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Physiological Work Load and Subjective Assessment of Micro Tillers for Homestead Farming

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Abstract: ***The cardio respiratory performance of men operators was studied in two models of micro tillers for homestead farming in Kerala. Psychophysical measurement technique was used to quantify the overall discomfort as well as body part discomfort. The mean heart rate of operator was 109 beats min^{-1} for model I while it was 111 beats min^{-1} for model II. The work pulse of the micro tillers are 38 beats min^{-1} and 40 beats min^{-1} respectively for models I and II which was well within the limit of continuous performance of 40 beats min^{-1}. The predicted oxygen consumption rate was 0.9589 l min^{-1} that is 47% of maximum aerobic capacity (VO_2 max) for model I while it was 0.99 l min^{-1} that is 48% of their aerobic capacity for model II which was above the acceptable limit of 35% of VO_2 max indicating that the micro tillers were could not be operated continuously for 8 hours without frequent rest-pauses. It is suggested that two operators may be engaged in shift for a day long work with micro tillers. The performance of the second model was better than I model and the operation was graded as moderately heavy for both models. The first model was best suited to sandy loam soil however the second model was suited to both sandy loam soil and laterite soil. The weeding index was found to be 79% and the area covered by the first model was 0.5acre/day while the weeding index was found to be 85% and the field capacity was 0.75acre/day for the second model. Mean overall discomfort rating on a 10 point visual analogue discomfort scale (0- no discomfort, 10- extreme discomfort) was 2.0 and scaled as " light discomfort" during weeding for model I while it was 4.0 and scaled as " more than light discomfort" for second model. Micro tillers are mainly used for weeding as well as tilling the soil and it can be also used for making furrows/ channels and models would be selected based on the type of soil.***

Keywords: Micro tillers, heart rate, maximum aerobic capacity, discomfort

1. Introduction

Homesteads farms of Kerala are peculiar in that they are very small farming units managed independently by farmers. Shortages of labour and high cost of hired labour are the two major constraints faced by the farmers. In this context farm mechanisation can go a long way in making these farms more profitable and economic than they are at present. A survey conducted in the homestead gardens of Kerala reveals the non availability of low cost equipments suited to homestead gardens (Sam 2008).

Micro tillers are mainly used for weeding as well as tilling the soil. It can work in between crop rows for intercultural operations. Management of weeds is an important component of crop production technique as removal of weeds is expensive and hard to achieve at later stages. Weeds take away nutrients and harbour destructive insects, cause reduction in yield.

In the past two decades, work has been done on non-chemical management techniques and environmentally safe alternatives to herbicides for weed control. Mechanical weeding is generally the most economical method of weed control. 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.

The performance of any machine especially manually operated ones could be considerably improved if ergonomic aspects are given due consideration (Gite, 1993). The application of ergonomics can help in increasing the efficiency and thereby productivity of the workers without jeopardizing their health and safety. Systematic efforts to evaluate the energy expenditure of the micro tillers 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 micro tillers can provide a rational basis for recommendation of methods and improvement in equipment design for more output and safety.

2. Materials and Methods

2.1. Subjects

Three healthy male operators based on age and medical fitness was 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 1.

2.2. Establishing relationship between Oxygen uptake and Heart Rate

On a separate day and before performing activities with micro tiller, 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 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. The oxygen consumption was measured using Benedict-Roth spirometer and the heart beat rate was recorded using computerized heart rate monitor (Polar make).

Table 1: Physiological characteristics of participants

Sl.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	69	69
5	ECG	Normal	Normal	Normal
6	Blood pressure, mm of Hg	120/80	120/ 80	120/ 80

2.3. Field Layout Experiments

The experiment was conducted at Farming Systems Research Station, Sadanandapuram. The micro tillers were put in proper test condition before conducting the tests. All the three subjects were equally trained in the operation of the micro tillers. They were asked to report at the work site at 7.30 am and have a rest for 30 minutes before starting the trial. To minimize the effects of variation, the treatments were given in randomized order. All the subjects used similar type of clothing. The subjects were given information about the experimental requirements so as to enlist their full cooperation.

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 micro tiller (already started by another person) for 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.

2.4. Data Analysis

The stabilized values of heart rate for each subject from 6^{th} to 15^{th} minute of operation were used to calculate the mean value for micro tillers. 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 2 (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

2.5. 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 micro tillers for duration of two hours.

2.5.1. 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. A scale of 70 cm length was fabricated having 0 to 10 digits marked on it equidistantly (Figure.1). A movable pointer was provided on the scale to indicate the rating.

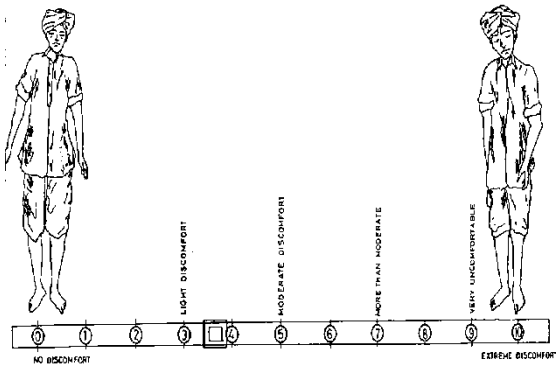

Figure 1: Visual analogue discomfort scale for assessment of overall body discomfort

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.

2.5.2 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 Figure.2. It has been successfully used by others for agriculture workers in other studies (Kumar, 1990 and Tiwari et al., 2005). A body mapping similar to that of Figure.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 subject was asked to fix the pin on the body part in the order of one pin for maximum pain, two pins for next maximum pain and so on. 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.

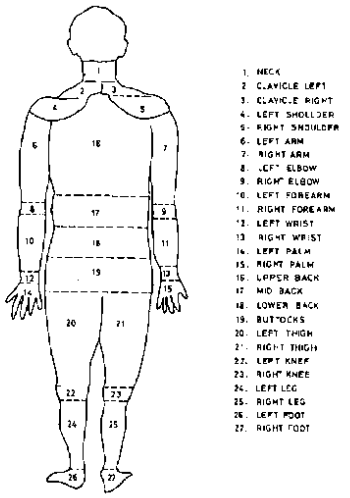

Figure.2: Regions for evaluating body part discomfort score

Weeding index was calculated by using the following formula (Anon 1985).

$e = [(W_1 – W_2)/W_1] \times 100$ …….. (1)

Where,
e = weeding Index, per cent
W_1= number of weeds/m^2 before weeding
W_2 = number of weeds/m^2 after weeding

Higher the value (e) means the weeder is more efficient to remove the weeds.

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 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. This linear relationship defers from one individual to another due to physiological differences of individuals (Kroemer *et al.,* 2000). The relationship between the two parameters oxygen consumption (Y) and heart rate (X) was expressed by the following linear equations.

For subject I, $Y = 0.0152X - 0.8824$ ($R^2 = 0.9628$) -- (1)
For subject II, $Y = 0.0199X - 1.2505$ ($R^2 = 0.9849$) -- (2)
For subject III, $Y = 0.0156X - 0.7415$ ($R^2 = 0.9575$)-- (3)

Where,

Y = Oxygen consumption, l min^{-1}
X = Heart rate, beats min^{-1}

It is observed that R^2 value (coefficient 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% by the heart rate for subject I, 98.49 % for subject II and 95.75% for subject III respectively.

3.2. Energy Cost of Operation

The average working heart rate of the operator was 109 beats min^{-1} for model I (Figure 3) and the corresponding value of oxygen consumption rate predicted from the calibration chart was 0.9589 l min^{-1}. The corresponding energy expenditure was 20.02 kJ min^{-1}. Based on the mean energy expenditure, the operation was graded as "Moderately heavy" for model I. The mean heart rate of the male operator was 111 beats min^{-1} for model II (Figure 4) , hardly 2 % higher than first model. The oxygen consumption rate was 0.99 l min^{-1} and the corresponding energy expenditure was 20.67 kJ min^{-1} for this model. However the performance of this second model was better than I model and the operation was graded as moderately heavy as in first model. The first model was best suited to sandy loam soil however the second model was suited to both sandy loam soil and laterite soil. The weeding index was found to be 79% and the area covered by the first model was 0.5acre/day while the weeding index was found to be 85% and the area covered by was 0.75acre/day for the second model. Both the micro tillers can be used for making furrows/ channels and models would be selected based on the type of soil. The micro tillers were best suited for kitchen garden and for women labourers. Both the machines require 1 litre petrol to cover 1 hr.

Figure 3: Photographic view of Power weeder (Model I)

Figure 4: Photographic view of Power weeder (Model II)

3.3. Acceptable Workload (AWL)

To ascertain whether the operations selected for the trails were within the acceptable workload (AWL), the oxygen uptake in terms of VO_2 max (%) was computed. 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. The oxygen uptake corresponding to the computed maximum heart rate in the calibration chart gives the maximum aerobic capacity (VO_2 max).

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 mean oxygen uptake in terms of maximum aerobic capacity was calculated and it was 47 % and 48% respectively for the models tested and the value was above the acceptable limit of 35% of VO_2 max indicating that the micro tillers were could not be operated continuously for 8 hours without frequent rest-pauses.

3.4. Overall Discomfort Rating (ODR)

Mean overall discomfort rating on a 10 point visual analogue discomfort scale (0- no discomfort, 10- extreme discomfort) was 2.0 and scaled as " light discomfort" during weeding for model I while it was 4.0 and scaled as " more than light discomfort" for second model.

3.5. Body Part Discomfort Score (BPDS)

The majority of discomfort was experienced in the left shoulder and right shoulder for all the subjects and the body part discomfort score of subjects during weeding with micro tiller model I was 23.08. For model II, the majority of discomfort was experienced in the left shoulder and right shoulder, upper back, left and right palm for all the subjects and the body part discomfort score of subjects was 24.97.

3.6. Limit of Continuous Performance (LCP)

The work pulse (Δ HR) was 38 beats min^{-1} and it was well within the limit of continuous performance of 40 beats min^{1} for model I while the work pulse was 40 beats min^{-1} for model II and was within the limit.

3.7. Work Rest Cycle

For every strenuous work in any field requires adequate rest to have an optimum work out put. Better performance results can be expected from both the operator and the worker only when proper attention is given for the work rest schedule for different operations.

The actual rest times taken for each subject were found from the heart rate response curves of respective operations. The rest time was measured from the cease of the operation till the heart rate of the subject reaches resting level. The rest time taken was averaged to arrive at the mean value for each selected implement.

The rest pause to the subject was calculated using the following formula as given by Pheasant (1991)

$$R = \frac{T\,(E-A)}{E-B}$$

Where.

R = Resting time (min)
T = Total working time/day (min)
E = Energy expenditure during working task (kcal/min)
A = Average level of energy expenditure considered acceptable (kcal/min)
B = Energy expenditure during rest (kcal/min)

Average level of energy expenditure considered acceptable was 4 kcal min^{-1}(Murrel, 1965).

Rest pause was calculated using the above formula as all the subjects operated continuously for the 30 min period and it was found that 8 min rest for model 1 and 9 min rest for model II could be provided to operator who was engaged in operating the equipment. The rest period calculated was also in agreement to the recovery heart rate of operator. If two operators are engaged with a machine in shift, it could be operated for day-long work.

4. Conclusions

An ergonomic evaluation of two models of micro tillers were carried out at Farming Systems Research Station, Sadanandapuram, Kottarakkara, Kerala for weeding/ interculture in upland field . The physiological cost was found out and the mean working heart rate of operator was 109 beats min^{-1} for model I while it was 111 beats min^{-1} for model II. The operation was graded as "moderately heavy". The work pulse of the micro tillers are well within the limit of continuous performance of 40 beats min^{-1}. The oxygen uptake in terms of VO_2 max was above the acceptable limit of 35% of VO_2 max indicating that the micro tillers were

could not be operated continuously for 8 hours without frequent rest-pauses. It is suggested that two operators may be engaged in shift for a day long work with micro tillers. The first model was best suited to sandy loam soil however the second model was suited to both sandy loam soil and laterite soil. The weeding index was found to be 79% and the area covered by the first model was 0.5acre/day while the weeding index was found to be 85% and the area covered was 0.75acre/day for the second model. Mean overall discomfort rating on a 10 point visual analogue discomfort scale (0- no discomfort, 10- extreme discomfort) was 2.0 and scaled as " light discomfort" during weeding for model I while it was 4.0 and scaled as " more than light discomfort" for second model. Shoulder and arm wrist regions are concerned areas of discomfort for operating micro tillers.

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