DEVOLOPMENT AND TESTING OF A DOMESTIC COCONUT CLIMBER

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PROJECT REPORT

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DECLARATION

We hereby declare that this thesis entitled **"DEVOLOPMENT AND TESTING OF A DOMESTIC COCONUT CLIMBER"** is a bonafide record of research work done by us during the course of academic programme in the Kerala Agricultural University and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this project report entitled **"DEVOLOPMENT AND TESTING OF A DOMESTIC COCONUT CLIMBER"** is a record of project work done jointly by Mr. Jithu P Ajith, Mr. Prithviraj V, and Mr. Shivendra Patel under my guidance and supervision and that it has not previously formed the basis for any degree, diploma, fellowship or associateship or other similar title of another University or Society.

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05/02/2019

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SYMBOLS AND ABBREVIATIONS

Symbols	Abbreviations
<	Less than
>	Greater than
%	Per cent
±	Plus or minus
≤	Less than or equal to
≥	Greater than or equal to
A.R.S	Agricultural Research Station
A.W.L	Acceptable Work Load
cm	centimeter
et al.	and others
etc.	et cetera
Fig.	Figure
h	Hour
IS	Indian Standard
KAU	Kerala Agricultural University
KCAET	Kelappaji College of Agricultural Engineering and Technology
Kg	Kilogram
L.C. P	Limit of Continuous Performance
m	meter
M.A	Mechanical Advantage
mi	mile
ODR	Overall Discomfort Rating
OSR	Overall Safety Rating

OER	Overall Ease of operation Rating
Rs.	Rupee
s	second
Sl. No.	Serial Number
viz	Namely
VO_2 max	Maximum oxygen consumption
w.r.t	with respect to

INTRODUCTION

CHAPTER I

INTRODUCTION

Coconut is one of the most useful crops in the plant kingdom due to its multipurpose uses: it is called Kalpavriksha in Kerala which means "The tree of abundance". It is mostly cultivated in the Asian and Pacific countries and India is the largest coconut producing country owing 31per cent of the global production. The crop adds around Rs.2,50,000 million to the country's GDP and earns an export value of Rs. 43,654 million (Anon., 2016). Due to the advancement of health sector multiple nutritional and medical aspects have been uncovered each day, which increases the demand both in domestic and international markets.

In India, around 98 per cent coconut holdings are owned by small and marginal farmers. According to All India estimate for the year 2016-17, the area and production of coconut in the country are 2.069 million hectares and 22237.99 million nuts respectively. Of which 7,81,496 hectares belongs to Kerala which accounts 33.57 per cent at national level. (Anon., 2017)

The coconut production in Kerala is being decreased every day due to rapid urbanization. The cultivation in Kerala is mainly domestic based and a major part of the palms are retained even after their economic life. Hence, about 20 per cent of the trees are senile and unproductive. Natural calamities, insect and pest diseases, labor cost, and fluctuation of coconut prices due to its seasonal nature also causes reduced production and productivity.

This mainly leads to abandoning the coconut trees as an income and only use the products for household purposes, which promote the retainment of old palms. A typical Kerala house consumes one nut per day, thus the farmers do not spend money on maintaining and nurturing trees. To fulfill the daily needs, it is essential to harvest coconut at a domestic level rather than a commercial one. The present climbing charge per palm is around Rs.30-45 that also to just pluck the coconut without any maintenance of tree, the gathering of nuts and transportation charges are yet to be met. Thus, the need for a domestic climber becomes necessary.

The major lacuna encountered during the development of a model of the coconut climber is the shape of its trunk. The trunk is having twist and turns which is unpredictable in comparison to other trees. It thus become quite difficult to account for the unforeseen variation in the straightness of the palms. Considering of the phytomorphology of coconut palm, the trunk is devoid of any branches having only pinnately compound leaf which splits into leaflets later on. This further deepens the issue associated with the climbing equipment as anchorage of the equipment is to be addressed.

The irregularity of the trunk is yet another issue which is to be addressed. Unlike arecanut palm, the trunk of coconut tree is characterized by distinct ring-shaped section throughout the trunk which further occlude the motion of the climber up and down the trunk. Though the trunk of the arecanut palm has lesser cross-sectional diameter than a coconut palm, the former has an inherent advantage of being straight in case of the trunk. Also, the surface of trunk is regular in comparison with that of coconut palm. From the anatomy point of view, the trunk of coconut palm is devoid of cambium cells which aid in secondary growth stage of the plants. The damaged cell on the outer bark cannot thus be replaced. Hence the climber for the coconut palm should have a least damage on its trunk due to mechanical damage during its course of its motion. Therefore, the method by which the equipment is attached to the trunk is also a matter of concern. Any means of intensive mechanical damage to the trunk affect the health and thus productivity of the plant as it is the vascular cells which are affected during such motion of climbers. Another factor to be considered is the safety aspect of the person during climbing the palm. When the operator is in the phase of ascending or descending the palm, there should not be any chances of mechanical failure of the climbing device.

In spite of having a variety of models, one which compensate the most issues are not fully available. This is due to the fact that the palm present with a variety of matter and concern needed to be addressed during the design procedure. Further with the advancement of technology, designing an equipment (climber) operated with automated power may be easy but the practical application becomes limited due to its weight. Hence an optimum design should be made considering the overall weight of the machinery, the safety aspect associated with it and the operational easiness of the machine. An ergonomic evaluation of the climbers will be useful in judging these performances. There exist a few models developed by individual farmers and institutions for the purpose. The major drawbacks associated with coconut climbers are its weight and less safety measures. When the climber could overcome the above problems, its acceptance will be more among the farmers.

Keeping these in view, the present investigation entitled "Development and testing of a domestic coconut climber" has been planned and carried out with the following objectives:

- To study the available models of coconut climbers.
- To develop a domestic coconut climber.
- To test and compare its performance based on ergonomic procedures.

Review of literature

CHAPTER II

REVIEW OF LITERATURE

Various research works carried out in the past related to coconut climbers and its mechanisms were reviewed in this chapter. Many types of climbers were developed and tested in different parts of our country. To comprehend the research towards the development of coconut climbers, literature reviews were done and are listed below.

2.1 Coconut climber

Graham *et al.* (2003) developed a tree climber that includes a seating and standing sections, each consists of inclined attachment bars adjacent to the section sides, seating and standing section cables and having handles at its ends. The climber can be used for varying tree diameters by adjusting the cables and latch pin insertion. The working of climber involved simultaneous coordination between seating section and standing section. The climber was found acceptable from the safety point of view but operator's fatigue was the main concern.

Kawasaki *et al.* (2008) studied a novel climbing method of Pruning Robot. The pruning robot was designed in such a way that the center of mass of whole unit located outside which helped in providing eccentric loading and smooth vertical climbing of pruning robot. The study availed numerical simulations coupled with kinematic analysis to indicate the importance of eccentric loading. The main advantage of this robot was that due to light weight it was easy to drive it up with four wheels, each driven by an individual DC servomotor through a worm gear that has no back drivability. The machine also had some drawbacks which included inconsistent performance due to variable tree diameter from bottom to top and high cutting impact on cutting blade while pruning the branches.

Dileep *et al.* (2011) studied various methods and devices involved in climbing. It may be manual or mechanical. Manually, the climbing person wraps his arms around the trunk of the tree and by alternatively moving the feet and hand moves up. Mechanical methods employed two models- Siting and standing type. Standing type device (also called Chembery model), the common model found among the mass, consisted of two identical units which is to be coordinated simultaneously for climbing. The person stands on the unit wrapped around the tree by means of the steel rope. For moving up, the person lifts one of his legs simultaneously lifting the respective unit and loading it by applying force upon it. The process is repeated to achieve the required height. For moving down, the person loosens the unit by raising his leg placing the unit down at a distance by hand and loading it again by pressuring the unit. The process is repeated alternatively for the two units. Sitting type climbing device consist of two individual units- the upper unit in which the person sits and the lower unit for foot rest. The upper unit is to be lifted by hand while the lower unit by legs. The method of climbing involves the synchronized movement of the two units, loading one at a time.

Harikrishna *et al.* (2013) studied on design of climbing mechanism for a tree climbing robot. The concept of climbing mechanism was derived from the movement of Stomatopod (an organism). A prototype of robot was made and the efficiency of the slinky type gripper was tested on few trees. Also, software simulation (Adams software) was done for this mechanism which showed positive results in terms of power consumption and time. The whole unit consisted two main parts, one that hold the robot against the tree (gripper) and other responsible for climbing. The gripper assembly designed uses a flexible casing which grasps the tree trunk of variable tree diameter within the predefined range.

Mohankumar *et al.* (2013) modified the upper frame of TNAU climbing model by decreasing the inclination of upper frame with respect to horizontal. As a result of this modification the centre of mass of climbing person was shifted towards tree trunk that makes the climbing person feel secure and stable. The modified climbing model 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 previous model. The modified climbing model was ergonomically superior in terms of safety, ease of operation and overall comfort but the time required for the operation was found to be higher. The modified climber resulted in 20.6% savings in cost and 11.8% savings in time of climbing compared to previous model.

Mani *et al.* (2014) developed a semi-autonomous coconut climber and harvester which was named as Cocobot. Cocobot comprised a climbing unit and a harvesting unit. The climbing unit consisted of an octagon shaped frame with four active wheels and the harvesting mechanism had an arm with circular saw having three degree of freedom and the bunch of nuts was located by a vision sensor fitted on wrist of arm. The paper exposed the advantages in usage of eccentric loading. The analysis proved that the eccentric loading incorporates both safety as well as easiness in operation. The cost involved in the fabrication of the machine was much higher.

Senthikumar *et al.* (2015) designed and fabricated a prototype of an automated coconut climber. The device consisted of a rectangular aluminum frame, three tracked wheels, three high torque geared DC motors, two L293D drivers, and a transmitter. A 12V, 3000 mAh battery was used to supply power to the all electrical devices. The whole device was controlled by an operator from the ground. Three tracked wheels spaced at 120 degree, were driven by high torque DC geared motors and also provide stability to the frame. The frame along with a rotary blade arm was conveyed at the top of tree very quickly. The material for frame and other components were selected in such a way that the overall weight of the device was not much heavy. This device was analyzed using ANSYS software that revealed positive results in terms of strength and stability.

Rahul *et al.* (2015) conducted a static analysis of the design was done using ANSYS software to ensure new model and its stability. The material used was GI steel. Three linear electrical actuators were used in this mechanism two for gripping and one for the vertical up and down motions. Each actuator carried 400kg. Final analysis was done using ANSYS and proved the design to be safe.

Jaikumaran *et al*. (2016) designed and developed a sitting type coconut palm climbing device namely "Kera Suraksha Coconut Climber". The unit was made of mild steel, and weighed 9.35 kg. Its field performance and ergonomic evaluation were conducted. The total time taken by the operator to climb a 12 m height palm using the developed climbing device was 3.16 minutes. The angle of inclination of the upper metal wire rope, lower metal wire rope and seat with horizontal were found to be below the safe value of 400. The bearing capacity of the materials and climbing device as a whole was found to be 165 kg. The model developed was named

Azarudeen *et al.* (2018) designed and developed an automated coconut tree climber which was economical and user friendly. The device consisted of three main motors that are used to drive the body. The driver used to drive the motor was L298D which in turn controlled by a RF transmitter/receiver. The remote control was a simple RF transmitter/receiver module. Power supply for different components in the device was transmitted from the main power source, the battery, to the regulator to the receiver and finally to the motor drivers. The proposed concept was lighter than those existing by about 30 percent due to the aluminum used in its construction.

2.2 Block and tackle system

Schwartz and Ralphie (2007) worked on the calculation of forces in pulley and its mechanical advantage. The study exposed the mechanical advantage of pulley. It also computed the direction in which the forces transmitted throughout the system. The study emphasized the mechanical advantage of using the pulley system.

Attila *et al.* (2015) studied on the dynamic analysis of block–and–tackle suspension system. They provided an insight to the use of block and tackle system to handle the heavy loads particularly its capability on reducing the effort required for handling.

Reutov *et al.* (2016) investigated on the dynamic modelling of lift hoisting mechanism block pulley. The modelling involved the use of Lagrange equations for the motion of block and pulley. The study also employed the computer model of the Block pulley system. The study revealed that there was ease of operation of the Pulley system for lifting operations.

Quing and Ling (2015) studied the effect of wear of pulley grooves and interpret analytical form based on the Hertz Contact Theory and Finite Element Analysis. The study indicated the use of pulley rope along the bottom center of the web 30 should have thickness equal to the rim thickness.

2.3 Lifting devices

Shyam Lal Sharma *(*2013) designed a lifting crane mechanism using a rope and pulley system. The crane machine was designed for maximum load capacity of 50 tones by incorporating eight rope falls and four sheave pulleys which provides theoretical mechanical advantage of 8. The study recommended the efforts could be reduced by increasing the rope falls and number of pulleys but it led to increase in length of rope, time of lifting and cost of machine.

Mehmood and Mehdi (2014) studied on the design of a motor driven household vertical lift elevator. The system was the modification of an elevator driven by rope and pulley in which the cabin was replaced by a chair. Selection of each part such as pulley sheave, hoisting rope, sheave shaft, motor shaft etc. were done based on the stress analysis. It was found that application of rope and pulley system for lifting weight of chair with climbing person was very much suitable. The study emphasized the usage of pulley system for lifting heavy loads with less effort.

Amit Tiwary (2015) designed and developed a double acting winch type elevator as a material handling equipment. The machine consisted of an electric motor, wire rope, rope drum and buckets. The machine had an additional advantage over conventional elevators that it utilized the power loss that was being wasted while return stroke of the rotating drum by incorporating buckets at the both the ends of wire rope. The design had low initial and maintenance cost.

2.4 Ergonomic evaluation

The incorporation of ergonomic studies helps in improving the efficiency and productivity of operator without imperiling their health and safety. Some of the reviews with regard to safety and efficiency aspects were evaluated through ergonomic principles are given below.

Passmore and Durnin (1956) estimated the energy consumed by a man and reported that basal metabolism of an adult was 1900 Kcal. He assessed the energy requirement for metabolic activity of 8 non-working hours and 8 hours of bed rest and were obtained as 5000 kcal and 1400 kcal respectively.

Astrand *et.al.* (1965) observed that for continuous work lasting for at least 5-6 min, oxygen consumption equalled oxygen demand and during the last 2-3 min of activity, pulmonary ventilation, heart rate and other cardiovascular parameters were constant.

Sen (1969) graded the manual jobs based on the physiological responses of young Indian male and female workers. The classification of different types of jobs based on physiological responses are given in Table 2.1.

Table 2.1 Classification of the manual jobs based on the physiological responses of male subjects

Grading	Physiological response		
	Heart rate (beats min^{-1})	Oxygen uptake (lit min^{-1})	Energy Expenditure (kcal min^{-1})
Very light	<75	<35	<1.75
Light	75-100	0.35-0.70	1.75-3.5
Moderately heavy	100-125	0.70-1.05	3.5-5.25
Heavy	125-150	1.05-1.40	5.25-7.00
Very heavy	150-175	1.40-1.75	7.00-8.75
Extremely heavy	>175	>1.75	

Saha *et al.* (1979) conducted study on the acceptable workload for Indian workers. It was found that 35% of relative load (RL) could be considered as acceptable workload (AWL). The energy expenditure and the corresponding heart rate at this level of work was estimated around 18 kJ min^{-1} (gross) and 110 beats min^{-1} respectively.

NIOSH (1981) found the increase in physiological parameters depending upon the workload, during any physical activity and the maximum values that could be attained in a normal healthy individual will be up to VO_2 max.

Brian *et al.* (1998) concluded on his study of ergonomic evaluation of hand hoes for hillside weeding and soil preparation in Honduras that the application of ergonomics in conjunction with other disciplines to small farmer mechanization problems can give valuable insight into the difference between options and on their adoptability. Ergonomics is a vital element in the search for improved implement design for farmers working in marginal conditions.

Sanders and McCormick (1993) reported that heart rate was the best predictor of oxygen consumption when moderate to heavy work was performed. It was also concluded that heart rate sampled continuously for full working hours or for a particular work, was useful as general indicator of physiological stress without reference of oxygen consumption or energy expenditure. They found that for different people the linear relationship between heart rate and oxygen consumption was different. The study recommended the calibration process for each person to determine the relationship between heart rate and oxygen consumption.

Thyagarajan *et al.* (2012) stated that in order to improve the relation between the physical demands of the tools and worker, ergonomic evaluation of farm tools was necessary.

Kolhe and Patil (2014) assessed the drudgery and physiological cost involved in the traditional method of tree climbing operation. For recording the heart rate, the digital polar heart rate sensor was used. The technical assessment involved the use of ODR, BPDS and biochemical models. Testing of feasibility, ease of operation, workers jeopardize safety health and efficiency by ergonomic evaluation were carried out.

Materials and Methods

CHAPTER 3

MATERIALS AND METHOD

This chapter comprises the materials used and description of various methodologies and techniques adopted in the study. It includes the selection of materials required for the experiment, installation of experimental set-up, and the various methods and mechanisms used for conducting the study. The detailed description of the different component and methods used in the study are discussed below.

3.1 STUDY OF AVAILABLE CLIMBERS

3.1.1 Chembery model

Chembery model is one of the most acceptable and popular coconut climbers (Plate 3.1) in south India. This is a stand type model developed by Mr. M.J.Joseph, a farmer from Chemberi village of Kannur district in Kerala. The device has two frames (left and right). The main frame is made of 12 mm diameter mild steel rods. Each frame comprises an adjustable wire rope of 8 mm diameter and length 1060 mm mounted around the palm and palm gripping semi-circular pad made of worn out rubber tyre which is fitted around the tree trunk. One end of the wire rope is attached to the rubber pad and the other end is placed on adjusting holes to change the rope length according to girth of palm tree. The adjusting holes comprise of bolts and wing nuts to fasten the ropes. The main frames having the foot rest with safety straps to prevent accidental slip during climbing up and down. The two main frames are fitted tree trunk enabling the operator to lift the frames conveniently using the sliding members.

Plate 3.1 Chembery model coconut climber

To fit the climber on the palm both right and left units are fixed one by one with the help of a wire rope. The climbing person holds the handles of both the units and climbs up by keeping the both legs in the foot rest provided. Then the right unit of the device is lifted by hand to about 30 to 40 cm, loosening the rope with the help of the right leg. After lifting the unit, the foot is pressed downwards to hold the coconut palm firmly by the rope and pad provided. The process is repeated by the left unit without releasing the body weight from the left unit. The process is repeated to achieve required height. For climbing down, the reverse process is followed, i.e. release the wire rope of the left unit by lifting the footrest. The climber brings down the left unit by 30-40 cm and then puts the body weight on the left footrest followed by the right unit. While climbing, care should be taken not to overlap the ropes of the climbing units which leads to jamming of the device.

This climbing device requires less effort as compared to the sit and climb type climber. The main problem associated with this climbing model is that the operator gets tired soon as the operation is carried out by in standing position. Another main problem observed was the breakage of the rope within 3-4 month of continue working. Safety is a matter of concern for this model. If the operator takes support of the trunk, the equipment becomes less stable as it is the self-weight which locks the equipment upon the tree. At the time when operator takes support of tree, effective weight on the device is reduced thus making the operator in vain. In case, if the operator by any chance faints, the safety is at high risk as the same loading problem comes into effect.

3.1.2 KAU Coconut palm climber

KAU Coconut palm climber is a modified version of TNAU coconut palm climber (Plate 3.2). It consists of top and bottom frames fitted with adjustable U frame members. The top frame is intended for comfort seating of operator and bottom frame is intended for comfort seating of the operator and bottom frame is attached with an actuating mechanism for climbing up and down palm.

Plate 3.2 KAU Coconut palm climber

Top frame has to bear an average weight of worker of about 60-70 kg without any bending to cantilever action. Galvanized iron was used as material for fabrication. The bottom frame is for placing the legs of operator and actuating the up and down motion. While climbing both frames are moved upward alternatively by means of combined action of hand and leg. These actions will just be reversed when climbing down. As the bottom frame is only for facilitating these supportive action aluminum alloys is selected as the material for its fabrication, which in turn reduces the weight of the unit. The total weight of the unit of both top and bottom frame is 9.50kg. Safety lock pin are provided for attaching U frame with main units which reduces the time for setting or removing the climber. Rubber bushes are provided in both frames as gripping material. The lifting of bottom frame with toes was a tough task for the users and induce strain to legs. Specially designed foot wears were provided to the bottom frame. The palm gripping section of top frame was made of U shape with an inclination to horizontal. Hence while climbing the top frame will remain parallel to the horizontal and hence ensure more stability to the climber. The same inclination is provided to the bottom frame for giving more safety to the operator. Sagging type rexin seat was provided on the upper frame which increased the comfort and safety of operator.

3.1.3 Chachoos Maramkeri

Chachoos Maramkeeri is a sit and stand type tree climber (Plate 3.3). It consisted of top and bottom frames fitted with adjustable wire rope. The top frame is intended for comfort seating of operator and the bottom frame is for supporting the foot. When person sit on top frame, the bottom frame become loose and is taken up or down by leg when the person stands on bottom frame the top frame become loose and it can be taken up or down the palm by hand.

Plate 3.3 Chachoos-Maramkeri

While climbing both frames move upward alternatively by means of combined action of hand and leg, these actions will be reversed while climbing down. Both top and bottom frames should carry the weight of about 40 to 100 kg depending upon the weight of the operator. The structural steel is used for its fabrication. The total weight of this climber including the both frames is 4.95 kg. Safety lock pins were provided for attaching the wire ropes with the main unit which reduces the time of fitting or removing of the climber. Rubber bushes were provided for foot rest and foot holder as cushioning material.

3.1.4 Kera suraksha coconut Climber

Kera Suraksha coconut climber (Plate 3.4) was developed by ARS Mannuthy. It is a sit and stand type climber. The coconut climber consisted of two units viz. upper and a lower units. Both the upper and lower units were made of 20 mm diameter mild steel hollow pipe. The upper unit can be operated by both hands and lower unit by both legs.

The upper unit consisted of a seat frame section and an adjustable palm attaching section. The seat frame consisted of seat for the operator, rear support frame with a safety rope and seat support. The palm attaching section included upper and lower 'Trapezoidal' shaped brackets, gripping aid, two vertical pipes connecting the brackets which is bent at the top as handles. The upper unit was attached to the palm using the 6 mm wire ropes. Holes were provided at right and left side of upper bracket to attach upper unit firmly on palm trees of varying diameter. At the upper bracket three 6 mm metal wire ropes and at the lower bracket one 6 mm metal wire rope were provided. The upper metal wire ropes were fixed with 'C' clamps at both the ends and are attached to brackets with locking pins. The locking pins with chains are inserted into holes provided at the right and left side of upper bracket.

Plate 3.4 Kera Suraksha coconut climber

Generally, the diameter of the palm decreases from bottom to top, in such situations the top two wire ropes can be adjusted with a lever assembly fitted on the right side of the upper bracket, as per the diameter of the palm without removing locking pins. This adjustment could be easily done by the operator during palm climbing while comfortably standing on the lower unit. The bottom wire rope was fixed with lower bracket through 'U' clamps to provide firm gripping to the palm. The lower unit consisted of a foot frame section and a palm attaching section. The palm attaching section included two metal wire ropes one at top bracket and other at bottom bracket. The foot frame section comprised foot supports and pair of pipes to insert feet. The lower unit was attached to palm tree in the same way as explained above for upper unit.

In order to climb the palm, the operator had to place his feet at the foot frame section of the lower unit and to sit on the seat. After sitting comfortably operator starts lifting his feet and legs in such a way to pull the lower unit upward. The operator then could stand by resting his feet on the lower unit and lifted the upper unit opposite to his waist position. The operator could then sit and again lifted the lower unit with his feet and legs. This process could be repeated to achieve required height of the palm. The reverse procedure could be followed to climb down.

Kera suraksha coconut climber was ergonomically evaluated and it is used by many farmers and householders. The device could be easily attached and detached from the coconut palm. While climbing operator feels more safety and comfort than other climbers. It is suggested that, even ladies and unskilled person can climb on coconut palm safely and comfortably. Small farm holders with 5-10 palms can use the device to harvest their palms by themselves. The cost of this climber was Rs. 3000 and weight 9.35 kg. Though the fixing time and climbing time were less but due to its more weight than other climbing models and bulkiness it became difficult to climb up more height as required to harvest the coconuts. After climbing few trees climbing person generally felt pain on his foot and back.

3.2 Concept of the development of a domestic type coconut climber

Almost all the existing coconut climbers employ the concept of eccentric loading. Equipping the load eccentrically proves to be an expedient solution for safety. As derived from the kinematic analysis, the eccentric load only adds to the safety of the equipment. The chances of falling can be avoided as the leverage produced by the load adds up mechanical advantage.

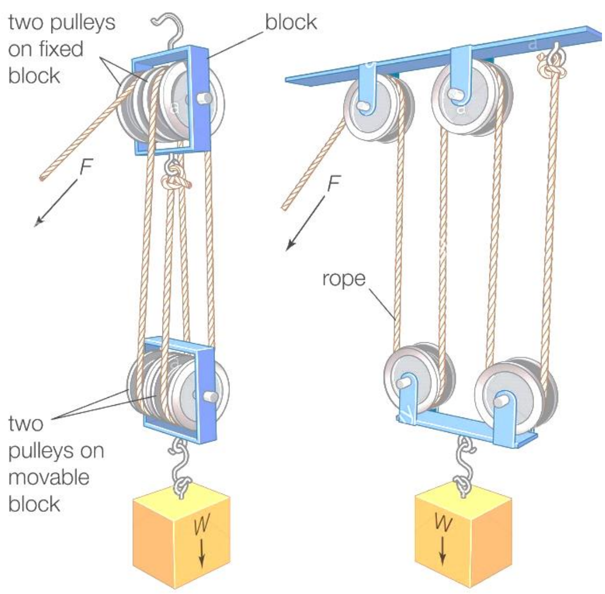


Fig. 3.1 Four pulley system to block and tackle system

The principle of block and tackle system (Fig.3.1) is employed in the new domestic coconut climber. It consists of two or more pulleys with a rope or a cable wound in between them. The pulleys are assembled together to form blocks and then blocks are paired so that one is fixed and the other one moves with the load. The rope is wound through the pulleys to provide mechanical advantage that amplifies the force applied to the rope. A block and tackle are characterized by the use of a single continuous rope to transmit a tension force around one or more pulleys to lift or move a load. Its mechanical advantage is the number of parts of the rope that act on load. The mechanical advantage of a block and tackle system indicates the easiness to lift a load.

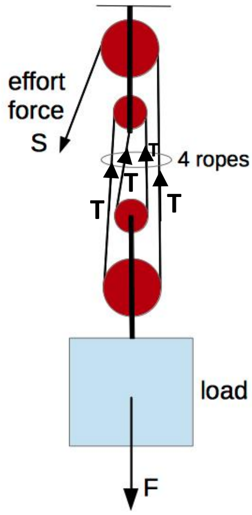


Fig. 3.2 Freebody diagram of four pulley system

The simple block and tackle system (Fig.3.2) consist of two double sheave pulleys and a rope wounded over four pulleys. One double sheave pulley is stationary and another one is free to move with the load. The one end of the rope is free to apply effort whereas the other end is tied with fulcrum of stationary pulley.

When effort is applied at the one end of rope the load starts moving up gradually and tension ‘T’ is generated in the rope. The direction of tension acting on rope at the free ends of movable pulley is upward and load is acting downward. The total tension acting on the rope was 4T which is equal to the load on the system and the tension on the rope is caused by the effort ‘E’.

$$\text{Mechanical advantage} = \frac{LOAD}{EFFORT} = \frac{4T}{T} = 4$$

This indicates that the effort needed for lifting the load is four times lesser than the load if the friction and weight of the pulleys are assumed as negligible. If the system is considered ideal then the work done on the system should be conserved.

Total force acting on load × displacement of load = Effort applied × displacement of rope

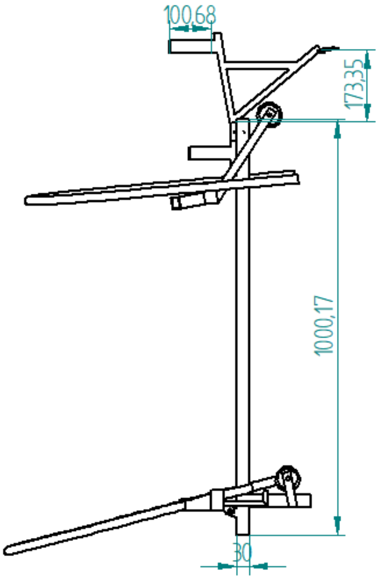
$$4T \times D = T \times \text{displacement of rope}$$

Which implies the displacement of rope is four times the displacement of load. This is the most important component of the study which reduces the efforts of lifting a load. By the incorporation of such an arrangement, the ease with which the operator can advance up or down a tree becomes facile. It also allows the operator to ascend up any tree regardless of its shape. This concept is used in the domestic type coconut climber.

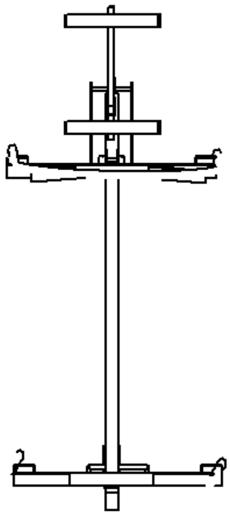
3.3 Development of the domestic coconut climber

The developed climber (Plate 3.5 and Fig. 3.3) has the ancillary benefit of being women friendly in addition to safety aspects. The climber incorporates the usage of block and tackle system along with eccentric loading which reinstate safety of the operator. The domestic type coconut climber (Fig. 4) consisted of three main units i.e. clamping unit, climbing unit and lifting unit.

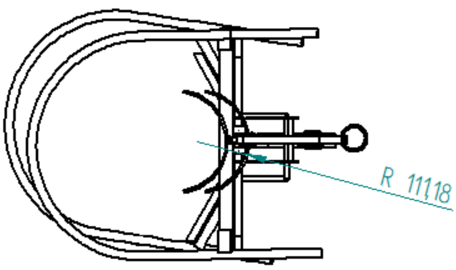
Plate 3.5 Domestic coconut climber



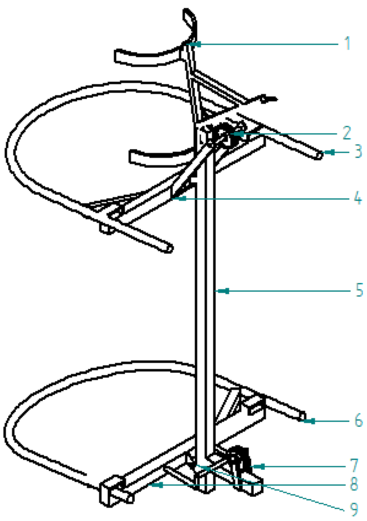
Elevation



Side view



Plan



List of parts		
Sl No	Item	Quantity
1	Clamping unit	1
2	Single sheave pulley (Top)	1
3	U clamp (Top)	1
4	Cross shaft (Top)	1
5	Vertical connector	1
6	U clamp (Bottom)	1
7	Single sheave pulley (Bottom)	1
8	Cross shaft (Bottom)	1
9	High tension spring	1

Fig 3.3 Domestic coconut climber

3.3.1 Clamping unit

This is the top most component of the climber (Plate 3.6) and it consisted of two C clamps, a triangular frame made M.S pipe of Φ 10mm. The vertical edge of this frame connects the two C-clamps by means of nut and bolt and the top end of inclined edge is welded with a ring through which wire rope is inserted. The two C clamps were made of M.S flat of 30 x 5mm. Four hooks and a clamping clip were welded on upper C-clamp to insert the wire rope. Also clamping clip was welded separately for locking one end of wire rope.

As the climber was made of mild steel, it can afford any tensile and compressive load. The major advantages of the model are that its fabrication materials are readily available, and the facilitated easiness of shaping and welding.

Plate 3.6 Clamping unit

3.3.2 Climbing unit

This is one of the most important functional components of the climber which lifts the entire unit. It essentially consists of two single sheave pulleys, two high tension springs, nylon rope (3 m), a vertical connector made of 30 x 30 mm M.S square pipe, two cross bars of 30 x 20 mm and two U- clamps. Using these U-clamps, the unit can be fixed to the palm of varying girth. One cross bar and pulley were hinged at the top while another fitted at the bottom of the unit with the vertical connector. One end of nylon rope was tied at the top of square bar while the other end wounded around the pulleys and kept free to apply efforts. As the effort was applied at the free end of nylon rope the two springs get compressed, which in turn force the vertical connector with the entire unit to move up the palm. When the rope was loosened, the springs extended to its normal length and unit gets arrested and then again rope was pulled down to apply effort and unit moves up and in this way by pulling and loosening the rope the unit along with upper metallic frame move up the palm.

3.3.3 Lifting unit

The unit comprised of those parts which aid the operator to ascend and descend the palm. It can be considered as another working part of the climber. The various parts of this unit viz. block and tackle unit, chair and locking unit and/or harness with locking unit are discussed below.

3.3.3.1 Block and tackle unit

The unit consisted of two pulleys one stationary and another movable. The pulleys which were used in the system are specified as double sheave pulleys (Plate 3.7) and had the capacity of lifting load up to 200kg. The stationary pulley was attached with hooked wire rope whereas movable pulley was free to move with climbing chair. Two sheave pulleys had the common fulcrum and both were mounted on a single bolt. The movable pulley was attached with climbing chair by means of a rope.

Plate 3.7 Double sheave pulley

3.3.3.2. Rope

The type of material used for the rope is the main determinant of the rope's strength, abrasion resistance, ease of use, and price. The most common type of rope used in hoisting heavy loads is the wire rope wherein the load to be lifted is in quintals or tones. Since the maximum load that to be lifted in the present study was less than 150 kg, cotton or nylon rope can also be used. The desired properties of rope for this study were abrasion resistance, less stretchable, soft and smooth, smaller diameter, and less weight. Hence a cotton rope of ϕ12 was used in the study

3.3.3.3 Chair and locking unit

A chair was provided to facilitate the security to the operator while climbing up and down the palm. The chair was made of M.S rods which were bend in elliptical shape suited for a convenient seating of operator. It was attached to the movable pulley by means of rope. The operator can be seated comfortably and safely while it moved up by the combined action of rope and pulley system. Foot rest was also provided with the chair for comfortable seating. Since the chair was attached by rope to the pulley, the ascend or descend was not affected by the irregularities of the palm. The foot rest also provides an additional advantage of standing at the top of the palm, which help operator to pluck the coconut easily.

Plate 3.8 Climbing chair with ratchet gear lock

The locking mechanism attached with the chair comprised of a shaft attached to a rachet gear and stopper. The unit was welded to the front side of climbing chair. A horizontal shaft was provided at the center of the ratchet gear on which the rope was wound while climbing the palm. One end of the rope from pulley was attached to the shaft so that as the shaft rotates, the rope winds upon the shaft. One end of the shaft was attached by means of a key. A stopper was provided along with the rachet gear to restrict free rotation occurred due to operator's weight. When the gear rotates in the opposite direction, the stopper gets locked in between the teeth restricting its opposite rotation.

3.3.3.3 Harness and locking unit

This can be used as an alternative to chair and locking unit. This technique provides ancillary benefit of being light in weight in addition to the safety and comfort of the operator. There are many types of harnesses available in the market depending on the type of climbing activity. A full-body harness is the combination of chest and shoulder harness as shown in Plate 3.9. This harness can be attached to movable pulley either by a carabiner or rope.

Plate 3.9 Full body climbing harness

3.4 Working

The working of the developed climbing model involved three steps. *Viz.* fixing the climbing unit, conveying the climbing unit with rope and pulley attachment and lifting the climbing person in a chair (seat). The climbing unit was attached with the palm by inserting the two U-clamps into the holes provided on cross shafts of main climbing unit. At both ends of U- clamps were provided with 8 to 10 small holes of Φ50mm spaced at 20mm were provided to lock the climbing unit according to the girth. After fixing the climbing unit the upper pulley was attached with wire rope and clamped with C-clamp. As the effort was applied at the free end of nylon rope the two springs get compressed, which in turn force the vertical connector with the entire unit to move up the palm. When the rope was loosed the springs extend to its normal length and unit gets arrested and then again rope was pulled down to apply effort and unit moves up and in this way by pulling and loosening the rope the unit along with upper metallic frame move up the palm. On reaching the top, lifting chair was attached with movable pulley by rope/carabiner.

The chair was made ready to lift the climbing person. The free end of the rope was tied with the shaft mounted on the chair. At one end of the shaft, a handle was provided and the other end was provided with a ratchet gear. When the climbing person starts rotating the handle, rope gets wrapped on horizontal shaft and chair start moving up. The chair movement can be locked with the help of ratchet gear when it reaches at the top of the palm or in between as desired by the operator. To bring the chair down, lock was released and hence the chair come down due to the weight of the operator. Harness and rope can also be used instead of climbing chair arrangement.

3.5 Performance evaluation

Performance evaluation of domestic climber was carried out using ergonomic principle**.** The physiological responses as heart rate, oxygen consumption were separately observed for selective subjects. The ergonomic evaluation studies implied a clear information on the ease of operation of the machine under study. It gives an index on the safety prospects of the machine or working environment in which the operation is carried out.

3.5.1 Calibration of the subjects

In order to evaluate the physical workload using heart rate, separate relationship between heart rate and oxygen uptake must be established for the selected subjects. Both quantities have to be measured in the laboratory under various load conditions. The process is termed as calibration of subjects. From the calibration chart unknown quantity can be read corresponding to the other known parameters.

The most practicable method of oxygen consumption was by indirectly measuring the heartbeat rate which yield a general picture of whole day's work or the specific time period of work. Calibration chart is obtained by using a treadmill, on which the subject was made to run till the subject acquired fatigue. Using polar pacer heart rate monitor, the heart beat rate of selected subjects during exercise was measured.

3.5.1.1 Polar pacer heart rate monitor

The equipment (Plate 3.10) was used to measure heart beat rate. This can be used directly in field applications where the telemetry system cannot be used. This equipment consisted of three basic components viz chest belt transmitter, elastic strap, receiver unit.

Two electrodes were fixed on grooved rectangular area underside of belt transmitter which after picking up heart beat rate from body of subject transmit via electromagnetic signals. When wetted with water, it performs better. The function of this part was to secure transmitter to chest as comfortable. The transmitter should fit without affecting any issues to normal breathing.

Plate 3.10 Chest belt transmitter **Plate 3.11 Elastic strap and Receiver unit**

The receiver receives the signals as transmitted and displays it on screen while recording the data in the memory. The unit was to be placed in one-meter range. It had the advantage of being able to be fixed in watch strap. It also had the provision to set limit for the heartbeat after which if exceeded would be indicated through alarm. Similarly, for low heart beat rate also. The detailed specification of the instrument is given in the Appendix I.

3.5.1.2 Benedict Roth Recording spirometer

This equipment (Plate 3.12) was used to measure the oxygen consumption of the subjects. It consisted of a 6 litre spirometer with a speed strip chart recorder. The bell of spirometer was hung by means of chain and counter weight was hung over a pulley which carried a light Perspex ink pen. The main base which houses kymograph gear box, three stop cocks was made of aluminum casing with levelling screws. The two way stop cock was carried by an adjustable arm and fitted with a rubber mouthpiece through corrugated rubber tubing. All air hoses are 25 mm inner diameter. The speed of the spirometer was adjusted to 20 min/rev with the help of speed selector.

Plate 3.12 Benedict-Roth recording spirometer

3.5.1.3 Treadmill

Plate 3.13 Viva fitness T1090 Treadmill

Treadmill (Plate 3.13) was used for calibration of subjects. It consisted of a moving platform the speed of which can be adjusted, a rigid frame, hydraulics for inclination. It possessed a single window display which depicted time, distance covered, speed of operation, calories and pulse rate of the subject during exercise. The load could be adjusted varying the speed and inclination as per requirement.

3.5.2 Procedure

The calibration process was necessary in estimating the performance of each subjects. The calibration of the test subjects involved estimation of basal metabolic rate and indirect assessment of oxygen uptake. The procedure involved is described in detail below.

3.5.2.1 Basal metabolic rate

The basal metabolic rate is the rate of energy expenditure when the body is at rest. It was estimated by Benedict Roth recording spirometer. The spirometer bell was filled with oxygen. The subjects were given rest for about half an hour before test was conducted.

The selected subject initially inhaled atmospheric air for some time. After breathing becomes normal, the saddle valve was opened to allow oxygen to flow from the spirometer bell. The kymograph recorded the consumption of oxygen on strip chart. The rate was measured by selecting a satisfactory uninterrupted section of exactly six minutes. Same procedure was repeated for all the selected subjects.

3.5.2.2 Indirect assessment of oxygen uptake

Before the day's work, the selected subjects were asked to relax for about half an hour. The blood pressure and heart beat rate were measured. If these were within the normal ranges, subjects were assigned the task else it was postponed. The assessment of oxygen uptake used Treadmill and Benedict Roth spirometer in combination. The subject was asked to perform work which utilizes the muscle most closely associated with their occupational work in treadmill. Oxygen from the cylinder was filled in the spirometer. The subject was allowed to take rest for half an hour before test. The mouthpiece was fitted to subject. The nose of the subject was clipped with help of nose clip.

The subject was allowed to inhale atmospheric air for some time initially. After normalization of breathing rate, the saddle valve was opened to inhale oxygen from spirometer. Then the workload of the subjects was increased gradually by increasing the speed. The subject inhaled oxygen through inspiriting valve that was connected to spirometer filled with oxygen and released carbon dioxide through the expiratory valve coupled to carbon dioxide absorber. The kymograph starts recording oxygen consumption pattern of the subject on chart continuously. Simultaneously the heart beat rate was recorded in the heart rate monitor fitted with the subject. The workload was gradually increased. The test continued till the subject attained fatigue. The same procedure was repeated for all the subjects. By using the data on heart rate and oxygen consumption rate, a calibration chart was prepared with heart beat rate on ordinate and oxygen uptake on abscissa.

3.5.3 Heart rate and oxygen consumption

Heart beat and oxygen consumption are the primary factors to be considered while the operation of any work. There exists a direct linear relationship between the consumed oxygen and heartbeat. Physiologically, for performance of any physical exertion more energy is to be liberated in the body through respiration process which employs oxygen. Also, for respiratory activates more quantity of nutrient and related contents are required which is supplied by the circulatory system of which heart is the prime organ. Hence more the physical exertion more is the quantity of oxygen consumed and more is the heartbeat. Among the two, heartbeat rate measurement is more advantageous as the body responds quickly to changes in work load as compared to oxygen consumed. Due to the inherent advantage, indirect assessment of oxygen consumption was made.

3.5.4 Energy cost of operation

The values of heart rate at resting level and 6^{th} minute of operation was used for calculating the physiological responses of the subjects (Tiwari and Gite,1998). The heart beat increases rapidly at the beginning of exercise and reaches a steady state by end of sixth minute (Davis *et al.*.,1964). The stabilized values of average heart rate for each subject from 6^{th} to 15^{th} minute of operation was used to calculate the mean value for all the selected implements. From the calibration chart, the values of oxygen consumption were obtained for corresponding values of heart rate obtained during the trials. The energy cost of operation was computed by multiplying the oxygen consumed during the operation with the calorific value of oxygen as 20.88 KJ lit^{-1}.

3.5.5 Acceptable work load

The acceptable work load is expressed in terms of individuals aerobic power i.e. the amount of individual's maximum aerobic power which is used up in performing the work under study. Thus, the maximum oxygen consumption and the workload be assessed individually.

3.5.5.1 Maximum aerobic capacity (VO_2 max)

Maximum aerobic capacity is the maximum oxygen consumed by a subject in which any further increase in load will not produce any increment in oxygen uptake. Also called as maximum oxygen consumption capacity, VO_2 is regarded as an international reference of fitness in relation to cardio vascular activities. The value is obtained on the basis of heart rate oxygen consumption relationship. The maximum heart rate of each subject was estimated using the relationship by Bridger (1995) Maximum heart rate (beats min^{-1}) =200-0.65x Age in years

The intersection of computed maximum heart rate of subject with plotted calibration chart line and the line of fit to the oxygen consumption defines the maximum aerobic capacity of the individual.During performing any physical activity, the physiological parameters increases depending upon the work performed whose limit in a fit individual is up to VO_2.The acceptable workload for Indian worker is 35 percent of $VO_{2\ max}$ (Saha 1979). To ascertain if the operation was carried within the acceptable work load (AWL), VO_2 for each climber was computed and recorded.

3.5.5.2 Limit of continuous performance (LCP)

The extend to which a person increase his work rate depend upon the increment in his heart rate from resting level to maximum level as it is directly related to cardiac output. (Rodahl 1989). To have a comparison of the responses Δ values (increase over resting values) for heart rate was calculated (Tiwary and Gite,1998). For the computation of above, average heart rate at rest and working condition were used. Heart rate values during rest and during the operation of climbers were taken. The calibration chart was used for computing Δ values for oxygen consumption. The values of heart rate and oxygen consumption were averaged to obtain a mean value for all the five subjects.

3.5.6 Subjective Rating Scale

The effort expenditure might be quantified by rating of perceived exertion. A 10-point scale was used for assessing the perceived exertion of subject during operation. As an investigating tool, rating of perceived exertion has been found to be suitable for studies. The overall discomfort score was taken as postural discomfort parameter and subjective evaluation of discomfort was done by recording overall discomfort experienced by the subject. The ease of operation and safety of operation was measured by using the scale as overall ease of operation rating (OER) and overall safety rating (OSR) scale.

3.5.6.1 Measurement of Overall Discomfort Rating (ODR)

Prior to conducting the experiment with all the selected implements, the subject was anchored to a 10-point overall discomfort rating scale. For the assessment of overall discomfort rating a 10-point rating scale was used (0-no discomfort, 10- extreme discomfort). At the end of each trail, subjects were asked to indicate their overall discomfort rating on the scale. The overall discomfort rating given by each of the selected subject was added and averaged to get the mean rating. The values were tabulated. The same procedure was repeated for all experiment.

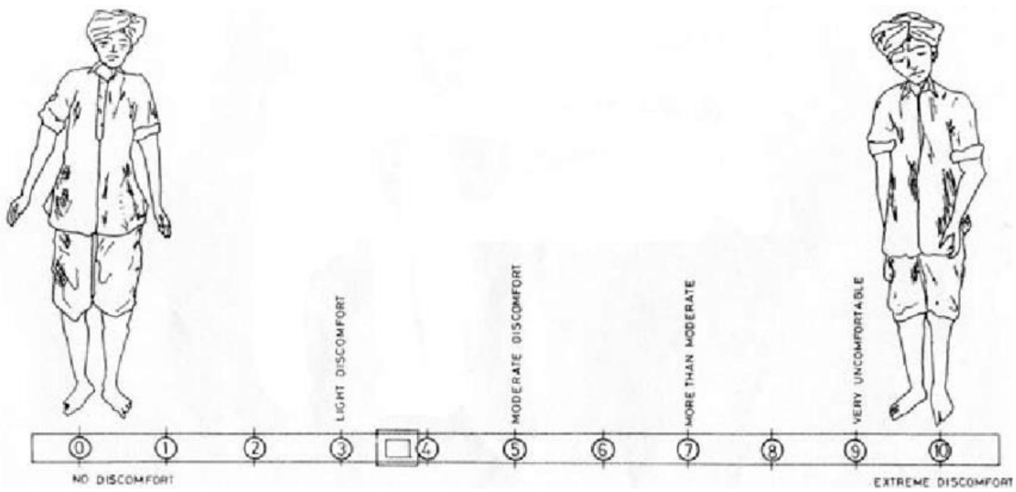


Fig. 3.4 Visual analogue discomfort scale for assessment of discomfort

3.5.6.2 Measurement of Overall Safety Rating (OSR)

The assessment of safety rating was measured using a 10-point rating scale (0 – completely secure and no fear, 10 – totally insecure and extreme fear) was used. At the end of each trail, subjects were asked to indicate their overall safety rating on the scale. The overall safety rating given by each of the subject was added and averaged to get the mean rating.

Table 3.1 Scale for ODR, OSR and OER

Levels	ODR	OSR	OER
0	No discomfort	Completely Secure and No fear	Very Easy
1			
2		Secure and Meagre Fear	Easy
3	Light Discomfort		
4		Moderately Secure and less fear	Less difficult
5	Moderate Discomfort		
6		Slightly secure and Moderate fear	Difficult to operate
7	More than Moderate		
8		Insecure and more fear	Very difficult
9	Very uncomfortable		
10	Extreme discomfort	Totally insecure and extreme fear	Extremely difficult

3.5.6.3 Measurement of Overall Ease of Operation Rating (OER)

In order to assess the ease of operation, a 10-point rating scale (0-very easy, 10 –extremely difficult) was used. At the end of each trail, subjects were asked to indicate their ease of operation rating on the scale. The overall safety rating given by each of the subject was added and averaged to get the mean rating.

3.6 Comparative performance evaluation

Performance of the climbers were analyzed by considering time involved for fixing the unit to palm as well as the risk associated with working. The latter is hence related to the performance. The various parameters taken during the ergonomic evaluation includes heart beat rate and oxygen consumption.

3.7 Cost analysis

Cost incurred for the development of the model was found using standard economic analysis. The cost of material and fabrication are framed as per the present standard rate in the market.

Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

This chapter explained the study on existing climbers and performance evaluation of domestic coconut climber using ergonomic principles. Also, it was compared with the available models. Physical and performance characteristic of the climber and physiological response while operating the climber are discussed. The economic analysis for the developed climber is also discussed.

4.1 Available Models

Popular coconut climbers of the State were studied. The existing methods of climbing consist variety of problems. A major hindrance to the usage of the mechanical climbing devices was due to irregularities in the shape of the palms. The wide variation in the shape of the trees makes the devices difficult to be operated especially in those having undue curvature. The main issues as encountered by the device are discusses below:

The chachoos-maramkeri tree climber is considered safe in providing an eccentric loading. As operator has to lift the lower unit by means of leg, pain to knee, joints etc. will be occurred. Back pain is also accompanied by the constant use of the equipment. Also, proper balance between the top and bottom halves is to be maintained while operation. Another drawback of the device is the setting time of the equipment. The time required for shifting of the equipment from one palm to another is time consuming and thus affecting the overall performance.

The Chembery model though require less effort take as compared to the Chachoos maramkeri, the main problem associated was that the operator gets tired soon after climbing. Another main problem was observed as the breakage of the rope within 3-4 month of operation. Safety is a matter of concern of this model. If the operator takes support of the trunk, the equipment becomes less stable as it is the self-weight which locks the equipment upon the tree. The moment operator takes support of palm, effective weight on the device is reduced thus making the operator in vain. In case, if the operator by any chance faints, the safety is at high risk as the same loading problem comes into effect.

The KAU coconut palm climber had the advantage of being light in weight owing to the preference of GI material and the ancillary benefit of providing eccentric loading. The Kera Suraksha coconut climber gave a more safety aspect to the operator by providing a frame suitable for the operator to sit. The model is a modification of sit and stand type climber in which encompasses the basic difficulties addressed in the basic climber. The bulkiness of the climber restricts its acceptance among the farmers.

4.2 Performance evaluation

The performance of 4 models viz. chembery model, chachoos maramkeri, KAU coconut palm climber and Kerasureksha coconut climber were conducted and the results are compared with w.r.t. weight, material used and setting time. Also, physiological parameters heart rate and oxygen consumption were observed. The results are given in Table 4.1.

4.2.1 Physical parameters

The physical parameters of the available models of climbers are given in Table 4.1. From the Table, it is clear that the total weight was highest for chembery model followed by KAU palm climber. The least weight was for chachoos maramkeri. The domestic model was the second least weighed model with a total weight of 7.5 kg. The setting tme was found to be lower for chachoos maramkeri (45 s) followed by chembery model (40 s). The removal time was the least for chachoos maramkeri (35 s) followed by chembery model (40 s). The domestic climber had the highest setting and removal time of 86 s and 54 s respectively. Girth adjustment was found possible only in domestic and chembery models while locking and safety systems were found exclusively in domestic model only.

Table 4.1 Comparison domestic climber model with other models

	Chembery Model	KAU Coconut palm climber (KCAET)	Kera Suraksha Coconut Climber	Chachoos-Maramkeri	Domestic Climber (New Model)
Weight of upper frame (kg)	5.35	5.10	5.35	2.75	-
Weight of lower frame (kg)	4.35	4.05	3.25	2.60	-
Total weight (kg)	9.85	9.15	8.6	5.35	7.5
Material used	Stainless steel/ Mild steel	GI pipe and Aluminium	Stainless steel	Structural steel	Mild steel
Time for setting up the unit (s)	40 s	75 s	68	45	86
Time for removing the unit (s)	40 s	60 s	42	35	54
Girth Adjustment	Yes	No	No	No	Yes
Locking system	No	No	No	No	Yes
Safety systems	No	No	No	No	Yes

4.2.2 Physiological parameters

The physiological parameters were evaluated ergonomically of selected climbers. The various instruments and methods used for evaluation are disused in the section 3.5 . The results so obtained and the respective inferences are discussed below.

4.2.2.1 Selection of subjects

Subjects were selected among male students of KCAET, Tavanur of the age group of 22-23 years of age. The subjects were tested medically for ensuring their fitness for the trials.

4.2.2.2 Calibration of subjects

All subjects selected for the trials were calibrated in the laboratory conditions by indirect assessment of oxygen uptake. Sanders and McCormick (1993) suggested the calibration of each person to determine the relationship between heart rate and oxygen consumption.

In order to plot the calibration chart, the basal metabolic rates of the selected subjects were to be determined. The basal metabolic rate of the subjects was calculated as per the procedure explained in section 3.5.2.1. The computed values are shown in Table 4.2. From the Table 4.2 it is observed that the basal metabolic rate varied between 1602.96 and 2003.7 kcal day^{-1} for the selected subjects. This may be due to the variation in body mass index of selected subjects.

Table 4.2 Basal Metabolic Rate

Sl. No	Subjects	Basal metabolic rate (kcal day^{-1})
1	Subject 1	1853.43
2	Subject 2	1803.33
3	Subject 3	1703.15
4	Subject 4	1602.96
5	Subject 5	2003.7

The computation of BMR is shown in Appendix III.

The selected subjects were calibrated in the laboratory by following the procedure explained in section 3.5.2. Astrand and Rofhal (1997) found in their study that there existed a linear relationship between the oxygen consumption and heart rate during calibration. By using the data collected about heart rate and oxygen consumption, a calibration chart (Fig. 4.1) was prepared with heart rate as the ordinate and the oxygen consumption as the abscissa for the subjects. Using the trendline setting the R^2 value and best fit line equation were found. The relationship between heart rate and oxygen consumption was expressed by the following equations.

For subject 1, $Y = 0.0039X - 0.0022$ ($R^2 = 0.9876$)

For subject 2, $Y = 0.0063X - 0.0022$ ($R^2 = 0.9895$)

For subject 3, $Y = 0.0058X + 0.0006$ ($R^2 = 0.9815$)

For subject 4, $Y = 0.0037X + 0.0004$ ($R^2 = 0.9808$)

For subject 5, $Y = 0.0058X + 0.0083$ ($R^2 = 0.9851$)

It showed that the R^2 value was very high for all the subjects selected for this study which means they all attained a good fit between the oxygen consumption and heart rate. The variation in the oxygen consumption was accounted at 98.08 to 98.95 per cent w.r.t the heart rate for all the selected subjects.

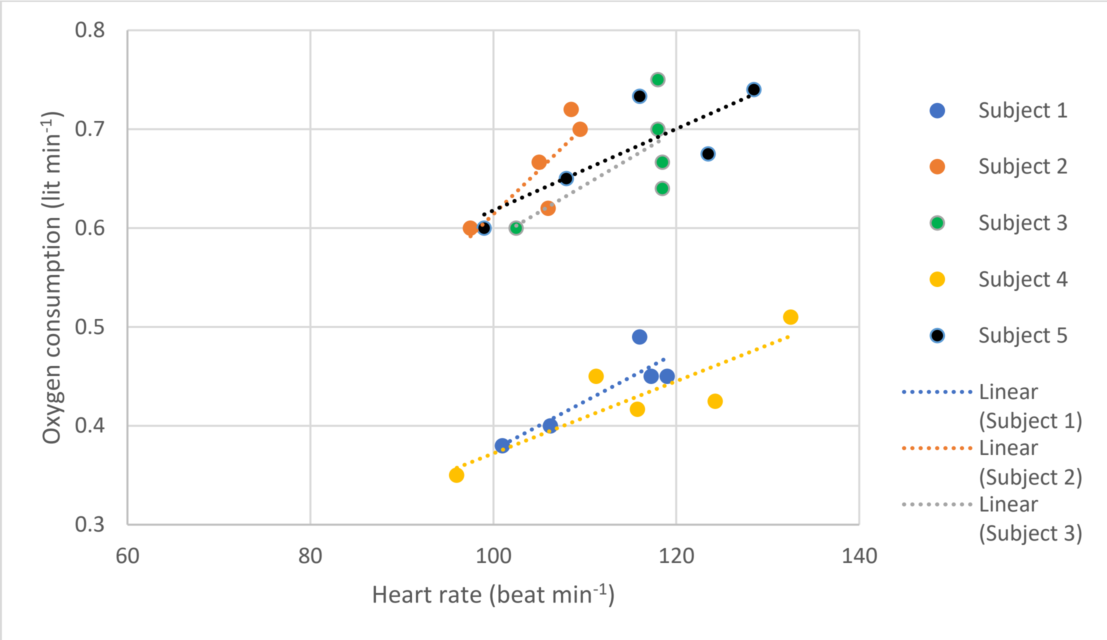


Fig. 4.1 Calibration chart of selected subjects

4.3 Physiological analysis

The physiological analysis viz. mean heart rate, oxygen consumption and energy cost of each subject were found out separately for the chembery model, Chachoos Maramkeri, KAU coconut palm climber, Kerasureksha coconut palm climber and domestic climber. Also, the energy cost of operation was computed for each of the climbers. The results are discussed below.

4.3.1 Chembery model coconut climber

The mean heart rate, oxygen consumption and energy cost of subjects on the use of Chembery model coconut climber are shown in Table 4.3.

Table 4.3 Physiological parameters on the use of Chembery model coconut climber

Subject	Mean HR (beats min^{-1})	Oxygen consumption (lit min^{-1})	Energy cost (kJ min^{-1})
Subject 1	119.33	0.46	9.6
Subject 2	115.33	0.72	15.03
Subject 3	115.33	0.67	13.99
Subject 4	134.66	0.5	10.44
Subject 5	118.67	0.7	14.62
Mean	**120.66**	**0.61**	**12.74**

The results indicated that the mean value of energy cost is 12.74 kJ min^{-1} for climbing of Chembery model coconut climber. Energy cost was found maximum for subject 2 (15.03 kJ min^{-1}) while it was minimum for subject 1 (9.6 kJ min^{-1}). The average heart rate measured was 120.66 beats min^{-1} and average oxygen consumption was 0.61 lit min^{-1} during climbing. The variation may be due to difference in body mass index of the subjects.

4.3.2 Chachoos-Maramkeri

The mean heart rate, oxygen consumption and energy cost of selected subjects on the use of Chachoos-Maramkeri are shown in Table 4.4.

Table 4.4 Physiological parameters on the use of Chachoos-Maramkeri

Subject	Mean HR (beats min^{-1})	Oxygen consumption (lit min^{-1})	Energy cost (kJ min^{-1})
Subject 1	126.66	0.49	10.23
Subject 2	112	0.7	14.62
Subject 3	139.66	0.81	16.91
Subject 4	143	0.53	11.07
Subject 5	116	0.68	14.2
Mean	**127.46**	**0.642**	**13.41**

The results revealed that mean energy cost for using chachoos-maramkeri was 13.41 kJ min^{-1}. Subject 3 showed highest energy cost expenditure (16.91 kJ min^{-1}) and subject 1 showed minimum energy cost expenditure (10.23 kJ min^{-1}) while climbing. A mean heart rate value of 127.46 beats min^{-1} and mean oxygen consumption of 0.642 lit min^{-1} were observed during climbing. The variation in the results might be due to the difference in physiological response of the subjects.

4.3.3 KAU Coconut palm climber coconut climbing device

The mean heart rate, oxygen consumption and energy cost of selected subjects on the use of KAU Coconut palm climber are shown in Table 4.5.

Table 4.5 Physiological parameters on the use of KAU Coconut palm climber

Subject	Mean HR (beats min^{-1})	Oxygen consumption (lit min^{-1})	Energy cost (kJ min^{-1})
Subject 1	117	0.45	9.4
Subject 2	120.33	0.76	15.87
Subject 3	110.66	0.64	13.36
Subject 4	131.33	0.49	10.23
Subject 5	117	0.69	14.41
Mean	**119.26**	**0.606**	**12.65**

Analysis indicated that the mean energy cost of operation was 12.65 kJ min^{-1}. Maximum energy cost of 15.87 kJ min^{-1} was found out for subject 2 and minimum energy cost of 9.4 kJ min^{-1} was found out for subject 1. The mean heart rate of subjects during operation was 119.26 beats min^{-1} along with mean oxygen consumption of 0.606 lit min^{-1}. The variations in results might be due to difference in body mass index of the subjects.

4.2.2.3.4 Kera Suraksha coconut climber

The mean heart rate, oxygen consumption and energy cost of selected subjects on the use of Kera Suraksha Coconut Climber is shown in Table 4.6.

Table 4.6 Physiological parameter on the use of Kerasuraksha coconut climber

Subject	Mean HR (beats min^{-1})	Oxygen consumption (lit min^{-1})	Energy cost (kJ min^{-1})
Subject 1	123.66	0.48	10.02
Subject 2	120	0.75	15.66
Subject 3	118.33	0.69	14.41
Subject 4	145	0.54	11.28
Subject 5	123.33	0.72	15.03
Mean	**126.06**	**0.636**	**13.28**

The mean energy cost of operation of Kerasuraksha coconut climber was 13.28 kJ min^{-1}. The maximum energy cost of 15.66 kJ min^{-1} was obtained for subject 2 and minimum energy cost of 10.02 kJ min^{-1} was obtained for subject 1. The mean heart rate and oxygen consumption during the operation were 126.06 beats min^{-1} and 0.636 lit min^{-1} respectively. The variation may be due to the difference in body mass index of subjects.

4.3.5 Domestic climber

The mean heart rate, oxygen consumption and energy cost of selected subjects on the use of Domestic Climber is shown in Table 4.7.

Table 4.7 Physiological parameters on the use of Domestic climber

Subject	Mean HR (beats min^{-1})	Oxygen consumption (lit min^{-1})	Energy cost (kJ min^{-1})
Subject 1	120	0.47	9.81
Subject 2	117.66	0.74	15.45
Subject 3	111.33	0.65	13.57
Subject 4	130.33	0.48	10.02
Subject 5	115	0.68	14.2
Mean	**118.86**	**0.604**	**12.61**

Analysis of energy cost of domestic climber showed a mean energy cost of 12.61 kJ min^{-1}. The maximum energy cost expenditure of 15.45 kJ min^{-1} was obtained for subject 2 and minimum energy cost expenditure of 9.81 kJ min^{-1} was obtained for subject 1. The mean heart rate obtained for selected five subjects were 118.86 beats min^{-1} and mean oxygen consumption obtained was 0.604 lit min^{-1}.

4.4 Grade of work

The work done by the climber can be classified based on physiological responses of the workers according to Sen (1969) as explained in section 2.4, Table 2.1. Table 4.8 shows the grading of work of subjects.

Table 4.8 Grade of work of subjects during climbing operation

Selected Model	Grade of work
Chembery model	Moderately Heavy
Chachoos-Maramkeri model	Moderately Heavy
KAU Coconut palm climber	Moderately Heavy
Kera Suraksha Coconut Climber	Moderately Heavy
Domestic climber	Moderately Heavy

4.5 Acceptable work load

According to Saha *et al*. (1979) the acceptable workload (AWL) of Indian workers are 35 percent of VO_2 max for endurance of 8 h work. The rate of energy expenditure and corresponding heart rate at this level of work would be 18kJ min^{-1} and 110 beat min^{-1} respectively.

4.5.1 Maximum aerobic capacity

Maximum aerobic capacity of all the subjects was obtained from the calibration chart as explained in section 3.5.5.1. Table 4.9 shows the maximum aerobic capacity of subjects.

Table 4.9 Maximum aerobic capacity of selected subjects

Subjects	Maximum heart rate (beats min^{-1})	Maximum aerobic capacity (lit min^{-1})
1	185.7	0.72
2	185.7	1.17
3	185.7	1.08
4	185.7	0.69
5	185.7	1.09
Mean	**185.7**	**0.95**

Maximum aerobic capacity of subjects ranged from 0.69 to 1.17 lit min^{-1}. The variation in VO_2 max values are due to difference in oxygen supply to parts of body along with genetic variations. The mean oxygen consumption in terms of maximum aerobic capacity with respect to all selected coconut climbers was calculated and presented in Table 4.9.

Table 4.10 Oxygen consumption in terms of VO_2 max of subjects

Selected models	Mean VO_2	Oxygen uptake in terms of VO_2 Max (per cent)	AWL (35 per cent of VO_2 max) = 33.25
Chembery model	0.61	64.21	>AWL
Chachoos-Maramkeri model	0.642	67.58	>AWL
KAU Coconut palm climber	0.606	63.79	>AWL
Kera Suraksha Coconut Climber	0.636	66.95	>AWL
Domestic climber	0.604	63.58	>AWL

It is observed that the all the climbers showed higher value of AWL which is greater than 35 percent. It implies that no coconut climber can be operated without frequent rest-pauses. The oxygen consumption in terms of VO_2 was found to be maximum of 67.58 percent for Chachoos-Maramkeri and minimum of 63.58 percent.

4.6 Limit of continuous performance

The difference between working pulse and resting pulse gives the work pulse. The average values of working pulse and resting pulse were used to calculate work pulse. Work pulse of subjects operating different climbers were given below in the Table 4.11.

Table 4.11 Work pulse rate of selected subjects while using coconut climbers

Selected Models	Work pulse (ΔHR), beats min^{-1}	LCP (40 beats min^{-1})
Chembery model	56.864	>LCP
Chachoos-Maramkeri model	63.664	>LCP
KAU Coconut palm climber	55.464	>LCP
Kera Suraksha Coconut Climber	62.264	>LCP
Domestic climber	55.064	>LCP

It is observed that all the work pulse values are way above the specified limit of 40 beats min^{-1} which indicated that workers cannot operate climber for continuous 8-h duration. The sit and stand type model showed the highest work pulse value of 63.664 beats min^{-1} that implied that the workers cannot operate the climber without frequent rest pauses.

4.7 SUBJECTIVE RATING SCALES

Ergonomic evaluation of the selected coconut climbers was also rated and each subject were asked to suggest their opinion of different climbers according to discomfort, ease of operation and safety. The mean value of ODR, OER and OSR for subjects are furnished in the Tables 4.12, Tables 4.13 and Tables 4.14.

Table 4.12 Overall Discomfort Rating (ODR) of selected coconut climbers.

Selected Models		ODR of selected subjects
Chembery model	Score	1.5
	Scale	> No discomfort
Chachoos-Maramkeri model	Score	3.5
	Scale	>Light discomfort
KAU Coconut palm climber	Score	4
	Scale	>Light discomfort
Kera Suraksha Coconut Climber	Score	4.5
	Scale	>Light discomfort
Domestic climber	Score	3.6
	Scale	>Light discomfort

It was observed that discomfort rating was highest for Kerasuraksha model with the score of 4.5 and scale of “>Light discomfort”. This might be due to overall bulkiness of the climber. Although the model provides better seating and safer position compared to Chachoos-Maramkeri the complicated structure increases the discomfort of climbing. The ODR for Chembery model was with score of 1.5 and scale of “>No discomfort”. The lower ODR value justifies the lower energy expenditure of earlier results. While the energy expenditure was least for the domestic climber it showed ODR rating of 3.6. It might be due to the position in harness or chair along with the pulling action.

Table 4.13 Overall Safety Rating (OSR) of selected coconut climbers

Selected Models		OSR of selected subjects
Chembery model	Score	4
	Scale	Moderately secure and less fear
Chachoos-Maramkeri model	Score	4.2
	Scale	> Moderately secure and less fear
KAU Coconut palm climber	Score	1.8
	Scale	> Completely secure and no fear
Kera Suraksha Coconut Climber	Score	3
	Scale	> Secure and meagre fear
Domestic climber	Score	1
	Scale	> Completely secure and no fear

It was found out that the safety was less for Chembery and Chachoos-Maramkeri with scale of "Moderately secure and less fear" and ">Moderately secure and less fear" with scale rating 4 and 4.2 respectively. This might be due to lack additional contacts with belt or wrapping between subject and climber other than physical contact. More safety was observed for Domestic climber with score 1 and scale ">Completely secure and no fear". This might be due to the more secure contact between climber and subject with harness.

Table 4.14. Overall Ease of Operation Rating (OER) of the selected coconut climbers

Selected Models		OER of selected subjects
Chembery model	Score	2.5
	Scale	> Easy
Chachoos-Maramkeri model	Score	2
	Scale	Easy
KAU Coconut palm climber	Score	2
	Scale	Easy
Kera Suraksha Coconut Climber	Score	3.8
	Scale	> Easy
Domestic climber	Score	4.5
	Scale	> Less difficulty

The result showed that domestic climber was difficult to operate as its score was 4.5 and hence under the scale of "> Less difficulty". This difficulty might be due to complex installation procedures and different ropes which are fixed to the climber. All the other models came under scale of "Easy".

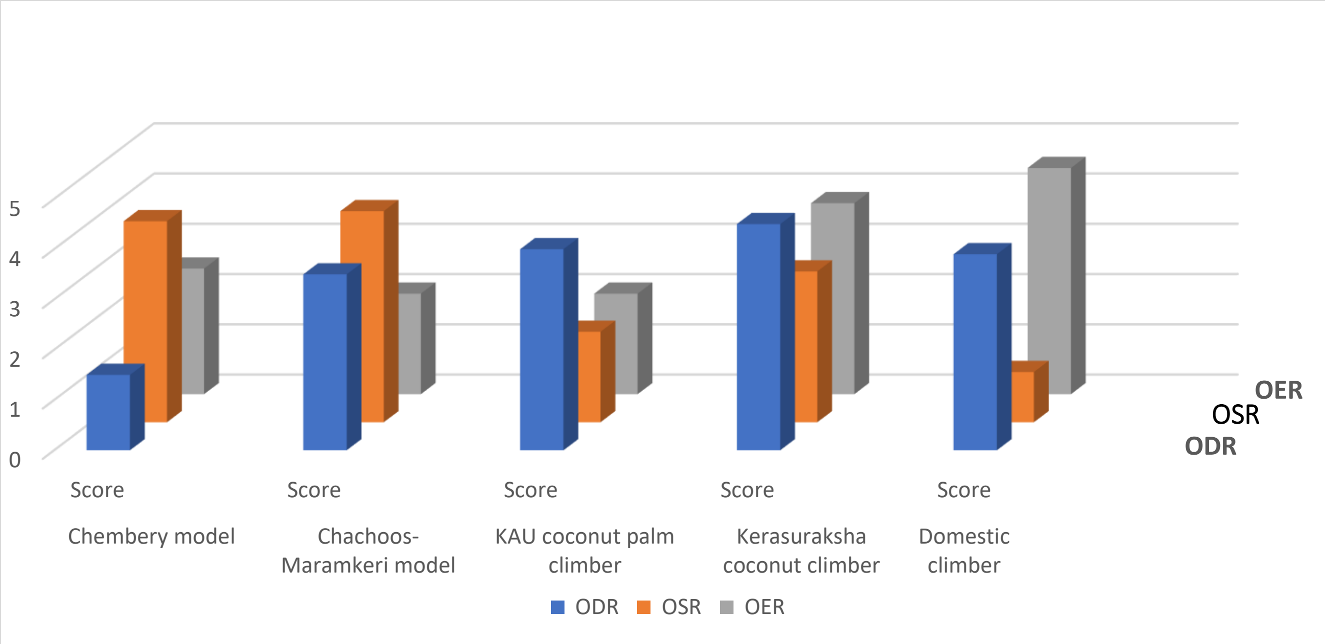


Fig. 4.2 Variations of ODR, OSR and OER of various coconut climbers

4.3 Cost analysis

The total cost of the machine was calculated based on the cost of different parts and its manufacturing expenses incurred for its development. The cost of climber using harness as lifting mechanism is Rs.7855 while with the usage of chair it reduces to Rs.6855. The detailed cost analysis of the machine is given in the Appendix IV.

Summary and Conclusion

Summary and Conclusion

Popular coconut climbers of the State were studied. The existing methods of climbing consist variety of problems. A major hindrance to the usage of the mechanical climbing devices was due to irregularities in the shape of the palms. The wide variation in the shape of the trees makes the devices difficult to be operated especially in those having undue curvature. The main issues as encountered by the device are discusses below:

The chachoos-maramkeri tree climber is considered safe in providing an eccentric loading. As the operator has to lift the lower unit by means of leg, pain to knee, joints etc. are the major problems. Back pain is also accompanied by the constant use of the equipment. Also, proper balance between the top and bottom frames is to be maintained during operation. Another major drawback of the device is its higher setting time with the palm. The time required for shifting of the equipment from one palm to another is also more time consuming hence affect the performance.

The Chembery model though require less effort as compared to the Chachoos-Maramkeri, the main problem associated was that the operator gets tired soon after climbing. Another main problem was observed as the breakage of the rope within 3-4 month of operation. Safety is a matter of concern of this model. If the operator takes support of the trunk, the equipment becomes less stable as its self-weight alone locks the equipment upon the tree. The moment operator takes support of palm, effective weight on the device is reduced thus making the operator in vain. If the operator faints, the safety is at high risk.

The newly developed domestic climber consists of three units viz. clamping unit, climbing unit and lifting unit. One cross bar and pulley are hinged at the top while another fitted at the bottom of the unit with the vertical connector. As the effort is applied at the free end of nylon rope the two springs get compressed, which in turn force the vertical connector with the entire unit to move up the palm. Clamping unit consists of two C clamps, a triangular frame made M.S pipe Four hooks and a clamping clip are welded on upper C-clamp to insert the wire rope. Lifting unit consist of block and tackle unit, chair with lock and/or harness with lock. The block and tackle system comprise of two double sheave pulley which are connected by a cotton rope attached to chair with lock or harness with locking mechanism. This aids the operator to ascend and descend the palm.

The domestic climber was tested for different physical and physiological parameters and separately for selected subjects using ergonomic principles. The results showed that the domestic climber had a total weight of 7.5kg with setting and removing times of 86 s and 54 s respectively. The domestic climber was found to possess adjustment for varying girth of palm, locking mechanism and safety system. The mean heart rate while using the developed domestic climber was found to be 118.86 beats min^{-1} while for Chembery model it was 120.66 beats min^{-1},127 beats min^{-1} for Chachoos-Maramkeri, 119.26 beats min^{-1} for KAU coconut climber and 126.06 beats min^{-1} for Kerasureksha climber. The oxygen consumption of 0.604 lit min^{-1} was obtained on use of domestic climber whereas it was 0.61 lit min^{-1}, 0.642 lit min^{-1}, 0.606 lit min^{-1} and 0.636 lit min^{-1} for Chembery, Chachoos-Maramkeri, KAU and Kerasureksha coconut climbers respectively. The energy cost on use of the domestic climber was 12.61 KJ min^{-1} while it was 12.74 KJ min^{-1} ,13.41 KJ min^{-1} , 12.65 KJ min^{-1} , 13.28 KJ min^{-1} for for Chembery, Chachoos-Maramkeri, KAU and Kerasureksha coconut climbers respectively The ODR rating showed a scale of 3.6 indicating light discomfort, OSR rating of 1.0 ascertaining good security and devoid of fear, OER rating of 4.5 revealing less difficulty of operation.

The main advantage of the domestic climber is that it can be used by both men and women, which cannot be possible in other models. The safety provided to the operator is also at higher degree than in other models. The climber can be used efficiently on palms which have irregularities in which other methods fails to operate. Also, there is reduction in the drudgery caused due to the operation of the climber in comparison to other climbers.

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Appendices

Appendix I

Technical specification of Polar pacer heart rate monitor

Training Computer

Item		Specification
Battery type	:	CR 2032
Battery life	:	Average 1 year (1 h/day, 7 days/week training)
Operating temperature	:	-10 °C to +50 °C / 14 °F to 122 °F
Wrist strap material	:	Polyurethane
Back cover and wrist strap buckle	:	Stainless steel complying with the EU Directive 94/27/EU and amendment 1999/C 205/05 on the release of nickel from products intended to come into direct and prolonged contact with the skin.
Watch accuracy	:	Better than ± 0.5 seconds/day at 25 °C / 77 °F temperature.
Accuracy of heart rate measurement	:	± 1% or ± 1 bpm, whichever larger, definition applies to steady state conditions.

Limit values

Item	Specification
Chronometer	23 h 59 min 59 s
Total time	0 - 9999 h 59 min 59 s
Total calories	0 - 999999 kcal/Cal
Total exercise count	65 535
Year of birth	1921 - 2020
Maximum speed with a GPS sensor	199.9 km h^{-1}
Maximum speed with footpod	29.5 km h^{-1}
Maximum files	16
Maximum laps	99
Maximum training session duration	99:59:59
Maximum training session distance	655.3 km
Maximum trip distance	9999.9 km mi^{-1}

Transmitter

Item	Specification
Battery type	Battery type
Battery type	Average 700 hours of use
Battery cap sealing ring	O-ring 20.0 x 1.0 Material FPM
Operating temperature	-10 °C to +50 °C / 14 °F to 122 °F
Connector material	Polyamide
Strap material	35% Polyester, 35% Polyamide, 30% Polyurethane

Appendix II

Technical Specifications: T-1090 Motorized Treadmill

Item		Specification
Motor	:	4 HP AC (2 HP continuous)
Speed	:	0.8 - 20 kmph
Incline	:	0 -15%.
Running surface	:	21 x 59 inches
Smart running system	:	Personal data management, time setting professional workouts, program workout programs, fitness test, Mp3 system with built in speakers and user record tracking.
Readout	:	Time, speed, distance, incline, and calories
Maximum User Weight	:	130 Kgs

Appendix III

Computation of BMR

Age of subject, years = 22

Weight of subject, kg = 55

Height of subject, m = 1.63

Room temperature (T_2) K = 303

Room pressure (P_2), bars = 0.99

Oxygen consumption

For a period of 6 min (V2), cc = 1700

Standard temperature (T1), K = 273

Standard pressure (P1), bars = 1.0325

Oxygen consumed under standard Temperature and pressure, lit = $\frac{P_1 \times V_2}{T_2} \times \frac{T_1}{P_1}$

$$= \frac{0.99 \times 1.85 \times 273}{303 \times 1.0325} = 1.5982$$

Energy produced in 6 min, kcal = 1.5982 x 4.832 = 7.7226 kcal

Energy per day, kcal $= \frac{7.096 \times 60 \times 24}{6}$

Basal Metabolic Rate, kcal day^{-1} = 1853.43

Appendix IV

Cost incurred for the development of the domestic climber

Table 1 (i) Statement of expenditure towards raw materials

Sl.No	Items	Quantity	Cost (Rs)
1	Single sheave pulleys	2 no	500
2	High tension spring	1 no	500
3	Carabeners	2 no	500
4	Cotton rope	50 m	900
5	Wire rope	3 m	800
6	Double sheave pulleys	2 no	1400
7	Harness	1 no	1500
8	Ratchet gear	1 no	200
9	Clamping clip	2 no	30
10	Raw materials	15 kg	525
	Total		**6855**

ii) Fabrication cost = 1500 (approx)

The total cost incurred for the development of the domestic climber = [i + ii]

=Rs.6855 + Rs.1500

= Rs.8250.

APPENDIX V

Specification of domestic coconut climber

Item	Specification
Bearing capacity	120 kg
Total length	1100 mm
Total width	500 mm
Total weight	7.5 kg
Cost	Rs..8250

1. Clamping unit

i.	C clamp	30 x 5 mm
ii.	Triangular frame	M.S pipe Φ 10 mm
iii.	Clamping clip	Φ 5 mm
iv.	Wire rope	Φ 5 mm

2. Climbing unit

i.	Nylon rope	3 m
ii.	Single sheave pulleys	Φ 60 mm
iii.	Vertical connector (M.S pipe)	30 x 30 mm
iv.	Cross bar (M.S pipe)	30 x 20 mm

3. Lifting unit

i.	Cotton rope	Φ 12 mm
ii.	Full body harness	Full size
iii.	Ratchet gear	180 teeth
iv.	Double sheaved pulleys	Φ 55 mm

DEVOLOPMENT AND TESTING OF A DOMESTIC COCONUT CLIMBER

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ABSTRACT OF THE REPORT

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In

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Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

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Kelappaji College of Agricultural Engineering & Technology, Tavanur

679 573

2019

ABSTRACT

Coconut climbing is difficult and drudgery involved operation. With the lack of labour available for climbing and harvesting the coconuts and the difficulties of using the available models of coconut climbers, a domestic coconut climber was developed and tested ergonomically. The developed climber incorporates a block and tackle mechanism for lifting the operator up and down the palm. The operator with a climbing unit moves with the force of the spring raising the clamping unit up the palm. The attachment of clamping unit is made with lifting unit by means of a double sheave pulley. The lifting unit is then operated using block and tackle system. The domestic climber was tested for various physical and physiological parameters using ergonomic principles. The results showed that the domestic climber had a total weight of 7.5 kg with a setting and removing times of 86 s and 54 s respectively. The climber was found to possess adjustment for varying girth of palm, locking mechanism and safety system. The mean heart rate while using the climber was found to be 118.86 beats min^{-1} while oxygen consumption of 0.604 lit. min^{-1} with an energy cost of 12.61 KJ min^{-1}. The ODR showed a scale of 3.6 indicating light discomfort, OSR of 1.0 ascertened good security and devoid of fear, OER of 4.5 revealed less difficulty in operation. The heart rate measured during the operation of the climbers elucidated the subjects recorded least heart beat rate for domestic climber. Also, the energy cost calculated showed a lower energy requirement for the domestic climber followed by Chembery model. Subjective rating scale employed for comparative evaluation of the climbers reaffirmed a better overall scale rating for the domestic climber compared to the popular coconut climbers in our State.