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.

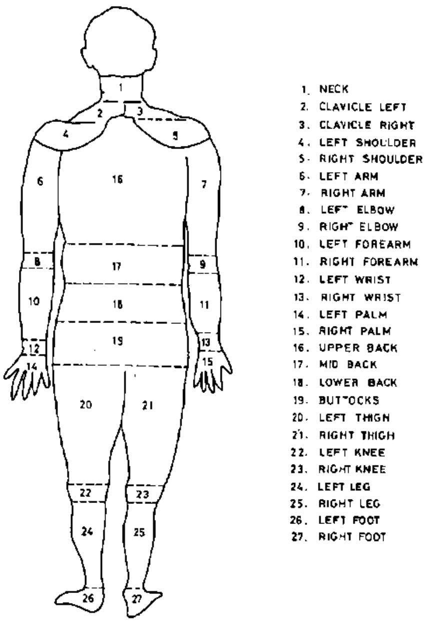

Figure 2: Regions for evaluating body part discomfort score

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

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

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.

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