www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(6): 378-383
© 2021 TPI
www.thepharmajournal.com
Received: 07-03-2021
Accepted: 16-04-2021

Moonty Baruah
Department of Family Resource Management, College of Home Science, Assam Agricultural University, Jorhat 13, Assam, India

Nasima Farhana Ali
Department of Family Resource Management, College of Home Science, Assam Agricultural University, Jorhat 13, Assam, India

Nandita Bhattacharyya
Department of Family Resource Management, College of Home Science, Assam Agricultural University, Jorhat 13, Assam, India

Corresponding Author:
Moonty Baruah
Department of Family Resource Management, College of Home Science, Assam Agricultural University, Jorhat 13, Assam, India

Ergonomic intervention for digging in tea gardens

Moonty Baruah, Nasima Farhana Ali and Nandita Bhattacharyya

Abstract
Digging in tea fields is a seasonal activity and is mostly performed by male workers. The activity is tiring and time consuming. An attempt was made to improve the digging hoe to minimize the physiological cost of work while digging for higher productivity. The modified tool was ergonomically compared with the traditional 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 digging hoe was better than the existing one. There was a significant difference in the heart rate while using the existing and improved tool. Energy expenditure was found to be reduced, grip fatigue was decreased. The quality of work with improved digging hoe in case of both sub drain and main drain working was enhanced with less requirement of time.

Keywords: Physiological workload, perceived exertion, grip fatigue, range of motion, musculo-skeletal problem

Introduction

The tea industry of Assam is highly labour intensive and employs a large number of labour forces. Workers are engaged at every stages of production starting from nursery development to the packaging work. Many of the activities performed by the workers (mostly the field activities) demand a high degree of physical effort leading to early fatigue. Activities like weeding, digging, pruning etc. were though seasonal activities but found to be the maximum drudgery prone activities in tea fields (Bhattacharyya *et al*. 2005) [1]. The productivity of labour depends on the working condition and their health status. Therefore, to make their best way of work performance and increasing overall productivity it should be the main attempt to reduce the early fatigue and incidence of musculoskeletal problems. Hence, to increase efficiency in work performances, importance should be given on the working condition, design of the work tools and health of the workers as well as better facility for them.

In tea fields, digging activity is performed by male workers (for both sub-drain and main drain digging) and is perceived as very heavy activity. Hand tool, that is, hoe is used for digging (Fig. 6). While performing the activity the worker stands in forward bending position with arms outstretched to hold hoe and move. Workers found the posture uncomfortable. Mostly the hoes supplied to the workers in the tea fields are available in the local market, which are designed without following any ergonomic principles. While designing hoe for digging the essential design considerations are size of the blade, angle between shaft and the blade and the length of the handle. From the literature survey and due consultation with ergonomists, efforts were made to modify the existing hoe. The modified hoe (Figs. 6 and 7) was ergonomically evaluated. Study was limited to the tea garden of Jorhat district with an attempt to study the physiological workload while performing digging using existing and improved digging tools.

Methodology

Seven physically fit male workers without having any physical disability and chronic ailments were selected for the study. All the subjects were well-acquainted with the equipment and digging activity. The subjects carried existing tool in hand while going to field and improved tool was provided at the field. Experiment was carried out for 35 minutes for each of the tools with the below mentioned evaluation parameters. Design considerations for the modifying digging hoe are presented in Table 1.

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 is calculated with the help of the formulae given by Varghese *et al*. (1995) [2]:

Energy Expenditure (kJ/min^{-1}) = 0.159 X AHR (beats per min)-8.72

The workload was categorized as per the workload classification developed by Varghese *et al*. 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 Varghese *et al*. (1994) [2] 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 with both the existing and improved hoe.

Postural stress and range of motion

Postural analysis of the activity at lumbo sacral region was done using dual inclinometer. Dual Inclinometer was used to study the Range of Motion (ROM) of joints by relevant software. Postural stress was studied on the basis of total spinal range of motion at lumbo sacral region while performing the activity with both existing and improved weeding hoe.

Musculo-skeletal problem

The musculoskeletal problems faced by the workers while performing the digging activity was studied by using a three point rating scale along with the body map. It was studied in terms of severity of pains in different body parts, that is, just noticeable pain, moderate pain and intolerable pain.

Findings and Discussion

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. Mean age of the workers was 33 years having height and weight of about 161.07cm and 50.3 kg respectively (Table 2). Body mass index, an important indicator of energy adequacy, of worker was about 19.39. More than half of the respondents (57.14%) were having mesomorph body type followed by ectomorph (28.57%) and only 14.28 percent respondents were having endomorph body type (Fig. 1).
Regarding BMI classification, maximum respondents (42.85%) fall in the category of normal followed by 28.57 percent of them fall in the category of Chronic Energy Deficit grade-I and about 14.28 percent respondents fall in the category of Chronic Energy Deficit grade-II and Obese Grade I respectively (Fig. 2).

Physical fitness index and aerobic capacity

On the basis of PFI test maximum respondents (50%) were having high average physical fitness followed by good (40%). Only 10 percent respondents had low average physical fitness. Aerobic capacity (VO_2 max) was found to be 33.5 ml/kg/min (Table 2).

Physiological workload while performing digging using existing and improved digging tools

Physiological workload of the workers was determined on the basis of various parameters like average and peak heart rate, energy expenditure, total cardiac cost of work, rating of perceived exertion and ease of comfort during digging activity, that is, both sub drain and main drain.

Heart rate

While digging sub drain, average working heart rate (WHR) was 128.54 b.min^{-1} for existing hoe and 118.29 b.min^{-1} for improved one. Improved digging hoe resulted in 8 percent decrease in heart rate. Similarly, peak heart rate was also lesser with the improved digging hoe (127.78 b.min^{-1}) in comparison to existing digging tool (140.87 b.min^{-1}). Table 3 shows that there was 9.29 percent reduction in peak heart rate with improved digging hoe (Fig. 3).
Similar trend was observed in the digging of the main drain. Table 4 revealed that average working heart rate of workers during digging main drain with existing digging hoe was 130.71 b.min^{-1} and while using improved digging hoe there was decrease in heart rate (120.7 b.min^{-1}), that is, 7.65 percent. Average peak heart rate with existing and improved was 149.60 b.min^{-1} and 130.16 b.min^{-1} respectively which show 12.99 percent reduction over existing digging hoe.

Energy expenditure

The energy expenditure rate indicates the level of bodily stress. Table 3 shows that energy expenditure for digging sub drain with existing tool was 11.70 kJ.min^{-1} whereas with improved tool it was 10.06 kJ.min^{-1}. Significantly, there was 14.02 percent reduction in energy expenditure with the use of improved digging hoe. Similarly, the peak energy expenditure was reduced up to 15.21 percent in case of improved hoe (Fig. 5). The result regarding energy expenditure while digging the main drain illustrates that there was significant difference in energy expenditure with existing (12.06 kJ.min^{-1}) and improved (10.47 kJ.min^{-1}) digging hoe, that is, of 13 percent (Table 4). Similarly, peak energy expenditure was reduced up to 20.52 percent with improved digging hoe.

Physiological cost of work

The physiological cost of work (PCW) was calculated on the basis of TCCW and duration of the activity which was for 35 minutes (Table 3). The average TCCW of digging of sub drain with existing hoe was 1843.51 beats, which was decreased to 1627.1 beats with improved digging hoe. There were significant differences in TCCW of 214.41 beats between the existing and improved hoe. Likewise, the results regarding average PCW of digging sub drain shows that use of improved digging tool decreased average PCW by 11.72 percent over existing one (Fig. 5).

Rating of perceived exertion

The tea workers considered digging sub drain as heavy activity with existing hoe and moderately heavy in case of improved hoe. The result shows that the improved hoe significantly reduced 19.13 percent drudgery in terms of RPE over the existing digging hoe.

Ease of comfort

Digging sub drain with improved hoe was reported comfortable as compared with the use of existing hoe, which was uncomfortable.

Rating of perceived exertion

The workers reported digging of main drain (Table 4) as heavy with improved digging hoe (3.18) whereas it was considered as very heavy (4.14) with existing hoe. Improved digging hoe reduced 23.18 percent drudgery in terms of RPE over existing one.

Postural stress and range of motion (ROM)

For postural analysis as shown in Table 5, total spinal range of motion at lumbo-sacral region was observed by inclinometer while performing digging of sub drain and main drain with both existing and improved digging hoe. In case of sub drain, data shows that total spinal range of motion with improved digging hoe was relatively less that is 56.24° for average flexion and 31.5° for average extension rather than existing digging hoe where average flexion was 60.7° and average extension was 31.5°.

As regards to extremity range of motion, upper extremity in particular, it was found that in case of shoulder joint average flexion and extension was less (98.35° and 47.34° respectively) with improved hoe in comparison to existing digging hoe for a sub drain where average flexion and extension was recorded as 103° and 50.6° respectively. Similar observations were made for wrist, where deviation of flexion and extension was less with improved digging hoe (92.6° and 46.7° respectively) than with existing digging hoe (95.2° and 50.42° respectively).

Moreover, as regards to main drain it was observed that the upper extremity range of motion of shoulder joint and wrist showed that the use of improved digging hoe moderately reduce degrees of flexion and extension, that is, 102.6° and 49.75° respectively in case of shoulder joint and 93.14° and 48.3° respectively for wrist. Whereas with existing digging hoe, it was found that average flexion and extension of shoulder was 106.75° and 52.8° respectively and that of wrist was 96.3° and 51.77° respectively.

It was evident from the findings that there was significant difference in total spinal ROM between existing and improved digging hoe resulting in reduction of postural stress in case of improved hoe to a desirable extent. Moreover, deviation of shoulder joint and wrist of the workers was reduced to a moderate degree in case of improved digging hoe for both sub drain and main drain.

Musculoskeletal problems faced

Table 6 illustrates that workers while using existing digging hoe reported maximum pain in lower back (3.0), followed by upper back (2.8), upper arms digging (2.6), shoulder joint (2.4) etc. Using improved digging hoe lead to significant reduction in pain relating to lower back and palms (13.33%) followed by fingers (12%), neck (11.11%), upper back (10.71%) and lower arms (9.09%). Legs, shoulder joint, mid back and upper arms also felt some relief of pain.

Digging efficiency

The digging efficiency with improved digging hoe was comparatively increased, that is, 17.5 ft. in case of sub drain and 12.75 ft. for main drain in terms of distance covered under operation as compared to existing hoe (15.5 ft. for sub drain and11.7 ft. in case of main drain). The quality of work with improved digging hoe in case of both sub drain and main drain was enhanced with less requirement of time. Moreover, improved digging hoe resulted in more distance coverage leading to more productivity/work output.

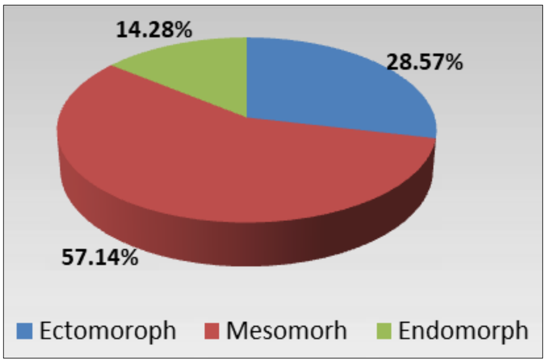

Fig 1: Body type

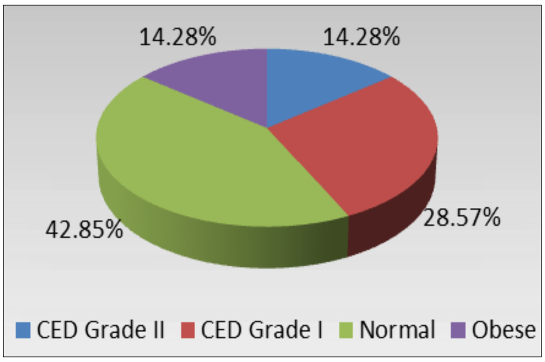

Fig 2: Body mass index

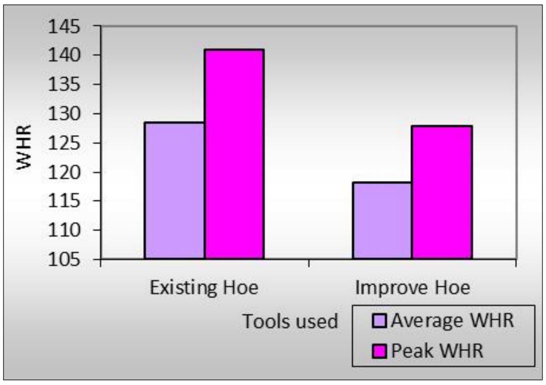

Fig 3: Average and peak WHR (Sub drain)

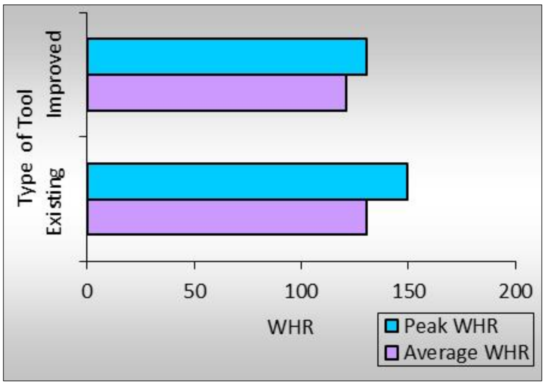

Fig 4: Average and peak WHR (Main drain)

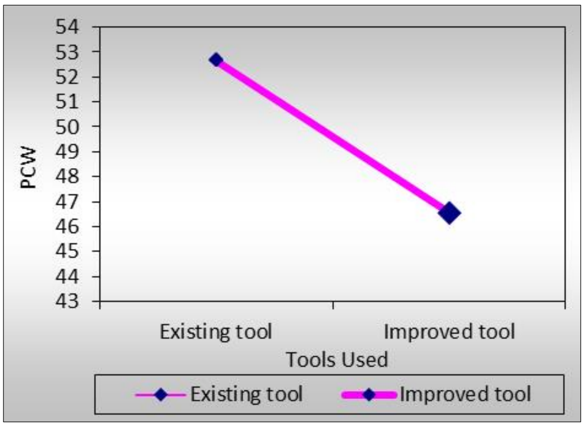

Fig 5: Average physiological cost of work

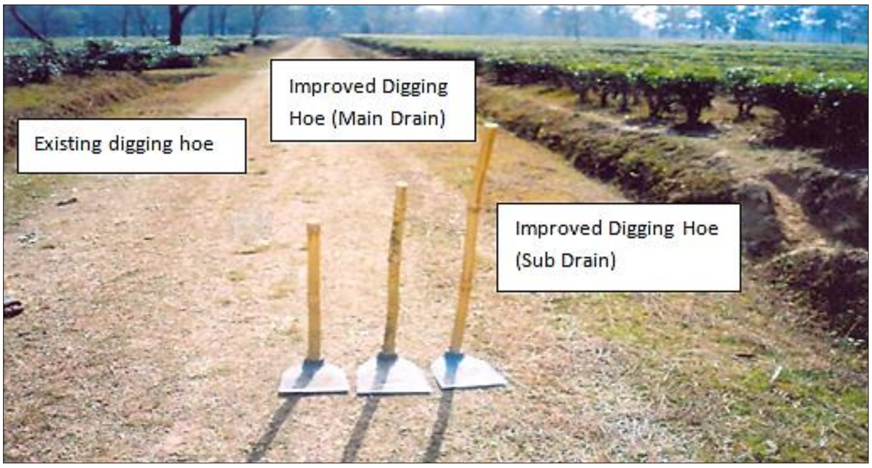

Fig 6: Existing and improved digging hoes

Fig 7: Improved blades for digging main drain and sub drain

Table 1: Physical features of the different digging hoes

S. No.	Specifications	Existing tool		Improved tool	
		Sub drain	Main drain	Sub drain	Main drain
1	Weight (kg)	2.60	2.76	2.55	2.45
2	Blade size: Length × Width (cm)	28 × 18	30 × 20	31 × 21	28 × 20
3	Handle length (cm)	102	80	110	90
4	Handle circumference	10.5	11.5	11	11
5	Angle	75°	75°	70°	70°
6	Material used	Iron with bamboo handle		Iron with bamboo handle	
7	Source	Local artisan		Local artisan	

Table 2: Physical characteristics of the workers (N = 7)

Name code	Age (years)	Weight (kg)	Height (cm)	BMI (kg/m^2)	VO_2 max (mL/kg/min)
SUB1	33	48	162	18.32	28
SUB2	40	48	158	19.2	34
SUB3	35	50	162	19.1	36
SUB4	27	46	162.5	17.42	23
SUB5	32	47	160	18.36	27

SUB6	28	52	162.5	19.7	43
SUB7	36	61	160.5	23.6	28
Mean	33	50.3	161.07	19.39	33.5
±SD	1.7	4.7	1.5	2.4	4.02

Table 3: Physiological workload while performing digging (sub drain) activity using existing and improved hoe

Parameters	Existing	Improved	Significant reduction in improved over existing (%)	F value	CD
Average WHR (b.min-1)	128.54	118.29	-10.25 (7.97)	41.43 **	3.47
Average peak HR (b.min-1)	140.87	127.78	-13.09 (9.29)	66.67 **	4.83
Average EE (kJ.min-1)	11.71	10.08	-1.63 (13.92)	45.46 **	0.53
Peak EE (kJ.min-1)	13.67	11.59	-2.08 (15.21)	30.92 **	0.95
Average TCCW	1843.51	1629.1	-214.41(11.63)	333.53 **	25.82
Average PCW	52.67	46.55	-6.12 (11.61)	333.10 **	0.74
Average RPE	3.71	3.00	-0.71 (19.13)	3.02 *	0.46
Ease of comfort	2.28	1.42	-0.86 (37.71)	9.82 **	0.60

*Significant, ** Highly Significant

Table 4: Physiological workload while performing digging (main drain) activity using existing and improved hoe

Parameters	Existing	Improved	Significant reduction in improved over existing hoe (%)	F value	CD
Average WHR (b.min-1)	130.71	120.7	-10.01 (7.65)	41.12 **	3.40
Peak HR rate (b.min-1)	149.60	130.16	-19.44 (12.99)	137.19 **	3.62
Average EE (kJ.min-1)	12.06	10.47	-1.59 (13.18)	43.51 **	0.53
Peak EE (kJ.min-1)	15.06	11.97	-3.09 (20.52)	136.27 **	0.58
Average TCCW	1872.12	1656.00	-216.12 (11.54)	115.92 **	42.52
Average PCW	53.49	47.31	-6.18 (11.55)	115.93 **	1.21
Average RPE	4.14	3.18	-0.96 (23.18)	7.20 *	0.70
Ease of comfort	2.28	1.28	- 1.00 (43.8)	14.7 **	0.57

*Significant, ** Highly Significant

Table 5: Postural analysis during digging with existing and improved hoe using inclinometer

Parameters	Total spinal range of motion (Lumbo-Sacral region)		Upper extremity			
			Shoulder		Wrist	
	Existing	Improved	Existing	Improved	Existing	Improved
Sub-drain						
Average Flexion	60.7°	56.24°	103°	98.35°	95.2°	92.6°
Average Extension	44°	31.5°	50.6°	47.34°	50.42°	46.7°
Main drain						
Average Flexion	62.83°	58.36°	106.75°	102.6°	96.3°	93.14°
Average Extension	49.16°	34.66°	52.8°	49.75°	51.77°	48.3°

Table 6a: Percent reduction in musculoskeletal problems using existing and improved tool while digging sub drain

Body parts	Existing	Improved	Significant reduction (%)
Neck	1.8	1.6	11.11
Shoulder joint	2.4	2.2	8.33
Upper back	2.8	2.5	10.71
Upper arms	2.6	2.4	7.69
Elbow	2.2	2.1	4.55
Mid back	2.4	2.2	8.33
Lower arms	2.2	2.0	9.09
Lower back	3.0	2.6	13.33
Wrist	1.6	1.5	6.25
Buttock	1.5	1.5	0
Knees	1.4	1.4	0
Palms	1.5	1.3	13.33
Fingers	2.5	2.2	12
Legs	2.3	2.1	8.69

Table 6b: Percent reduction in musculoskeletal problems using existing and improved tool while digging main drain

Body parts	Existing	Improved	Significant reduction (%)
Neck	1.8	1.6	11.11
Shoulder joint	2.5	2.3	8
Upper back	2.8	2.6	7.14
Upper arms	2.6	2.4	7.69

Elbow	2.2	2.1	4.55
Mid back	2.6	2.3	11.54
Lower arms	2.3	2.1	8.69
Lower back	3.0	2.8	6.66
Wrist	2.2	2.0	9.09
Buttock	1.8	1.8	0
Knees	1.5	1.5	0
Palms	1.6	1.4	12.5
Fingers	2.5	2.3	8
Legs	2.3	2.1	8.69

Conclusion

From the foregoing discussion it can be concluded that improved digging hoe was better than the existing digging hoe. There was a reduction in the heart rate and energy expenditure. The quality of work with improved digging hoe in case of both sub drain and main drain was enhanced with less requirement of time. Moreover, improved digging hoe resulted in more distance coverage leading to more productivity/work output. Therefore it is recommended that Improved Digging Hoe can be used in place of existing hoe (Specification given in Table 1).

Acknowledgments

The authors gratefully acknowledge the financial assistance received from NTRF, Kolkata.

References

1. Bhattacharyya N, Baruah SC, Borah R, Bhagawati P. Ergonomic Assessment of Working Postures Assumed by Workers in Tea Cultivation. Report submitted to National Tea Research Foundation, Kolkata 2005.
2. Varghese MA, Atreya N, Saha PN. A rapid appraisal of occupational workload from a modified scale of perceived exertion. Ergonomics 1994;37:485-491.