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Research Paper

Physiological workload of weeding operation by using existing and improved hoe in tea fields of Assam

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ABSTRACT : Weeding is a tiring and time consuming activity. An attempt was made to improve the weeding hoe used in tea fields of Assam. The modified tool was ergonomically compared with the existing hoe. Seven physically fit male workers without having any physical disability and chronic ailments were selected for the study. It was found that quality of work carried out with the help of improved weeding hoe was better than the existing one. There was a significant difference in the heart rate of the workers using existing and improved tool. Energy expenditure was found to be reduced, grip fatigue was decreased. The handle of improved weeding hoe was found to be well suited to the task and workers in terms of length and circumference that helped the workers to adopt a neutral posture and relief them from pain in hands as a result of offering greater leverage.

KEY WORDS : Physiological workload, Perceived exertion, Postural stress, Range of motion, Musculo-skeletal problem

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A strong relationship exists between the occupational stress of workers and their productivity. Occupational stress of the workers results in reduced production due to inefficiency of the workers and sickness absenteeism. Moreover, the workers have to be paid sickness benefits and compensation wherever applicable. In many cases workers have to face the loss *i.e.*, no work no pay.

Occupational stress is becoming an increasingly global phenomenon affecting all countries, all professions and all categories of workers, families and society in general. The major occupational stress concerning work motivation and quality productivity in India is the musculo-skeletal injuries. The emerging need should be focused on a pro-active response to occupational stress, with emphasis on preventive measures and elimination of the causes, rather than on the treatment of its effects and there by bringing occupational wellness among the workers.

The main objective of ergonomics is to achieve an optimal relationship between people and their work environment, where the approach has to be context specific. The work environment of workers may be hazardous due to various responsible ergonomic risk factors while at work situations. The factors that play roles in the process of occupational wellness and stress are body postures, movements, exertion required, environmental factors, and poor design of work method/work tools, technical systems, inappropriate relationship between workers performance and their tasks demands.

Ergonomics principles and its application attempt to harmonise work and working environment to promote individual as well as organisational well-being through optimising the effort of the workers. The role of occupational ergonomics in the management of occupational stress is to look into measures and methods of prevention of occupational stress.

Weeding in tea fields is a tiring and time consuming activity in tea fields of Assam. It is highly hazardous and performed by the workers either in standing with a bend near

Table A : Physical features of the different weeding hoes

Sr. No.	Specifications	Existing tool	Improved tool
1.	Weight (kg)	1.38	1.5
2.	Blade size [Length x Width (cm)]	28 x 16	32 x 20
3.	Handle length (cm)	114	125
4.	Handle circumference	10.3	10
5.	Angle	80°	75°
6.	Material used	Iron blade with Bamboo handle	Iron blade with Bamboo handle
7.	Source	Local artisan	Local artisan

lumber or by squatting on the ground. The tool used by the workers while performing the activity made the workers to assume awkward posture for a long period of time. To facilitate the worker's efficiencies, modifications were brought into the size of the blade of weeding hoe, angle between the shaft and blade and the length of handle. The modified tool was ergonomically compared with the traditional tool. The study was related to tea gardens of Jorhat district with an attempt to study the physiological workload while performing weeding using existing and improved weeding hoe.

■ RESEARCH METHODS

A sample of seven physically fit male workers, without having any physical disability and chronic ailments were selected purposively for the study. All the selected subjects were well acquainted with the equipment and weeding operation. The subjects carried existing tool in hands while going to field and improved tool was provided at field. Experiment was carried out for 35 minutes for each of the tools. Three design specifications *i.e.*, size of the blade, length of the handle, angle between shaft and the handle were considered while designing the improved hoe for weeding. As regards to size of the blade, three sizes (29cm×17cm, 30cm×18cm and 32cm×20cm) were considered for field trials. After the trials, the appropriate size was selected. Likewise the appropriate angle between shaft and the handle was selected out of three angles *i.e.*, 70°, 75° and 80°. Depending on the shoulder height (SH), the length of handle *i.e.*, 0.6 SH, 0.7 SH, 0.8 SH and 0.9 SH were fixed and appropriate handle length was identified. Consequently, with the appropriate blade size, angle and handle length, the improved hoe was designed (TableA) and the improved hoe was compared with the traditional hoe.

Evaluation of physiological workload:

The physiological workload of the sample was determined by recording the heart rate after every five minutes during work using polar heart rate monitor.

Energy expenditure was calculated with the help of the formula given by Vargese *et al.* (1995).

Energy expenditure (kj/min) =0.159xAHR (beats per min)-8.72

The workload was categorized as per the workload classification developed by Vargese etal on the basis of heart rate and energy expenditure. The Total Cardiac Cost of Work (TCCW) was calculated as the sum of Cardiac Cost of Recovery (CCR) and Cardiac Cost of Work (CCW).

Rating of perceived exertion:

A modified rating scale of perceived exertion(RPE) developed by Vargese *et al.* (1994) based on Borgs 10 point scale (Borg, 1982) was adopted to measure the perceived exertion in terms of Very light(1),light(2),moderately heavy (3), heavy (4) and very heavy (5).

Grip fatigue:

It was measured by using Grip Dynamometer before and after completion of activity separately for the right and left hand.

Postural stress and range of motion:

Postural analysis of lumbo sacral region was done using dual inclinometer. Postural stress was studied on the basis of total spinal range of motion of lumbo sacral region while performing the activity with both existing and improved weeding hoe.

Musculo skeletal problem faced:

To ascertain musculo skeletal problems in terms of severity of pain in different body parts among respondents a three point scale was developed by the investigator *i.e.* just noticeable pain, moderate pain and intolerable pain.

■ RESEARCH FINDINGS AND DISCUSSION

The findings obtained from the present investigation are presented below:

Health status of workers:

Health status of workers was depicted through physical characteristics *viz.*, age, weight, height, body mass index, body type, aerobic capacity and physical fitness index (Table 1).

Mean age of the workers selected for the field test was 31 years having height and weight of about 162.5 cm and

Table 1 : Physical characteristics of the workers

Workers	Age (Yrs)	Weight (kg)	Height (cm)	LBM (kg)	BMI (kg/M^2)	VO_2 max	Fat weight
SW1	28	49	161.5	18.85	27	28	28
SW2	27	51	162	19.47	34	34	27
SW3	38	64	163	24.06	32	36	38
SW4	34	53	162.8	20	42	23	34
SW5	32	47	163	17.67	33	27	32
SW6	31	51	162.5	19.32	35	43	31
SW7	27	46	163	17.29	26	28	27
Mean	31	51.57	162.5	31.6	19.51	31.28	15.4
S.D	3.8	5.6	0.6	3.4	1.9	7.5	2.3

51.57 kg, respectively. Lean body mass and fat weight of the worker was, respectively about 31.6 kg and 15.4 kg.

Body mass index, an important indicator of energy adequacy, of worker was about 19.51, which fall in the normal category. Equal percentage of respondents (nearly 43 percent) had ectomorph and mesomorph body type and only 14.28 per cent respondents had endomorph body type (Fig. 1).

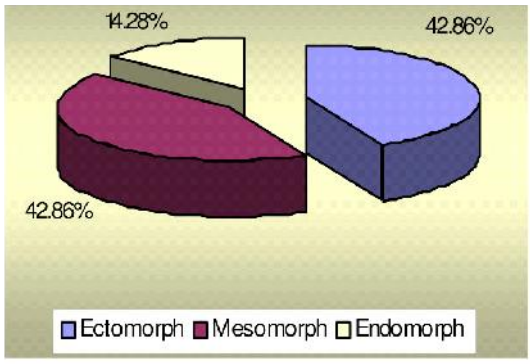

Fig. 1 : Body type

Regarding BMI classification, more than half of the respondents (57.14%) fall in the category of normal and about 14.9 per cent respondents fall in the category of CED grade-II, CED grade-I and obese grade-I, respectively (Fig. 2).

Fig. 1 : BMI

Physical fitness index and aerobic capacity:

Physical fitness index on the basis of step stool test exhibited that more than half of the respondents (57.14%) were having good physical fitness followed by high average (28.57%) and very good (14.28%) for rest of the respondents. Physical fitness of workers with respect to aerobic capacity indicated that average aerobic capacity (VO_2 max) was found to be 31.28 ml/kg/min(Table 1).

Details of the activity:

Physiological workload while performing weeding by using different weeding hoes

Physiological workload comprised of average and peak heart rate, energy expenditure, total cardiac cost of work, rating of perceived exertion and ease of comfort.

Heart rate:

During weeding, average and peak working heart rate of the workers was 114 b.min^{-1} and 126.28 b.min^{-1}, respectively for improved weeding tool whereas in case of existing tool the average working heart rate was 123 b.min^{-1} and that of peak heart rate was 135.43 b.min^{-1}. It is evident that, there was a reduction of 9 beats per minute with improved tool in case of both average and peak heart rate. Statistically there was significant difference in heart rate of workers using existing and improved tool.

Energy expenditure:

The energy expenditure determines the level of bodily stress. The table 2 highlights that the average energy expenditure for weeding activity with existing and improved hoe was 10.83 kj.min^{-1} and 9.41 kj.min^{-1}, respectively and as a result there was significant reduction of 13.11 per cent in case of improved tool over existing one. Similarly, peak energy expenditure was found reduced up to 11.39 per cent for improved weeding hoe.

Physiological cost of work (PCW):

Physiological cost of work was calculated on the basis of total cardiac cost of work (TCCW) and total time taken

Table 2 : Physiological workload of weeding activity with traditional and improved hoe

Parameters	Traditional	Improved	Significant reduction in improved over existing (%)	F value	CD
Average WHR (b.min^{-1})	123	114	-9.00 (7.32)	11.44 **	6.35
Average peak HR (b.min^{-1})	135.43	126.28	-9.15 (6.75)	18.64 **	8.15
Average EE(kj.min^{-1})	10.83	9.41	-1.42 (13.11)	11.47 **	1.02
Peak EE(kj.min^{-1})	12.81	11.35	-1.46 (11.39)	18.74 **	1.30
Average TCCW	1692.44	1394.70	-297.74 (17.59)	132.66 **	56.32
Average PCW	48.35	39.83	-8.52 (17.6)	132.63 **	1.61
Average RPE	3.71	2.00	-0.71 (19.14)	15.00 **	0.40
Ease of comfort	2.00	1.14	-0.86 (43.00)	36.00 **	0.31

during the activity. Regarding TCCW, it was observed that improved weeding hoe showed comparatively lower cardiac cost /stress (1394.7 beats) than existing one (1692.44 beats). It was found that 17 per cent of reduction was recorded in case of improved hoe over existing one. Correspondingly, average PCW with the use of existing weeding hoe was high *i.e.*, 48.55 b.min^{-1} as compared to the improved hoe (39.85 b.min^{-1}). It was evident from the table that improved weeding hoe resulted 17.59 per cent reduction in PCW over existing weeding hoe.

Rating of perceived exertion:

Workers considered weeding activity as light activity with improved hoe in comparison to traditional hoe with which the weeding activity was considered as heavy activity. Table 3 shows that significant reduction in case of improved weeding tool was 19.14 per cent over existing weeding hoe.

Ease of comfort:

As regards to ease of comfort Table 2 indicates that weeding activity with ergonomically designed weeding hoe has been considered as comfortable as compared to existing weeding hoe which was regarded as uncomfortable. Working with improved tool showed 43 per cent of reduction over existing one.

Grip fatigue:

The grip strength of the workers were measured with the help of "Grip Dynamometer", before and after the completion of the activity for both right and left hand separately. The difference between these two values was used to measure fatigue of the hand muscles. Fig. 3 shows that grip fatigue was more with existing weeding hoe *i.e.*, 7.37 per cent for right hand and 6.39 per cent for left hand as compared to improved weeding hoe (6.49 % for right hand and 5.22 % for left hand). It was owing to the fact that the circumference of handle of the improved hoe was proportionate to the handgrip of workers that accordingly reduced grip fatigue over existing one.

Postural stress and range of motion (ROM):

To determine the suitability of the technologies, spinal and extremity range of motion were recorded during the

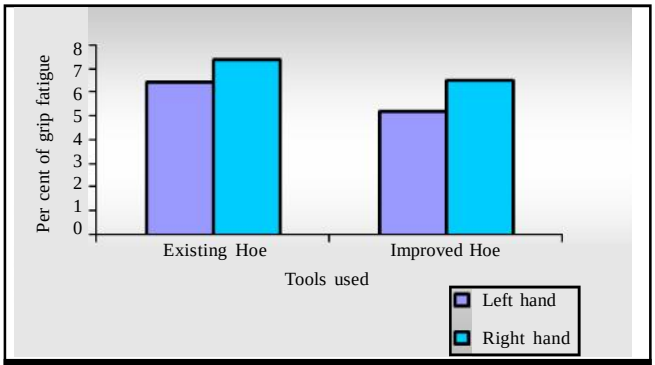

Fig. 3 : Grip fatigue

performance of the activity with the help of dual inclinometer. Postural stress was studied on the basis of total spinal range of motion of lumbo-sacral region while performing the activity with both existing and improved weeding hoe. Likewise, extremity range of motion was recorded for upper extremity *i.e.*, shoulders and wrist during the activity with existing as well as improved weeding hoes (Table 4).

Data regarding total spinal range of motion exhibits that the use of improved weeding hoe minimize the angle of average flexion (51.24°) and extension (28.6°) as compared to use of existing weeding hoe where angle of average flexion and extension was found to be higher *i.e.*, 56.87° and 33.75°, respectively.

There was substantial difference in total spinal ROM between existing and improved as clear from the highlighted data in Table 4, which result in eliminating postural stress in case of, improved weeding hoe to a considerable extent. Diminishing the angle of deviation predominantly enhanced the posture adopted during weeding with improved hoe that leads to less energy expenditure. Findings pertaining to upper extremity ROM shows that average flexion and extension was comparatively less *i.e.*, 91.36° and 47.25° in case of shoulder joint and 84.68° and 44.25° in case of wrist, respectively than existing weeding hoe.

Musculo-skeletal problems:

On the basis of human body map, musculo-skeletal

Table 3 : Total spinal and upper extremity range of motion (ROM)

Parameters	Total Spinal range of motion (lumbo-sacral region)		Upper extremity			
			Shoulder		Wrist	
	Existing	Improved	Existing	Improved	Existing	Improved
Average flexion	56.87°	51.24°	96.57°	91.36°	88.45°	84.68°
Average extension	33.75°	28.6°	50.45°	47.25°	46.43°	44.25°

Table 4 : Per cent reduction in musculoskeletal problems using traditional and improved tool while performing weeding

Body parts	Traditional	Improved	Significant reduction (%)
Neck	1.6	1.4	12.5
Shoulder joint	2.2	2.0	9.09
Upper back	2.6	2.3	11.54
Upper arms	2.5	2.4	4
Elbow	2.0	1.8	10
Mid back	2.3	2.0	13.04
Lower arms	2.2	2.0	9.09
Lower back	2.8	2.5	10.71
Wrist	2.1	1.8	14.29
Buttock	1.8	1.8	0
Knees	1.2	1.2	0
Palms	1.4	1.2	14.29
Fingers	2.4	2.0	16.66
Legs	2.2	2.1	4.55

problems were determined at three point scale ranging from just noticeable pain, moderate pain and intolerable pain. Table 5 demonstrates that workers while using existing weeding hoe accounted maximum pain in lower back (2.8), followed by upper back (2.6), upper arms (2.5), fingers (2.4), mid back (2.3) etc. Working with improved weeding hoe brought about significant reduction in pain relating to fingers (16.66%) followed by palms and wrist(14.29%), mid-back (13.04%), neck (12.5%) and upper back (11.54%). Lower back, elbow, lower arms, legs and upper arms also experienced some relief of pain.

Table 5 : Weeding efficiency of existing and improved weeding hoes

Sr. No.	Parameters	Existing hoe	Improved hoe
1.	Area covered (sq.ft)	900	995
2.	Weeding efficiency (%)	80	88.4

Weeding efficienty:

Weeding efficiency or output was assessed in terms of area covered under operation and weeding efficiency with both existing and improved weeding hoe. Coverage of land under operation with improved hoe was highest *i.e.*, 995 sq.ft as compared to existing hoe (900 sq.ft) within a given period of time. Furthermore, weeding efficiency of improved weeding hoe was 88.4 per cent and that of existing hoe was 80 percent. As per the efficiency, it was found that quality of work carried out with the help of improved weeding hoe was better than the existing hoe.

Conclusion:

From the foregoing discussion it can be concluded that improved weeding hoe was better than the existing weeding hoe since the efficiency was more, the decrease in the heart rate proved that improved weeding hoe was more effective and easy to handle. There was significant reduction of energy expenditure. The long handle of the hoe made the activity less tiring. Working with improved hoe resulted less strain on shoulder, arms and hands.

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