farming units managed independently by different farmers. Shortage of labour and high cost of hired labour is two major constraints faced by the farmers. A survey conducted in the homestead gardens of Kerala reveals the non availability of low cost equipments suited to homestead gardens.

Weeding is an important but equally labour intensive agricultural operation. Weeding requires a lot of labour force compared to other operations. Mechanical weed control not only uproots the weeds between the crop rows but also keeps the soil surface loose, ensuring better soil aeration and water intake capacity. At present power weeders are available in the market but are reported not suited to the lateritic soils of Kerala.

The application of ergonomics can help in increasing the efficiency and thereby productivity of the workers without jeopardizing their health and safety. The performance of any machine especially manually operated ones could be considerably improved if ergonomic aspects are given due consideration (Gite, 1993). Systematic efforts to evaluate the energy expenditure of the power weeders are generally non-existent. These measurements are also important from the safety point of view because whenever the physical capacity of a person is exceeded, it is bound to cause considerable fatigue and large reduction in the alertness of the person making the operation unsafe. Thus, investigations on ergonomical evaluation of power weeders can provide a rational basis for recommendation of methods and improvement in equipment design for more output and safety.

METHODOLOGY

Subjects:

Three healthy male operators based on age and medical fitness were selected for the study. The strength or power is expected to be maximum in the age group of 25 to 35 years (Grandjean, 1982; Gite and Singh, 1997). Hence, three subjects were chosen from the age group of 25 to 35 years. The physiological characteristics of selected subjects are given in Table A.

Table A : Physiological characteristics of participants				
Sr. No.	Variable	Subjects		
		1	II	III
1.	Age, years	28	25	32
2.	Body weight, kg	65	52	70
3.	Height, m	1.65	1.63	1.83
4.	Resting heart rate, beats min^{-1}	60.00	69.00	69.00
5.	ECG	Normal	Normal	Normal
6.	Blood pressure, mm of Hg	120/80	120/80	120/80

Establishing relationship between oxygen uptake and heart rate:

On a separate day and before performing activities with power weeder, the relationship between heart rate and oxygen uptake for each subject was determined. This relationship is used to indirectly evaluate physiological workload. The selected three subjects were calibrated in the laboratory by measuring oxygen consumption and heart rate simultaneously while running on the treadmill to arrive at the relationship between heart rate and oxygen consumption.

Measurement of physiological responses:

The oxygen consumption was measured using Benedict-Roth spirometer and the heart beat rate was recorded using computerized heart rate monitor (Polar make). The subject was allowed to take complete rest for half an hour before the commencement of the test. The subject inhaled oxygen through the inspiratory valve that was connected to the spirometer filled with oxygen and released carbon dioxide through the expiratory valve coupled to carbon dioxide absorber. The kymograph records the oxygen consumption pattern of the subject on the chart continuously. Simultaneously, heart rate was recorded in the computerized heart rate monitor.

The test started with a submaximal load, which would serve as a warming-up activity by keeping the inclination of the treadmill constant (5 degrees). Finally the workload of the subjects was increased by increasing the linear speed of the belt gradually until the subject was exhausted. For determination of the subject's maximum oxygen uptake, the workload was increased gradually until he reached complete exhaustion. The same procedure was repeated for all the subjects.

Field layout experiments:

The experiment was conducted at Farming Systems Research Station, Sadanandapuram. The specification of the selected power weeder is furnished in Table B. The power weeder was put in proper test condition before conducting the tests. All the three subjects were equally trained in the operation of the power weeder. They were asked to report at the work site at 7.30 am and have a rest for 30 minutes before starting the trial. All the subjects used similar type of clothing. The subjects were given information about the experimental requirements so as to enlist their full cooperation.

Table B : Specification of the power weeder used for measurements		
Sr. No.	Description	Specification
1.	Engine type	Petrol engine
2.	Power	4.0 KW (5.5 HP)
3.	Starter	Recoil starter
4.	Gear box	1 forward and 1 reverse
5.	Transmission	Chain and belt
6.	Working width	93 cm

The heart rate was measured and recorded using computerized heart rate monitor for the entire work period. Each trial started with taking five minutes data for physiological responses of the subjects while resting on a stool under shade. They were then asked to operate the power weeder (already started by another person) for a duration of 15 minutes. As per the studies of Tiwari and Gite (2002) and Vidhu (2001), the duration of measurement was fixed as 15 minutes and same procedure was repeated to replicate the trials for all the selected subjects.

Data analysis:

The recorded heart rate values from the computerized heart rate monitor were transferred to the computer and the values of heart rate at resting level and from 6th to 15th minute of operation were taken for calculating the physiological responses of the subjects. 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 three subjects) by the calorific value of oxygen as 20.88 kJ lit^{-1} (Nag *et al.*, 1980). The energy cost of the subjects thus obtained was graded as per the tentative classification of strains in different types of jobs given in ICMR report as shown in Table C (Vidhu, 2001).

Table C : 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

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 operate the power weeder for duration of two hours. Sufficient rest period was given for each subject between the two trials on the same day with the same subject. The same procedure was repeated three times for all the selected subjects.

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. A scale of 70 cm length was fabricated having 0 to 10 digits marked on it equidistantly (Fig. A). A movable pointer was provided on the scale to indicate the rating.

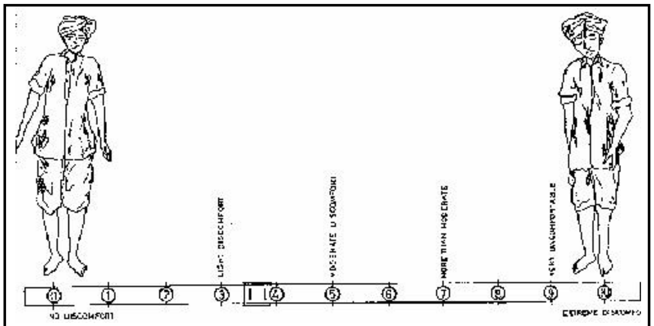

Fig. A : **Visual analogue discomfort scale for assessment of overall body discomfort**

At the ends of each trial subjects were asked to indicate their overall discomfort rating on the scale. The overall discomfort ratings given by each of the three subjects were added and averaged to get the mean rating.

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. B. A body mapping similar to that of Fig. B was made to have a real and meaningful rating of the perceived exertion of the subject. The subject

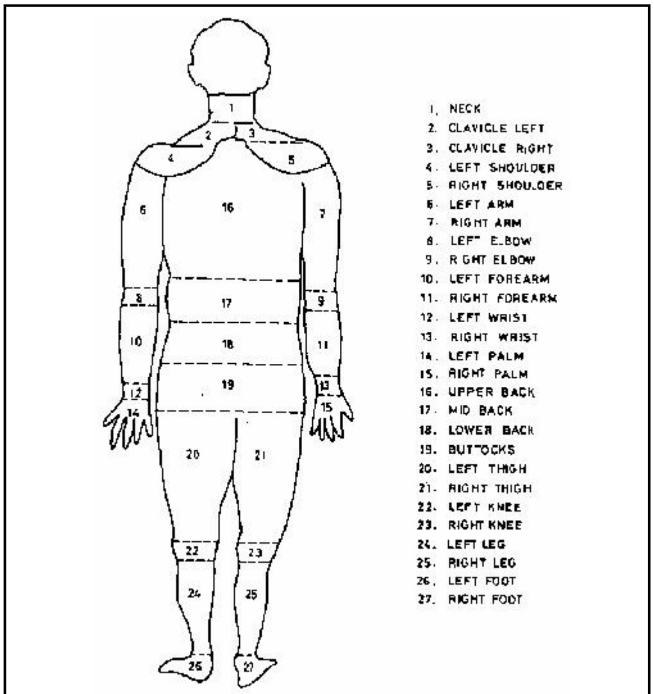

Fig. B : **Regions for evaluating body part discomfort score**

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 number of different groups of body parts which are identified from extreme discomfort to no discomfort represented the number of intensity levels of pain experienced. Each separately reported group can be seen as being separated by a recognizable difference in the level of discomfort. 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. The body discomfort score of all the subjects was added and averaged to get a mean score.

RESULTS AND DISCUSSION

The experimental findings obtained from the present study have been discussed in following heads:

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 three subjects.

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. The relationship between the two parameters oxygen consumption (Y) and heart rate (X) was expressed by the following linear equations.

For subject I, $Y=0.0152\,X - 0.8824\ (R^2 = 0.9628)$ (1)

For subject II, $Y=0.0199\,X - 1.2505\ (R^2 = 0.9849)$ (2)

For subject III, $Y=0.0156\,X - 0.7415\ (R^2 = 0.9575)$ (3)

where,

Y = Oxygen consumption, l min^{-1}

X = Heart rate, beats min^{-1}.

It is observed that R^2 value (co-efficient of determination) was very high for all the subjects which indicated that a good fit was arrived between oxygen consumption and heart rate. The variation in oxygen consumption was accounted by 96.28 per cent by the heart rate for subject I, 98.49 per cent for subject II and 95.75 per cent for subject III.

Energy expenditure in weeding:

Power weeder works well in sandy loam soil. In lateritic soil, the performance of the machine was not satisfactory. Hence, modification was done by attaching a rear wheel behind the weeder so as to improve the penetration in the soil and there by removing the weeds effectively (Fig. 1a and 1b).

Fig. 1a : Power weeder

Fig. 1b : Power weeder after modification

The cardiac cost involved in operation of power weeder was found out and the mean working heart rate value of the subject was 128 beats min^{-1} before modification. The corresponding value of energy expenditure was 22.2 kJ min^{-1}. Based on the mean working heart rate, the operation was graded as " heavy". After modification, the average heart rate was reduced to 116 beats min^{-1}. The corresponding value of energy expenditure was 16.94 kJ min^{-1}. The human energy expenditure was reduced to the tune of 25% and the operation was graded as " moderately heavy". The weeding efficiency was found to be 80%. Area covered by the weeder was 1acre/ day.

Energy expenditure in transport:

Power weeders are not provided with wheels for transport. Hence additional wheels were also fabricated and fitted in the unit for easy transport of the machine. The heart rate was measured during transport of power weeder. The mean working heart rate value of the subject was 130 beats min^{-1} before modification. The corresponding value of energy expenditure was 22.83 kJ min^{-1}. Based on the mean working heart rate, the operation was graded as " heavy". After modification, the average heart rate was reduced to 117 beats min^{-1}. The corresponding value of energy expenditure was 17.25 kJ min^{-1} and the operation was graded as " moderately heavy".

Acceptable work load (AWL):

Work load can be expressed as percentage of the individual's maximal aerobic power *i.e.* how much of the individual's maximal aerobic power has to be taxed in order to accomplish the work in question. Saha *et al.* (1979) reported that 35% of maximum oxygen uptake (also called maximum aerobic capacity or VO_2 max) 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´ 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).

The mean oxygen uptake in terms of maximum aerobic capacity was calculated and it was 61.22 % before modification where as it was 51.7 % after modification and was above the acceptable workload. During transport mode oxygen uptake in terms of VO_2 max was 62.7 % before modification where this value was 52.6 % after modification and the values were above the acceptable limit of 35% of VO_2 max.

Overall discomfort rating (ODR):

Mean overall discomfort rating on a 10 point visual analogue discomfort scale (0- no discomfort, 10- extreme discomfort) was 5.0 and scaled as "moderate discomfort" before modification where as ODR was 4.0 and scaled as "more than light discomfort" after modification during weeding. The overall discomfort scores during transport was 5 and scaled as "moderate discomfort" before modification while it was 3 and scaled as "light discomfort" after modification.

Body part discomfort score (BPDS):

It is observed that the pattern of regional discomfort varied with different operating conditions. The majority of discomfort was experienced in the left shoulder, right shoulder, left wrist and right wrist region for all the subjects during weeding. In transport mode, the majority of discomfort was concentrated in the left shoulder, right shoulder, left arm, right arm, mid back and lower back region while after fitting additional wheels, discomfort was experienced only on left and right palm. The body part discomfort score of subjects during weeding with power weeder before modification was 31.84 while the BPDS was 28.13 during operation of modified power weeder, the decrease being 12%. The body part discomfort scores rated by subject during transport was 29.73 before modification whereas the BPDS was 22.48 after modification, the decrease being 24%.

Conclusion:

An ergonomic evaluation of power weeder was carried out at Farming Systems Research Station, Sadanandapuram, Kottarakkara, Kerala. The physiological cost was found out and the mean working heart rate value of the subject was 128 beats min^{-1}. The corresponding value of energy expenditure was 22.44 kJ min^{-1}. Based on the mean working heart rate, the operation was graded as " heavy". It works well in sandy loam soil. In lateritic soil, the performance of the machine was not satisfactory. Hence, modification was done by attaching a rear wheel behind the weeder so as to improve the penetration in the soil and there by removing the weeds effectively. Additional wheels were also fabricated and fitted in the unit for easy transport of the machine. The weeder was tested and it was found that the average heart rate was reduced to 116 beats min^{-1}. The corresponding value of energy expenditure was 16.94 kJ min^{-1}. The human energy expenditure was reduced to the tune of 25% and the operation was graded as "moderately heavy". Mean overall discomfort rating on a 10 point visual analogue discomfort scale (0- no discomfort, 10- extreme discomfort) was 5.0 and scaled as "moderate discomfort" before modification where as ODR was 4.0 and scaled as "more than light discomfort" during operation of modified power weeder. Shoulder and arm wrist regions are concerned areas of discomfort for operating power weeder.

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