Figure 3: 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.

2.6.2 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.4. A body mapping similar to that of Fig.4 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 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.

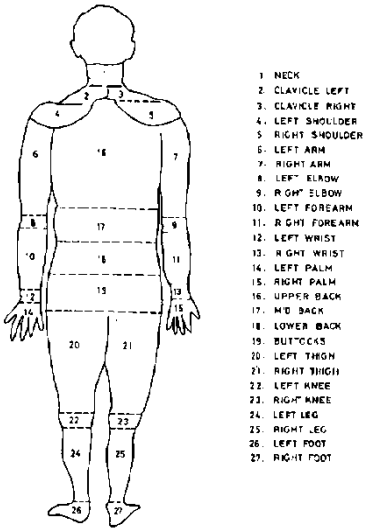

Figure 4: Regions for evaluating body part discomfort score

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, $Y=0.0152 X - 0.8824 (R^2 = 0.9628)$ -- (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 who 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 128 beats min^{-1} and the corresponding energy expenditure was 22.44 kJ min^{-1} for the power weeder. However, the mean working heart rate of the operator was reduced to 102 beats min^{-1} and the corresponding energy expenditure was 14.35 kJ min^{-1} after modification. The human energy expenditure was reduced to the tune of 36% after modification. The weeding index was found to be 85%. Based on the mean energy expenditure, the operation was graded as “Moderately Heavy”.

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 41% and the value was above the acceptable limit of 35% of VO_2 max indicating that the modified power paddy 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 4.0 and scaled as " More than Light discomfort" during weeding while it was 5.0 and scaled as "Moderate Discomfort" before modification.

3.5. Body part discomfort score (BPDS)

The majority of discomfort was experienced in the left shoulder, right shoulder, left wrist, right wrist, left arm and right arm region for all the subjects during weeding and the body part discomfort score of subjects during weeding with modified power weeder was 21.55.

3.6. Limit of continuous performance (LCP)

The work pulse (Δ HR) was 31 beats min^{-1} and it was within 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 power weeder.

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 5 min 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

The blade system of existing power weeder was modified into helical blades for avoiding entangling of the weeds in the blade unit and was ergonomically evaluated at Farming Systems Research Station, Sadanandapuram, Kottarakkara, Kerala for weeding in dry land cultivation. The physiological cost was found out and the mean working heart rate of operator was 102 beats min^{-1}. The operation was graded as "Moderately Heavy". The work pulse of the modified power weeder is 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 power 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 power weeder. The weeding index was found to be 85%. Mean overall discomfort rating on a 10 point visual analogue discomfort scale (0- no discomfort, 10- extreme discomfort) was 4.0 and scaled as "More than Light discomfort". Shoulder and arm wrist regions are concerned areas of discomfort for operating power weeder. The human energy expenditure was reduced to the tune of 36% after modification.

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