# ERGONOMIC EVALUATION OF COCUNUT CLIMBERS

# AND

# REFINEMENT OF TNAU CLIMBER

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## PROJECT REPORT

**Submitted in partial fulfilment of the requirement for the degree of**

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# DECLARATION

We hereby declare that this project report entitled **"ERGONOMIC EVALUATION OF COCUNUT CLIMBERS AND REFINEMENT OF TNAU CLIMBER"** is a *bonafide* record of project work done by us during the course of academic programme in the Kerala Agricultural University and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

Tavanur
14-12-2011

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**(2007-02-016)**

# CERTIFICATE

Certified that this project report entitled **“ERGONOMIC EVALUATION OF COCUNUT CLIMBERS AND REFINEMENT OF TNAU CLIMBER”** is a bonafide record of project work jointly done by Mr. Manoj Thomas *(Admn. No. 2007-02-015)*, Mr. Nandakumaran Unny, M *(Admn. No 2007-02-018)* and Mr. Sreerag, P.M *(Admn. No 2007-02-016)* under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship, associateship, or other similar title of any other University or Society to them.

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14-12-2011

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Dedicated to

The Profession of

Agricultural Engineering

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| | | |
|---|---|---|
| $^0C$ | - | Degree centigrade |
| AWL | - | Acceptable workload |
| BPDS | - | Body Part Discomfort Score |
| beats $min^{-1}$ | - | Beats per minute |
| gms | - | Grams |
| h | - | Hour |
| HR | - | Heart rate |
| KCAET | - | Kelappaji College of Agricultural Engineering and Technology |
| kCal | - | Kilo Calories |
| kJ $min^{-1}$ | - | Kilo Joule per minute |
| l $min^{-1}$ | - | Litre per minute |
| m $s^{-1}$ | - | Metre per second |
| m | - | Metre |
| min | - | Minute |
| mm | - | Millimetre |
| N | - | Newton |
| ODR | - | Overall Discomfort Rating |
| OER | - | Overall Ease of operation Rating |
| OSR | - | Overall Safety Rating |
| s | - | Second |
| TNAU | - | Tamil Nadu Agricultural University |
| $VO_2$ | - | Volume of Oxygen consumed |

# Introduction

# CHAPTER 1

# INTRODUCTION

Coconut belongs to the *arecacea* family which comprises of about 200 genera and 2,500 species. Over five billion coconuts are harvested every year in India. It play an important role in the economy of several countries. The major coconut producing States in India are Kerala, Tamil Nadu and Karnataka, the Lakshadweep and Andaman islands and the Caribbean countries. Coconuts are exported in tonnes around the world bringing huge revenue to various tropical countries. Coconut is the second most important crop after paddy occupying about 38% of the gross cropped area in Kerala. It accounts for about 68% of the gross cropped area under cocunut in India and its share in all India production is 66%.

Appropriately the coconut palm is referred to as *The palm of life* by villagers, as every part of it is utilized for various purposes. The outside husk is used to make strong ropes, while the leaves are used as roofing material. Also the tender coconut water is a delicious and nutritious drink. More importantly, tender coconuts are used as a medicine for diseases such as thyroid, diarrhoea, etc.

The majority of coconuts are harvested by climbing the palm and cutting the nuts down by hand. This process may seem to be simple but it is quite dangerous. An experienced climber takes about 4-5 minutes just to climb the palm alone (this doesn't include cutting the coconuts and the return trip). Due to its strenuous nature professional coconut climbers are now a few in number and farmers are finding it difficult to harvest the nuts. In response, there is a genuine need to develop a device which is safe and efficient to assist the climbers. At present there are afew models of coconut climbers available in the market. Most of the climber's safety and efficiency aspects are being questioned and needs to be comparatively evaluated and modified.

Normally skilled workers climb the palm to harvest the coconuts. Since coconut palms are very tall, any fall from top of the palm can result in severe injury. The climbers employed for climbing coconut palm suffer from musculoskeletal disorders which disable individuals at rates near or above those of traumatic, respiratory and dermatological injuries.

The health hazards associated with coconut palm climbing include slip during rainy days, ant and insect bites, bees attack and formation of wart in the palms and legs of the climber**.**

Keeping in view of the above facts, the present investigation on "Comparative evaluation and modification of coconut palm climbing device" was undertaken with the following specific objectives.

i. To ergonomically evaluate selected coconut palm climbing devices.

ii. To carry out refinements in the selected palm climbing device for reduced drudgery, operational comfort and safety.

# Review of literature

# CHAPTER 2

# REVIEW OF LITERATURE

The research work pertaining to various aspects having direct bearing to the present investigation is being reviewed below. It is broadly divided into palm climbing devices and ergonomic evaluation.

## 2.1 Palm climbing devices

Palm climbing devices are essential for harvesting coconut palms. Commercial palm climbing devices are available in the world but none of them palm is ergonomically designed.

Horace (1985) developed a palm climbing apparatus as shown in Figure 2.1. It comprises of a climbing platform characterized by a platform yoke having a seat for supporting the user and a folding foot support having a foot support yoke and a cooperating foot platform for intermittent support of the user while the climbing platform was caused to ascend a palm engaged by the platform yoke and foot support yoke. Both the platform yoke and the foot support yoke features a Y-shaped segment and a removable blade for engaging the palm on opposite sides to support the platform yoke at a first selected elevation and the foot support yoke and companion foot platform at a second selected elevation beneath the platform yoke.

Williams (1989) developed a combined climbing and hang-on palm stand with optional climbing aid having a platform, a seat collapsible between a position overlying the platform and a position upstanding from the platform, and a climbing band for encircling the palm as shown in Figure 2.2. The platform, seat and band engages the palm at three discrete points to afford stability. A safety rope is secured to the seat and is provided with a Chinese knot for tightening the rope against the palm. A climbing aid comprising generally of a rectangular frame with one ‘end frame member’ slidable towards and away from the opposite ‘end frame member’ to adjustably lock in a selected position depending upon the girth of the palm was provided.

Amacker (1992) developed a universal compact and versatile palm stand with a seating section Figure 2.3 having at least one pair of longitudinal side members supporting a seat and means for gripping a palm connected at one end of the side members. A cross member is provided so as to reversibly extend the seating section which can also be completely removed from the seating section. A foot supporting section with a rectangular frame is divided into two frame sections. The two frame sections could be separated so that the frame is reassembled for climbing and used as a palm stand or disassembled to reduce the length of the foot supporting section for transportation and storage. The seating section can also be used as an hand climber.

Gardner (1992) developed a climbing palm stand as shown in Figure 2.4. The apparatus for climbing the palm comprise of two frames, each frame having a rigid base portion with flexible adjustable palm encircling band mounted thereon. A turnbuckle was connected to the end of each band for drawing together and separating the ends so as to change the effective length of the band. The rigid base portion of each frame had palm gripping edges which together with the bands and resiliently biased braces act to secure each frame to the palm. Adjustment of turn buckles changes the attitude of the base relative to the ground. One of the frame is positioned above the other on the palm and they are alternatively raised up the palm or lowered down the palm. The upper frame has a seat which hangs from the rigid base and is slidable, vertically adjustable and pivotable relative to the base. The lower frame has a platform upon which the foot of a user rests while standing or sitting on the seat. A pivotable brace member mounted on each base and resiliently urged against the palm aids in holding each frame against the palm during the climbing phase and the upper brace member functions as a back rest for the user.

Louk (1993) developed a hunter’s palm stand having two platforms as shown in Figure 2.5. Both platforms has a supporting metal frame, one covered with an open metal grid for standing, and other having a web fabric seat for comfortable seating. Each platform is supported by rigid folding side rails, which can be folded for easy storage. A flexible, encased steel cable extending from one side rail around the trunk of the palm is fastened to the other side rail, and adjusted in length by a snap ring clip. A blunt round edge toothed blade extending from the metal frame, in combination with the encased cable, holds the stand securely to the palm under load but without penetrating the bark or otherwise injuring the palm. The encased cable and folding support confirmed to the shape of the palm, and gave the user a secure feeling while climbing in the palm stand.

Reggin (1994) developed a portable palm stand assembly comprising of a horizontal platform easily mountable to a trunk of a palm as shown in Figure 2.6. A vertical mounting structure is connected to the rear side of the horizontal platform and extends vertically downward from the horizontal platform. A cantilevered support structure is connected between the front side of the horizontal platform and the base of vertical mounting structure, which allows the upper surface of the horizontal platform to be unobstructed. A plurality of spurs protruding rearward from the vertical mounting structure grips the surface of a palm without causing substantial damage to the palm. A link chain secured the stand to the palm without requiring cinching or tightening.

Stuart (1997) developed a palm stand shroud as shown in Fig 2.7. The shroud partially covers the hunter and enclose the palm stand during use. The shroud formed from a flexible camouflage fabric could be easily folded into a small package for carrying by the hunter. The shroud included loop straps fasteners along the top edge for releasably attaching the shroud to the palm stand. A draw cord along the bottom edges allowed the shroud to be closely gathered around the footrest section of the palm stand to prevent deer or other animals from being frightened by inadvertent movement of the hunter.

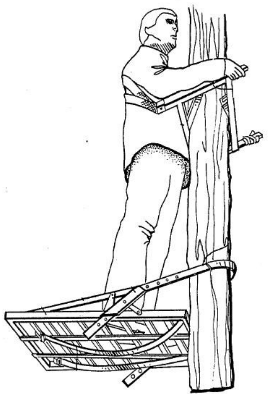
Louk *et al.* (1999) developed a convertible palm stand for rifle/bow use as shown in Figure 2.8. The palm stand consists of two platforms each having a supporting frame, one covered with an open grid member for standing, while the other had a seat for comfortable seating. The seating platform could be mounted to a palm in one of the two positions. One position would locate the front end thereof in a downward direction. This which opens the front end for use in bow hunting. The other or second position was inverted, with the front end located in an upward direction so that it would define a rest surface for rifle hunting. A flexible cable extending from one side of the outer end of the platform, through a side support around the palm to another pivotal side support was connected to the other side of the outer end, supporting each platform. The cable is adjustable in length to accommodate different diameter palms.

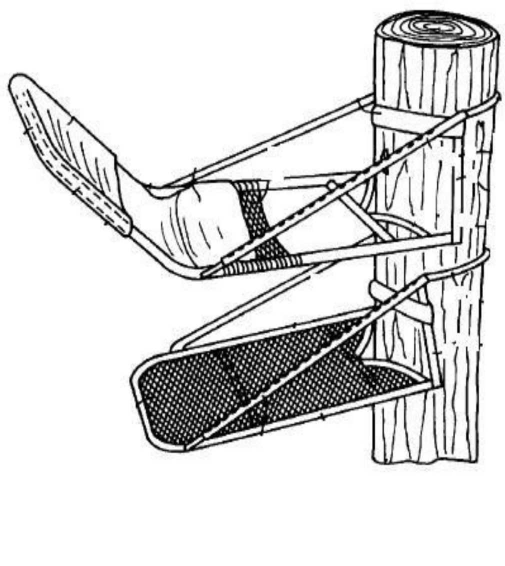
Morris (2002) developed a climbing palm stand Figure 2.9 having a first platform and a second platform having a base frame, a first arm and a second arm, a support arm, first and second illumination assemblies, and a blade attached to an upper bracket of the base frame. The first and second arms were pivotally attached to the base frame and were releasably engageable with the support arm. The support arm had a curved portion at an opposed distal end of the first arm and second illumination assembly attached to a distal end of the second arm of each platform. The second platform included a foot support lifting bracket attached to its base frame. The foot support lifting bracket comprised of rigid non flexible structure.

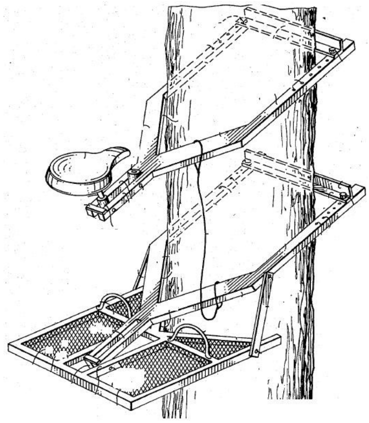
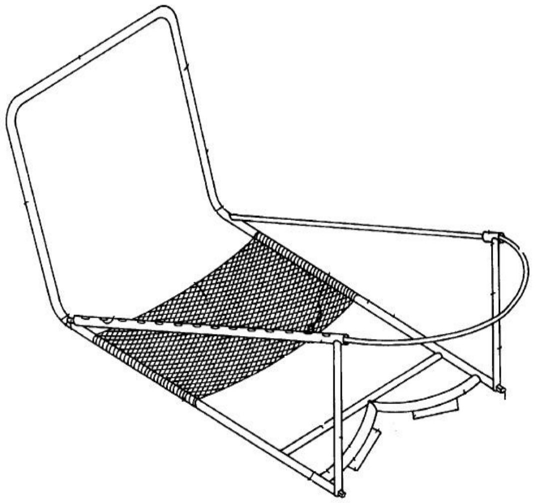
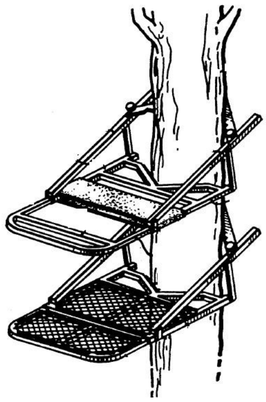
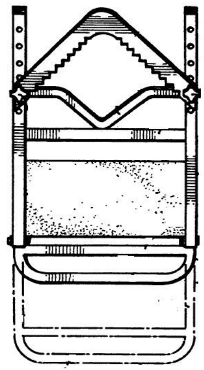
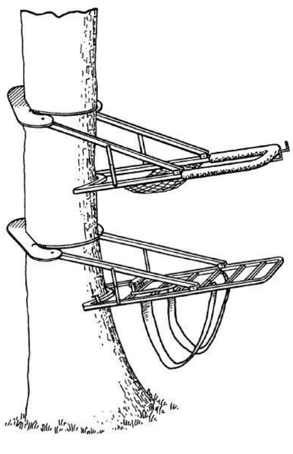
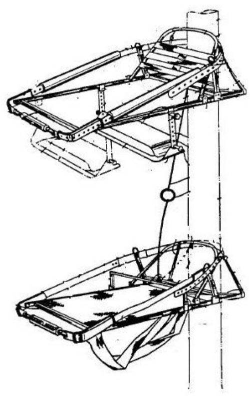
Graham *et al*. (2003) developed an adjustable palm stand comprising of a seating section Figure 2.10 and a standing section, each having inclined attachment bars adjacent the section sides, and seating and standing section cables, each having first and second ends with handles at each of the ends. Each attachment bar had outer and inner faces with a plurality of spaced, aligned attachment holes extending between the faces, and a plurality of spaced, aligned latch holes alternating with the attachment holes. Each of the handles had a pair of flanged projections insertable into adjacent attachment holes in an attachment bar, and a latch pin insertable into a latch hole between the adjacent holes. Each projection was moveable from an insertion position to a locked position within a hole when the cable was tensioned, and was prevented by the latch pin from moving back to the insertion position when the cable was relaxed.

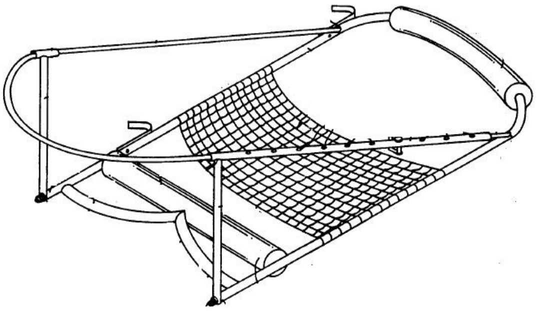
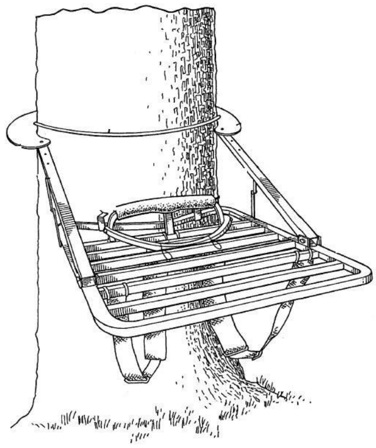
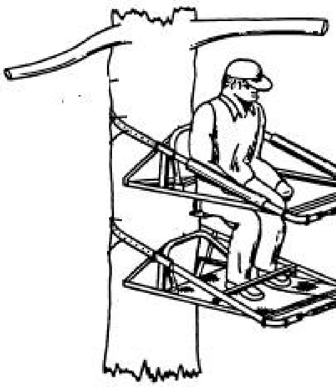
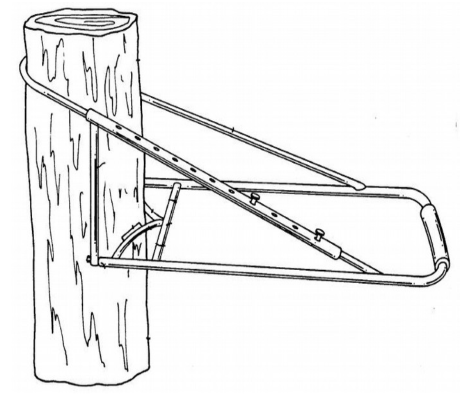
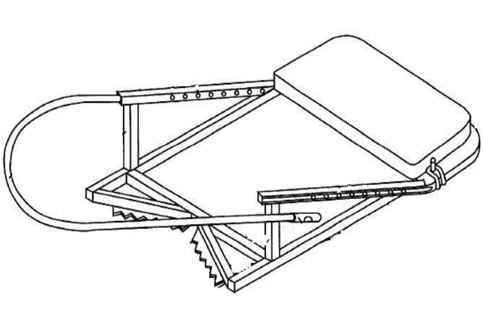
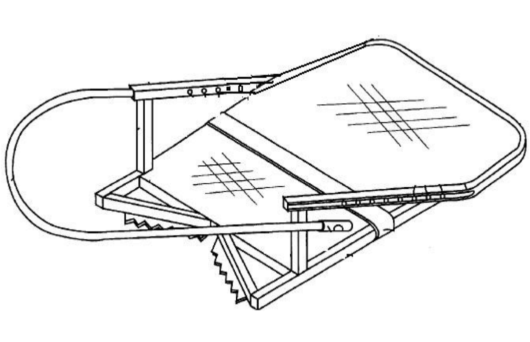
Joseph (2006) developed a coconut-climbing device having two frames (left and right). Each frame have flexible adjustable encircling iron rope mounted around the palm and a palm gripping rubber pad. Each frame member had adjustable lock for changing rope length according to girth of the palm. An elastic strap helps the climber hold his feet inside a strap. The two main frames were fitted on the palm side by side enabling the operator to lift the frames conveniently using the sliding member.

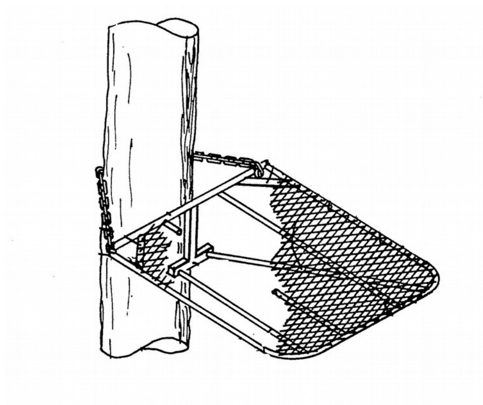
Laborde (2006) developed a climbing palm stand apparatus with an upper and lower platforms that are independently movable up the palm by alternatively sitting Figure 2.11 and standing on one or the other of the platforms. In order to adjust the angular position of the selected platform relative to the palm, an easily accessible adjustable anchor point was provided. The anchor point enables the cable associated with each platform to be lengthened or shortened in order to maintain the orientation of the platform in a nearly horizontal position.

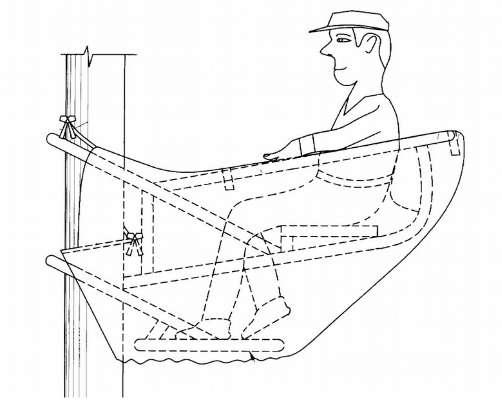


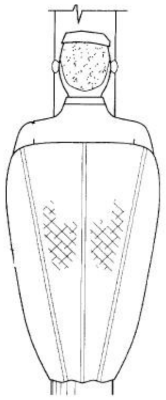


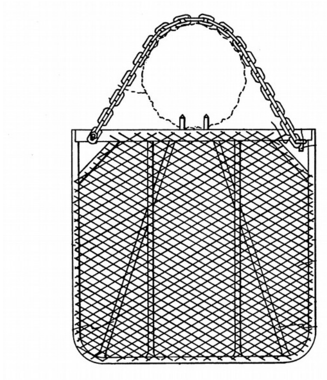















## 2.2 Ergonomic evaluation

### 2.2.1 Work physiology

Astrand *et al.* (1965) stated that maximal oxygen uptake; heart rate, stroke volume, pulmonary ventilation and muscle strength decreased significantly with old age. The maximal aerobic power reached a peak at the age of 18-20 years followed by a gradual decline.

Grandejan( 1982) observed that the maximum force a muscle or group of muscle capable of depends upon age. The peak muscle strength for both man and women is reached between the ages of 25 and 35 years. Older workers aged between 50 and 60 can produce only about 75-85 per cent of muscular strength.

Grandejan(1988) presented the relation between the oxygen consumption and age of the workers and inferred that the maximum percentage of work could be expected during 20 to 30 years.

Rodahl (1989) reported that maximum heart rate declines with age.

Mc Ardle *et al*. (1994) reported that the various measures of bodily function generally improve rapidly during childhood to reach a maximum between age 20 and 30 years and then a gradual decline in functional capacity with advancing years.

Gite and Singh (1997) reported that the maximum strength can be expected from the age group of 25 to 35 years. Maximum muscle strength and the cross sectional area of muscles was also found higher for this age group (Nigg and Herzog, 1999).

Mc Ardle *et al.* (2001) investigated the strength of male and female workers and concluded that both usually attain the highest strength levels between 20-40 years of age. It was also reported that the arm strength deteriorates more slowly than leg strength for male and female workers.

**2.2.2 Response of subjects**

Curteon (1947) reported that basal metabolic rate, heart beat rate and oxygen consumption rate are the pertinent parameters for assessing the human energy required for performing various types of operation.

Davies and Harris (1964) reported that the heart rate increases rapidly in the beginning of an exercise and reaches a steady state by the end of sixth minute. At the start of the exercise, there is a rapid rise in pulse rate and the maximum pulse rate is achieved within 5 seconds.

Astrand and Rodhal(1977) pointed out that there is a linear relationship between heart rate and oxygen consumption in general. The heart rate under standardized conditions may be used as an index of oxygen uptake for a given task.

Brockway (1978) stated that the heart beat rate predicts the energy expenditure.

Durnin (1978) correlated the heart beat rate and oxygen consumption by indirect calorimetry and indicated the possibility of extrapolating the energy expenditure from the stabilized heart beat rate.

Roswe (1993) concluded that of the available physiological variables for assessing the workload, heart rate is the most useful. Heart rate and oxygen consumption have been used to assess the workload of human subjects.

Kroemer and Grandjean (2000) stated that measuring the heart rate is one of the most useful ways of assessing the workload as it can be done so easily.

### 2.3 Overall discomfort rating (ODR)

Borg (1962) developed a category scale for the rating of perceived excretion (RPE). The scale ranges from 6 to 20 with every second number anchored by verbal expressions.

In 1970s, Borg developed a 15-point graded category scale to increase the linearity between the ratings and the workload. Using this scale, ratings of perceived exertion (RPE) values were shown to be approximately one-tenth of heart rate values for healthy, middle-aged men performing moderate to heavy exercise.

### 2.4 Body Part Discomfort Score (BPDS)

Corlett and Bishop (1976) used body mapping for assessment of postural discomfort at work. In this method, the perceived discomfort is referred to a part of the body. The subject's body is divided into 27 regions and the subject is asked to indicate the regions which are most painful. The subject is also asked to assess total discomfort from the worst on a particular body part, using a five or seven point scale. The scales are graded from "no discomfort" to "maximal discomfort".

Lusted *et al.* (1994) developed a body area chart discomfort checklist. It was used to rate the discomfort under dynamic condition to identify body area experiencing discomfort. Two discomfort checklists are filled, one at the start of the test and the second after a long period in the seat. The ratings are then compared to estimate the level of discomfort.

Kroemer and Grandjean (2000) defined the fatigue symptom as a general sensation of weariness. They reported the subjective and objective symptoms *viz.*, subjective feeling of weariness, faintness and distaste for work; sluggish thinking; reduced alertness; poor and slow perception and unwillingness to work.

Borah *et al.* (2001) reported that out of 30 women, 70 percent experienced severe pain in the shoulder joints and 68 percent found low back pain due to long hours of bending for uprooting of seedlings.

Gupta *et al.* (2004) studied the musculo skeletal problems and rating of perceived exertion of women in different farm activities and compared the results between existing and improved units.

# Materials and Methods

# CHAPTER 3

# MATERIALS AND METHODS

In this chapter, constructional features of the available coconut palm climbing devices are detailed. The principle of gripping mechanism and the selection of subjects for ergonomic evaluation of selected palm climbing devices are briefly explained. The details of computation of heart rate, oxygen uptake, energy consumption and the assessment of overall discomfort rating (ODR), overall safety rating (OSR), overall rating for ease of operation (OER) are mentioned. Body Part Discomfort Score (BPDS) and Rated Perceived Exertion (RPE) in the operation of the selected palm climbing devices are also detailed. Based on the evaluation, ergonomic refinements were carried out in selected coconut palm climbing device and a new model was developed.

## 3.1 Selection of coconut palm

Coconut palm was selected based on its height, straightness and inclination. The palm was selected such that it was not completely straight and had slight inclination.

### 3.1.1 Height of palm

The selected palms had a moderate height of 14 m. The height of coconut palm is influenced by its variety and age. Increment in stem height of coconut palm per year varied between 23 to 37 cm for a period of   years and significantly varied based on the cultivars and hybrids (Kasturi Bai *et al*., 1996).

### 3.1.2 Trunk diameter

The girth of the palm was measured at three levels of height respectively at 1 m above ground level , at 1 m below the bottom most frond level  and at  middle portion. The girth was measured using a measuring tape and the observations were recorded.The mean of three girth reading was taken for trunk diameter calculation Since the cross section of the trunk is circular, the cross sectional diameter of the coconut palm was calculated using the following expression,

$$D = \frac{C}{\pi}$$

where,

D = Diameter of trunk of coconut palm,  cm

C = Perimeter of the coconut palm, cm

### 3.2 Selection of climbing device

Ergonomic evaluation of palm climbing device is necessary to improve fit between physical demands of tools and workers who perform the work. The coconut climbing devices of various models selected were Kerala,TNAU and Keraki respectively.

#### 3.2.1 Kerala model

Mr. M.J.Joseph, a farmer from Chemberi village of Kannur district in Kerala developed a coconut-climbing device during 2003 (Plate 3.1). The device has two frames (left and right). The main frame is made of 12 mm diameter mild steel rod. Each frame comprises of flexible adjustable encircling iron rope of 8 mm diameter and length 1060 mm mounted around a palm and palm gripping semi circular pad made of worn out tyre rubber pad fitted against a palm trunk. One end of the iron rope is attached to rubber pad and another end placed on adjusting holes to changing rope length according to girth of the palm. The adjusting holes comprise of bolts and wing nuts to fasten the ropes. The main frames having the foot rest comprise of a safety strap to prevent accidental slip during engagement with the climber’s feet while ascending and descending the palm. The two main frames are fitted on the palm side by side enabling the operator to lift the frames conveniently using the sliding member.

Before climbing, the climber fixes the climbing device, both left and right units, to the palm with the help of the wire rope provided. The climber holds the handles of both the units and climbs on by keeping both legs in the footrest provided. Then the right unit of the device is lifted by hand to about 30 to 40 cm, after 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 operation is repeated by the left unit without releasing the body weight from the left unit. The operation is repeated to reach the required height. For climbing down, the reverse operation will be 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

**Plate 3.1 Kerala model coconut palm climbing device**

weight on the left footrest followed by the right unit. While climbing down, care should be taken not to overlap the ropes of the climbing units which leads to jamming of the device.

### 3.2.2 TNAU model

A coconut palm climbing device was developed under All India Coordinated Research project on Farm Implements and Machinery in TNAU during 2006 (Plate 3.2).

The device consists of constructed of an upper frame and a lower frame which are independently movable and positionable along the coconut palm trunk. The upper frame member is a tubular frame work consisting of a rigid base section and an adjustable palm gripping section. The rigid base section carries a seating arrangement for accommodating the user, front support rail, cross rear rail and side rails. The user can sit comfortably facing the palm and receive support from the cross rear rail and the side rails. The seat is a flexible sagging type made of rexin fabric attached through loops between the rear and front cross rails of the frame.

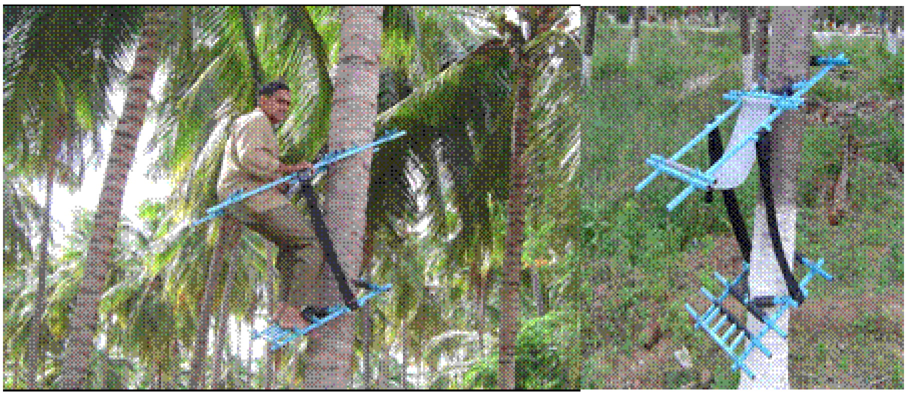


**Plate 3.2 TNAU model coconut palm climbing device**

The palm gripping setion has gripping aids to engage it on three points on the circumference of the palm. The gripping aid is a rubber bush inserted into a tubular square bar. The gripping section has three members which form a triangular throat that encompasses the upright coconut palm trunk, thereby permitting the upper frame member to be fixed to the palm. One of the removable gripping members is attached to the extendable arm and the other two are attached in “V’ shape to the front support bar of the seating frame. The spacing between the gripping members is adjustable with the help of extendable arm to suit the girth of the coconut palm.

The lower frame member is also a tubular frame work consisting of a rigid base section and a palm gripping section similar to upper frame member except that the rigid base section is located adjacent to the palm trunk to support the weight of the user when the upper frame is repositioned on coconut palm. The rigid base section carries a pair of parallel tubular bar with rubber bushes for the user to insert his feet and lift the unit. Cushioning material is also provided around the rubber bushes for sophisticated purpose of user feet.

The upper and lower frame members are connected with canvass belt to prevent them from slipping down the palm trunk. Handles provided on the side rails of the upper frame enable the user to lift the unit during ascending or descending the palm. After reaching the coconut palm top, the unit can be fitted to the one of the frond with the help of hook so that the user can get into the crown of palm for harvesting coconuts.

The spacing of the gripping members is set initially to engage both the upper and lower frames with the outermost ends such that the inclination of the seat and foot rest is horizontal or parallel to the ground. To ascend the coconut palm, the user places his feet on the lower frame member, and then rests his weight on the seating section of the upper frame while using his feet and legs to pull the lower frame upward. The user then stands by resting his feet on the lower frame and uses his hand to raise the upper frame to waist high position. The user then sits and again raises the lower frame with his feet and legs.

### 3.2.3 Keraki model

The climber consists of two parts such as the lower part with two separate frames on which the foot rests and the upper part consists of a frame for holding on to the palm and an handle. The upper part has a handle on it. The climber is made of 25mm hollow square aluminium pipe. Both frames are similar in dimensions. The frames have bolts and adjustable holes for different palm girths. A rope along with safety strap are provided for overall safety of the operator.

**Plate 3.3 Keraki model coconut palm climbing device**

The climbing action is accomplished by alternate movement of leg frames along with the upper part that acts as a support to hold on to the palm. One needs to hold to the handle with one arm and other arm on to the palm and then lift one leg frame. Then the next leg frame needs to be lifted and then the upper frame. The lower frame has shoes attached for better stability and ease of operation.

## 3.3 Material for gripping

Selection of gripping material is crucial since it may influence weight of device, flexibility and resistance to wear and tear. Hard material injures palm and doesn't have flexibility. Hence cylindrical rubber was used as the gripping material.

## 3.4 Selection of subjects

The subjects should be physically and medically fit to undergo the trials. They should not be affected by illness or handicaps and they should be a true representative of user population in operation of the selected coconut palm climbing device. They were selected based on age and ratio of height to weight of the subject (H/W ratio).

### 3.4.1 Age

Ten people at an age group 21-30 years were selected as subjects for the purpose of evaluation of the climbing device.

### 3.4.2 H/W ratio

The subjects selected were having different body dimensions and H/W ratio

**Table 3.1 Details of the subjects**

| Subjects | Age | Height, cm | Weight, kg | H/W ratio |
|---|---|---|---|---|
| S 1 | 23 | 172 | 56 | 3.07 |
| S 2 | 22 | 179 | 60 | 2.98 |
| S 3 | 22 | 171 | 66 | 2.59 |
| S 4 | 25 | 166 | 54 | 3.07 |
| S 5 | 23 | 172 | 60 | 2.86 |
| S 6 | 25 | 178 | 87 | 2.04 |
| S 7 | 30 | 179 | 56 | 3.19 |
| S 8 | 21 | 161 | 51 | 3.15 |
| S 9 | 22 | 178 | 78 | 2.28 |
| S 10 | 23 | 172 | 68 | 2.52 |

## 3.5 Ergonomic evaluation of selected coconut palm climbing devices

Ergonomic evaluation of selected coconut palm climbing devices was conducted for assessing their suitability with the ten selected subjects. The evaluation was carried out on the parameters such as heart rate, oxygen uptake, energy consumption, overall discomfort rating (ODR), overall safety rating (OSR), overall ease of operation rating (OER) and body parts discomfort score (BPDS)

### 3.5.1 Heart rate

The heart rate of the selected subjects was measured using Polar S810 computerized heart rate monitor. It is a compact portable instrument to monitor the heart rate. This can be used in the field directly where the telemetry system cannot be used. This polar pacer has the three basic components viz., chest belt transmitter, elastic strap and receiver unit.

#### 3.5.1.1 Chest belt transmitter (Polar coded)

It has two electrodes fixed in the grooved rectangular area on the underside of the belt transmitter, which picks up heart rate from the body of the subject and converts to electromagnetic signals. For better sensing, the electrodes are wetted with water.

#### 3.5.1.2 Elastic strap

This is to secure the belt transmitter as high under the pectoral muscles (breasts) as comfortable. The belt transmitter should fit comfortably and allow normal breathing. The transmitter with the elastic strap is secured on the subject along with the receiver.

#### 3.5.1.3 Receiver

This unit receives the signals from the transmitter and displays it on screen and record the data in the memory with the help of battery CR 2025 fixed in it. It is placed within one-meter range and can be fitted either in watchstrap or mounted on Bike Mount supplied as accessory with the unit. It has provision to set up high target zone and low target zone limits. When the subject reaches that limit of heartbeat, it will indicate through alarm or visual alarm. Similarly the low heart rate target zone will be helpful in certain critical condition. It is water resistant to 20-m water column.

### 3.5.2 Heart rate and oxygen uptake

There is a close interaction between circulatory and metabolic processes. For proper functioning, nutrients and oxygen must be brought to the muscle or other metabolizing organs with the removal of metabolic by-products afterwards. Therefore, heart rate as a primary indicator of circulatory function and oxygen consumption, representing the metabolic conversion taking place in the body, has a linear and reliable relationship. Heart rate measurements have a major advantage over oxygen consumption as an indicator of metabolic process. Heart rate responds more quickly to changes in work demands and hence indicates more readily quick changes in body function due to changes in work requirement (Kroemer *et al*., 1997). Only the heart rate of the subject performing the task was noted. The heart rate at rest, during climbing (at middle and top) and after climbing down was monitored.

### 3.5.3 Energy consumption

The heart rate during climbing (at top) was used to calculate the mean value for all the selected climbing devices. From the values of heart rate (HR) observed during the trials, the corresponding values of oxygen uptake ($Vo_2$) and energy consumption of the subjects for all the selected palm climbing devices were determined using the equations in Table 3.2 as suggested by Phillip (2001). The values of heart rate, oxygen consumption and the energy expenditure for all the subjects were averaged to get the mean values for all the selected coconut palm climbing devices.

**Table 3.2 Relationship between heart rate, oxygen uptake and energy consumption**

| H/W ratio | $VO_2$ uptake (l/min) | Energy consumption(kJ/min) |
|---|---|---|
| Below 2.5 | 0.018HR – 0.7765 | 0.2372HR – 15.554 |
| 2.5 – 3 | 0.0102HR – 0.5324 | 0.203HR – 10.483 |
| Above 3 | 0.0088HR – 0.4952 | 0.1768HR – 9.918 |

### 3.5.4 Overall Discomfort Rating (ODR)

For the assessment of overall discomfort rating a 10 - point psychophysical rating scale (0 - no discomfort, 10 - extreme discomfort) was used which is an adoption of Corlett and Bishop (1976) technique. A scale of 70 cm length was fabricated having 0 to 10 digits marked on it equidistantly. A moveable pointer was provided to indicate the rating. At the end of each trial, subjects were asked to indicate their overall discomfort rating on the scale. The overall discomfort ratings given by each of the ten subjects are added and averaged to get the mean rating.

### 3.5.5 Overall Safety Rating (OSR)

For the assessment of safety rating, a 10 - point psychophysical rating scale (0 – completely secure and no fear, 10 – Totally insecure and extreme fear) was used which is an adoption of Corlett and Bishop (1976) technique. A scale of 70 cm length was fabricated having 0 to 10 digits marked on it equidistantly. A moveable pointer was provided to indicate the rating. At the end of each trial, subjects were asked to indicate their safety rating on the scale. The overall safety ratings given by each of the ten subjects are added and averaged to get the mean rating.

### 3.5.6 Overall Ease of Operation Rating (OER)

For the assessment of ease of operation, a 10 - point psychophysical rating scale (0 – very easy, 10 – extremely difficult) was used which is an adoption of Corlett and Bishop (1976) technique. A scale of 70 cm length was fabricated having 0 to 10 digits marked on it equidistantly. A moveable pointer was provided to indicate the rating. At the end of each trial, subjects were asked to indicate their ease of operation rating on the scale. The overall ease of operation ratings given by each of the ten subjects are added and averaged to get the mean rating. The scale for ODR, OSR and OER are given in Table 3.3

**Table 3.3 Scale for ODR, OSR and OER**

| Levels | ODR | OSR | OER |
|---|---|---|---|
| 0 | No discomfort | Completely secure and no fear | Very easy |
| 1 | | | |
| 2 | | Secure and meager fear | Easy |
| 3 | Light discomfort | | |
| 4 | | Moderately secure and less fear | Less difficulty |
| 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 |

### 3.5.7 Body Part Discomfort Score (BPDS)

In the Corlett and Bishop (1976) technique, subject's body is divided into 27 regions. A body mapping given in Figure 3.1 was made with thermocoal to have a real and meaningful rating of the perceived exertion of the subject. The subject was asked to mention all body parts with discomfort, starting with the worst, the second worst and so on until all parts have been mentioned (Lusted *et al*., 1994). The subject was asked to fix the pin on the body part in the order of one pin for maximum pain, two pins for next maximum pain and so on (Legg and Mohanty, 1985). The number of different groups of body parts which are identified from extreme discomfort to no discomfort, represented the number of intensity levels of pain experienced. Each separately reported group could be seen as being separated by a recognizable difference in the level of discomfort.

The maximum number of intensity levels of pain experienced for the operation of unit will have to be categorized. The rating will be assigned to these categories in an arithmetic order as explained below. *viz*., If the maximum number of intensity levels of pain experienced for the operation was 6 categories, first category (body parts experiencing maximum pain) rating was maximum and for second category (body parts experiencing next maximum pain) rating was allotted as 5 and so on, for the sixth category (body parts experiencing least pain) rating was allotted as 1. The number of intensity levels of pain experienced by different subjects might vary. For example, if one subject has experienced 4 categories, first category (body parts experiencing maximum pain) rating was allotted as 6 and for second category (body parts experiencing next maximum pain) rating was allotted as 4.5 and so on for the fourth category (body parts experiencing least pain) rating was allotted as 1.5. The body part discomfort score of each subject will be the rating multiplied by the number of body parts corresponding to each category. The total body part score for a subject will be the sum of all individual scores of the body parts assigned by the subject. The body discomfort score of all the subjects is to be added and averaged to get mean score. The same procedure was repeated for the entire palm climbing device with all the selected subjects.

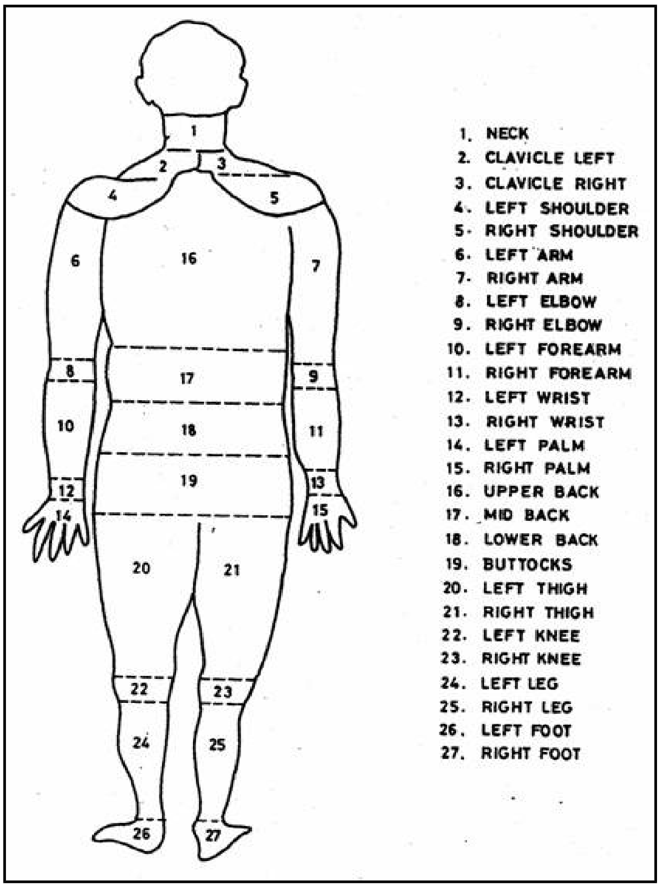



**Fig. 3.1 Regions for evaluating BPDS**

### 3.6 Ergonomic evaluation of coconut palm climbing devices

The evaluation of coconut palm climbing devices was conducted with selected subjects at the farm of KCAET, Tavanur. The trials were conducted between 7.00 am and 5.00 pm during the month of November. The details of experiment were explained to all subjects to avoid confusions. Each subject was given 10 minutes rest before evaluation. After the rest, they were given sufficient time to complete the operation. The procedure was repeated for all subjects.

### 3.7 Modifications

The ergonomical modification reduces the physical demands of work, simplifying the operation and also be perceptible in terms of health and comfort. Based on ergonomical evaluation and subjects' feedback, ODR, BPDS, PER suitable ergonomic design refinements were incorporated. The model was also evaluated based on the procedure mentioned in section 3.5.

### 3.8 Performance testing

Comparative studies were conducted using the new and existing models and the following observations were made.

i. Time for setting up the unit on to the palm

ii. Time for climbing up the coconut palm

iii. Time for climbing down the coconut palm

iv. Time for removing the unit from the palm

v. Oxygen uptake ($VO_2$)

vi. Energy consumption

vii. Overall Discomfort Rating (ODR)

viii. Overall Safety Rating (OSR)

ix. Overall Ease of Operation Rating (OER)

x. Body Part Discomfort Score (BPDS)

# Results and Discussions

# CHAPTER 4

# RESULTS AND DISCUSSION

In this chapter, palm characteristics, computed values of oxygen uptake and energy consumption are mentioned. The overall discomfort rating, overall safety rating, overall ease of operation rating, body parts discomfort score, perceived rate of exertion are found out and discussed. The ergonomic design refinements carried out in the selected climbing devices for an increased comfort of the operator are detailed.

## 4.1 Selection of Coconut palm

The coconut palms were selected based on its height and trunk diameter. The palms had a height of around 14 m. and was not completely straight and had a slight inclination.

The mean girth was found to be 67 cm. Using this value, trunk diameter was found to be 21.32 cm using equation mentioned in section 3.1.2.

## 4.2 Selection of climbing device

The Kerala, TNAU and Keraki models of coconut palm climbing devices were used for ergonomical evaluation.

### 4.2.1 Kerala model

Various parameters of the Kerala model coconut palm climbing device were measured and is shown in Table 4.1

**Table 4.1 Specifications of Kerala model coconut palm climbing device**

| S.No. | Parameters | Quantity |
|---|---|---|
| i | Over all dimensions of main frame (L x B x H), mm | 245 x 275 x 970 |
| ii | Sliding height, mm | 570 |
| iii | Weight of the unit, kg | 8.78 |
| iv | Size of the foot rest, mm | 110 x 110 |
| v | Height of the handle from foot rest, mm | 960 |
| vi | Thickness of rubber pad, mm | 22 |
| vii | Length of iron rope, mm | 1060 |
| viii | Thickness of canvas belt, mm | 2 |
| ix | Width of canvas belt, mm | 55 |

### 4.2.2 TNAU model

Various particulars of the TNAU model coconut palm climbing device were measured and given in Table 4.2.

**Table 4.2 Specification of TNAU model coconut palm climbing device**

| Sl. No. | Parameters | Quantity |
|---|---|---|
| i | Size of the upper frame, mm | 1060 x 510 |
| ii | Size of the lower frame, mm | 620 x 510 |
| iii | Size of rigid base section in upper frame (L x B), mm | 540 x510 |
| iv | Size of palm gripping section (L x B), mm | 470 x510 |
| v | Number of cross rail in upper frame | 5 |
| vi | Number of cross rail in lower frame | 4 |
| vii | Diameter of locking knob gripping section, mm | 60 |
| viii | Diameter of rubber gripping bush, mm | 50 |
| ix | Length of rubber gripping bush in inclined rail of palm gripping section, mm | 150 |
| x | Length of rubber gripping bush in cross rail of palm gripping section, mm | 200 |
| xi | Gripping diameter of palm trunk in extendable arm | 250 -350 mm adjustable in 5 steps |
| xii | Number of bushes in upper frame | 3 |
| xiii | Number of bushes in lower frame | 7 |
| xiv | Length of safety strap, mm | 1100 |
| xv | Width of the belt, mm | 50 |
| xvi | Weight of the upper frame, kg | 7.15 |
| xvii | Weight of the lower frame, kg | 6.25 |
| xviii | Width of canvas belt, mm | 55 |

### 4.2.3 Keraki model

Various particulars of the Keraki model coconut palm climbing device were measured and given in Table 4.3

**Table 4.3 Specifications of Keraki model coconut palm** climbing device

| Sl. No. | Parameters | Quantity |
|---|---|---|
| i | Upper frame dimensions(L x B), mm | 530 x 270 |
| ii | Lower frame dimensions(L x B), mm | 530 x 270 |
| iii | Weight of the unit, kg | 2.90 |
| iv | Size of the foot rest where shoe is fixed, mm | 90 x 90 |
| v | Handle dimensions, mm | 90 x 90 |
| vi | Adjustable length, mm | 150 in 10 steps |

## 4.3 Selection of subjects

Ten male subjects were selected at random for the testing. All the subjects selected were physically sound and free from illness during operation.

The age of the subjects selected for ergonomic evaluation were in the range 21 to 30 years. The subjects had H/W ratio in the range of 2 - 3.5. They were further classified into three categories such as less than 2.5, 2.5 – 3 and more than 3.

### 4.4 Ergonomic evaluation of selected coconut palm climbing devices

#### 4.4.1 Heart rate

The heart rate at rest, during climbing and after climbing down for all subjects were observed and given in Appendix I. The heart rate at top was used to calculate the mean value for all the selected climbing devices. The data is given in Table 4.4.

**Table 4.4 Mean heart rates for all three models of coconut climbing devices**

| Subject | Kerala model (mean HR in beats/min) | TNAU model (mean HR in beats /min) | Keraki model (mean HR in beats /min) |
|---|---|---|---|
| S1 | 147 | 139 | 151 |
| S2 | 142 | 145 | 146 |
| S3 | 145 | 140 | 143 |
| S4 | 147 | 143 | 146 |
| S5 | 145 | 139 | 143 |
| S6 | 142 | 142 | 144 |
| S7 | 143 | 139 | 144 |
| S8 | 146 | 140 | 145 |
| S9 | 144 | 142 | 148 |
| S10 | 147 | 141 | 149 |
| **Mean** | **145** | **141** | **148** |

#### 4.4.2 Oxygen uptake and Energy consumption

The oxygen uptake and energy consumption were found out directly using Table 3.2. The data for all the subjects is given in Appendix II. The mean value for each coconut climbing device is given in Table 4.5.

**Table 4.5 Mean oxygen uptake and energy consumption**

| Parameter | Kerala model | TNAU model | Keraki model |
|---|---|---|---|
| Oxygen uptake (l/min) | 1.05208 | 1.01484 | 1.06756 |
| Energy consumption(kJ/min) | 17.57386 | 16.85326 | 17.80982 |

### 4.4.3 Ergonomic ratings - ODR, OSR, OER and BPDS

The overall discomfort scores, overall safety rating, overall ease of operation rating and Body Parts Discomfort Score of each of the ten male subjects for all the selected palm climbing devices were found out as explained in section 3.5.4, 3.5.5, 3.5.6 and 3.5.7 respectively. The mean values of overall discomfort rating (ODR), overall safety rating (OSR) and overall ease of operation rating (OER) and Body Parts Discomfort Score (BPDS) of the subjects are furnished in Table 4.6.

**Table 4.6 Ergonomic ratings for the different models**

| Parameter | Kerala | | TNAU | | Keraki | |
|---|---|---|---|---|---|---|
| | Score | Scale | Score | Scale | Score | Scale |
| ODR | 5 | Moderate discomfort | 4.3 | >light discomfort | 7.7 | > more than moderate |
| OSR | 7.6 | < insecure and more fear | 2.3 | > secure and meager fear | 7.9 | < insecure and more fear |
| OER | 4.4 | > less difficulty | 4.8 | > less difficulty | 5.5 | < difficult to operate |
| BPDS | 29.2 | | 34.2 | | 33.6 | |

## 4.5 Modifications

Based on the above evaluations it was found that the TNAU model coconut climber is the best suited for our operating conditions. Hence TNAU model coconut climber was selected for our ergonomic refinements. The following modifications were incorporated so that the drudgery of the climber decreased and the efficiency is hence increased.

i. In the TNAU model coconut climber, as one ascends the inclination of the upper frame with the horizontal will increases if there is a gradual reduction in coconut palm diameter. Thus modified the upper frame suitably by providing a palm the palm gripping section was made

‘U’ shape with an inclination to the horizontal. As one climbs up the palm, the upper frame will remain almost parallel to the horizontal thus providing more stability to the climber.

ii. The lifting of lower frame with toes was a tough task for the users and it induced a lot of strain on them. The lower frame lifting was made easier by providing more area of contact to the lifting toe region. Rubber padding was also provided at the region for avoiding bruises to the toe region.

iii. The time for inserting bolts and tightening the upper and lower frame to the palm could be reduced by introducing spring loaded lock system by just pressing into the holes. This mechanism also reduced time for removing the bolts, thus time for setting the climber as well as removing the climber from the palm could easily be reduced.

iv. The weight of the lower and upper frame was reduced to 10.10 kg from 13.40 kg for easy operation. This was done by reducing the thickness of material construction. The material was tested in Universal Testing Machine for its load carrying capacity. The cross rail near the seating in upper frame was avoided and thus the seating was given comfortably.

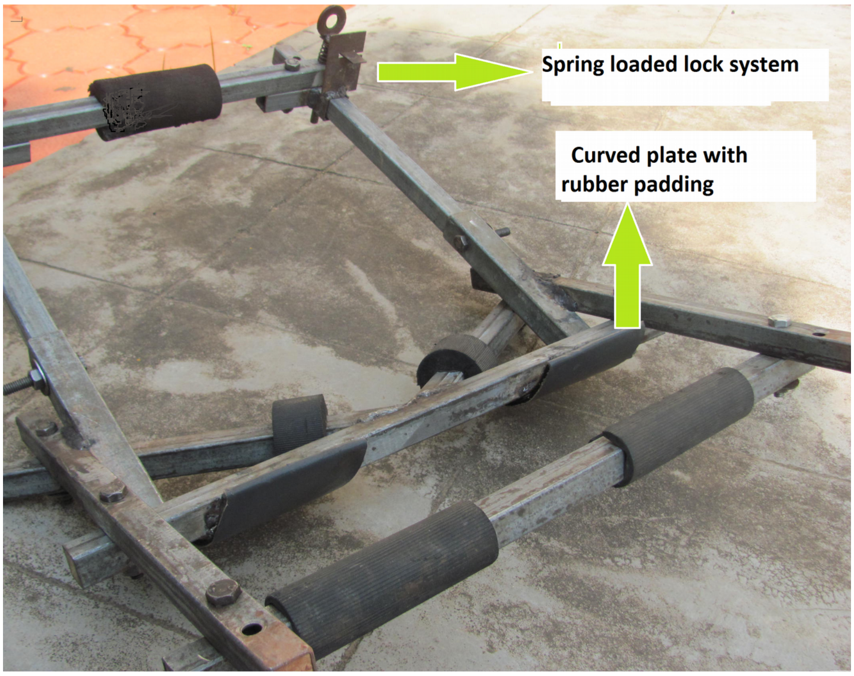



**Plate 4.1 Details of lower frame of the modified model of coconut palm climbing device**

**Plate 4.2 Testing with modified coconut palm climbing device**

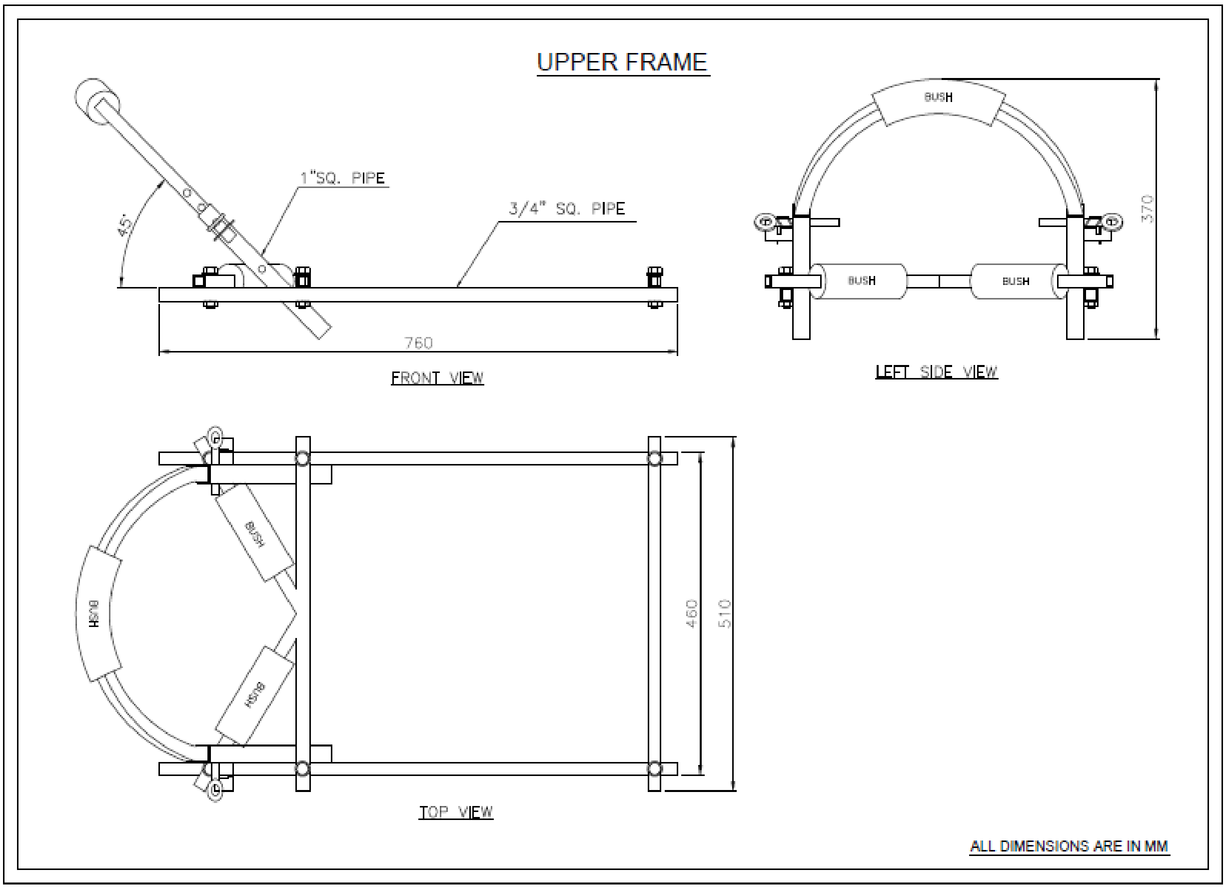



**Fig 4.1 Orthographic view of upper frame of modified model**

**Plate 4.3 Upper frame of the modified model of coconut palm climbing device**

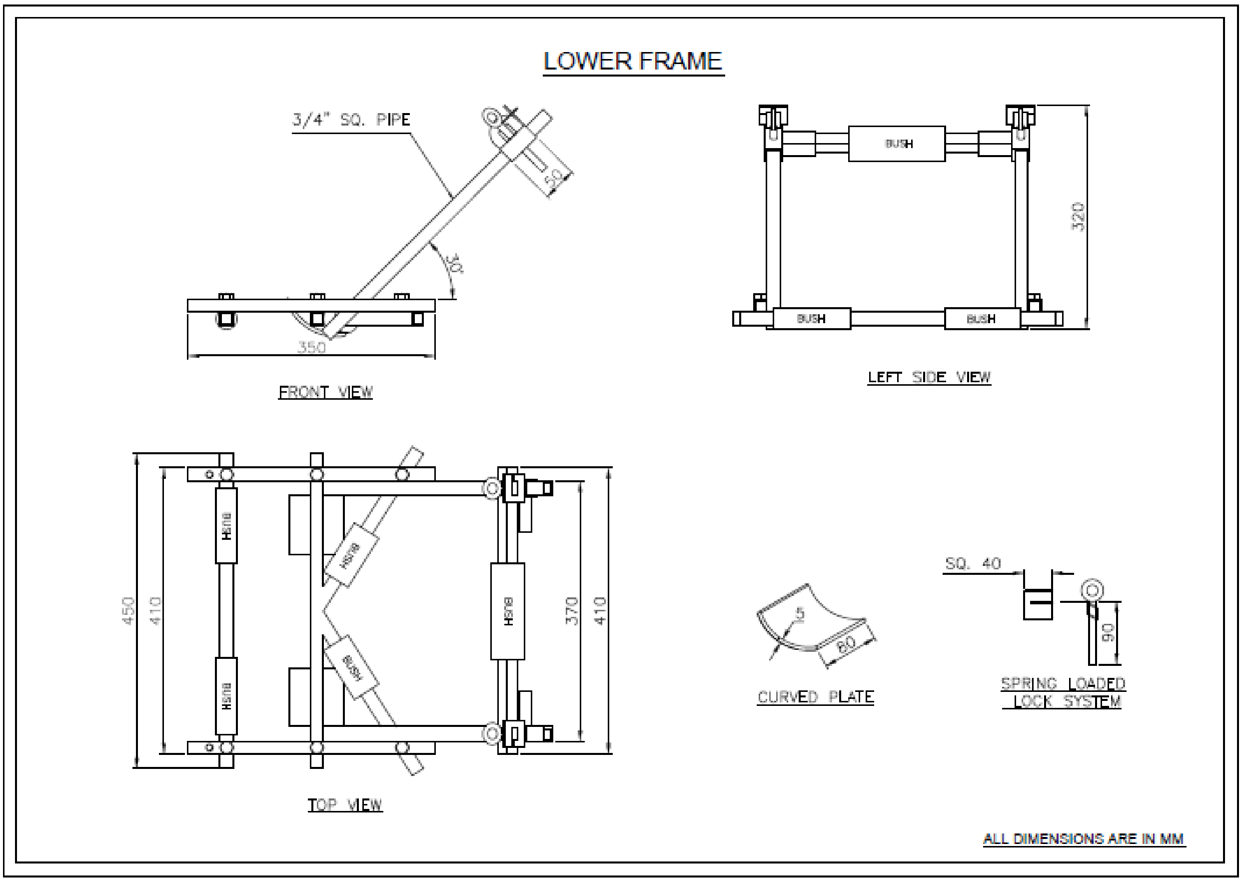



**Fig. 4.2 Orthographic views of lower frame of the modified model of coconut palm climbing device**

**Plate 4.4 Lower frame of the modified model of coconut palm climbing device**

## 4.6 Evaluation of the modified model

### 4.6.1 Time

The time for setting up the climber on to the palm, time for climbing up and down the palm and time for removing the unit from the palm were evaluated for all the climbers and tabulated in Table 4.7.

**Table 4.7 Time characteristics of different models**

| Time for | Modified model | Kerala model | TNAU model | Keraki model |
|---|---|---|---|---|
| **Setting up unit** | 1:44 | 2:11 | 3:07 | 3:32 |
| **Climbing up** | 1:44 | 2:00 | 2:10 | 2:32 |
| **Climbing down** | 1:22 | 2:13 | 1:33 | 2:44 |
| **Removing unit** | 1:01 | 1:26 | 2:24 | 2:44 |

### 4.6.2 Heart rate

The heart rates for different subjects were determined during the operation of modified model. The mean heart rate is determined as mentioned in section 4.4.1 and is given in Table 4.8.

**Table 4.8 Mean heart rates for modified model**

| Subject | Heart beats /min |
|---|---|
| S1 | 136 |
| S2 | 140 |
| S3 | 136 |
| S4 | 139 |
| S5 | 137 |
| S6 | 134 |
| S7 | 134 |
| S8 | 137 |
| S9 | 133 |
| S10 | 138 |
| **Mean** | **136** |

### 4.6.3 Oxygen uptake and Energy consumption

The oxygen uptake and energy consumption were found out to be 0.95676 (l/min) and 15.90062 (kJ/min) directly using the Table 3.2.

### 4.6.4 Ergonomic ratings - ODR, OSR, OER and BPDS

The overall discomfort scores, overall safety rating, overall ease of operation rating and Body Parts Discomfort Score of each of the ten male subjects for the modified palm climbing device were found out as explained in section 3.5.4, 3.5.5, 3.5.6 and 3.5.7 respectively. The mean values of overall discomfort rating (ODR), overall safety rating (OSR) and overall ease of operation rating (OER) and Body Parts Discomfort Score (BPDS) of the subjects are furnished in Table 4.9.

**Table 4.9 Ergonomic ratings for the modified model**

| Parameter | Modified model | |
|---|---|---|
| | Score | Scale |
| ODR | 3.2 | > Light discomfort |
| OSR | 2.3 | > Secure and meager fear |
| OER | 1.9 | < Easy |
| BPDS | 18.4 | - |

### 4.7 Comparison

A comparative performance of all the models was furnished based on parameters mentioned in section 3.8 and the data is tabulated in Table 4.10. The percentage change of these parameters for the modified model from the TNAU model was calculated and shown in Table 4.10.

**Table 4.10** Comparison of parameters between all models

| Parameter | Kerala model | TNAU model | Keraki model | Modified model |
|---|---|---|---|---|
| **Time for setting up the unit** | 2:11 | 3:07 | 3:32 | 1:44 |
| **Time for climbing up** | 2:00 | 2:10 | 2:32 | 1:44 |
| **Time for climbing down** | 2:13 | 1:33 | 2:44 | 1:22 |
| **Time for removing unit** | 1:26 | 2:24 | 2:44 | 1:01 |

| | | | | |
|---|---|---|---|---|
| **Oxygen uptake ($VO_2$) (l/min)** | 1.05208 | 1.01484 | 1.06756 | 0.95676 |
| **Energy consumption (kJ/min)** | 17.57386 | 16.85326 | 17.80982 | 15.90062 |
| **ODR** | 5 Moderate discomfort | 4.3 > light discomfort | 7.7 > more than moderate | 3.2 > Light discomfort |
| **OSR** | 7.6 < insecure and more fear | 2.3 > Secure and meager fear | 7.9 < insecure and more fear | 2.3 > Secure and meager fear |
| **OER** | 4.4 > Less difficulty | 4.8 > Less difficulty | 5.5 < Difficult to operate | 1.9 < easy |
| **BPDS** | 29.2 | 34.2 | 33.6 | 18.4 |

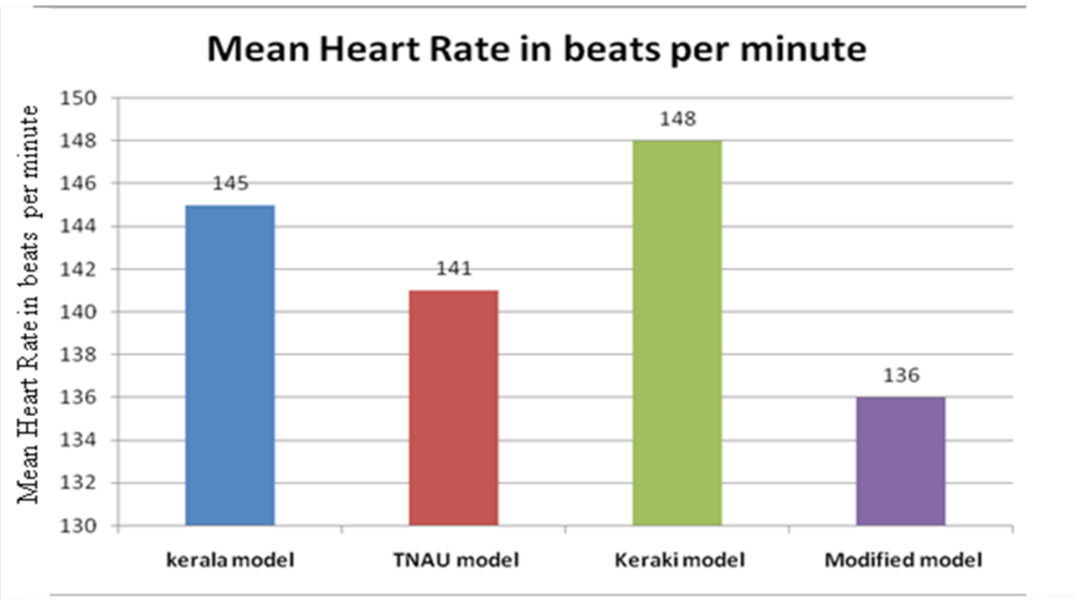



**Fig 4.3 Comparison of mean heart rate of different models of coconut climber**

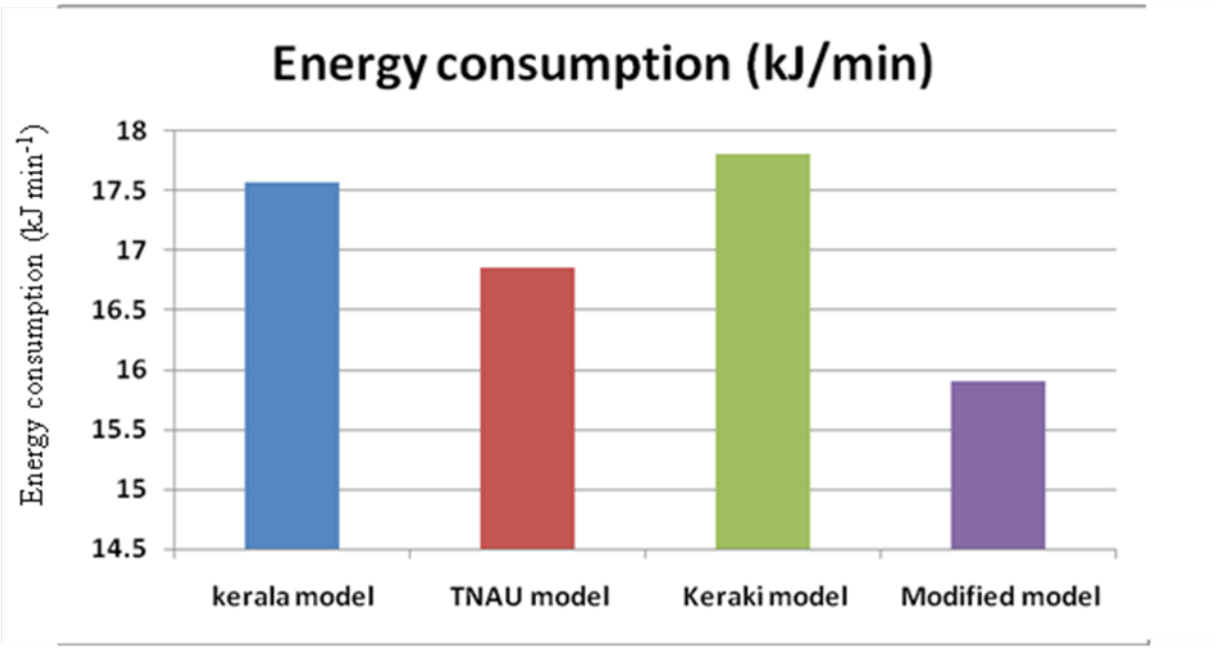



**Fig 4.4 Comparison of energy consumption of different models of coconut climber**

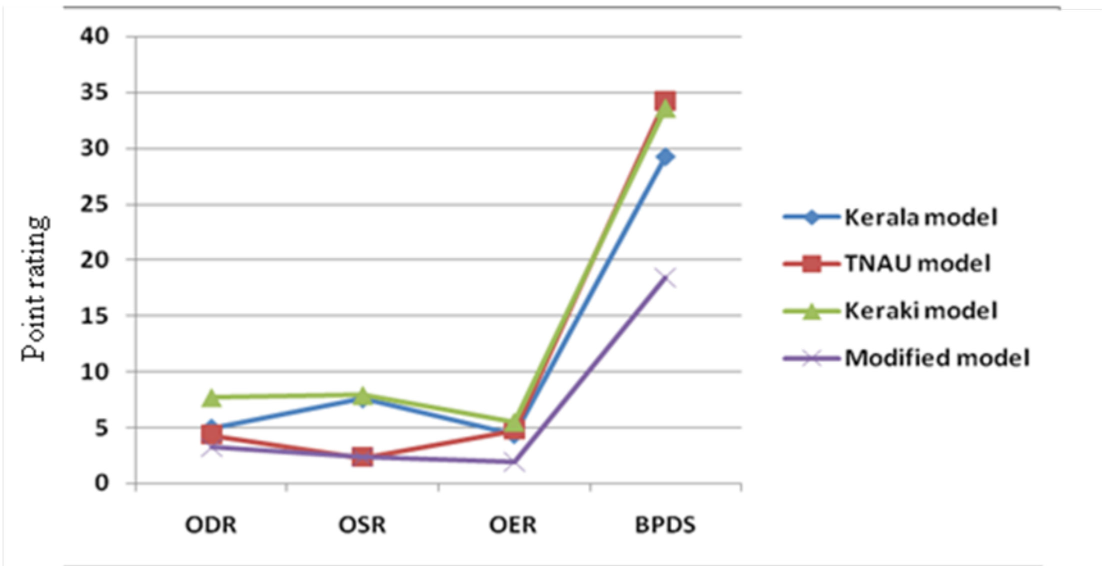



**Fig 4.5 Comparison of overall discomfort rating (ODR), overall safety rating (OSR) Overall ease of operation (OER), Body part discomfort score (BPDS) of different models of coconut climber**

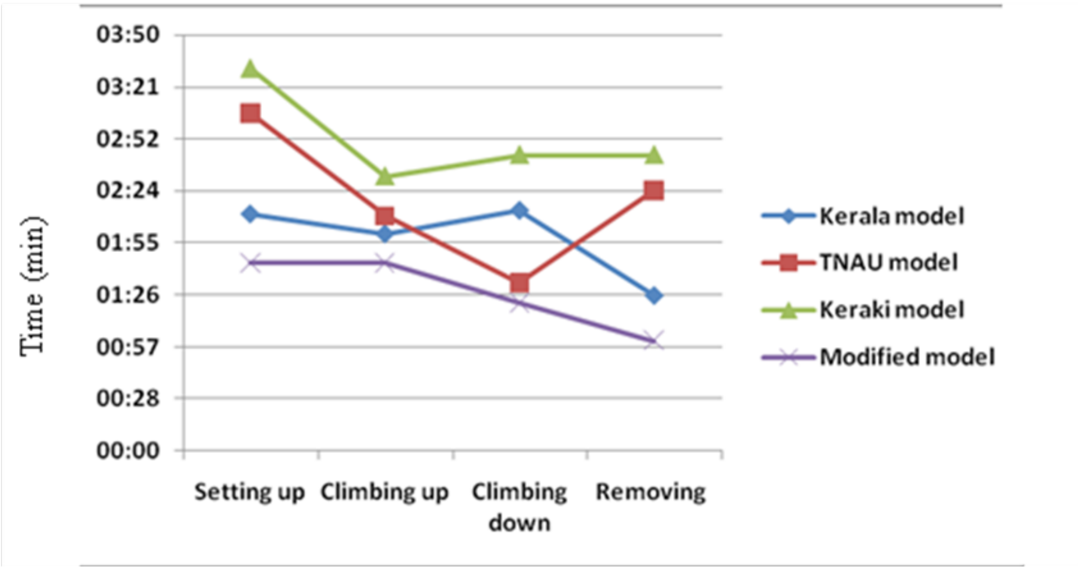



**Fig 4.6 Comparison of time taken by different models of coconut climber**

**Table 4.11 Percentage change in parameters for modified** model from TNAU model

| Parameter | TNAU model | Modified model | % reduction of parameters |
|---|---|---|---|
| **Time for setting up the unit** | 3:07 | 1:44 | 44.4 |
| **Time for climbing up** | 2:10 | 1:44 | 20.0 |
| **Time for climbing down** | 1:33 | 1:22 | 11.8 |
| **Time for removing unit** | 2:24 | 1:01 | 57.6 |
| **Oxygen uptake ($VO_2$) (l/min)** | 1.01484 | 0.95676 | 5.7 |
| **Energy consumption (kJ/min)** | 16.85326 | 15.90062 | 5.6 |
| **ODR** | 4.3 | 3.2 | 25.5 |
| **OSR** | 2.3 | 2.3 | 0 |
| **OER** | 4.8 | 1.9 | 60.4 |
| **BPDS** | 34.2 | 18.4 | 46.2 |

# Summary and Conclusions

# CHAPTER 5

# SUMMARY AND CONCLUSIONS

Ergonomics and its applications attempt to harmonize work and the working environment to raise productivity, work efficiency and promote individual well-being through optimizing the effort of the worker or user. Much of the ergonomics research to improve productivity has been focused in the industrial sector; little work of an ergonomics nature has been done in small scale or subsistence agriculture. There are now an increasing number of examples of ergonomics interventions in agricultural operations where performance or health and safety have been improved.

Skilled workers commonly climb the palms to harvest the coconuts. Since coconut palms are very tall any falls from the top of palms can result in severe injury. Also the workers employed for climbing coconut palm suffer from physical strain and musculoskeletal disorders. Thus an ergonomical evaluation was conducted on the coconut climbing devices and suitable modifications were made so as to make it more user-friendly.

**5.1. Ergonomical evaluation of selected coconut palm climbing devices**

Ten male subjects were selected based on their age and body dimensions (H/W ratio). They were used to evaluate three models of coconut palm climbing devices viz., Kerala , TNAU and Keraki models palm climbing device. The models were evaluated by measuring the parameters such as heart rate (HR), oxygen uptake ($VO_2$), energy consumption, overall discomfort rating (ODR), overall safety rating (OSR), overall ease of operation rating (OER) and body part discomfort score (BPDS). Based on the analysis the following conclusions were drawn:

i. The Oxygen uptake in the Kerala , TNAU and Keraki models were respectively as 1.05208, 1.01484 and 1.06756 l $min^{-1}$.

ii. The Energy consumption in the Kerala, TNAU and Keraki models were 17.57386, 16.85326 and 17.80982 kJ $min^{-1}$ respectively.

iii. The Overall Discomfort Rating (ODR) for the Kerala, TNAU and Keraki models were 5, 4.3 and 7.7 respectively.

iv. The Overall Safety Rating (OSR) for the Kerala, TNAU and Keraki models were 7.6, 2.3 and 7.9 respectively.

v. The Overall Ease of operation Rating (OER) for the Kerala, TNAU and Keraki models were 4.4, 4.8 and 5.5 respectively.

vi. The Body Part Discomfort Score (BPDS) for the Kerala, TNAU and Keraki models were 29.2, 34.2 and 33.6 respectively.

It was found that the TNAU model coconut climber was the best suited for coconut climbing. Hence TNAU model coconut climber was selected for our ergonomic refinements.

**5.2 Modificafion of selected coconut palm climbing device**

The following modifications were incorporated in the TNAU coconut climber so that the drudgery of work decreased and the work efficiency was improved.

i. The upper frame was modified suitably such that as one climb up the palm it will remain parallel to the horizontal thus providing more stability to the climber.

ii. The lower frame was made easier by providing more area of contact to the lifting toe region. Rubber padding was also provided at the region for avoiding bruises to the toe region.

iii. The time for fitting the upper and lower frame to the palm could be reduced by introducing spring loaded lock system.

iv. The weight of the lower and upper frame was reduced from 13.40 kg to 10.10 kg for easy operation.

The modified coconut climber was ergonomically evaluated and it was found that it could reduce the drudgery of work and improve efficiency. This model resulted in 44.4, 20.0, 11.8, 57.6, 5.7, 5.6, 25.5, 60.4 and 46.2 percent reduction respectievly in time for setting up the unit, time for climbing up and down, and removing the unit, oxygen uptake, energy consumption, overall discomfort rating (ODR), Overall Safety Rating (OSR), overall ease of operation rating (OER) and body parts discomfort score (BPDS), when compared to the TNAU model of coconut palm climbing device.

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# Appendices

# APPENDIX I

## Heart rate data for different coconut tree climbing devices

| Subjects | Heart rate in beats /min | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kerala model | | | TNAU model | | | Keraki model | | | Modified model | | |
| | At rest | At middle | At top | At rest | At middle | At top | At rest | At middle | At top | At rest | At middle | At top |
| S1 | 75 | 148 | 147 | 80 | 127 | 139 | 73 | 141 | 151 | 74 | 131 | 136 |
| S2 | 84 | 135 | 142 | 91 | 140 | 145 | 85 | 140 | 146 | 93 | 128 | 140 |
| S3 | 86 | 137 | 145 | 75 | 128 | 140 | 79 | 125 | 143 | 83 | 124 | 136 |
| S4 | 83 | 142 | 147 | 78 | 138 | 143 | 74 | 137 | 146 | 93 | 121 | 139 |
| S5 | 87 | 130 | 145 | 85 | 131 | 139 | 85 | 139 | 143 | 96 | 128 | 137 |
| S6 | 78 | 136 | 142 | 89 | 119 | 142 | 86 | 132 | 144 | 76 | 129 | 134 |
| S7 | 79 | 129 | 143 | 90 | 122 | 139 | 91 | 129 | 144 | 72 | 134 | 134 |
| S8 | 82 | 140 | 146 | 77 | 137 | 140 | 88 | 143 | 145 | 77 | 137 | 137 |
| S9 | 81 | 141 | 144 | 74 | 133 | 142 | 94 | 147 | 148 | 78 | 131 | 133 |
| S10 | 89 | 138 | 147 | 79 | 138 | 141 | 76 | 140 | 149 | 91 | 128 | 138 |

# APPENDIX II

Oxygen uptake and Energy consumption in different models of coconut tree climbing devices

| Subjects | Kerala model | | | TNAU model | | | Keraki model | | | modified model | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | HR/min | Oxygen uptake (l/min) | Energy consumption (kJ/min) | HR/min | Oxygen uptake (l/min) | Energy consumption (kJ/min) | HR/min | Oxygen uptake (l/min) | Energy consumption (kJ/min) | HR/min | Oxygen uptake (l/min) | Energy consumption (kJ/min) |
| S1 | 147 | 0.7984 | 16.0716 | 139 | 0.728 | 14.6572 | 151 | 0.8336 | 16.7788 | 136 | 0.7016 | 14.1268 |
| S2 | 142 | 0.916 | 18.343 | 145 | 0.9466 | 18.952 | 146 | 0.9568 | 19.155 | 140 | 0.8956 | 17.937 |
| S3 | 145 | 0.9466 | 18.952 | 140 | 0.8956 | 17.937 | 143 | 0.9262 | 18.546 | 136 | 0.8548 | 17.125 |
| S4 | 147 | 0.7984 | 16.0716 | 143 | 0.7632 | 15.3644 | 146 | 0.7896 | 15.8948 | 139 | 0.728 | 14.6572 |
| S5 | 145 | 0.9466 | 18.952 | 139 | 0.8854 | 17.734 | 143 | 0.9262 | 18.546 | 137 | 0.865 | 17.328 |
| S6 | 142 | 1.7795 | 18.1284 | 142 | 1.7795 | 18.1284 | 144 | 1.8155 | 18.6028 | 134 | 1.6355 | 16.2308 |
| S7 | 143 | 0.7632 | 15.3644 | 139 | 0.728 | 14.6572 | 144 | 0.772 | 15.5412 | 134 | 0.684 | 13.7732 |
| S8 | 146 | 0.7896 | 15.8948 | 140 | 0.7368 | 14.834 | 145 | 0.7808 | 15.718 | 137 | 0.7104 | 14.3036 |
| S9 | 144 | 1.8155 | 18.6028 | 142 | 1.7795 | 18.1284 | 148 | 1.8875 | 19.5516 | 133 | 1.6175 | 15.9936 |
| S10 | 147 | 0.967 | 19.358 | 141 | 0.9058 | 18.14 | 149 | 0.9874 | 19.764 | 138 | 0.8752 | 17.531 |
| **Mean** | **144.8** | **1.05208** | **17.57386** | **141** | **1.01484** | **16.85326** | **145.9** | **1.06756** | **17.80982** | **136.4** | **0.95676** | **15.90062** |

# APPENDIX III

**ODR, OSR and OER values for different models of coconut tree climbing devices**

| Subjects | Kerala model | | | TNAU model | | | Keraki model | | | Modified model | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ODR | OSR | OER | ODR | OSR | OER | ODR | OSR | OER | ODR | OSR | OER |
| S1 | 4 | 7 | 5 | 5 | 2 | 2 | 9 | 7 | 4 | 3 | 2 | 2 |
| S2 | 5 | 9 | 5 | 6 | 2 | 3 | 9 | 9 | 7 | 3 | 2 | 1 |
| S3 | 5 | 7 | 5 | 3 | 1 | 5 | 7 | 8 | 5 | 3 | 1 | 1 |
| S4 | 6 | 7 | 4 | 3 | 3 | 5 | 6 | 8 | 6 | 4 | 3 | 4 |
| S5 | 4 | 7 | 6 | 4 | 2 | 5 | 7 | 7 | 5 | 5 | 2 | 2 |
| S6 | 5 | 8 | 4 | 5 | 2 | 5 | 8 | 9 | 5 | 2 | 2 | 4 |
| S7 | 5 | 7 | 3 | 5 | 4 | 5 | 8 | 7 | 6 | 2 | 4 | 1 |
| S8 | 6 | 7 | 2 | 4 | 3 | 6 | 8 | 8 | 6 | 3 | 3 | 1 |
| S9 | 5 | 9 | 6 | 4 | 2 | 6 | 7 | 9 | 6 | 5 | 2 | 2 |
| S10 | 5 | 8 | 4 | 4 | 2 | 6 | 8 | 7 | 5 | 2 | 2 | 1 |
| **Mean** | **5** | **7.6** | **4.4** | **4.3** | **2.3** | **4.8** | **7.7** | **7.9** | **5.5** | **3.2** | **2.3** | **1.9** |

# APPENDIX IV

BPDS for different models of coconut palm climbing device

| Kerala model | I | II | III | Total |
|---|---|---|---|---|
| S1 | 12,13,14,15 | 26,27 | 22,23 | |
| | 24 | 8 | 4 | 36 |
| S2 | 8,9,14,15,16 | 17,18,19 | 6,7 | |
| | 30 | 12 | 4 | 46 |
| S3 | 8,9,14,15 | 12,13 | 26,27 | |
| | 24 | 8 | 4 | 36 |
| S4 | 8,9,12,13 | 6,7 | | |
| | 24 | 6 | | 30 |
| S5 | 6,7,12,13 | 24,25 | | |
| | 24 | 6 | | 30 |
| S6 | 4,5,6,7 | 26,27 | | |
| | 24 | 6 | | 30 |
| S7 | 8,9 | 4,5 | | |
| | 12 | 6 | | 24 |
| S8 | 12,13 | 10,11 | 6,7 | |
| | 12 | 8 | 4 | 24 |
| S9 | 22,23 | 12,13 | | |
| | 12 | 6 | | 18 |
| S10 | 26,27 | 22,23 | | |
| | 12 | 6 | | 18 |
| **BPDS** | | | | **29.2** |

| TNAU model | I | II | III | Total |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| S1 | 7,6,26,27,20, 21 | 10,11,22,23 | | 48 |
| | 36 | 12 | | |
| S2 | 8,9,27,26 | 4,5,17 | | 33 |
| | 24 | 9 | | |
| S3 | 2,3, 26,27 | 14,15 | 4,5 | 40 |
| | 24 | 8 | 4 | |
| S4 | 26,27,10,11 | 22,23 | | 30 |
| | 24 | 6 | | |
| S5 | 26,27,14,15 | 22,23,24,25 | 4,5,17 | 46 |
| | 24 | 16 | 6 | |
| S6 | 26,27,14,15 | 4,5,17 | | 33 |
| | 24 | 9 | | |
| S7 | 26,27 | 22,23 | | 24 |
| | 12 | 6 | | |
| S8 | 4,5,14, 15 | 26,27 | | 28 |
| | 24 | 6 | | |
| S9 | 14,15,26,27 | 22,23 | | 30 |
| | 24 | 6 | | |
| S10 | 26,27,14,15 | 5,17 | | 30 |
| | 24 | 6 | | |
| **BPDS** | | | | **34.2** |

| **Keraki model** | **I** | **II** | **III** | **Total** |
|---|---|---|---|---|
| S1 | 22,23,4,5 | 14,15 | 6,7 | 36 |

| | | | | |
|---|---|---|---|---|
| | 24 | 8 | 4 | |
| S2 | 22,23,6,7 | 12,13 | | 30 |
| | 24 | 6 | | |
| S3 | 22,23,10,11 | 14,15 | 8,9 | 36 |
| | 24 | 8 | 4 | |
| S4 | 22,23,10,11 | 4,5 | 6,7 | 36 |
| | 24 | 8 | 4 | |
| S5 | 22,23,12,13 | 8,9 | 6,7 | 36 |
| | 24 | 8 | 4 | |
| S5 | 22,23,8,9 | 12,13 | | 30 |
| | 24 | 6 | | |
| S6 | 22,23,4,5 | 14,15 | | 30 |
| | 24 | 6 | | |
| S7 | 22,23,8,9 | 14,15 | | 30 |
| | 24 | 6 | | |
| S8 | 22,2312,13 | 8,9 | 6,7 | 36 |
| | 24 | 8 | 4 | |
| S9 | 22,23,12,13 | 8,9 | 4,5 | 36 |
| | 24 | 8 | 4 | |
| S10 | 22,23,4,5 | 8,9 | 12,13 | 36 |
| | 24 | 8 | 4 | |
| **BPDS** | | | | **33.6** |

| Modified model | I | II | III | Mean |
|---|---|---|---|---|
| S1 | 26,27 | 22,23 | | 18 |
| | 12 | 6 | | |
| S2 | 14,15 | 22,23 | 10,11 | |

| | | | | |
|---|---|---|---|---|
| | 12 | 8 | 8 | 28 |
| S3 | 6,7 | 8,9 | | 18 |
| | 12 | 6 | | |
| S4 | 26,27 | 6,7 | | 18 |
| | 12 | 6 | | |
| S5 | 14,15 | | | 12 |
| | 12 | | | |
| S5 | 26,27 | 22,23 | | 18 |
| | 12 | 6 | | |
| S6 | 26,27 | 8,9 | | 18 |
| | 12 | 6 | | |
| S7 | 6,7 | | | 12 |
| | 12 | | | |
| S8 | 10,11 | 14,15 | | 18 |
| | 12 | 6 | | |
| S9 | 24,25 | 6,7 | | 18 |
| | 12 | 6 | | |
| S10 | 10,11 | 14,15 | | 18 |
| | 12 | 6 | | |
| **BPDS** | | | | **18.4** |

# APPENDIX V

Time characteristics for different models of coconut climbing device

| Kerala model | Time (min:sec) | | | |
|---|---|---|---|---|
| | Setting up unit | Climbing up | Climbing down | Removing unit |
| S1 | 2:11 | 1:53 | 2:09 | 1:29 |
| S2 | 2:22 | 1:56 | 2:18 | 1:21 |
| S3 | 2:17 | 2:12 | 2:22 | 1:09 |
| S4 | 2:24 | 1:42 | 2:01 | 1:33 |
| S5 | 1:53 | 1:58 | 2:05 | 1:23 |
| S6 | 2:15 | 2:05 | 2:24 | 1:37 |
| S7 | 2:03 | 2:11 | 2:17 | 1:32 |
| S8 | 2:20 | 2:23 | 2:26 | 1:26 |
| S9 | 1:58 | 1:47 | 2:00 | 1:23 |
| S10 | 2:09 | 1:54 | 2:13 | 1:31 |
| **Mean** | **2:11** | **2:00** | **2.13** | **1:26** |
| **TNAU model** | **Time (sec)** | | | |
| | **Setting up unit** | **Climbing up** | **Climbing down** | **Removing unit** |
| S1 | 3:10 | 2:10 | 1:25 | 2:30 |
| S2 | 2:58 | 2:22 | 2:01 | 2:11 |
| S3 | 3:13 | 2:06 | 1:35 | 2:05 |
| S4 | 3:19 | 2:18 | 1:51 | 2:35 |
| S5 | 2:51 | 1:53 | 1:29 | 2:28 |
| S6 | 3:05 | 1:59 | 1:18 | 2:18 |
| S7 | 3:01 | 2:13 | 1:23 | 2:21 |
| S8 | 3:16 | 2:31 | 1:32 | 2:31 |
| S9 | 3:12 | 2:12 | 1:21 | 2:44 |
| S10 | 3:08 | 2:04 | 1:41 | 2:19 |
| **Mean** | **3:07** | **2:10** | **1:33** | **2:24** |

| Keraki model | Time (sec) | | | |
|---|---|---|---|---|
| | Setting up unit | Climbing up | Climbing down | Removing unit |
| S1 | 3:40 | 2:40 | 2:50 | 2:50 |
| S2 | 3:21 | 2:44 | 2:40 | 2:09 |

| | | | | |
|---|---|---|---|---|
| S3 | 3:37 | 2:18 | 2:38 | 2:38 |
| S4 | 3:44 | 2:32 | 2:41 | 2:19 |
| S5 | 3:16 | 2:37 | 2:58 | 2:59 |
| S6 | 3:29 | 2:19 | 2:28 | 2:48 |
| S7 | 3:36 | 2:27 | 2:54 | 3:11 |
| S8 | 3:31 | 2:48 | 3:01 | 2:47 |
| S9 | 3:23 | 2:21 | 2:44 | 2:49 |
| S10 | 3:48 | 2:42 | 2:31 | 2:56 |
| **Mean** | **3:32** | **2:32** | **2:44** | **2:44** |
| **Modified model** | **Time (sec)** | | | |
| | **Setting up unit** | **Climbing up** | **Climbing down** | **Removing unit** |
| S1 | 2:19 | 1:39 | 1:11 | 1:00 |
| S2 | 1:52 | 1:38 | 1:43 | 0:54 |
| S3 | 2:18 | 1:53 | 1:19 | 0:49 |
| S4 | 1:58 | 1:57 | 1:23 | 1:14 |
| S5 | 2:27 | 1:43 | 1:21 | 1:06 |
| S6 | 2:23 | 1:44 | 1:14 | 1:02 |
| S7 | 2:35 | 1:41 | 1:34 | 1:09 |
| S8 | 2:22 | 1:33 | 1:18 | 0:51 |
| S9 | 2:06 | 1:39 | 1:23 | 0:59 |
| S10 | 2:29 | 2:02 | 1:20 | 1:11 |
| **Mean** | **1:44** | **1:44** | **1:22** | **1:01** |

# ERGONOMIC EVALUATION OF COCUNUT CLIMBERS
# AND
# REFINEMENT OF TNAU CLIMBER


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**ABSTRACT OF THE PROJECT REPORT**

**Submitted in partial fulfilment of the requirement for the degree of**

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**In**
**Agricultural Engineering**


**Faculty of Agricultural Engineering and Technology**

**Kerala Agricultural University**

***Department of Farm Power Machinery and Energy***

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**2011**

# ABSTRACT

The majority of coconuts are harvested by climbing the tree and cutting the nuts down by hand. This process may seems to be simple but it is quite dangerous. An experienced climber takes about 4-5 minutes just to climb the tree alone (this doesn't include cutting the coconuts and the return trip). The workers employed for climbing coconut tree suffer from various musculoskeletal disorders. Due to its strenuous nature professional coconut climbers are now a few in number and farmers are finding it difficult to harvest the nuts. In response, there is a genuine need to develop a device which is safe and efficient to assist the climbers. At present there are a few models of coconut climbers available in the market. Most of the climber's safety and efficiency aspects are being questioned and needs to be comparatively evaluated and modified.

The present study on "Comparative evaluation and refinement of coconut palm climbing device" selected coconut palm climbing devices were ergonomically evaluated and suitable ergo refinements in selected palm climbing device for reduced drudgery, operational comfort and safety. Ten male subjects were selected based on their age and body dimensions (H/W ratio). They were used to evaluate three models of coconut palm climbing devices viz., Kerala, TNAU and the Keraki model coconut tree climbing devices. The models were evaluated by measuring the parameters such as heart rate (HR), oxygen uptake ($VO_2$), energy consumption, overall discomfort rating (ODR), overall safety rating (OSR), overall ease of operation rating (OER) and body part discomfort score (BPDS). From the analysis it was found that the TNAU model coconut climber was the best suited for our operating conditions. Hence TNAU model coconut climber was selected for our ergonomic refinements.

The following modifications were incorporated in the TNAU coconut climber so that the drudgery of work decreased and the work efficiency was improved.

i. The upper frame was modified suitably such that as one climb up the palm it will remain parallel to the horizontal thus providing more stability to the climber.

ii. The lower frame was made easier by providing more area of contact to the lifting toe region. Rubber padding was also provided at the region for avoiding bruises to the toe region.

iii. The time for fitting the upper and lower frame to the palm could be reduced by introducing spring loaded lock system.

iv. The weight of the lower and upper frame was reduced from 13.40 kg to 10.10 kg for easy operation.

The modified coconut climber was ergonomically evaluated and it was found that it could reduce the drudgery of work and improve efficiency. This model resulted in 44.4, 20, 11.8, 57.6, 5.7, 5.6, 25.5, 60.4 and 46.2 percent reduction in time for setting up the unit, time for climbing up and down, and removing the unit, oxygen uptake, energy consumption, overall discomfort rating (ODR), Overall Safety Rating (OSR), overall ease of operation rating (OER) and body parts discomfort score (BPDS) respectively when compared to the TNAU model of coconut palm climbing device.