Ergonomic Evaluation of Cono Weeder for Wet Land Paddy

Bini Sam

Farming Systems Research Station, Kerala Agricultural University, Sadanandapuram, Kottarakkara, Kerala, India

Abstract: *Weeding is one of the most important field operations & consumes 15% of the total energy spent in crop production. The cardio respiratory performance of men operators was studied in cono weeder for weeding paddy in wet land cultivation. Psychophysical measurement technique was used to quantify the overall discomfort as well as body part discomfort. The average working heart rate of the subject was 121 beats min^{-1}. The predicted oxygen consumption rate was 1.146 l min^{-1} that is 56% of their aerobic capacity (VO$_2$ max) which was above the acceptable limit of 35% of VO$_2$ max. The weeding index was found to be 75%. Area covered by the cono weeder was 15 cent/hour ((row to row spacing is 23.8 cm while using self propelled rice transplanter) and area covered by the cono weeder was 20 cent/hour while planting 30 cm row spacing. 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". It is suggested that two operators may be engaged in shift for a day long work with the cono weeder. It is easy to maintain this machine and the price was low. Wheels can be adjustable depending on the row. However weeding efficiency was less in hard soil and working is difficult in hard surface.*

Keywords: conoweeder, heart rate, aerobic capacity, weeding index, discomfort.

1. Introduction

Weed growth is a major problem for wet land crops particularly in wet land rice, causing a considerable lower yield. In Kerala, this operation is mostly performed manually that requires higher labor input and also time consuming process. Moreover, the labor requirement for weeding depends on weed flora, weed intensity, time of weeding and efficiency of worker. Often several weeding are necessary to keep the crop weed free. Reduction in yield due to weed alone is estimated as 16-42% depending on crop and location and involves one third of the cost of cultivation (Rangasamy *et al*, 1993).

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 weightage (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 cono weeder 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 cono weeder 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 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 1**.

Table 1: Physiological characteristics of participants

S. No	Variable	Subjects		
		1	II	III
1	Age, years	29	26	33
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

2.2. 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 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.

Paper ID: SUB155629

2818

The oxygen consumption was measured using Benedict-Roth spirometer and the heart beat rate was recorded using computerized heart rate monitor (Polar make).

2.3. Field layout experiments

The experiment was conducted in farmers feld in Chadayamangalam Block of Kollam District, Kerala, India. Cono weeder is a manually operated implement and designed to work in between the rows of 20 cm spacing in wet lands. It works by the push pull action and the weeds were uprooted and buried in the field itself. A float provided in the front portion prevents the unit from sinking into the puddled soil. It disturbs the topsoil and increases the aeration also. Cono weeder is having two truncated rollers one behind other fitted at the bottom of a long handle. The conical rollers have serrated blades on the periphery. The weight of equipment was about 9 kg. A float provided in front portion prevents the unit from sinking into the soil.

The cono weeder was put in proper test condition before conducting the tests. All the three subjects were equally trained in the operation of the cono 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. 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 cono weeder (already started by another person) for duration of 15 minutes and same procedure was repeated to replicate the trials for all the selected subjects.

2.4. 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. The stabilized values of heart rate for each subject from 6th to 15th minute of operation were used to calculate the mean value for cono weeder. 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** (Sen, 1969 and Sam, 2014).

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). The subjects were asked to report at the work site at 8.00 AM and have a rest for 30 minutes before starting the trial. After 30 minutes of resting, the subject was asked to operate the cono 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.

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 (**Fig.1**). A movable pointer was provided on the scale to indicate the rating.
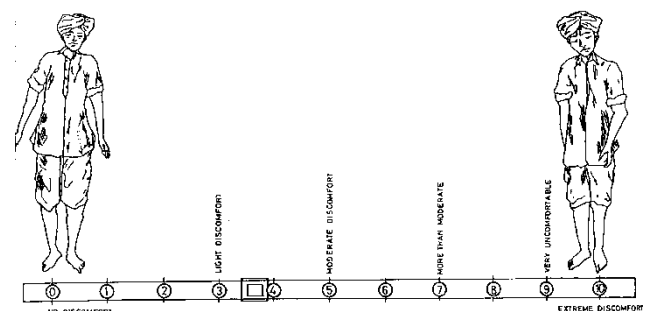

Figure 1: Visual analogue discomfort scale for assessment of overall body discomfort

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 **Fig.2**. 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 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 body part discomfort score of each subject was the rating multiplied by the number of body parts corresponding

Paper ID: SUB155629

2819

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.
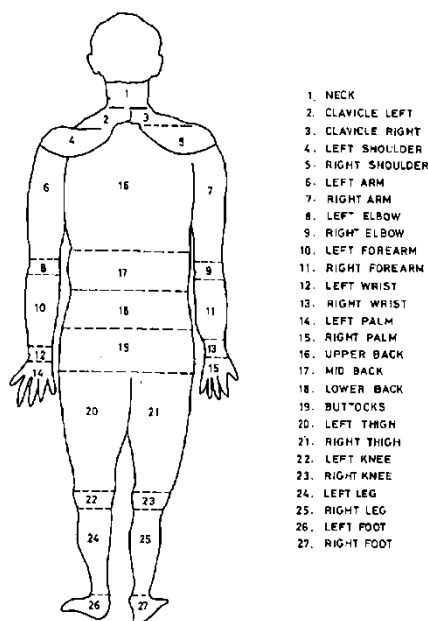

Figure 2: Regions for evaluating body part discomfort score

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

$$e = [(W_1 - W_2)/W_1] \times 100 \quad \text{.............. (1)}$$

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, $Y = 0.0152 X - 0.8824$ ($R^2 = 0.9628$) --- (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 (coefficient of determination) was very high for all the subjects which indicated that a

good fit was arrived between oxygen consumption and heart rate.

3.2 Energy Cost of Operation

The average working heart rate of the operator was 121 beats min^{-1} and the corresponding value of oxygen consumption rate predicted from the calibration chart was 1.146 l min^{-1}. The corresponding energy expenditure was 23.93 kJ min^{-1}. Based on the mean energy expenditure, the operation was graded as "Moderately heavy" . In hand weeding 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. Since the cono weeder is provided with a long handle, the subjects can do the weeding in a standing posture (**Fig.3**).

The weeding index was found to be 75%. Area covered by the cono weeder was 15 cent/hour ((row to row spacing is 23.8 cm while using self propelled rice transplanter) and area covered by the cono weeder was 20 cent/hour while planting 30 cm row spacing.

Figure 3: Photographic view of cono weeder working in the field

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 56% and the value was above the acceptable limit of 35% of VO$_2$ max indicating that the cono weeder is 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 5.0 and scaled as " Moderate discomfort" during weeding.

3.5 Body Part Discomfort Score (BPDS)

The majority of discomfort was experienced in the right palm, left palm, right wrist, left wrist, right shoulder, left shoulder, right knee, left knee and mid back region for all the subjects during weeding and the body part discomfort score of subjects during weeding with cono weeder was 26.28.

3.6 Limit of Continuous Performance (LCP)

The work pulse (Δ HR) was 50 beats min^{-1} and it was above the limit of continuous performance of 40 beats min^{-1}.

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 time taken for each subject was 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 13min rest 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 cono weeder is carried out at Farming Systems Research Station, Sadanandapuram, Kottarakkara, Kerala for weeding paddy in wet land cultivation. The physiological cost was found out and the mean working heart rate of operator was 121 beats min^{-1}. The operation was graded as " moderately heavy". The work pulse of the cono weeder is above 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 cono weeder was 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 cono weeder. The weeding index was found to be 75%. Area covered by the cono weeder was 15 cent/hour ((row to row spacing is 23.8 cm while using self propelled rice transplanter) and area covered by the cono weeder was 20 cent/hour while planting 30 cm row spacing. 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". The majority of discomfort was experienced in the right palm, left palm, right wrist, left wrist, right shoulder, left shoulder, right knee, left knee and mid back region for all the subjects during weeding.

References

[1] Anonymous, 1985. RNAM test codes and procedure for farm machinery, Technical series No. 12, Economic and Social Commission for Asia and the Pacific, Regional Network for Agricultural Mechanization, Bangkok, Thailand.

[2] Bridger, R. S.1995. Introduction to Ergonomics.3rd Edn., Mc Graw-HIll, Inc, New york.

[3] Corlett, E.N. and R.P.Bishop.1976. A technique for assessing postural discomfort. Ergonomics, 19,175-182.

[4] 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.

[5] Gite, L.P and G Singh.1997. Ergonomics in agricultural and allied activities in India. Technical Bulletin No. CIAE/97/70.

[6] Grandjean, E.1982. Fitting the task to the man- An ergonomic approach. Taylor& Francis Ltd., London

[7] Kroemer, K. H. E., H.B.Kroemer and K. E. E. Kroemer.2000. Ergonomics-How to design for ease and efficiency. Prentice-Hall Inc., Upper saddle River, New Jersey

[8] Maritz,J. S., J. F.Morrison, J.Peters, N. B.Strydon, and C.H.Wyndham.1961. A practical method of estimating an individuals maximum oxygen uptake.Ergonomics, 4 (2),120-125.

[9] Murrell, K. F. H. 1965. Human performance in industry. Reinhold Publishing Corporation, New York.

[10] Nag, P.K., Sebastian, N.C. and M.G. Malvankar.1980. Occupational workload of Indian agricultural workers. Ergonomics, 23, 91–102.

[11] Nag, P. K. and S.K. Chatterjee.1981. Physiological reactions of female workers in Indian agricultural work. Human Factors, 23, 607–14.

[12] Phesant, S.1991. Ergonomics, Work and Health. London:The Macmillan Press Ltd.

[13] Rangasamy, K., M. Balasubramanium and K.R.Swaminathan. 1993. Evaluation of power weeder performance.Agricultural Mechanisation in Asia, Africa and Latin America, 24(4),16-18.

Paper ID: SUB155629
2821

[14] 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.

[15] Sam, B.2014. Ergonomic evaluation of paddy harvester and thresher with farm women. International Journal of Science and Research, 3(11): 1644-1648.

[16] 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.

[17] Tiwari, P. S. and L. P. Gite. 2002. Physiological Responses during Operation of a Rotary Power Tiller, Bio systems Engineering, 82(2), 161-168.

Paper ID: SUB155629

2822