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Performance Evaluation of Selected Coconut Tree Climbing Practices Based on Ergonomic Considerations

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The traditional way of climbing coconut tree is quite tedious, risky and requires lot of skill. Difficulty in getting the services of skilled climbers in time and their high wage are thus perceived as important constraints. Tree climbing devices developed to facilitate ascending and descending of coconut tree. The available coconut tree climbing devices *viz*., FIM (CT_1), Commercial (CT_2) and Kerala (CT_3) models were ergonomically evaluated for assessing the suitability of the user. Ergo refinements were carried out in CT_1-model for enhanced comfort, safety and ease of operation of the user. The ergo refined coconut tree climbing device (CT_4) enhanced the comfort and safety of male subjects with 7.8, 12.2, 10.7 and 20.5 per cent reduction in Heart rate, Energy expenditure, Overall Discomfort Rating and Body Part Discomfort Score respectively and 2.6 and 4.1 per cent increase in Overall Safety and Ease of Operation Rating respectively when compared to CT_1.

Key words: Ergonomics, Coconut tree, Climbing device.

Skilled workers commonly climb to harvest the coconuts from the tree. The coconut trees are very high, and fall can result in severe injury. Injuries associated with coconut tree climbing, particularly fall from coconut trees are common in coconut plantations of Tamil Nadu. The workers employed for climbing coconut tree suffer musculoskeletal disorders than any other type of injury or illness. With sufficient attention to the larger goals of whatever work is underway, investments in ergonomics can often pay for themselves many times over.

Pashupathy (1984) developed a three wheeled petrol engine operated tree climber. A steel rope hanging from top of the palm tree was fastened to the machine. The climbing was accomplished by winching up the machine by using the steel rope. Control was done through the engine clutch. Joseph (2006) developed a coconut-climbing device having two frames (left and right). Each frame was having flexible adjustable encircling iron rope mounted around a tree and tree gripping rubber pad. The two main frames were fitted on the tree side by side enabling the operator to lift the frames conveniently using the sliding member. Laborde (2006) developed a climbing tree stand apparatus with upper and lower platforms that were independently movable up the tree by under alternatively sitting and standing on one or the other of the platforms. Mohanty *et al.* (2008) reported that modification carried out on women operated pedal thresher with help of ergonomics consideration and significant reduction in physiological cost of work on ergonomic evaluated pedal thresher.

Materials and Methods

The practices of coconut tree climbing selected for ergonomic evaluation are furnished below. The operational view of tree climbing devices are shown in Fig.1.

i. FIM model - CT_1,

ii. Kerala model - CT_2 and

iii. Commercial model - CT_3.

Twelve male coconut plantation workers were selected as subjects for the investigation. The subjects were screened for normal health through medical investigations. The age, weight and height of the selected male subjects were 32±2.6 years, 58.8±4.5 kg and 165.5 ±.6.8 cm respectively. The selected twelve male subjects were calibrated in the laboratory by indirect assessment of oxygen uptake. Ergonomical evaluation of the selected coconut tree climbing practices was conducted for assessing the suitability of the user with respect to comfort, safety and ease of operation. The evaluation was carried out with the twelve selected subjects interms of heart rate (HR), oxygen consumption rate (OCR), energy cost of operation (ECR), acceptable work load (AWL), limit of continuous performance (LCP), over all discomfort rating (ODR), over all safety rating (OSR), over all ease of operation rating (OER) and body part discomfort score (BPDS).

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Fig.1. Operational view of CT_1, CT_2 and CT_3 models

The heart rate data was recorded using computerized heart rate monitor (Polar S 810i). From the down loaded data, the energy cost of operation of the selected tree climbing practices were computed for all the subjects. The mean values of heart rate, oxygen consumption rate and the energy expenditure rate for all the subjects were computed for performing coconut tree climbing operation with selected practices. The energy cost of subjects for the operation of selected coconut tree climbing practices thus obtained was graded as per tentative classification of strains in different types of jobs according to the young Indian male workers given in ICMR report (Sen, 1969). The acceptable workload (AWL) for Indian workers was the work consuming 35 per cent of VO_2 max (Saha *et al.,* 1979). To ascertain whether all the selected coconut tree climbing practices are within the acceptable workload (AWL), the oxygen consumption rate in terms of VO_2 max was computed. To have a meaningful comparison of physiological responses, work pulse ("H) values (Increase over resting values) were calculated. The mean values of work pulse for coconut tree climbing operation were compared with the acceptable work pulse values of 40 beats min^{-1} as Limit of continuous performance.

Fig.2. Adjustable and pivotable seat

For the assessment of overall discomfort rating (ODR), localized discomfort (BPDS), over all safety rating (OSR) and over all ease of operation rating (OER), a 10 - point psychophysical rating scale was used which is an adoption of Corlett and Bishop (1976) technique. The work time was fixed as 60 minutes of operation. At the end of each trial with the selected coconut tree climbing practice, the subject was asked to indicate their level on the 10-point rating scale. The indicated values given by each of the twelve male subjects were recorded and mean value was computed.

Results and Discussion

A comparison of the CT_1, CT_2 and CT_3 model was made to ascertain the improved comfort, safety and ease of operation and the values are furnished in Table 1.

Table 1. Comparison of ergonomic parameters of selected coconut tree climbing devices

Parameter	Coconut tree climbing practices		
	CT_1	CT_2	CT_3
Heart rate, beats min^{-1}	138	144	141
Energy expenditure, kJ min^{-1}	28.6	30.7	30.1
Grading of energy cost	Heavy	Very heavy	Heavy
Work pulse ("H), beats min^{-1}	51.8	59.0	69.2
AWL	62.2	66.3	67.7
LCP	51.8	56.7	59.0
ODR	5.6	6.7	6.3
Over all safety rating (OSR)	7.8	7.2	6.2
Ease of operation rating (OER)	7.2	7.3	6.9
BPDS	41	45	44

Ergo refinements

Among the three models of coconut tree climbing devices, CT_1 model recorded the lower value of physiological cost and reduced discomfort and higher values of safety and ease of operation. Based on the result and feedback analysis from the user, the following ergonomic refinements were incorporated in the CT_1 model for enhanced comfort and safety of the user.

Fig.3. 'U' shaped gripping member

The flexible sagging type rexin fabric seat was replaced with rigid seating arrangement (Fig.2) to enable the user to exercise firm grip in lifting the unit. The rigid base section carries a seat, front support rail, concave rear rail and side rail. The device offers the user the side support in any direction, thus

Table 2. Specification of Ergo refined tree climbing device

Particulars	Values
Over all dimensions of upper frame (L x B x H), mm	1030 x 520 x 730
Over all dimensions of lower frame (L x B), mm	650 x 510
No of adjustment in extendable 'U" frame, mm	5 steps between 225- 410
Length of safety strap, mm	840
Weight of the upper frame, kg	9.7
Weight of the lower frame, kg	4.0

eliminating the danger of falling down when the user ascends or descends the tree. The seat is adjustable towards and away from the back rest and pivotable relative to the upper frame so that the user can choose convenient position for comfort. The concavity of the rear cross rail accommodates the back of the user. Since the spacing between the gripping aids is not automatically adjustable in both upper frame and lower frame, the optimum angle of the two members relative to the upright coconut tree trunk cannot be maintained throughout the ascent and /or descent. With increase in height of tree, the diameter of coconut tree trunk decreases. The inclination of upper frame of coconut tree climbing device (CT_1) with respect to horizontal increases.

Fig.4. Ergo refined coconut tree climbing device fitted in tree

The centre of gravity of the user shifts outside of the body and the user feels insecure and unstable. The upper frame of coconut tree climbing device was suitably modified to avoid downward inclination. The

Table 3. Comparison of ergonomic parameters of CT_1 and CT_4 devices

Parameters	Coconut tree	Climbing device
	CT_1	CT_4
Heart rate, beats min^{-1}	138.1	127.3
Energy expenditure, kJ min^{-1}	28.6	25.1
Work pulse ("H), beats min^{-1}	51.8	43.8
AWL	62.2	54.5
LCP	51.8	43.8
ODR	5.6	5.0
Over all safety rating (OSR)	7.8	8.0
Ease of operation rating (OER)	7.2	7.5
BPDS	41	34

tree holding section with triangular gripping aids was replaced with telescopic 'I' section and 'U' shaped gripping member (Fig.3). The 'U' shaped member with one gripping aid and two gripping aids fitted in inclined cross rails of tree holding section in the form of "V" encircle the girth of coconut tree, aid in gripping the tree trunk with enough friction. Initially the upper frame is fitted in an inclined position towards the trunk of the tree. As the user ascends the tree, with decrease in diameter the upper frame becomes exactly horizontal and parallel to the ground. This prevents shifting of centre of gravity of user to unsafe position and ensures

Fig.5. Operational view of ergo refined coconut tree climbing device

stability. A back rest is also provided for additional safety of the user. To suit the convenience of the tree climber, the operator's work space in the coconut tree climbing device was modified (Fig.4), keeping

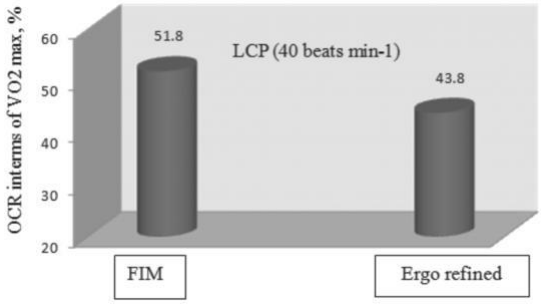

Fig.6. Energy expenditure in terms of VO_2 max for FIM and Ergo refined tree climbing device

the values of pertinent anthropometric dimensions of agricultural workers of Tamil Nadu. The specifications of ergo refined device are furnished in Table 2.

The ergonomical evaluation of ergo refined coconut tree climbing device with safety features (CT_4) was conducted (Fig.5) with plantation workers in coconut field.

A comparison of the CT_1 and CT_4 was made to ascertain the improved comfort, safety and ease of operation and the values are furnished in Table 3. Energy expenditure in terms of VO_2 max for CT_1 and CT_4 is depicted in Fig.6.

Among the three models of coconut tree climbing devices FIM model recorded the lower value of physiological cost and reduced discomfort and higher values of safety and ease of operation. Ergo refinements were carried out in coconut tree climbing device FIM model for enhanced comfort, safety and ease of operation of the user. The ergo refined coconut tree climbing device enhanced the comfort and safety of male subjects with 8.5, 14.2, 14.2, 14.2, 18.3, 11.4 and 21.3 per cent reduction in Heart rate, Oxygen consumption, Energy expenditure, Acceptable Work Load, Limit of Continuous Performance, Overall Discomfort Rating and Body Part Discomfort Score respectively and 2.6 and 4.1 per cent increase in Overall Safety and Ease of Operation Rating respectively when compared to existing model of tree climbing device CT_1.

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