ERGONOMIC EVALUATION OF MANUAL COCONUT DEHUSKERS

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PROJECT REPORT

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KERALA, INDIA

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DECLARATION

We hereby declare that this project report entitled **'ERGONOMIC EVALUATION OF MANUAL COCONUT DEHUSKERS'** is a bonafide record of the project work done by us during the course of the 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.

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Certified that this project report entitled **'ERGONOMIC EVALUATION OF MANUAL COCONUT DEHUSKERS'** is a bonafide record of the project work done by Miss. Ansila K.A. (Admission No: 2013-02-011), Miss. Athira Kondaram Kadavath (Admission No: 2013-02-045), and Miss. Sethulakshmi K.M. (Admission No: 2013-02-036) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associate ship, fellowship, or other similar title of any other University or Society to them.

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ANSILA K.A.

ATHIRA KONDARAM KADAVATH

SETHULAKSHMI K.M.

DEDICATED

TO

THE ALMIGHTY GOD

AND

OUR LOVING PARENTS

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LIST OF SYMBOLS AND ABBREVIATION

Avg	-	Average
/	-	Per
%	-	percent
AWL	-	Acceptable Work Load
BPDS	-	Body Part Discomfort Score
beatsmin^{-1}	-	beats per minute
Cm	-	centimetre
et al.	-	and others
Fig	-	Figure
G	-	Gram
HR	-	Heart Rate
ICA	-	Integrated Composite Anthropometer
KAU	-	Kerala Agricultural University
KCAET	-	Kelappaji College of Agricultural Engineering and Technology
kcal	-	kilo calories
kg	-	kilogram
kg$_f$	-	kilogram force
kJmin-1	-	kilo joules per minute
L	-	litres
Lmin^{-1}	-	litres per minute
LCP	-	Limit of Continuous Performance
Max	-	maximum
Min	-	minimum
O_2	-	Oxygen
ODR	-	Overall Discomfort Rating
rpm	-	revolutions per minute
s	-	Second
VO_2	-	Volume of Oxygen consumed

APPENDIX I

Energy cost (kJmin^{-1}) of male subjects

MODEL 1				
Subject	**H R**	**O2 Consumption (Lmin^{-1})**	**Energy cost (kJmin^{-1})**	**Avg Energy cost (kJmin^{-1})**
1	118	0.88	18.37	18.444
	117	0.88	18.37	
	118	0.89	18.58	
2	127	1.22	25.47	26.2392
	129	1.3	27.14	
	127	1.25	26.10	
3	119	1.11	23.18	23.8032
	118	1.11	23.18	
	123	1.2	25.06	
4	122	1.02	21.30	21.1584
	123	1.02	21.30	
	122	1	20.88	
MODEL 2				
Subject	**H R**	**O2 Consumption (Lmin^{-1})**	**Energy cost (kJmin^{-1})**	**Avg. energy cost (kJmin^{-1})**
1	109	0.77	16.08	15.7296
	108	0.73	15.24	
	109	0.76	15.87	
2	114	1.03	21.51	21.2976
	112	1	20.88	
	115	1.03	21.51	
3	108	0.86	17.96	18.0264
	108	0.85	17.75	
	109	0.88	18.37	
4	110	0.89	18.58	18.1656
	111	0.89	18.58	
	107	0.83	17.33	

APPENDIX II

Energy cost ($kJmin^{-1}$) of female subjects

MODEL 2				
Subjects	**H R**	**O2 Consumption ($Lmin^{-1}$)**	**Energy cost ($kJmin^{-1}$)**	**Avg energy cost ($kJmin^{-1}$)**
1	118	1.14	23.80	24.0816
	118	1.12	23.39	
	117	1.2	25.06	
2	113	0.99	20.67	20.88
	112	0.99	20.67	
	114	1.02	21.30	
3	118	1.09	22.76	22.8288
	116	1.08	22.55	
	120	1.11	23.18	
4	114	0.9	18.79	18.444
	114	0.88	18.37	
	112	0.87	18.17	
MODEL 1				
Subjects	**H R**	**O2 Consumption ($Lmin^{-1}$)**	**Energy cost ($kJmin^{-1}$)**	**Avg energy cost ($kJmin^{-1}$)**
1	128	1.28	26.73	26.7264
	126	1.27	26.52	
	129	1.29	26.94	
2	124	1.12	23.39	23.8032
	122	1.1	22.97	
	126	1.2	25.06	
3	130	1.26	26.31	26.1000
	131	1.29	26.94	
	128	1.2	25.06	
4	127	1.04	21.72	22.0632
	124	0.99	20.67	
	130	1.14	23.80	

Calculation:

$$\text{Energycost}(kJmin^{-1}) = O_2 \text{ consuption}(Lmin^{-1}) \times 20.88(kJmin^{-1})$$

APPENDIX III

Body part discomfort scoring Model 1

BODY PART DISCOMFORT SCORING (MODEL 1)								
part no	**Male 1**	**Male 2**	**Male 3**	**Male 4**	**Female 1**	**Female 2**	**Female 3**	**Female 4**
1	4	4	4	4	4	4	4	4
2	4	4	4	4	4	4	4	4
3	4	4	4	4	4	4	4	4
4	2.2	2	2.2	1.9	2	2.4	2.2	2.3
5	1.1	1.1	1.2	1.1	1.2	1.1	1.2	1.1
6	1	1.1	1	1.2	1.2	1.3	1.1	1.2
7	4	4	4	4	4	4	4	4
8	4	4	4	4	4	4	4	4
9	1.1	1.2	1	1.1	1.2	1	1.2	1
10	2.2	2	2.2	1.9	2	2.4	2.2	2.3
11	1	1.1	1	1.2	1.2	1.3	1.1	1.3
12	2.2	2	2.2	1.9	2	2.4	2.2	2.3
13	1	1.1	1	1.2	1.2	1.3	1.1	1.3
14	0.8	0.8	0.9	0.6	0.8	0.9	0.9	0.8
15	0.6	0.5	0.4	0.6	0.6	0.5	0.6	0.6
16	0.8	0.8	0.9	0.6	0.8	0.9	0.9	0.8
17	0.6	0.5	0.4	0.6	0.6	0.5	0.6	0.6
18	1.4	1	1.1	1.2	1.1	1.3	1.1	1
19	1.4	1	1.1	1.2	1.1	1.3	1.1	1
20	1.8	1.5	1.9	1.8	1.6	1.7	1.6	1.5
21	1.8	1.5	1.9	1.8	1.6	1.7	1.6	1.5
22	1.4	1	1.1	1.2	1.1	1.3	1.1	1
23	1.4	1	1.1	1.2	1.1	1.3	1.1	1
24	0.5	0.2	0.1	0.2	0.5	0.4	0.2	0.2
25	0.5	0.2	0.1	0.2	0.5	0.4	0.2	0.2
26	0.5	0.2	0.1	0.2	0.5	0.4	0.2	0.2
27	0.5	0.2	0.1	0.2	0.5	0.4	0.2	0.2
SUM	45.8	42	43	43.1	44.4	46.2	43.7	43.4

APPENDIX IV

Body part discomfort scoring Model 2

BODY PART DISCOMFORT SCORING (MODEL 2)								
part no	**Male 1**	**Male 2**	**Male 3**	**Male 4**	**Female 1**	**Female 2**	**Female 3**	**Female 4**
1	3	3	3	3	3	3	3	3
2	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3
4	2.6	2.5	2.5	2.6	2.5	2.6	2.6	2.5
5	1.1	1.1	1.2	1.1	1.2	1.1	1.2	1.1
6	1.5	1.4	1.5	1.6	1.6	1.5	1.7	1.6
7	3	3	3	3	3	3	3	3
8	3	3	3	3	3	3	3	3
9	1.1	1.2	1	1.1	1.2	1	1.2	1
10	2.6	2.5	2.5	2.6	2.5	2.6	2.6	2.5
11	1.5	1.4	1.5	1.6	1.6	1.5	1.7	1.6
12	2.6	2.5	2.5	2.6	2.5	2.6	2.6	2.5
13	1.5	1.4	1.5	1.6	1.6	1.5	1.7	1.6
14	0.8	0.8	0.9	0.6	0.8	0.9	0.9	0.8
15	0.6	0.5	0.4	0.6	0.6	0.5	0.6	0.6
16	0.8	0.8	0.9	0.6	0.8	0.9	0.9	0.8
17	0.6	0.5	0.4	0.6	0.6	0.5	0.6	0.6
18	1.4	1	1.1	1.2	1.1	1.3	1.1	1
19	1.4	1	1.1	1.2	1.1	1.3	1.1	1
20	1.8	1.5	1.9	1.8	1.6	1.7	1.6	1.5
21	1.8	1.5	1.9	1.8	1.6	1.7	1.6	1.5
22	1.4	1	1.1	1.2	1.1	1.3	1.1	1
23	1.4	1	1.1	1.2	1.1	1.3	1.1	1
24	0.5	0.2	0.1	0.2	0.5	0.4	0.2	0.2
25	0.5	0.2	0.1	0.2	0.5	0.4	0.2	0.2
26	0.5	0.2	0.1	0.2	0.5	0.4	0.2	0.2
27	0.5	0.2	0.1	0.2	0.5	0.4	0.2	0.2
SUM	43.5	39.4	40.4	41.4	42.1	42.4	41.7	40

APPENDIX V

Overall Discomfort Rating

ODR		
Subjects	**Model 1**	**Model 2**
Male 1	4	3
Male 2	3	3.5
Male 3	4	3
Male 4	4.5	3.5
Female 1	5	4
Female 2	4.5	4
Female 3	5	5
Female 4	5	4.5

CHAPTER I

INTRODUCTION

Kerala is the land named after the coconut tree, with “*kera*” meaning coconut tree and “*alam*” meaning land. Coconut is one of the major crops in Kerala, the coconut palm *(Cocos nucifera*) being the most significant of all cultivable palms. Kerala contributes around thirty per cent of the total coconut production of our country. There are number of products such as coconut oil, tender coconut water, neera, coconut flower syrup, coconut palm jaggery, coconut palm sugar, copra etc. produced from the coconut palm, and contribute to the state’s agricultural economy.

Coconut de-husking is an important post harvest operation in coconut production. Being an integral part of the culture and cuisine of Kerala, dehusking of coconut is done both at the domestic and industry level. But manual de-husking of coconut involves discomfort to the operator. At domestic level, the number of coconuts to be dehusked in a household in a day is very small, but thousands of coconuts need to be dehusked in a day, in each coconut industry. At the domestic level, dehusking is carried out manually using small tools like machete, crowbar (*paara*), KAU coconut husking tool named *Keramithra* (Jippu and Joby, 1998), etc. The first two are the commonly used and traditional tools. The traditional method of dehusking with chopping knife or the machete is difficult, time consuming, and risky. Though dehusking with a crowbar is quicker, it involves considerable discomfort. Despite a few models of power operated coconut dehusking machines being available, most of commercial scale dehusking operations, for further processing of coconut, are still carried out manually by skilled male labour using the crowbar. With people becoming more capable in the use of dehusking tools like *Keramithra,* and decline in the number of people proficient in using crowbars, large scale dehusking of coconuts is also now being done using *Keramithra* and similar tools.

The ergonomic efficiency of this popular tool remains to be assessed, however. Through ergonomic evaluations, the ease of operation, and discomfort while operating the agricultural equipments can be evaluated, and the equipments can be modified to ensure the comfort and safety of the operator. A good understanding of ergonomics and human interaction is a necessity for any successful product. Through ergonomic evaluation, the discomfort during operation of agricultural equipments can be reduced and the energy cost of the operation can be assessed.

The International Ergonomics Association defines ergonomics as the scientific discipline concerned with the understanding of interactions among humans and various other elements of a system. It can relate to physical interaction, such as with tools, machines, and the environment, or cognitive interaction, such as skilled knowledge, stress, and decision making. Ergonomic evaluation consists of an assessment of the overall posture of head, neck, back, upper body, forearms, wrists, hands, legs and feet, repetitive movement, forces, contact stress, static loading and environmental factors. The application of ergonomics to the design or modification of an equipment can help in increasing the efficiency and thereby productivity of the worker.

Different models of coconut dehuskers are available in the market. Though *Keramithra* was the design of the coconut dehusking tool released by the KAU, its immense popularity has led to several variants of the design being commonly available in the market. Often, these are marketed under the label of the original. Some of these variants are observed to be very popular too; ease of operation often being cited as a reason for its popularity. Hence it was decided to ergonomically evaluate *Keramithra* and another locally popular manual coconut dehusking tool to identify their ergonomic performance.

The project work “Ergonomic evaluation of coconut de-huskers” was carried out with the following specific objectives:

1.To estimate the energy cost of dehusking coconuts using the selected models
2.To assess the work load on the operator during operation of the tools
3.To assess the ease of operation and discomfort involved

CHAPTER II

REVIEW OF LITERATURE

Agriculture is generally recognized as the nation's most hazardous industry and displays high rates of musculoskeletal disorders with evidence to suggest that ergonomic risk factors are involved. Agricultural equipments should be ergonomically evaluated to avoid the risk factors. This chapter deals with brief reviews of the different coconut dehusking tools and different steps used for the ergonomic analysis.

2.1 Different coconut dehusking tools

Dehusking of coconut is among the most difficult post harvest operations relevant to coconut, involving human drudgery. Dehusking is generally done manually, using either a machete or a crowbar. Great skill, training, and endurance are required for this. Different models of manually operated coconut dehusking tools have also been developed.

Jippu (1999) reported that "coconut husking might have started with single-blade instruments like wedge-shaped rock pieces, sharpened wooden-crowbars, etc". He classified the manually-operated coconut husking tools broadly as:

a. Single-blade coconut-husking tool : e.g., machete, axe, crowbar, etc.

b. Twin-blade coconut-husking tool : e.*g*., coconut spanner, *keramithra*, etc.

c. Multi-blade coconut-husking tool : e.g. CPCRI coconut dehusker

In the case of a single-blade coconut husking tool, its single blade acts as both the wedge and the lever. As the wedge enters the husk longitudinally and normal to its surface, the husk is ripped open, divided and then pushed aside. Then, the blade, in the case of a coconut resting on a floor/ground, or the coconut, in the case of the tool resting on a floor/ground, is twisted in a peculiar orientation, as with a lever, to widen the slit, detach a sector of the husk from the kernel, and scoop it out. In this twisting, the wedge or blade acts as the lever and provides a mechanical advantage greater than one. In husking using single-blade tools, all unit operations are carried out manually. Since a very large force is to be applied as the effort, due to the small mechanical advantage, husking is tough and hard, and hence involves considerable drudgery.

In respect of twin-blade or multi-blade coconut husking tool, the juxtaposed blades act as the wedge at the time of impaling the coconut on them. Further ripping open, detachment of one or more sector(s) of husk from the kernel, and its scooping out are carried by the moving blade actuated by an extended lever. Though the extended lever provides more mechanical advantage than that of the single-blade tool, husking is still laborious and involves drudgery, though lesser than in the single blade model.

A modified version of the smithy tongs was the earliest twin-blade husking tool developed by Waters (1946). It had two lips sharpened like thin wedges. In the juxtaposed or closed position, it was swung and placed on the coconut, and then separated to loosen the husk. This unit operations should be repeated three or four times to finally take out the kernel. It did not become popular at all because it is not very convenient to use.

The tool developed by Titmas and Hickish (1929), another twin-blade tool, appeared to be better than that of Waters (1946). This tool was mounted on a wooden platform, and stood upright when placed on the floor. Coconut was held by hand and placed on the stationary tool. The depressing of the foot lever each time caused the separation of one sector of the husk. Repetition of these operations three or four times caused complete removal of the husk. Resetting of its movable blade on to the stationary blade, to keep them in the juxtaposed upright position, was achieved with the aid of a tension spring of high spring constant. Slipping of the foot from the pedal, when depressing it, would cause quick return of the pedal, and any part of the leg or body coming in the way of its path would get an impact, which could inflict injury. Moreover, depressing of the pedal by the operator in standing posture, with one foot, in coconut husking is not that advantageous, as this action destabilizes the operator. These disadvantages might have prevented the acceptance of this tool.

The KAU Coconut Husking Tool (*Keramithra*) developed in the Kerala Agricultural University, was simple not only in construction but also in use (Jippu and Joby (1998)). It consisted of a stationary wedge, a movable wedge, a hinge pin, a wedge seat, a lever and a pedestal with a base. The coconut is impaled with both the hands on to the two juxtaposed wedge-like blades oriented upwards. On pulling the lever upwards by one hand, the movable blade or wedge placed on the load arm of the lever swings away from the stationary blade loosening a sector of the husk from the nut. By repeating twice or thrice the husk can be separated completely from the coconut. It takes only about eight to twenty seconds for husking a nut depending upon the variety, maturity of nut and skill of operator. It is light in weight (2.5 kg), and simple to use and handle. Though this tool is quite acceptable at the domestic level, it is not so in large-scale husking. In this case too, the actuation of movable blade is manual.

According to Jippu (2007), a foot operated husking tool was developed by Aboobekkar and Narayanan. The movable blade gets separated from the stationary blade, by depressing the foot pedal downwards using one foot, thus, ripping apart a sector of the husk of the coconut that is impaled on the juxtaposed blades. The husk was completely removed by repeating these operations three or four times. In this case too, the blade/blades are actuated manually. On a comparison with the *Keramithra*, it was seen to be offering only lesser advantage.

According to Gubash *et al*., (2008), in Central Plantation Crop Research Institute (CPCRI), Kasaragod, a manually-operated dehusker was developed and improved. It consisted of three sharp separable blades, which initially faced upwards and in a juxtaposed position. In operation, the blades go up and outward by swinging about their pivots at the bottom. In the process, the husk of the coconut impaled upon the blades is torn apart and the nut is ejected. The impaling of coconut and actuation of the blades are carried out using a hand-lever and a foot-lever. This is however a cumbersome process and hence has not been accepted widely. Moreover, the feeding and its movable blade actuation are done manually. The major drawback of this device was its large size.

A rotary coconut dehusker was developed in the Kelappaji College of Agricultural Engineering and Technology (KCAET), Tavanur (Muhammad, 2002 and 2005). It was intended for large-scale application. This powered-machine consists of a stationary concave, enveloping a rotating drum. The clearance space between the drum and the concave formed a converging volute which acted as the inlet to the whole coconut and accommodated the husked smaller nut at the outlet. Numerous small blades are fixed on the outer surface of the drum and the inner surface of the concave. The coconut fed at the inlet and in the clearance between the inlet and the drum is compressed slightly by the system and forced to execute rolling motion. In the process, the blade penetrates the husk and punctures it along different planes. The shear force exerted upon the coconut by the blades of the rotating drum and the concave causes the husk to rip open along different planes. In some cases, the coconuts are completely husked and the nut emerges out at the outlet. In some cases, full coconuts with punctured and softened husk emerge out. Such coconuts require secondary operations to remove the husk. Overall, the machine, as the first prototype, functioned satisfactorily.

Ghosal *et al,* were conducted a study at College of Agricultural Engineering and Technology, OUAT Bhubaneswar in 2013, to develop and evaluate the performance of a power operated coconut dehusker suitable to Odisha. The aim of the study was to develop a power operated dehusker which would become safe to operate, easy to fabricate, commercially feasible and economically viable. It was observed that the developed dehusker could dehusk 300 nuts h^{-1} with a dehusking efficiency of about 92 per cent. It was operated by a one hp electric motor with a reduction unit for actuation of sharp edged metallic fingers (one fixed and other movable) with the help of a movable cam to dehusk the manually fed coconut. The reduction unit was used to reduce the 1440 rpm of motor to 25 rpm so that coconut could be easily fed to the fingers by their slow movement. Power was available at the pulley connected to the prime mover. With the help of belt and pulley arrangement, the power was transmitted to the shaft of the coconut dehusker. An idler pulley was used to maintain the belt tension.

2.2 Ergonomic Evaluation

Ergonomics (or human factors) is described as fitting tasks, workplaces and interfaces, to the capacities, needs and limitations of human beings. The aim of ergonomics is to optimise safety, health, comfort and efficiency for the human in the work system. The tools which are used and the production systems which are controlled, are numerous and varied. Due to the variety of tools and differences between users in terms of body size, muscular strength, and cognitive abilities, favourable human-task matches will not arise as a matter of course. Therefore, designing human-machine systems is a complex task, characterised by the need for an interdisciplinary approach.

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-farm mechanization problems can give valuable insight into the differences between options and on their adoptability. Ergonomics is a vital element in the search for improved implement design for farmers working in marginal conditions.

Naieni *et al.* (2014) reported that ergonomists were capable of providing a safer work environment for the agricultural workers in both developing and developed countries. In addition, the results show that it needs global cooperation of international organizations to enhance the occupational health intervention in agriculture.

2.2.1 Anthropometric dimensions

Engineering anthropometry is defined as the application of scientific physical measurement methods to human subjects for the development of engineering design standards and specific requirements for evaluation of engineering drawing, mock ups and manufactured products for assuring suitability of these products for the intended user population.

Tiwari and Philip (2002) conducted a preliminary anthropometric survey of 137 female subjects of Kerala and its implication on tool design were discussed.

A survey was conducted by Aware and Powar (2008) to find the anthropometric strength data of agricultural workers from Konkan region. In this study, a data of 649 males and 377 female subjects were selected from four districts. The collected data were analyzed for its distribution and were modeled for prediction of some anthropometric parameters and this data could be used for various equipments' design, with respect to the suitability of anthropometry. Five base parameters were used to predicting 13 anthropometric dimensions.

2.2.2 Selection of subjects

Selection of subjects has an important role in ergonomic evaluation. These selected subjects should be able to do all the works required for the ergonomic evaluation studies and these selected subjects should be fit for the work. Age, weight and medical fitness were the three important factors while selecting the subjects.

Astrand *et al.* (1965) determined that maximal oxygen uptake, heart rate, stroke volume, pulmonary ventilation and muscle strength decreased significantly with old age. A peak value of the maximum aerobic power could be achieved at the age of eighteen to twenty, after that a gradual decline took place.

Reinberg *et al*. (1970) stated that the workers (both male and female) in the age group of 25 to 30 years reach a peak muscle strength. But the older workers in the age group of 50 to 60 years could achieve only about 75 to 80 per cent compared to their younger days.

2.2.3 Basal metabolic rate

Energy expenditure of a human in his resting state can be calculated by determining basal metabolic rate of that human.

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

Brockway (1978) and Kathirvel (1986) reported that a linear relationship existed between heart beat rate and oxygen consumption rate for all the subjects.

Saraswathi *et al*. (1987) and Rao (1997) confirm that the BMR of male workers varied from 1462 to 1721 kcal/day whereas the BMR of female workers ranged from 1080 to 1152 kcalday^{-1}.

Narashingrao (1997) conducted investigation on the ergonomics of man machine system on sprayers and estimated the BMR of three subjects which are ranged from 1507 to 1744 kcalday^{-1}.

2.2.4 Calibration of subjects

Calibration is used to evaluate the physiological workload using heart rate. For this, the relationship between heart rate and oxygen uptake must be determined for each subject.

Cornick (1970) described the procedure to be adopted for the calibration of subjects when heart rate is to be taken as the yardstick for oxygen consumption and thus the energy expenditure. For this purpose, the person should perform a task in a simulated environment in the laboratory at different levels of effort while both heart rate and oxygen consumption had to be measured.

Davies and Harris (1964) determined that the heart rate increases rapidly in the beginning of exercise and at the end of sixth minute it reaches a steady state. There is a rapid rise in pulse rate at the start of the exercise and within five minutes it achieves the maximum pulse rate.

Astrand and Rodhal (1977) reported that the oxygen consumption and heart rate are linearly related and hence these variables could be determined during the required task and an extrapolation could be made to determine the maximal heart rate and oxygen consumption. By measuring the heart rate, assessment of workload could be done, since it is easy to measure the heart rate.

Sanders and McCormick (1993) found that the heart rate was best used as a predictor of oxygen consumption when moderate to heavy work was performed. They also stated that heart rate continuously sampled over a work day or task, was useful as a general indicator of pointed physiological stress without reference to oxygen consumption or energy expenditure. They reported that for different people the linear relationship between heart rate and oxygen consumption was different. Hence it was suggested that each person be calibrated to determine the relationship between heart rate and oxygen consumption.

2.2.5 Physiological cost of work

Physiological cost of the work is influenced by the health of the operator, nutrition, basal metabolic rate (BMR) and energy expended while working. Grandjean (1973) stated the extensive use of heart rate as a measure to know the extent of stress, particularly under static conditions, and also that heart rates within certain limits increase in direct proportion to the energy expenditure.

Nag *et al.* (1980) reported that during the working hours the average energy expenditure obtained was 11.11 kgmin^{-1} or about 28 per cent of VO_2 max. It was suggested that the workers might be allowed to work up to the limit of 40 per cent VO_2 max, for longer duration, if an increase in productivity was desired. This activity levels should not exceed 35 to 50 per cent of VO_2 max for long duration work.

In 2001, a study was carried out by Central Institute of Agricultural Engineering, Bhopal, India to measure heart rate and oxygen consumption rate of six male operators during rototilling and rotopuddling operations by a 6.7 kW rotary power tiller. Another set of experiments was conducted to measure the physiological responses while the operators walked alone on a puddled field. Physiological responses were measured under actual field conditions using an ambulatory metabolic measurement system. The data were collected at three levels of forward speed obtained in three low speed gears at about three quarters of the rated engine speed. Physiological responses during rototilling and rotopuddling operations varied linearly with forward speed.

Sam (2014) stated that the maximum energy cost was 20.58 kJmin^{-1} for harvesting with sickle whereas for harvesting with self-propelled harvester, this was 17.93 kJmin^{-1}, for the ergonomic evaluation of the paddy harvester and thresher with farm women. The energy cost was observed to be 15.53 kJmin^{-1} for threshing with mini thresher, whereas for manual threshing this value was 21.55 kJmin^{-1}. The oxygen uptake in terms of VO_2 max was above the acceptable work load for all selected operations.

2.2.6 Grade of work

Sen (1969) classified the manual jobs based on the physiological responses of the workers, both male and female. In this classification manual jobs are classified as very light, light, moderately heavy, heavy, very heavy and extremely heavy.

Nag *et al*. (1980) classified the occupational work load as “light”, “moderate”, “heavy” and “extremely heavy” which corresponded up to 25 per cent, 25-50 per cent, 50-75 per cent and above 75 per cent of the maximal oxygen uptake respectively, obtained from rhythmic bicycle ergometry.

2.2.7 Acceptable work load

Gite (1993) reported that workload requires oxygen at a rate of about 35 per cent of VO_2 max, was considered as the acceptable workload for Indian workers and the values worked out to be 0.70 $Lmin^{-1}$ and 0.63 $Lmin^{-1}$ for male and female workers respectively. The corresponding heart rate values for this workload would be about 110 $beatsmin^{-1}$ and 105 $beatsmin^{-1}$.

2.2.7.1 Maximum aerobic capacity (VO_2 max)

Astrand and Rodahl (1970) found that during continuous work lasting for at least five to six minutes, oxygen uptake equaled oxygen demand and during the last two to three minutes of the activity, pulmonary ventilation, heart rate and other cardiovascular parameters were constant. They also reported the same heart rates at a given sub maximal workload in old and young. However, maximal oxygen uptake, heart rate, stroke volume, pulmonary ventilation and muscle strength decreased significantly with age.

Muthamilselvan *et al.* (2006) observed that the heart rate of the subjects increased steadily from the beginning of the operation and stabilized in the range of 121.0 ± 4.56 $beatsmin^{-1}$ after sixth minute of operation. The average oxygen consumptions were 0.53 and 0.45 $1min^{-1}$ for machine and conventional picking respectively. Average energy expenditure for operation of the cotton picker was 11.16 $kJmin^{-1}$ and the operation of the machine could be graded as moderately heavy. The average per cent VO_2 max (29.71 percent) was lesser than that of the acceptable work load (AWL) limits of 35 percent.

2.2.8 Overall discomfort rating (ODR)

Borg (1962) developed a category scale for the rating of perceived exertion (RPE). The scale ranges from six to twenty 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.

Corlett and Bishop (1976) developed a technique for the assessment of overall discomfort rating in which a 10 - point psychophysical rating scale (0 – no discomfort, 10 - extreme discomfort) was used.

Sam (2014) developed the mean overall discomfort rating on a 10 point visual analogue discomfort scale (0- no discomfort, 10- extreme discomfort) and reported the discomfort rating for harvesting with self-propelled harvester was lesser than that for manual harvesting. For threshing with mini thresher, the rating was scaled at 6.3 as “moderate discomfort”, while for manual threshing, the rating was 8.5 as “more than moderate discomfort”.

2.2.9 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 was divided into twenty seven regions and the subject was asked to indicate the regions which were most painful.

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 were filled, one at the start of the test and the second after a long period in the seat. The ratings were then compared to estimate the level of discomfort.

CHAPTER III

MATERIALS AND METHODS

The chapter describes the materials used and the methodology adopted in conducting this study. The procedures for calibration of the selected subjects and the ergonomic evaluation of the selected models of manual coconut dehuskers are explained.

3.1 Selection of subjects

Subjects for the ergonomic evaluation of manual coconut dehusker were selected from among the farm workers of the campus, based on their experience in operating the manual coconut dehuskers. Four male and four female subjects, in the age group 25 to 35 years and medically fit, were selected for the study. The anthropometric dimensions of these subjects, with reference to the dimensions and positions of the functional components of coconut dehuskers were identified and fifteen different body dimensions and strength measurements were selected for the study. The stature, weight, acromion height, grip diameter, hand length, palm length, fore-arm hand length, grip strength, leg push, muscle strength of the selected male and female subjects were measured in the laboratory.

The anthropometric dimensions of the male and female subjects were measured using the following equipments.

- Integrated Composite Anthropometer
- Electronic push pull dynamometer
- Back-Legs-Chest dynamometer
- Digital hand dynamometer
- Finger goniometer
- Grip diameter cone

3.1.1 Integrated Composite Anthropometer

Integrated Composite Anthropometer (ICA), developed by IIT, Kharagpur (plate 3.1), comprised of a base platform, an adjustable backrest plate, and an adjustable seat, selectively placed with respect to various measuring units, so as to facilitate measuring body dimensions, both in standing and sitting posture; and a linkage mechanism assembly adapted for strength measurement. The ICA was positioned on a level surface without undulations. The subjects were made to stand erect in posture to record the standing body dimensions, such as stature, shoulder height and acromion height. The sitting and standing body dimensions of all subjects were measured using the ICA. Multiple body parameters of selected subjects were measured within a short time.

Plate 3.1 Integrated Composite Anthropometer

3.1.2 Electronic push pull dynamometer

Plate 3.2 Electronic push pull dynamometer

The electronic push-pull dynamometer manufactured by M/s Baseline Enterprises is used for measuring hand pull strength. The gauge was powered by an internal 9 V battery. It comprised of a hook, connected to the digital recorder, to measure the pull strength, and pressure pads, for measuring the push strength. Plate 3.2 shows the push pull dynamometer.

3.1.3 Back-Legs-Chest dynamometer

The strength of back, leg and chest muscles was measured using the back-legs-chest dynamometer. The instrument, shown in plate 3.3, had an adjustable chain to accommodate for height differences or to vary the point of force application, and expressed the force measured in pounds and kilograms. It was ensured that the pointer on the gauge was reset to zero before testing another subject.

Plate 3.3 Back-Legs-Chest dynamometer

3.1.4 Digital hand dynamometer

The grip strength of male and female subjects was measured using the hand grip dynamometer and the readings were expressed in kilograms of force. The handle of the instrument was set to the desired position. Each subject was made to hold the dynamometer in a comfortable position and squeeze the handle using his/her maximum effort. The maximum effort was read off the indicator in kgf. The pointer was reset before the grip strength of the next subject was measured. Plate 3.4 shows the digital hand dynamometer.

Plate 3.4 Digital hand dynamometer

3.1.5 Finger goniometer

The finger goniometer, calibrated in degrees, was used for the measurement of joint flexion (postural angle). The fulcrum of the goniometer was aligned with the anatomical fulcrum of the joint being measured. The flat arm of the goniometer was attached to the dial indicator on the centre of the limb to be measured. Both arms of the goniometer were held together and the joint to be measured was moved through its entire range of motion. The range of motion was read directly from the dial indicator. The finger goniometer is depicted in plate 3.5.

Plate 3.5 Finger goniometer

3.1.6 Grip diameter cone

The grip diameter of the subjects was measured using the grip diameter cone. Each subject was asked to grip the cone so that the thumb and middle finger could touch together. The corresponding diameter of the circles marked on the cone was noted, which was the measure of the grip diamter of the subject. The instrument is shown in plate 3.6.

Plate 3.6 Grip diameter cone

3.1.7 Weighing balance

A platform balance (Model: A&D EM-150KAL) was used for measuring the weight of each subject. The weight in kilograms of each subject was indicated on the digital read out screen. Fitness, both physical and mental, is essential for a subject to effectively participate in an ergonomic evaluation. The medical fitness levels of the selected ten subjects were ensured by screening for normal health through medical examination.

3.2 Calibration of subjects

In order to evaluate the physiological workload using heart rate, the relationship between heart rate and oxygen uptake should be determined for each subject. Both variables have to be measured simultaneously in the laboratory at a number of sub maximal loads. This process is called calibration of subjects.

Calibration is an important process to find out maximum oxygen uptake of a subject and it is essential for computing the energy expenditure in terms of oxygen consumption rate for corresponding value of heart beat rate of the subject.

For calibration, each subject was made to work on a tread mill at different loads. The data of oxygen consumption and the corresponding heart rate at different load conditions were measured, to arrive at a relationship between heart rate and oxygen consumption. The oxygen consumption was measured using Benedict- Roth recording spirometer and the heart beat rate using Polar pacer heart rate monitor.

3.2.1 Instruments used for calibration

3.2.1.1 Treadmill

Treadmill (Model VIVO) was used for working the subjects during the calibration process. It had a moving belt, two handles, and a speed regulating system to adjust the speed of the moving belt within the range of 0.8 to 20 kmh^{-1}. Plate 3.7 shows the treadmill used.

Plate 3.7 Treadmill

3.2.1.2 Benedict- Roth Recording Spirometer

The oxygen consumption of the selected subjects was estimated by using Benedict- Roth recording spirometer (plate 3.8). The apparatus consisted of a 6 L spirometer, with a speed strip chart recorder. The spirometer bell was hung by means of a chain and counter weight over a pulley. The counter weight carried the light perspex ink writing pen. The main base was made of aluminium casting with levelling screws and housed the kymograph gear box, three stop cocks - one to serve as water outlet and the other two for oxygen outlet. The two outlets provided on the left side of the base were connected to the stop cock. One of the outlet housed a rubber outlet valve and the other had provision to take a thermometer. The two way stop cock (breathing valve) was carried by an adjustable arm and fitted with a rubber mouth piece through a corrugated rubber tubing. All air hoses were of 25 mm inside diameter. The speed of the spirometer was adjusted to 20 minutes per revolution with the help of the speed selector

Plate 3.8 Benedict- Roth Recording Spirometer

3.2.1.3 Polar heart rate monitor

Heart rate monitor (model- Polar RS300X) is a compact portable instrument to monitor the heart beat rate. This can be used in the field directly. This heart rate monitor has three basic components.

- Chest belt transmitter
- Elastic strap
- Receiver unit

3.2.1.3.1 Chest belt transmitter

It has two electrodes with a grooved rectangular area on the underside of the belt transmitter, which picks up heart beat rate from the body of the subject and converts it into electromagnetic signals. For better sensing, the electrodes were wetted with water.

3.2.1.3.2 Elastic strap

This was used to secure the belt transmitter as high under the pectoral muscles (breasts) as comfortable. The belt transmitter should fit snugly and comfortably and allow normal breathing.

3.2.1.3.3 Receiver

This unit received the signals from the transmitter and displayed it on screen with the help of battery fixed in it. This receiver unit was placed within one meter range and it can be fitted in watch strap. The receiver had two buttons below the screen to operate the heart rate monitor. There was provision to set up high target zone and low target zone limits. When the subject reached the limits of heart beat, an alarm would sound, so that exerting the subject beyond this level could be stopped. Similarly, the low heart beat rate target zone was helpful in certain critical conditions.

(a) Receiver **(b) Elastic strap**

Plate 3.9 Polar Heart Rate Monitor (Model Polar RS300X)

The heart rate of the selected subjects was measured using this heart rate monitor. Plate 3.9 shows the different components of the instrument.

The operation of all instruments were clearly demonstrated to the subjects to familiarize them with the instruments so that they could use them without any tension and fear. The subjects were trained for about a month in using all the instruments separately and in combination, before starting the experiments.

3.2.2 Basal Metabolic Rate

The first step in calibration was measurement of the basal metabolic rate (BMR), which indicated the energy expenditure of a human in his resting state. The basal metabolic rate of a subject was measured in post absorptive stage using both Benedict Roth apparatus and heart rate monitor . The subject was allowed to take rest for half an hour in a semi reclining position before commencement of the test. The Benedict- Roth recording spirometer bell was filled with oxygen from the oxygen storage cylinder. The mouth piece was connected to the apparatus safely and properly, and was then fitted to the mouth of subject. The nose of the subject was closed with the help of a nose clip. The subject was initially allowed to inhale atmospheric air for some time. After normalization of breathing rate, the oxygen valve was turned on. The subject inhaled oxygen through the mouth piece which was connected to the spirometer, filled with oxygen, and released carbon dioxide through the expiratory valve coupled to carbon dioxide absorber. The Benedict Roth apparatus had a time setting mechanism for its revolution. The time was set as twenty minutes. A chart, having time as ordinate and consumption rate as abscissa, was fixed on the revolving drum of the apparatus and the consumption data was plotted. The same procedure was repeated for all selected subjects.

3.2.3 Calibration procedure

Treadmill and Benedict-Roth recording spirometer were used simultaneously for the calibration of selected subjects. The electrodes contained in the chest belt transmitter of heart rate monitor were wetted with water and fastened on the chest of the subject. The subject was allowed to take rest for half an hour before the commencement of the test. Then the Benedict-Roth spirometer was set up for calibration. The spirometer bell was filled with oxygen. The subject was fitted with the mouthpiece and nose clip and made to inhale atmospheric air through mouthpiece at the initial stage. Heart rate was monitored on the display unit. After normalization of breathing rate, the valve was turned on and the subject inhaled the oxygen present in the spirometer bell through the inspiriting valve. Carbon dioxide absorbers were present in the instrument for absorbing the released carbon dioxide through the expiratory valve. The workload of the subject was increased by increasing the speed of treadmill, until the subject was exhausted. The kymograph recorded the oxygen consumption pattern of the subject on the chart continuously. Simultaneously, heart rate was recorded in heart rate monitor fitted on the subject. The same procedure was repeated for all the subjects. By using the data on heart rate and oxygen consumption rate, calibration chart was prepared with heart rate as the ordinate and the oxygen uptake as the abscissa, for the selected eight subjects.

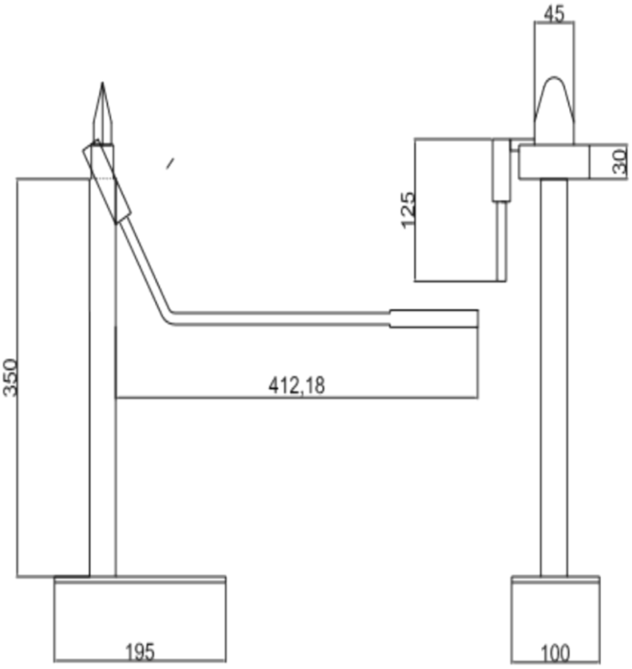
Plate 3.10 Calibration of subjects

3.3 Selection of coconut dehusking tools

A number of tools are in use for dehusking coconuts. The most common manually operated coconut dehusker in Kerala is the *Keramithra*, an implement developed by KCAET. Though the authentic model is marketed by RAIDCO, due to the immense acceptability of design, it is observed that several variants of *Keramithra* are also available in the market under the same name. The customer usually does not get the authentic *Keramithra* model. These small and simple dehuskers are very common at small scale level, and for household dehusking operations They are widely used by women and children. Often, the locally available model find great popularity too.

Hence it was decided to evaluate *Keramithra* model for its ergonomic performance and compare it with another commonly available coconut dehusker, similar in operation but different structurally. The manual coconut dehuskers selected for the study are shown in plate 3.11 and 3.12.

Figures 3.1 and 3.2 indicate the schematic diagram of the two models of manual coconut dehuskers selected for the study.



. (All dimensions in mm)

Fig. 3.1 Manually operated coconut dehusker Model 1 (*Keramithra*)

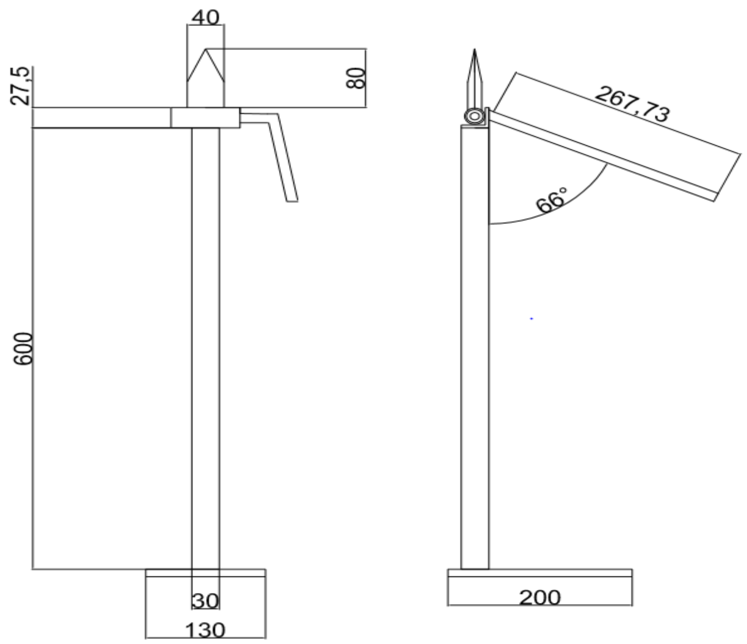


Fig. 3.2 Manually operated coconut dehusker Model 2 (All dimensions in mm)

Plate 3.11 Manually operated coconut dehusker Model 1

Plate 3.12 Manually operated coconut dehusker Model 2

3.4 Ergonomic evaluation of the selected coconut dehusking devices

Ergonomic evaluation of the selected coconut dehusking devices was conducted, for assessing their performance. The study was conducted at the Ergonomics Laboratory of KCAET, Tavanur, with coconuts having an average weight of 500 g. The subjects were given prior and complete information about the experimental requirements, so as to enlist their full cooperation. A thorough training was given to the subjects for a week to get them familiarized with the coconut dehusking device, even though they already had experience in coconut dehusking using the implement. The work was started after attaining a complete experience on each device. The subjects were rested for 30 minutes before starting the trial. The electrodes contained in the chest belt transmitter of heart rate monitor were wetted with water and fastened on the chest of the subject. Each trial started with taking five minutes' data for physiological responses of the subjects while resting on a bed. Heart rate during the dehusking was measured by the heart rate monitor. Each trial was replicated three times for each subject. The same procedure was repeated for testing the two selected dehuskers models for the eight subjects.

3.4.1 Energy cost of operation

Each of the subjects were made to work on both the selected coconut dehusking tools for about 25 minutes. The corresponding heart rates were measured. From the values of heart rate (HR) observed during the trials, the corresponding values of oxygen consumption rate (VO_2) of the subjects for the selected coconut dehusking tools were obtained from the calibration chart of the subjects. The energy cost of operation of the selected coconut dehusking tools was computed, by multiplying the oxygen consumed by the subject during the trial period with the calorific value of oxygen (20.88 kJ/L) for all subjects. Sufficient rest period was given to the subject between trials using the different models. The values of heart rate, oxygen consumption and the energy expenditure for all the subjects were measured using this method.

Plate 3.13 Energy Cost Evaluation

3.4.2 Workload classification

Workload can be classified based on the energy expenditure and oxygen consumption during the operation. Workload can be categorized as light, moderate, heavy and unduly heavy as per this classification.

3.4.2.1 Acceptable workload

The workload should be expressed as a percentage of the individual's maximal aerobic power, i.e., how much of the individual's maximal aerobic power has to be taxed in order to accomplish the work to be done. Ideally, therefore, the individual maximal oxygen (O_2) uptake should be determined, and the workload should be similarly assessed individually. Saha (1979) gave the acceptable workload (AWL) for Indian workers as the work consuming 35 per cent of VO_2 max.

3.4.2.2 Maximum aerobic capacity

The maximum oxygen uptake is the highest oxygen uptake attained by the subject, where a further increase in workload will not result in an increase in oxygen uptake. The maximum aerobic capacity, also called as maximum oxygen uptake capacity or VO_2max, is an international reference standard of cardio-respiratory fitness (Gite and Singh, 2005). Maximum oxygen consumption (VO_2 max) was estimated using the data on the heart rate-oxygen consumption relationship. Each subject's maximum heart rate was estimated by the following relationship (Bridger, 2008).

Maximum heart rate (beatsmin^{-1}) = 200 – (0.65 x Age in years)

The intersection of the computed maximum heart rate of the subjects with the plotted calibration chart line and the line of fit to the oxygen uptake, defines the maximum aerobic capacity (VO_2max) of the individual. To ascertain whether the operation of all the selected coconut climbing devices are within the acceptable workload (AWL), the VO_2 max for each treatment was computed and recorded.

3.5 Subjective rating

3.5.1 Overall Discomfort rating

A ten point Rated Perceived Exertion (RPE) scale was used by the subjects to denote the level of discomfort experienced during operation of the implement. Intensity of discomfort increased from 1 to 10, 1 being rating for least discomfort and 10 the most discomfort. A moveable pointer was provided to indicate the rating. At the end of each trial, the RPE scale was shown to the subjects to identify the level of perceived exertion while using the selected coconut dehuskers. The subject was asked to select a number that corresponds to how hard the subject perceives himself or herself to be working. This feeling should reflect how heavy and strenuous the exercise feels, combining all sensations and feelings of physical stress, effort, and fatigue, heart rate, breathing rate and perspiration, by the subject.

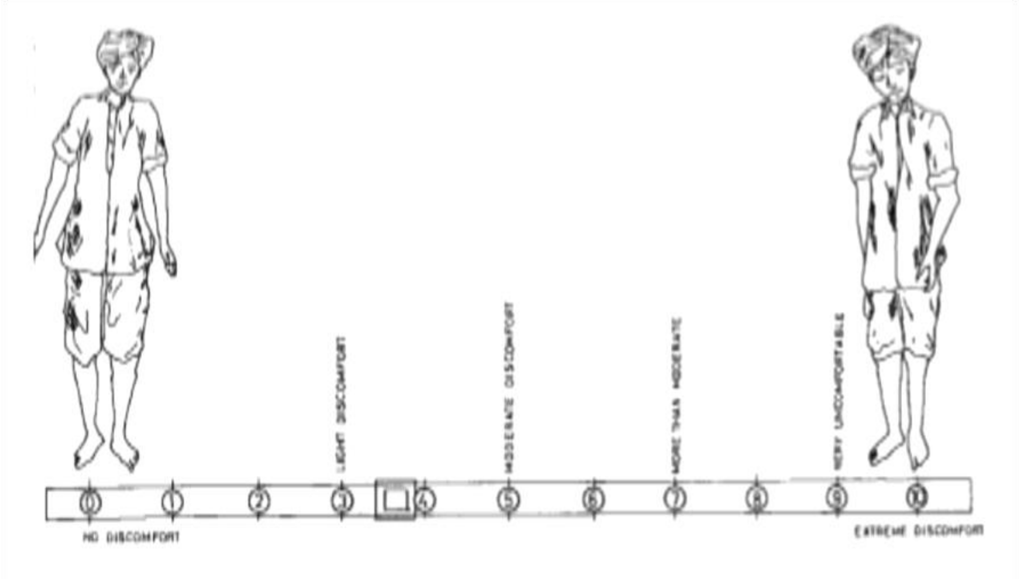


Fig 3.3 Ten point Rated Perceived Exertion (RPE) scale

3.5.2 Body part discomfort score

A body mapping technique was used to have meaningful rating of the discomfort perceived by the subject during operation. The subject was shown the image (fig. 3.4) that divides the human body into 27 regions where discomfort due to physical activities are felt. The subject was asked to mention all body parts with discomfort, starting with the worst, the second worst and so on until all parts had been mentioned. The maximum number of intensity levels of pain experienced for the operation were categorized. A rating was assigned to these categories in an arithmetic order. The intensity levels of pain experienced for the dehusking operation was divided into four categories; for the first category (body parts experiencing maximum pain) rating was maximum as four, for second category (body parts experiencing next maximum pain) rating was allotted as 3.5, for the third category it was 1.5 and for the last category (body parts experiencing least pain) rating was allotted as 1. The pain experienced by different subjects might vary in different body parts. The body part discomfort score of each subject was the rating multiplied by the number of body parts corresponding to each category. The total body part score for a subject was the sum of all individual scores of the body parts assigned by the subject. The body parts discomfort score of all the subjects was added and averaged to get the discomfort mean score. The procedure was followed for both the coconut dehuskers.

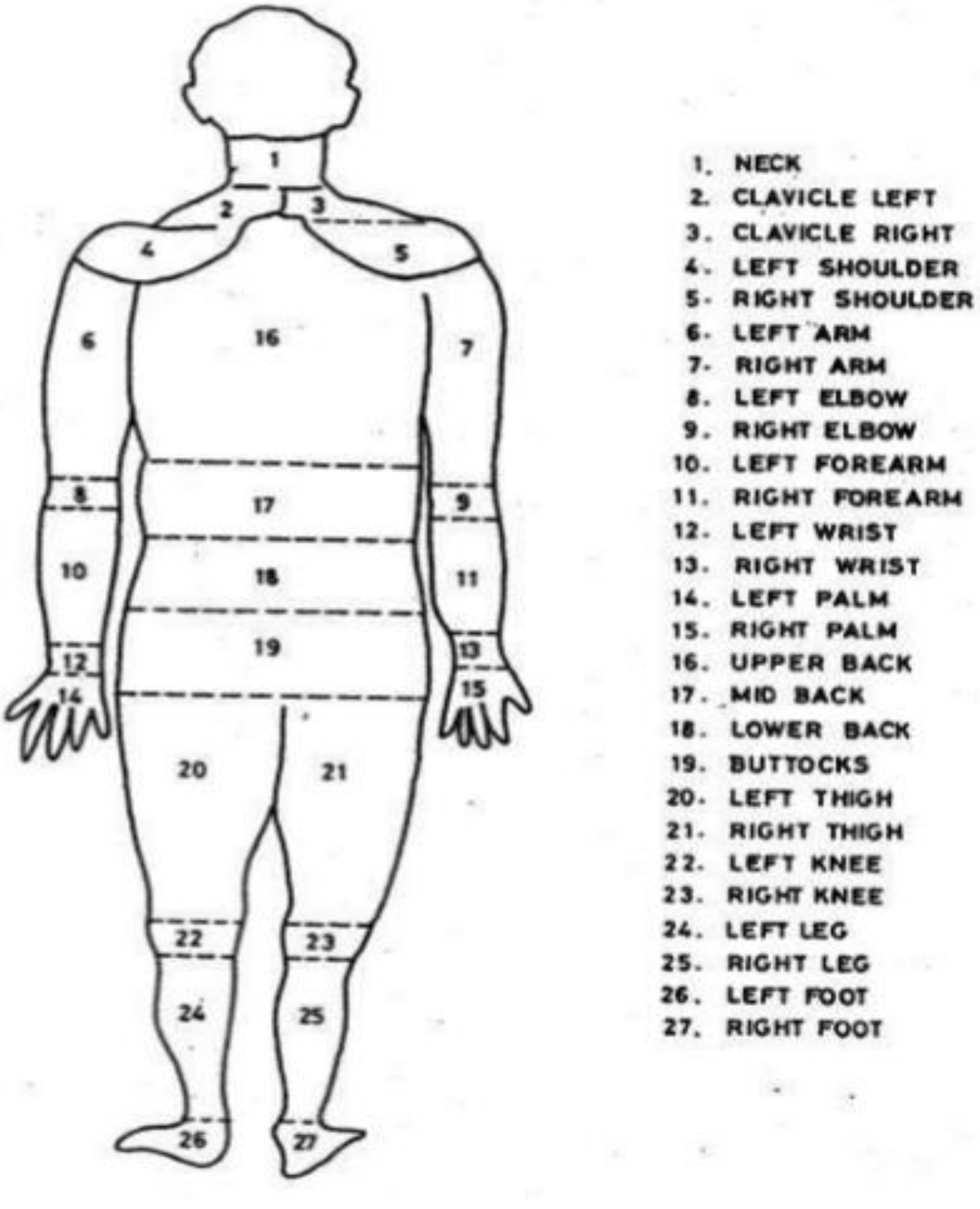


Fig 3.4 Regions for evaluating Body Part Discomfort Score

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained from the studies conducted for ergonomic evaluation of the manual coconut dehuskers is presented in this chapter.

4.1 Selection of subjects

Four male and four female subjects, medically fit and in the age group of twenty five to thirty five years, were selected from the farm workers of the college. All the subjects had more than five years of experience in operation of the manual coconut dehuskers.

4.1.1 Analysis of anthropometric data and strength parameters

Table 4.1 Analysed anthropometric data and strength parameters of male subjects

Sl. No	**Parameters**		**Subjects-Male**			
			Subject 1	Subject 2	Subject 2	Subject 4
1	Stature (cm)		171	167	172	169
2	Weight (kg)		68.2	62.8	68.9	61
3	Acromion height (cm)		100	92	93	97
4	Grip diameter (cm)		11	10	10	12
5	Hand length (cm)		79.5	75	78.5	74
6	Palm length (cm)		19.5	18	20	20
7	Palm width (cm)		9	10	10	11
8	Forearm hand length (cm)		45.5	46	46	46.5
9	Grip strength (kg_f)	Right	15	27	28	45
		Left	13	25	27	42
10	Hand pull - both hand (kg_f)		34	27	25	20
11	Leg push (kg_f)	Right	50	50	42	32
		Left	42	48	40	36
12	Muscle strength (kg_f)		130	128	130	150

Table 4.2 Analyzed anthropometric data and strength parameters of female subjects

Sl. No	Parameters		Subjects-Female			
			Subject 1	Subject 2	Subject 3	Subject 4
1	Stature (cm)		145	142.5	153	156
2	Weight (kg)		50.8	54.5	52	54
3	Acromion height (cm)		87.5	85	91	94
4	Grip diameter (cm)		9	7	8	9
5	Hand length (cm)		63	61	69	66
6	Palm length (cm)		17	15.5	19	19.5
7	Palm width (cm)		9.8	9	10	11
8	Fore arm hand length (cm)		39	36	39	40
9	Grip strength (kg$_f$)	Right	11	14	17	15
		Left	10	12	15	12
10	Hand pull-both hands (kg$_f$)		15	17	20	18
11	Leg push- (kg$_f$)	Right	40	47	48	47
		Left	32	45	42	45
12	Muscle strength (kg$_f$)		55	75	76	88

Anthropometric data of selected four male and four female subjects were collected and tabulated. The measured data of men and women are given in table 4.1 and 4.2 respectively.

The stature and weight of the male subjects ranged from 167 cm to 172 cm and 61 kg to 70 kg, while stature and weight of female subjects ranged from 142 cm to 153 cm and 50 to 55 kg respectively.

4.2 Calibration of subjects

All the selected subjects (both male and female) were calibrated in laboratory. Sanders and McCormick (1993) suggested the calibration of each person to determine the relationship between heart rate and oxygen consumption.

4.2.1 Basal Metabolic Rate

The basal metabolic rate of the subject was measured by the following procedure. Sample calculations of both male and female subjects is shown below.

a) Computation of BMR (for male subject I)

Age of the subject, years = 27

Weight of subject, kg = 68.2

Height of subject, cm = 171

Room temperature (T_2), K = 303

Room pressure (P_2), bars = 0.99

Oxygen consumption for a period of 6 min (V_2), cc = 1300

Standard temperature (T_1), K = 273

Standard pressure (P_1), bars = 1.0325

Oxygen consumed under standard

Temperature and pressure (L) $= \frac{P_2 V_2}{T_2} \times \frac{T_1}{P_1}$

$$\frac{0.99 \times 1.300}{303} \times \frac{273}{1.0325}$$

=1.1462

Energy produced in 6 min, kcal = 1.1462× 4.832

= 5.538Kcal

Energy per day, kcal = 5.552 x 60 x 24 /6

Basal Metabolic Rate, kcal /day = 1329.12

b) Computation of BMR (for female subject I)

Age of the subject, years = 30

Weight of subject, kg = 50.8

Height of subject, cm = 145

Room temperature (T_2), K = 303

Room pressure (P_2), bars = 0.99

Oxygen consumption for a period of 6 min (V_2), cc = 900

Standard temperature (T_1), K = 273

Standard pressure (P_1), bars = 1.0325

Oxygen consumed under standard Temperature and pressure, L = $\frac{P_2V_2}{T_2} \times \frac{T_1}{P_1}$

$$\frac{0.99 \times 0.900}{303} \times \frac{273}{1.0325}$$

= 0.7775

Energy produced in 6 min, kcal = 0.7775 × 4.832

= 3.757 kCal,

Energy per day, kcal = 3.882 x 60 x 24 /6

Basal Metabolic Rate, kcal /day = 901.68

Basal metabolic rate of male subjects ranged from 1100 kcalday^{-1} to 2300 kcal/day. For female subjects it ranged from 900 kcalday^{-1} to 2000 kcalday^{-1}.

4.2.2 Calibration chart

The selected subjects were subjected to calibration tests, to determine a relation between their heart rate and oxygen consumption. Calibration charts were prepared for the selected four male and four female subjects. The calibration charts were plotted with heart rate as the ordinate and the oxygen consumption as abscissa, to obtain a linear relationship, as first reported by Astrand and Rodhal (1977) through their studies on the same. This linear relationship obtained is also in consonance with the result reported by Sam (2014) for all the subjects.

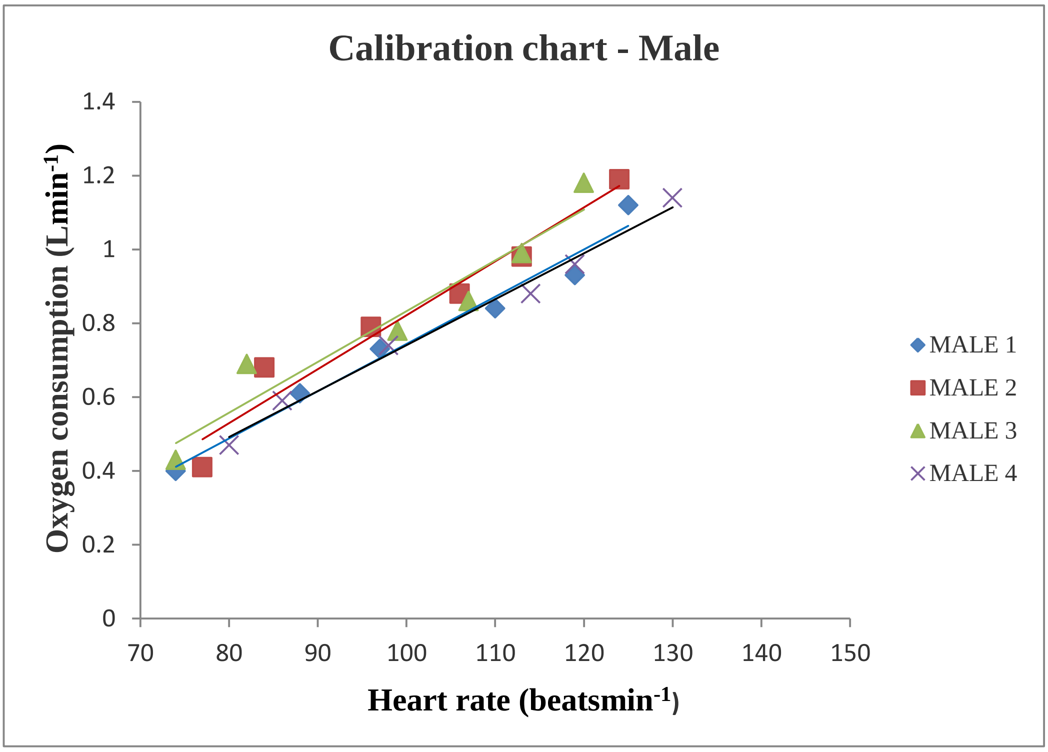


Fig. 4.1 Calibration chart of male

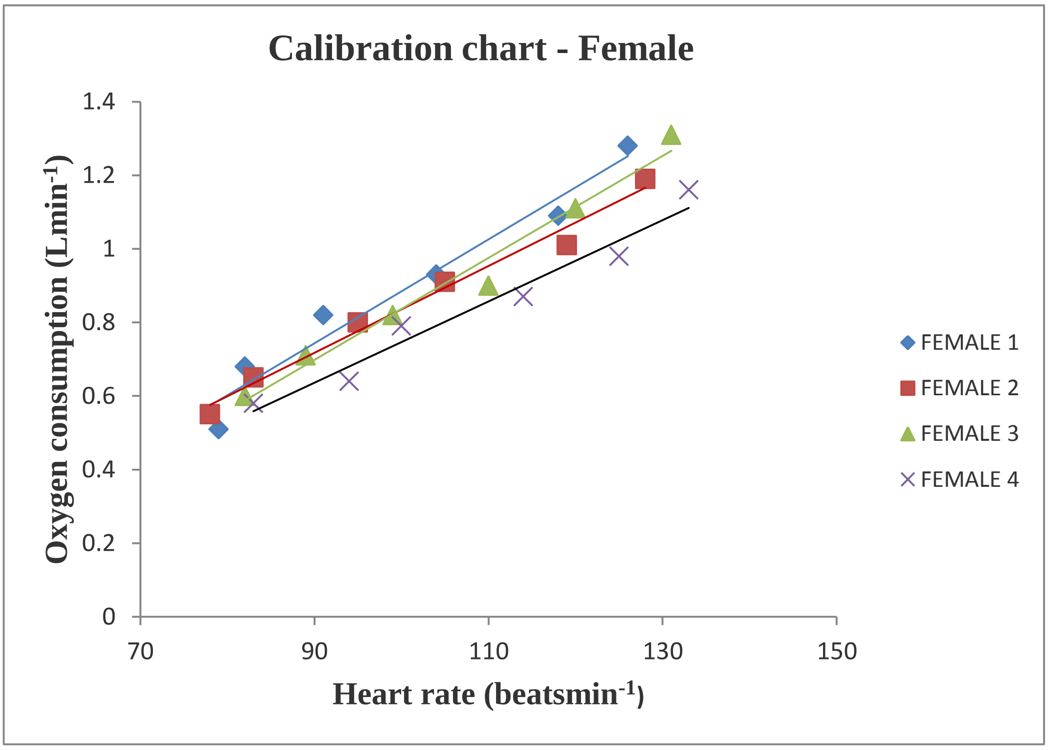


Fig. 4.2 Calibration chart of female subjects

The calibration chart of male and female subjects, are shown in figure 4.1 and 4.2 respectively. It is observed that for different subjects, the linear relationship between heart rate and oxygen consumption was different due to physiological differences of individuals. The relationship between the two parameters, oxygen consumption (Y) and heart rate (X), was expressed by the following linear equations.

For male subject 1, $Y = 0.128X - 0.5348$ $(R^2 = 0.9731)$
For male subject 2, $Y = 0.0146X - 0.6399$ $(R^2 = 0.9518)$
For male subject 3, $Y = 0.0138X - 0.5428$ $(R^2 = 0.9244)$
For male subject 4, $Y = 0.0125X - 0.5051$ $(R^2 = 0.9875)$
For female subject 1, $Y = 0.0141X - 0.5269$ $(R^2 = 0.9593)$
For female subject 2, $Y = 0.0118X - 0.3441$ $(R^2 = 0.9829)$
For female subject 3, $Y = 0.01139X - 0.5499$ $(R^2 = 0.9755)$
For female subject 4, $Y = 0.011X - 0.3579$ $(R^2 = 0.9607)$

It is seen that the R^2 value was very high for the male and female subjects selected for this study, which means they attained good fit between oxygen consumption and heart rate.

4.3 Energy cost of operation

The heart rate, oxygen consumption and energy expenditure of each subject were averaged for getting mean values, for the selected two coconut dehusking tools.

Mean heart rate, predicted oxygen consumption and energy cost of male and female subjects while operating with model 1 is shown in table 4.3 and 4.4 respectively. Tables 4.5 and 4.6 respectively show the mean heart rate, predicted oxygen consumption and energy cost of male and female subjects while operating with model 2.

Table 4.3 Heart rate, oxygen consumption and energy cost of male subject while operating coconut dehusker model 1

Subject	Avg heart rate (beatsmin^{-1})	Avg O_2 Consumption (Lmin^{-1})	Avg Energy cost (kJmin^{-1})
1	117.5	0.88	18.44
2	127.67	1.26	26.24
3	120	1.14	23.8
4	122.33	3.04	21.16

Table 4.4 Heart rate, oxygen consumption and energy cost of female subjects while operating coconut dehusker model 1

Subject	Avg heart rate (beatsmin^{-1})	Avg O_2 Consumption (Lmin^{-1})	Avg Energy cost (kJmin^{-1})
1	127.67	1.28	26.73
2	124	1.14	23.8
3	129.67	1.25	26.1
4	127	1.06	22.06

Table 4.5 Heart rate, oxygen consumption and energy cost of male subjects while operating coconut dehusker model 2

Subject	Avg heart rate (beatsmin^{-1})	Avg O_2 Consumption (Lmin^{-1})	Avg Energy cost (kJmin^{-1})
1	108.67	0.75	15.73
2	113.67	1.02	21.3
3	108.33	0.86	18.03
4	109.33	0.87	18.16

Table 4.6 Heart rate, oxygen consumption and energy cost of female subjects while operating coconut dehusker model 2

Subject	Avg heart rate (beatsmin^{-1})	Avg O_2 Consumption (Lmin^{-1})	Avg Energy cost(kJmin^{-1})
1	117.67	1.15	24.08
2	113	1	20.88
3	118	1.09	22.83
4	113.33	0.88	18.44

The energy cost involved in operating the manual coconut dehuskers was assessed. A two sample t-test was performed to compare the energy expended in the operation of the selected dehuskers, by male and female operators. The results are expressed in table 4.7 and table 4.8.

Table 4.7 Comparison of energy cost in operating manual coconut dehuskers by female operators

Energy cost (kJmin^{-1})	Model 1	Model 2
Average	24.68	21.56
SD	2.15	2.27
t-value	3.452**	

** - significant at 1% level

Table 4.8 Comparison of energy cost in operating manual coconut dehuskers by male operators

Energy cost (kJmin^{-1})	Model 1	Model 2
Average	24.41	18.31
SD	3.10	2.11
t-value	3.79**	

** - significant at 1% level

It is observed that there is a highly significant difference in the energy costs of operation between the models, when operated both by males and females. The energy cost observed for model 1 was significantly higher than that for model 2.

The energy cost experienced by male and female operators in operating each model of the manual coconut dehuskers was also observed. The results of the t-tests are presented in tables 4.9 and 4.10

Table 4.9 Energy cost of operating manual coconut dehusker model 1 by male and female operators

Energy cost (kJmin^{-1})	**Female subjects**	**Male subjects**
Average	24.68	22.41
SD	2.15	3.10
t-value	2.08*	

*- significant at 5% level

Table 4.10 Energy cost of operating manual coconut dehusker model 2 by male and female operators

Energy cost (kJmin^{-1})	**Female subjects**	**Male subjects**
Average	21.56	18.31
SD	2.27	3.10
t-value	3.64**	

** - significant at 1% level

There was a significant difference in energy cost of operation of model 1 and model 2, between female and male subjects. Females exercised more energy to perform the dehusking operation using both models, when compared to male subjects. The difference in energy cost for male and female subjects for model 1 was however lesser, when compared to the highly significant difference observed between male and female subjects, while operating model 2. This indicates that both males and females expended greater energy in operating model 1 than model 2. The model 2 is better for operation in terms of energy cost, both for male and female subjects. However, the female subjects needed to expend more energy to operate model 2 than the male subjects.

The energy cost observed for model 1, when operated by male subjects ranged from 18.44 to 26.24 kJmin^{-1}, while for model 2, this varied from 15.73 to 21.3 kJmin^{-1}. When model 1 was operated by female subjects, the energy cost varied from 22.06 to 26.73 kJmin^{-1} and these values ranged from 18.44 to 24.08 kJmin^{-1} for model 2.

The maximum and minimum energy cost of both male and female subjects while operating model 1 and model 2 of the selected coconut dehuskers are shown in figure 4.3.

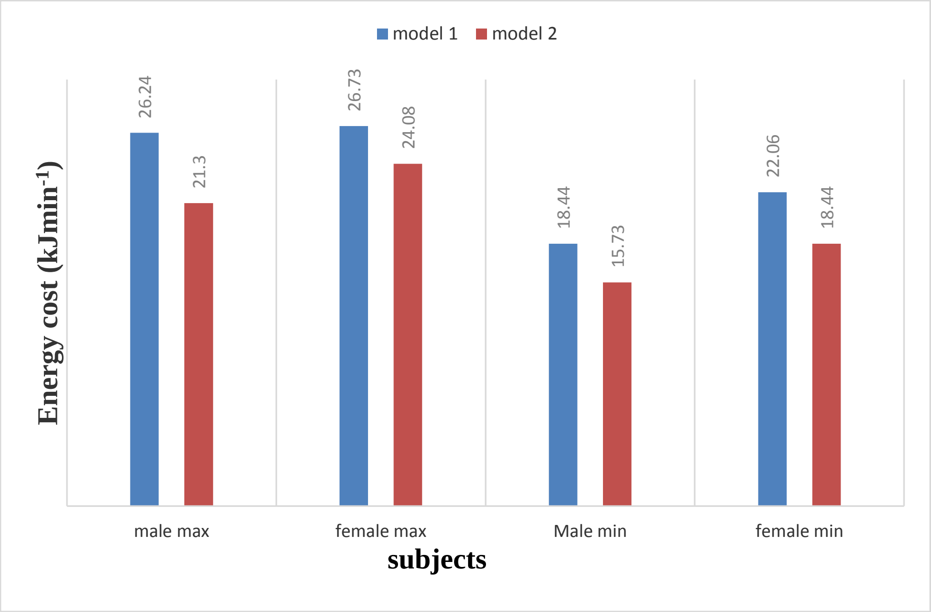


Fig 4.3 Maximum and minimum energy cost of male and female subjects in operation of model 1 and model 2

The greater height of model 2, when compared to model 1, may be the reason for the reduced energy cost of operation of model 2; as the operator does not have to bend forward too much to pierce the coconut on the blade. The physiological differences and the difference in muscle strength of the female subjects resulted in the higher energy cost experienced by them, during operation.

4.4 Maximum aerobic capacity and acceptable work load

Maximum aerobic capacity (VO_2) of each subject determined from the calibration chart are shown in Table 4.12 and 4.13. The acceptable workload (AWL) for Indian workers is calculated as the work consuming 35 per cent of VO_2 max (Saha *et al*., 1979).

Table 4.11 Maximum aerobic capacity of male and female subjects

Subjects	**Males**		**Females**	
	Maximum heart rate (beatsmin^{-1})	**Maximum aerobic capacity (Lmin^{-1})**	**Maximum heart rate (beatsmin^{-1})**	**Maximum aerobic capacity (Lmin^{-1})**
1	176	1.57	179	1.98
2	180	1.88	183	1.67
3	179	1.78	181	1.81
4	175	1.59	177	1.59
Mean	177.5	1.71	179.25	1.76

4.4.1 Acceptable work load classification

Maximum aerobic capacity of male subjects varied from 1.57 to 1.88 Lmin^{-1} and for female subjects it is varied from 1.59 to 1.98 Lmin^{-1}. The mean oxygen uptake in terms of maximum aerobic capacity of all selected subjects, during operation of selected models was calculated and is presented in tables 4.14 and 4.15.

Table 4.12 Acceptable work load classification

Subject	Model	Mean O_2 consumption ($Lmin^{-1}$)	O_2 consumption in terms of $VO_{2\ max}$ (%)	AWL (35% of VO_{2max})
Male	Model 1	1.07	62.5	>AWL
	Model 2	0.88	51.4	>AWL
Female	Model 1	1.18	69.0	>AWL
	Model 2	1.03	60.2	>AWL

It is observed that the all the values were much higher than that of the AWL limits of 35 per cent indicating that the selected dehuskers could not be operated continuously for 8 hours without frequent rest-pauses. The oxygen uptake in terms of VO_2 max was less for model 2 for both male and female operators and the values were 51.4 per cent and 60.2 per cent respectively. The maximum VO_2 max is observed to be 69 per cent for model 1 for female operators.

4.5 Overall discomfort rating

Table 4.13 Overall Discomfort Rating for male and female subjects

Model		Male	Female
Model 1	Score	4.1	5
	Scale	> Light discomfort	Moderate discomfort
Model 2	Score	3.4	4.2
	Scale	> Light discomfort	> Light discomfort

It is observed that the overall discomfort rate was higher for model 1 for both male and female subjects in comparison to model 2. It was also found that the ODR was high in the case of female subjects, as compared to males.

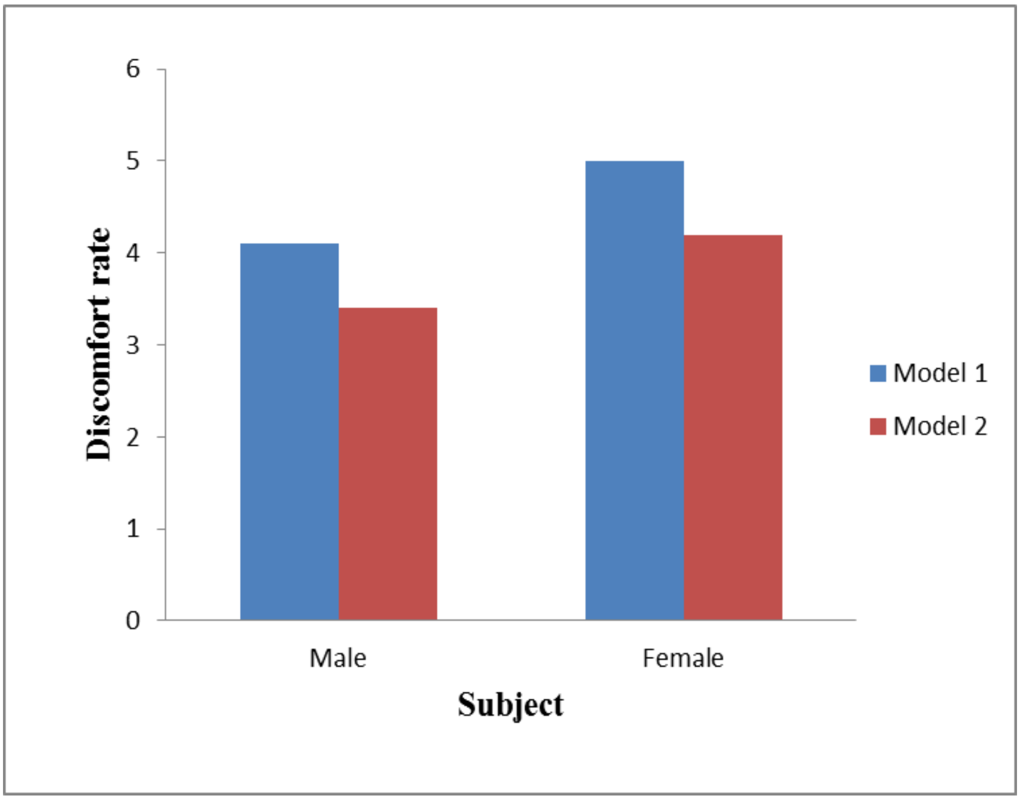


Fig. 4.4 Comparison of Overall Discomfort Rating

4.6. Body part discomfort score

The average discomfort score for male and female subjects for both model 1 and model 2 are shown in table 4.16

Table 4.14 Body Part Discomfort Score for male and female subjects

Model	**Male**	**Female**
Model 1	43.48	44.43
Model 2	41.17	41.55

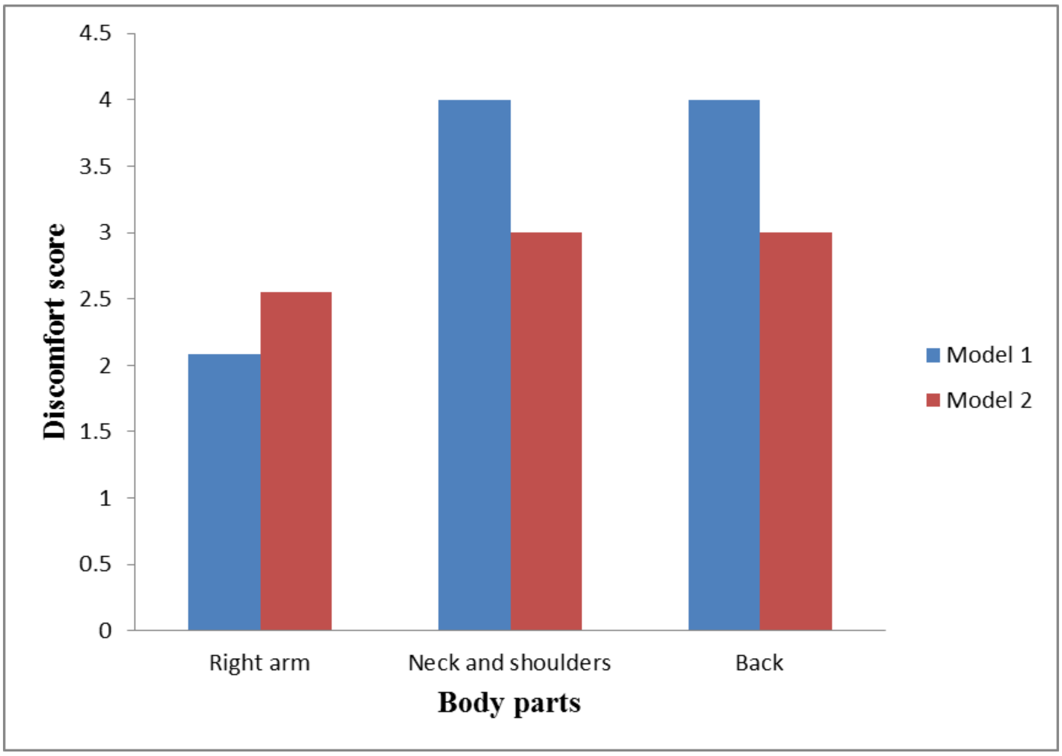


Fig 4.5 Comparison of highest discomfort among models in male subjects

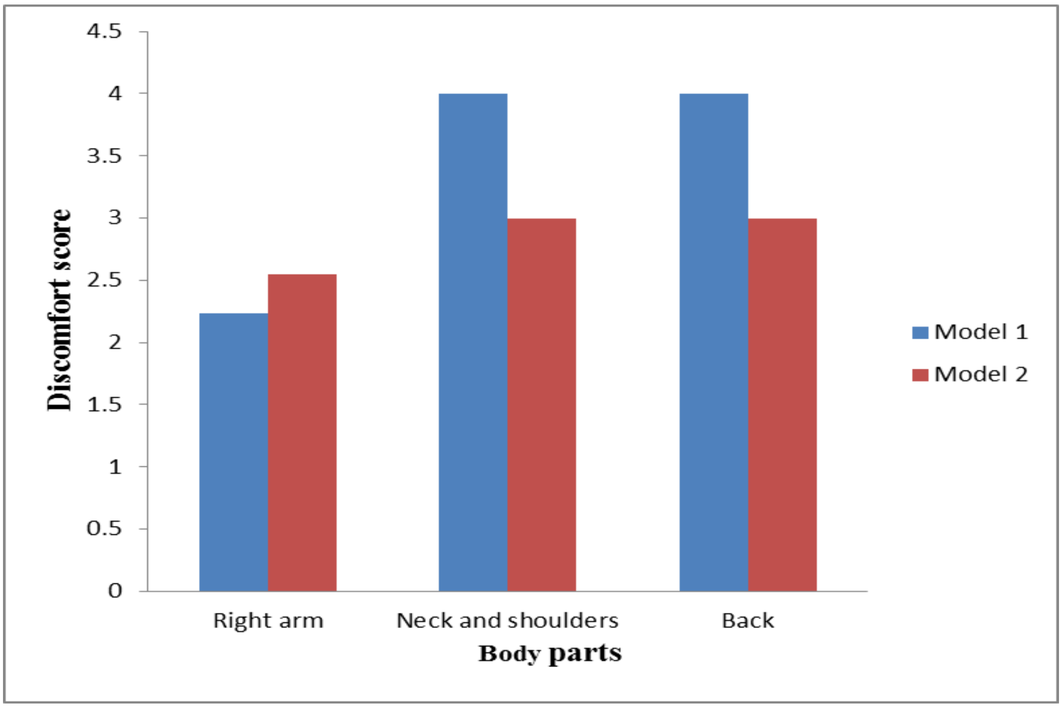


Fig 4.6 Comparison of highest discomfort among models in female subjects

By comparing the body part discomfort score results, it is found that the discomfort on shoulders, neck, mid back and lower back was high in model 1 for both male and female subjects, as compared to model 2. This may be due to the height difference between the models. But the discomfort for right arm was less in model 1 than model 2. This may be due to the difference in shape of the lever handle and the blade. The angle of the handle provides for an effortless lift, leading to lesser strain on the arm that operated it. The curvature or shape of the blade helps pierce a greater length of the coconut husk, enabling easier rupture of husk and as such it eases the strain on the arm when lifting and cutting through the husk.

CHAPTER V

SUMMARY AND CONCLUSIONS

One of the major post-harvest operations performed on coconuts is its dehusking. Different types of manual coconut dehuskers are available in Kerala. Two commonly used models of coconut dehuskers were selected for ergonomic evaluation (model 1 and model 2). Eight subjects (four each for men and women), who were in the age group of twenty five to thirty five years, medically fit and well versed in the operation of the coconut dehuskers were selected for this study. All the subjects were calibrated in the laboratory to determine the relationship between heart rate and oxygen uptake. The oxygen consumption of the subjects was measured with the Benedict- Roth Recording Spirometer and the heart rate using Polar heart rate monitor.

Basal metabolic rate of male subjects ranged from 1100 kcalday^{-1} to 2300 kcalday^{-1}. For female subjects it ranged from 900 kcalday^{-1} to 2000 kcalday^{-1}. The energy cost observed for model 1, when operated by male subjects ranged from 18.44 to 26.24 kJmin^{-1}, while for model 2, this varied from 15.73 to 21.3 kJmin^{-1}. When model 1 was operated by female subjects, the energy cost varied from 22.06 to 26.73 kJmin^{-1} and these values ranged from 18.44 to 24.08 kJmin^{-1} for model 2.

The energy cost of operating model 1 was greater than model 2, for both male and female subjects. This indicates that design modifications are required in model 1 to reduce the energy cost. Provisions for adjustment of the height of the dehusker can be provided, to reduce the energy expenditure for model 1. Energy cost of operation was higher for female subjects compared to males. This is due to the anthropometric, physiological and strength differences of females from males. This also indicates the need to further modify the design of the dehuskers to suit the anthropometry of female operators and to reduce the drudgery of operation. The overall discomfort of operation of model 1 was higher than that of model 2. On analysis of the body part discomfort score, it was observed that model 2 offered lesser discomfort, when compared to model 1. It is seen that maximum discomfort was observed on neck and shoulders, mid and lower back and operating (right) arm. The subjects operating model 2 experienced lesser discomfort on neck and shoulders and low and mid back regions, in comparison to model 1. In the case of the discomfort in the operating arm however, operators experience lesser discomfort while working with model 1. This is due to the shape of the handle that provides better mechanical advantage for the operation.

Suggestions for further studies

- The design of *Keramithra* model may be modified with provisions for an adjustable height.
- Force analysis studies may be conducted to optimise the shape of blades and hence reduce the force required for the operation

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ERGONOMIC EVALUATION OF MANUAL COCONUT DEHUSKERS

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ABSTRACT

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2017

ABSTRACT

The different models of coconut husking devices presently available have not been evaluated in the context of operator discomfort and ease of operation. The KAU coconut husking tool (*Keramithra*) is the most popular dehusker and it is the widely accepted one. In this study, two coconut husking devices were selected, *viz.*, the *Keramithra*, and a variant of the design, available in the local market. Through this study, work load, energy cost and subjective rating aspects of the selected models of the coconut huskers could be assessed. Four male and four female subjects were selected for this study in the age group twenty five to thirty five years, medically fit and experienced in operating the manual coconut husking tools. The anthropometric dimensions of these subjects, particularly the functionally relevant components, with respect to operation of the coconut huskers, were measured with instruments such as Integrated Composite Anthropometer, electronic push pull dynamometer, back-legs-chest dynamometer, digital hand dynamometer, finger goniometer and grip diameter cone. The selected eight subjects were calibrated in the laboratory by indirect assessment of oxygen uptake. The relationship between the heart rate and oxygen consumption of the subjects was found to be linear for all the subjects. Then, energy cost of operation of the selected coconut de-husking devices were computed by multiplying the oxygen consumed by the subject during the trial period with the calorific value of oxygen as 20.88 kJlit^{-1}. Energy cost of operating model 1 was in the range of 18 kJmin^{-1} to 26 kJmin^{-1} while model 2 had a range of 15 kJmin^{-1} to 24 kJmin^{-1}. Energy cost is comparatively less for the locally available model as compared to that of the *Keramithra*, indicating that design modifications are required in *Keramithra* to reduce the energy cost. The overall discomfort rate was higher for model 1, for both male and female subjects, when compared to model 2. Provisions for adjustment of the height of the husker can be provided to reduce the energy expenditure for model 1. Energy cost of operation was higher for female subjects compared to males. This is due to the anthropometric, physiological and strength differences of females from males. The mean heart rate, during the operation of the coconut de-husker, for male subjects (177.5 beatsmin^{-1})

was less than that of female subjects (179.25 beatsmin^{-1}), while the aerobic capacity of male subjects (1.71 Lmin^{-1}) was more than that of female subjects (1.76 Lmin^{-1}). Acceptable workload for this operation was much higher than that of the AWL limits of 35 per cent, indicating that dehusking of coconut using these huskers could not be done continuously for 8 hours, without frequent rest-pauses. De-husking with model 2 was found to be easier than using model 1, as indicated from the overall ease of rate calculation. The subjects operating model 2 experience lesser discomfort on neck, shoulders, and low and mid back regions in comparison to model 1. In the case of discomfort in the operating arm, however, operators experience lesser discomfort while working with model 1. Through this study, it was found that model 2 was easier and more comfortable to the operators, due to its height. However, the lower discomfort in operating arm, which indicates a lesser strain and hence a possibly longer duration of operation, while using the model 1, show that model 1 would reduce discomfort when its design is modified, with provisions for an adjustment of height of tool. Studies on force analysis may be conducted to optimise the shape of blades and hence reduce the force required for husking operation.