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Development and ergonomic evaluation of improved pruning knife for light pruning in tea gardens

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■ **ABSTRACT :** Pruning is a vital operation in tea gardens to limit the top growth and to rejuvenates the tea bush and brings it to growth of new pluckable shoots. Pruning is an exceedingly repetitive task and usually carried out with forceful exertion that involves movement of hand muscles, shoulder and wrist joint. In this study, an effort was made to modify the pruning knife used for light pruning activity in order to minimize drudgery involved in the activity and to increase work efficiency of the tea workers. It was limited to the light pruning activity only since it is the standard recurring pruning carried out in Assam. Thus, the present study is an attempt to ergonomically evaluate drudgery involved in light pruning activity using conventional and improved pruning knives. Eight physically fit tea workers (four male and four female) without having any physical disability and chronic ailments were selected for the field trial of the improved pruning knife. The results showed that improved pruning knife was found to be very effective in reducing drudgery of tea workers in terms of physiological workload, grip fatigue and musculoskeletal problems as compared to existing pruning knife. The curved or 'S' shaped handle of the improved knife makes the workers to grip it comfortably with lesser shocks while striking the tea bushes. In addition, the weight of the improved knife was kept balanced between blade and handle which allows the workers to prune effortlessly with clean cut.

■ **KEY WORDS :** Physiological workload, Rating of Perceived Exertion, grip fatigue, musculoskeletal problems, pruning efficiency

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Tea is indigenous to India and is an area where the country can obviously take a lot of pride. India is one of the major producer, consumer and exporter of tea. The tea industry provides employment to more than 1.1 million Indian workers. It occupies an important role in the Indian economy not only due to its capacity to earn foreign exchange, but also because it has lot of impact on the livelihoods of scores of people employed directly and indirectly by the industry. Hence, this industry is highly labour intensive industry where both male and female workers are engaged. Activities like weeding, digging, pruning etc. were found to be the maximum drudgery prone activities in tea cultivation (Bhattacharyya, 2005). Pruning is a worker intensive operation which requires a certain degree of skill to ensure that the pruning height parameter is being followed and also that the cuts should be clean and that the wood is not split.

Pruning is the cutting of branches of a tea bush at a pre-determined height and at a specified interval in order to reinvigorate and bring tea bushes within reach of the pluckers. Pruning is an exceedingly repetitive task. Repetition of stress is especially considerable as the worker never prunes with both the hands alternately. In pruning operation, the movement of hand muscles, shoulder and wrist joint are very extensive and repetitive with forceful exertions. Since the use of human power is extensive in operating farm tools and machinery, the assessment of work methods and tools is a potent factor to suggest performance improvement of the workers (Nag and Nag, 2004). In almost all the surveyed tea gardens, regardless of stages of pruning, the activity was found performed by using knives having 8 inches blade. But from the literature survey it was found that for different stages of pruning, different sizes of blades should be used. As regards to handle of the knife no principles were seen followed while fixing to the blades and there was no specific dimension of the handle as well. The use of inappropriate tools and

Table A : Physical features of the different pruning knife

Sr. No.	Specifications	Existing knife	Improved knife
1.	Weight (g)	440	400
2.	Blade size (inch)	8	6
3.	Handle length (inch)	6	No particular size
4.	Handle circumference (cm)	9	9.7
5.	Material used	Iron with wooden handle	Iron with wooden handle
6.	Source	Local artisan	Local artisan

techniques by the tea pruners adversely affect their health, safety and work efficiency. In the present study, an attempt was made to modify the presently used knives. Among the various types of pruning, light pruning is the standard recurring pruning carried out in Assam, hence, it was considered for modification of tool.

METHODOLOGY

Eight physically fit tea workers (four male and four female) without having any physical disability and chronic ailments were selected for the field trial of the improved pruning knife. All of them were given practice with three types of pruning knife with different specifications for 3 days before starting the trials. The experiment was conducted for the period of three months from January to March 2010 in Kakajan tea estate under Tata Tea Limited of Jorhat district. The experiment was performed with eight healthy (four male and four female) subjects. All the subjects were well acquainted with the equipment and pruning operation. The subjects carried existing tool in hand while going to field and improved tool was provided at field. Experiment was carried out for 35 min for each of the tool. From the survey it was found that in almost all the surveyed tea gardens, the workers were found using knives with eight inches blade almost for all types of pruning. Handles were used to be fixed to the blades without considering the comfort of the users. In the present study while modifying the knife emphasis was put on the design of the handle. In all the three designs, handle weight was kept equal to the blade weight. The modified knife was compared with the mostly used knife. Design consideration for the modified pruning knife is presented in Table A.

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. Measuring the heart rate (pulse) is a useful way of assessing the real workload. It is also the simplest way to assess the strain on the worker. Based on heart rate values, energy expenditure is calculated with the help of the formulae given by Varghese *et al.* (1994):

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

The workload was categorized as per the workload classification developed by Varghese *et al.* (1994) 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) 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 for the right or the left hand whichever is used by the workers while performing the pruning activity.

Musculoskeletal problem:

The musculoskeletal problems faced by the workers while performing the pruning 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 *i.e.*, just noticeable pain, moderate pain and intolerable.

RESULTS AND DISCUSSION

The results of the present study as well as relevant discussions have been presented under following sub heads:

Health status of workers :

The workers under the study had an average age of 24.75 years in case of male and 28.75 years for female. The average weight and height of the workers was found to be 49.75 kg and 160 cm in case of male workers and that of 43.75 kg and 151.25 cm for female workers, respectively (Table 1). Result regarding BMI shows that both male and female workers fall in the category of normal weight *i.e.*, 19.41 kg/m^2 (male) and 19.12 kg/m^2 (female).Regarding body type, cent per cent of male workers were having ectomorphic body type whereas in case of female tea workers, it was found that 75 per cent

Table 1 : P hysical characteristics of the workers

Name code	Age (years)	Weight (kg)	Height (cm)	BMI (kg/m^2)	VO_2 max (ml/kg/min)
SMP1	23	48	152	20	30
SMP2	24	50	149	18.91	28
SMP3	27	52	163	18.8	32
SMP4	25	49	158	18.85	29
Mean	24.75	49.75	160	19.41	33.5
±SD	1.5	1.9	1.9	0.3	3.4
SFP1	35	46	159	18.97	38
SFP2	22	42	160	19.53	35
SFP3	30	44	153	19.55	29
SFP4	28	43	151	19.63	32
Mean	28.75	43.75	151.25	19.12	29.75
±SD	4.7	1.5	1.5	0.5	1.5

SMP indicates male and SFP indicates female workers

of the workers were having ectomorphic body type followed by mesomorphic body type (25%). Regarding BMI classification, cent per cent of the male respondents fell in the category of normal weight and in case of female, it was found that maximum of the respondents (75%) fell in the category of normal weight followed by only 25 per cent that fells in the category of obese (Grade I).

Physical fitness index and aerobic capacity :

Physical fitness index on the basis of step stool test exhibited that majority of the male respondents (75%) were having good physical fitness (Fig. 1) followed by high average (25%). However, with regards to female tea workers (Fig. 2), it was found that 75 per cent had high average physical fitness followed by good (25%). Physical fitness of workers with respect to aerobic capacity indicated that average aerobic capacity (VO_2 max) was found to be 33.5 ml/kg/min for male and 29.75 ml/kg/min in case of female tea workers (Table 1).

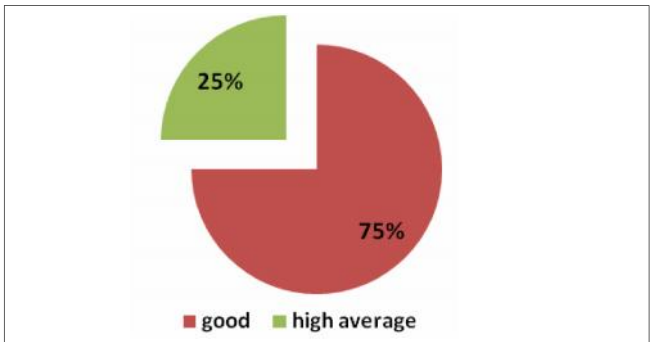

Fig. 1 : Physical fitness index of male workers

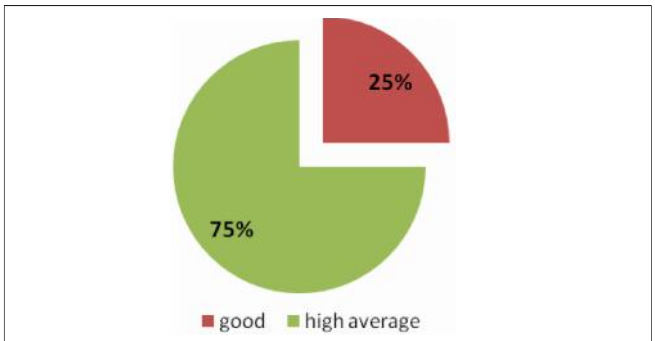

Fig. 2 : Physical fitness index of female workers

Physiological workload while performing pruning by using different pruning knives:

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 light pruning, the average heart rate (beats/min) of the male workers was recorded as 118.23 b/min by using existing pruning knife and 112.95 b/min with improved pruning knife. Table 2a shows that there was significant reduction in average heart rate of 4.46 per cent for male workers while working with improved knife over existing one. Similarly, average heart rate of female workers was found to be high while using existing pruning knife (123.45 b/min) as compared to improved pruning knife (118.65 b/min). Significant reduction in average heart rate of about 3.89 per cent was observed in case of female workers with the use of improved knife (Table 2b).

Correspondingly, peak heart rate of male workers was found to be maximum *i.e.*,126.5 b/min while working with existing pruning knife as compared to improved pruning knife (123 b/min). There was 2.77 per cent of reduction in peak heart rate in case of improved pruning knife over existing one. Also, the peak heart rate of female workers decreased

with the use of improved pruning knife *i.e.*, 3.59 per cent reduction while using improved knife over existing one.

Energy expenditure:

Energy expenditure was calculated on the basis of average and peak heart rate. From Table 2a and 2b, it was observed that improved pruning knife lessened energy expenditure of male and female workers on an average (9.24 kJ/min and 10.14 kJ/min, respectively) as compared to existing pruning knife (10.08 kJ/min and 10.91 kJ/min, respectively). Thus, significant reduction in energy expenditure was found *i.e.*, 8.33 per cent for male and 7.06 per cent for female workers by using improved pruning knife as compared to existing knife. Peak energy expenditure of both male and female workers was also reduced while working with improved pruning knife.

Total cardiac cost of work (TCCW) and physiological cost of work (PCW):

Table 2a and 2b exhibits that the average TCCW of male workers and female was found to be highest while using existing pruning knife (1534.77 beats and 1601.98 beats, respectively) as compared to improved knife (1480.33 beats and 1527.58 beats, respectively). Likewise, the average PCW of male workers by using improved and existing pruning knife was found to be 43.85 beats and 42.29 beats, respectively. Moreover, the average PCW of female workers was more during pruning with existing knife (45.77 beats) as compared to improved knife (43.65 beats). Further perusal of Table 2a reflects that significant reduction of nearly 3.56 per cent in terms of TCCW and PCW was recorded for male workers while working with improved pruning knife over existing one. Besides, in case of female workers, Table 2b exhibits that significant reduction of 7.64 per cent and 4.63 per cent was observed while pruning with improved knife over existing with respect to TCCW and PCW, respectively.

Rating of perceived exertion (RPE):

As regards to RPE data (presented in Table 2a and 2b) reveals that light pruning was perceived as moderately heavy activity while working with improved pruning knife (3) by both male workers and female workers. On the other hand, it was found heavy with existing pruning knife (3.15 and 3.75) by both male and female workers, respectively. As a result, 20 per cent and 4.76 per cent of reduction was found in terms of RPE with improved knife over existing knife of female and male workers, respectively

Ease of comfort:

Regarding ease of comfort, it was noticed that LP

Table 2a : Physiological workload while performing light pruning (LP) activity using existing and improved knife(male)

Parameters	Existing	Improved	Significant reduction in improved over existing (%)	F value	CD
Average WHR (b.min^{-1})	118.23	112.95	-5.28 (4.46)	30.36 **	2.34
Peak HR (b.min^{-1})	126.5	123	-3.5 (2.77)	9.8 *	2.74
Average EE (kj.min^{-1})	10.08	9.24	-0.84 (8.33)	30.25 **	0.37
Peak EE(kj.min^{-1})	11.39	10.84	-0.55 (4.83)	31.08 **	0.25
Average TCCW	1534.77	1480.33	-54.44 (3.55)	4220.68 **	2.05
Average PCW	43.85	42.29	-1.56 (3.56)	3540.41**	0.06
Average RPE	3.15	3.00	-0.15 (4.76)	2.08 **	0.14
Ease of comfort	2.5	1.0	-1.5 (60.00)	6.08 *	1.05

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 2b : Physiological workload while performing light pruning (LP) activity using existing and improved knife (female)

Parameters	Existing	Improved	Significant reduction in improved over existing (%)	F value	CD
Average WHR (b.min^{-1})	123.45	118.65	-4.8 (3.89)	34.73 **	1.99
Peak HR (b.min^{-1})	132.25	127.5	-4.75(3.59)	6.19*	4.67
Average EE (kj.min^{-1})	10.91	10.14	-0.71 (7.06)	35.26**	0.32
Peak EE(kj.min^{-1})	12.31	11.53	-0.78(6.34)	3.90 **	0.78
Average TCCW	1601.98	1527.58	-74.4 (7.64)	16.45 **	44.88
Average PCW	45.77	43.65	-2.12 (4.63)	16.49**	1.28
Average RPE	3.75	3.00	-0.75 (20.00)	3.17 **	0.68
Ease of comfort	2.8	1.25	-1.55 (55.35)	9.13 *	0.69

* and ** indicate significance of values at P=0.05 and 0.01, respectively

activity with improved pruning knife has been found 'very comfortable' by male workers and 'comfortable' by female workers as compared to the existing pruning knife which was ranked uncomfortable. It was due to the fact that the curved or slightly S shaped handle of improved pruning knife allows the workers to grip the knife comfortably. In addition, the knob provided at the end of the handle prevents it from slipping out of grip (Fig. 4).

Grip fatigue :

While performing pruning activity, excessive hand exertion is required, results in grip fatigue. Table 3 reflects that reduction of grip strength of workers was more with existing pruning knife as compared to improved knife after work for both male and female workers. A perusal of Fig.3 shows that grip fatigue of male and female workers were comparatively less with improved pruning knife *i.e.*, 8.35 per cent and 10.77 per cent, respectively as compared to existing knife (11.43% and 12.75%, respectively). It can be concluded that the curved shaped handle of improved knife absorbs shocks partly that arises when it strikes to the tea bushes as well as gets well fitted with handgrip causing less fatigue as compared to existing one. The balanced weight between blade and handle of improved knife facilitates the workers to perform the activity efficiently without causing much strain on palm and wrist.

Table 3 : Grip strength while using existing and improved pruning knife

Parameters	Existing		Improved	
	Male	Female	Male	Female
At rest	21	15.3	20	15.5
After work	18.6	13.35	18.33	13.83

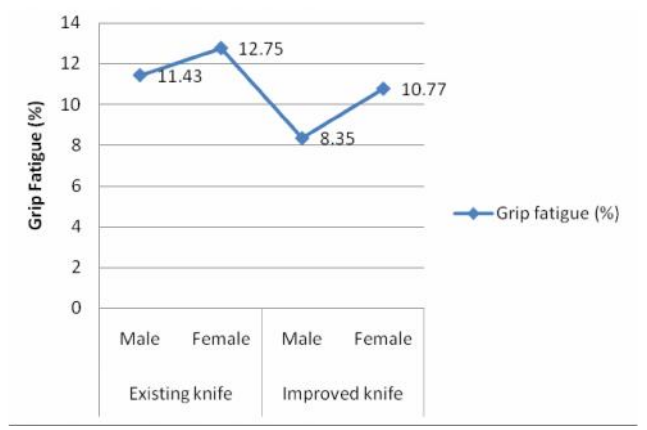

Fig. 3 : Grip fatigue of workers while working with existing and improved pruning knives

Fig. 4 : Improved pruning knife for light pruning

Musculoskeletal problems :

Musculoskeletal impairments impact significantly on the population, the health care utilization and the cost for society. The workplace is a significant source of occupational injury, occupational illness and related disability. The ILO estimates that 40% of all costs related to work-related injuries and diseases are due to musculoskeletal disorders (Rajgopal, 2000). From Tables 4a and 4b, it was found that both male and female workers reported intolerable pain in upper arms (2.8) while using existing pruning knife followed by shoulder joint, upper back, elbow, fingers etc. Using improved pruning knife lead to significant reduction in musculoskeletal problems concerning to fingers, palms, wrist and shoulder joint. In case of male workers maximum reduction in pain was seen in fingers (25%) and for female reduction was observed in palms (18.18%).

The corresponding results regarding muscular pain shows that there was significant reduction in wrist, shoulder joint, upper arms and lower back of both male and female

Table 4a : Per cent reduction in musculoskeletal problems using traditional and improved knife while performing light pruning (male)

Body parts	Traditional	Improved	Significant reduction (%)
Neck	2.0	1.8	10
Shoulder joint	2.6	2.3	11.54
Upper back	2.5	2.3	8
Upper arms	2.8	2.5	10.71
Elbow	2.4	2.3	4.16
Mid back	1.6	1.3	18.75
Lower arms	2.5	2.3	8
Lower back	1.8	1.6	11.11
Wrist	2.2	1.8	18.18
Palms	2.0	1.6	20
Fingers	2.4	1.8	25

Table 4b : Per cent reduction in musculoskeletal problems using traditional and improved knife while performing light pruning (female)

Body parts	Traditional	Improved	Significant reduction (%)
Neck	2.0	1.8	10
Shoulder joint	2.7	2.4	11.11
Upper back	2.6	2.4	7.69
Upper arms	2.8	2.6	7.14
Elbow	2.4	2.3	4.16
Mid back	1.8	1.5	16.66
Lower arms	2.5	2.3	8
Lower back	2.0	1.8	10
Wrist	2.4	2.0	16.66
Palms	2.2	1.8	18.18
Fingers	2.4	2.0	16.66

tea workers with the use of improved knife.

Pruning efficiency :

Efficiency of work is always referred to the output and the quality of inputs required. In pruning, it was observed that with the help of improved pruning knife the workers were able to prune 8.5 numbers of bushes on an average out of 10 numbers of bushes within a given period of time. However, pruning with existing knife showed that 7.25 numbers of bushes on an average were pruned. While assessing pruning efficiency, it was found that with improved pruning knife the efficiency counted was 87.5 per cent and that of with existing knife was 75 per cent. The difference in work output and efficiency may be due to the fact that curved shaped handle of the knife proved to be more comfortable to grip and workers' friendly resulting in better productivity with less requirement of energy and time (Fig. 5).

Fig. 5 : Pruning with improved knife by tea worker

Conclusion:

The ergonomic evaluation of light pruning of tea plants using improved knife showed positive outcome overall in terms of physiological workload, grip fatigue, musculoskeletal problems and work efficiency as compared to existing pruning knife. Improved pruning knife proved to be very effective in reducing drudgery to a desirable level. This is, of course, due to the curved or slightly S shaped handle of the knife which makes the workers to grip comfortably with lesser shocks while striking the tea bushes. Further, the weight of the improved knife was kept balanced between blade and handle which allows the workers to prune effortlessly with clean cut. Conclusively, the improved pruning knife proved to be very compatible to the tea workers.

Recommendations:

Use of proper blade size and handle of the pruning knife for different types of pruning is highly recommended by the tea workers. The design specifications of any tool must meet the ergonomic standards in order to eliminate occupational health hazards of the workers and to augment better work performance and productivity as well.

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