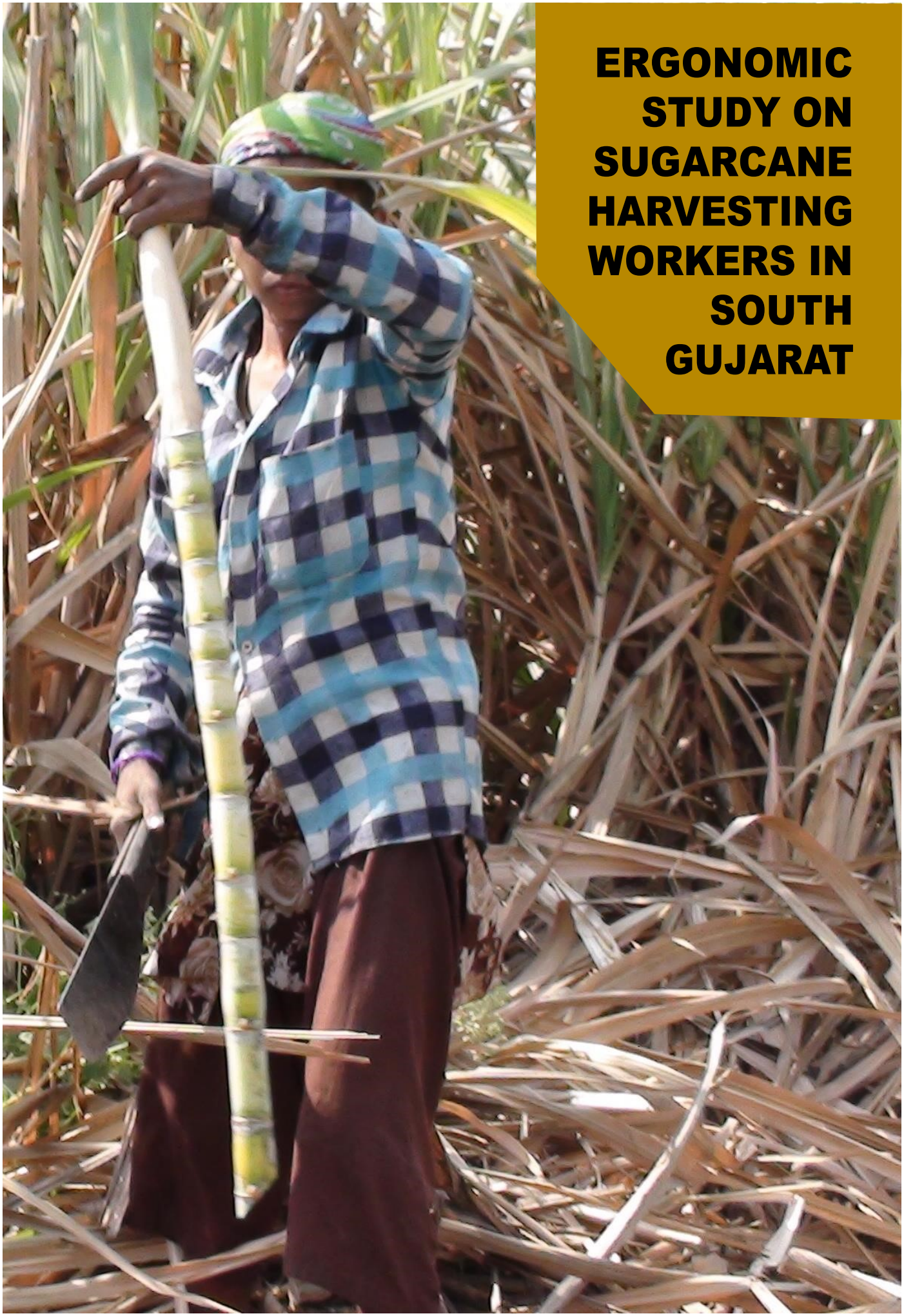
ERGONOMIC STUDY ON SUGARCANE HARVESTING WORKERS IN SOUTH GUJARAT



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CHAPTER 1
INTRODUCTION

CHAPTER 1 - INTRODUCTION

1.1 History of Study

India is a country that is dependent on farming as the main source of income for many families. In India, agriculture is facing serious challenges like scarcity of agricultural labour, living with family on the outskirts of the villages of the land owners – in conditions devoid of basic amenities, viz; clean water, sanitation, and medical facilities, children remain out of education, low wages paid generally at the end of the harvesting season mainly by the mukaddams or labour contractors. About 7.5% of the rural population, covering about 60 million agricultural laborers are engaged in sugarcane cultivation, harvesting, and ancillary activities. Sugarcane, the main source of sugar (80%) globally is a tropical plant and grown as a cash crop in the world. It is grown over 49.18 lakh hectares (ICAR-All India Coordinated Research Project on Sugarcane, AICRPs Technical Bulletin No.1) in India. India holds the second position in producing sugar immediately after Brazil. Maharashtra and the adjoining areas of Gujarat, Karnataka, and Andhra Pradesh record higher sugar recovery due to long sunshine hours, cool nights with the clear sky which is favourable for sugar accumulation.

In India, sugarcane plantation is done during different months, called planting seasons which mainly include- Autumn, Spring, and Summer. Generally, it takes 15-18 months for the planted crops to be prepared for harvesting. This harvesting process involves some phases – cutting the plant from the ground, separating the cane and the leaves, bundling the canes, carrying, and loading the bundles to the loading trucks. All of these processes are done completely manually in many areas. Hand knives, cutting blades, or hand axes are used for manual harvesting. It requires skilled laborers as an improper harvest of cane leads to loss of cane and sugar yield, poor juice quality, and problems in milling due to extraneous matter. Manual involvement results in the utilization of a large amount of physiological fuels leading to high energy expenditure. On the other hand, this condition is further enhanced if a particular task including bad postures is continued for a long time.

1.2 Background of Study

A short-term project was received by the Industrial Design Centre, Indian Institute of Technology Bombay (IITB) from Prayas Centre of Labour Research and Action (CLRA). CLRA is an organization located in Ahmedabad, Gujarat, that seeks to

a) organize workers into trade unions that can take up the struggle for decent wages and improved work conditions

b) undertake policy advocacy with the state so that workers receive their due entitlements.

The calculated average values on the time required and corresponding energy expenditure will be handed over to Prayas CLRA for their further use towards negotiating with the government and employers to increase the wages.

1.3 Study Objectives

As expected from the study proposal given by Prayas Centre for Labour Research and Action (PCLRA), directs that the project objective should be to do a systematic time-motion analysis and energy expenditure taking place to harvest one tonne of sugarcane, starting from cutting to loading in the truck, and provide a brief description of the research project including scientific rationale, hypothesis, study design and statistical basis for the structure of the investigation.

- Accordingly, the purpose of the present study and methodologies involved have been described below.
- A pictorial representation has been given below where the phases of sugarcane harvesting in a sequential manner is shown.

Phases and Description	Figure
1. Cutting Cutting of the plants and separation of cane.	
2. Bundling Making of the bundles.	
3. Loading Loading of the bundles in the truck.	

Figure 1: Three distinct phases of sugarcane harvesting.

CHAPTER 2
AIM OF THE STUDY

CHAPTER 2 - AIM OF THE STUDY

The main aim of the study is to find out the time taken to cut and load one tonne of sugarcane in a truck and work-related energy spent to complete the job for the sugarcane harvesters. These calculated average values on the time required and corresponding energy expenditure will be handed over to Prayas Centre for Labour Research and Action. Based on the following data and results which would be found, wage fixation will be done according to their nutritional requirement and socio-economic factors. Accordingly, the following steps were considered to fulfil the purpose which is as follows:

1. Observe in detail the total job content starting from cutting to loading the sugarcane in the truck.
2. Grouping of workers according to job type or category.
3. The number of workers involved in each category.
4. How much time do the workers need to complete one tonne of sugarcane cutting, bundling and loading.
5. How much Human Energy Expenditure takes place in each step according to productivity, which is one tonne.

Towards this purpose, various approaches were taken such as time-motion study, energy expenditure measurement, and measurement of nutritional indices, which will help to give a complete idea and record of the worker's status and time requirement through a proper study design.

A short description of the approaches is given below which will help to fulfil the purpose of the study.

1. Time Motion Study

One of the objectives of the study is time-motion analysis, i.e., to find out the average time taken to cut and load one tonne of sugarcane in a truck. This requires various procedures carried out, such as recording the activities, finding out the time required for each of the job elements and preparation of a final datasheet to be handed over to Prayas Centre of Labour Research for their further use.

2. Measurement of Energy Expenditure

Another aim of the study is to calculate the energy expenditure for cutting, bundling, and loading one tonne of sugarcane in a truck. Energy expenditure values will be related to the time-motion analysis and will be used to classify the workload, which will be a primary basis for their wage fixation.

3. Recording of the Nutritional Indices

Recording of the nutritional indices will be done by means of body mass index (BMI), ponderal index, body fat percentage, lean body mass, and waist-hip ratio. These will be related to the energy expenditure and time motion analysis to sketch out a map of the elements and the requirements in a sugarcane harvesting process.

CHAPTER 3
MATERIAL

CHAPTER 3 - MATERIAL

Subjects

The study was conducted on a total number of 50 persons, comprising of 25 males and 25 females engaged in different sugarcane harvesting operations. Depending upon the nature of their work, three main groups of workers are present in the field. The groups are those involved in:

1. Cutting the sugarcane
2. Bundling the sugarcane
3. Loading the sugarcane

However, the type of work is not fixed for a particular group of workers, and they change their work type based on the requirements of their work. The workers are generally tribal and migratory and the work starts and ends in a seasonal manner. The subjects work in a group, usually, husband and wife, commonly known as "Koyta" which is an unit, and the whole group made up of Koyta is called "Tukdi", who are responsible for sugarcane harvesting and loading in the truck. All the workers present had a work experience of more than three years and free from any kind of physical deformity and illness. Before doing the study, proper consent was being taken individually, and no forceful inquiry was done throughout the study.

The work schedule does not remain fixed on every working day and depends upon the workload and the amount of work to be done. The cutting and bundling procedures generally take place throughout the day, depending upon the area of the field to be covered in presence of daylight. The loading takes place after that, which may be in the day time or during the night. The loading is completely dependent upon the demand for sugarcane or the presence of a loading truck.

Table 1 Distribution of the subjects.

Variables	Mean (± SD)	
	Male (n = 25)	Female (n = 25)
Age (year)	26.34 (7.03)	26.08 (6.22)
Body Weight (kg)	51.50 (6.14)	46.00 (8.07)
Stature (cm)	164.23 (5.89)	154.25 (6.20)

The study was done in a locality called Saniya Hemad, Surat, Gujarat at the end of November, 2019.

CHAPTER 4
METHODS

4.1 Physical Parameters

Hand Grip Strength (HGS)

It is the force applied by the hand to pull on objects and is a specific part of overall hand strength. It is the measure of the muscular strength or force or tension generated by one's forearm muscles. HGS is extensively used in many areas of medicine and sport science as a functional test. The purpose of this test is to measure the maximum isometric strength of the hand and forearm muscles. Grip Strength is also used as an indicator of general health and nutritional status.

The maximum grip strength was determined (shown in Figure 2) using a calibrated hydraulic handgrip dynamometer (Baseline, USA) and was categorized based on the gender and age of the subjects, based on the chart given below.

Figure 2 Hand Grip Dynamometer

Source: https://www.prohealthcareproducts.com/hydraulic-hand-dynamometers/

Table 2 Grip Strength rating for Males and Females (in kg)
[Source: Camry electronic hand dynamometer instruction manual]

Age (years)	Weak		Normal		Strong	
	Male	Female	Male	Female	Male	Female
18 – 19	< 35.7	< 19.2	35.7 – 55.5	19.2 – 31.0	> 55.5	> 31.0
20 – 24	< 36.8	< 21.5	36.8 – 56.6	21.5 – 35.3	> 56.6	> 35.3
25 – 29	< 37.7	< 25.6	37.7 – 57.5	25.6 – 41.4	> 57.5	> 41.4
30 – 34	< 36.0	< 21.5	36.0 – 55.8	21.5 – 35.3	> 55.8	> 35.3
35 – 39	< 35.8	< 20.3	35.8 – 55.6	20.3 – 34.1	> 55.6	> 34.1
40 - 44	< 35.5	< 18.9	35.5 – 55.3	18.9 – 32.7	> 55.3	> 32.7

Waist- Hip Ratio (WHR)

It measures the ratio of the waist circumference and the hip circumference in standing condition. It determines how much fat is stored on the waist, hips, and buttocks. The WHR has been used as an indicator or measure of health, and the risk of developing serious health conditions. According to the World Health Organization (WHO), a healthy WHR is 0.9 or less in men and 0.85 or less for women. The table given below is used to determine the health risk.

Table 3 Waist-hip ratio chart.

Health risk	Women	Men
Low	0.80 or lower	0.95 or lower
Moderate	0.81 – 0.85	0.96 - 1.0
High	0.86 or higher	1.0 or higher

Body Fat Percentage

The body fat percentage is the total mass of fat expressed as a percentage of the total body mass. Body fat includes essential body fat and storage body fat. The body fat percentage is a measure of fitness level since it is the only body measurement which directly calculates a person's relative body composition without regard to height or weight. Skinfold thickness at four different sites was measured. Skinfold thickness at the biceps, triceps, forearm, and suprailiac locations (on the dominant side of the body with subjects in standing position) were obtained (shown in Figure 3) by using a Lange Skinfold Caliper. Percentage of body fat (Fat%, Siri 1961) and body density (Durnin and Womersley, 1974) was determined by using the following formulas:

- Body density (D) = 1.1631 – [0.0632 × log of (sum of the four-skinfold thicknesses] [for men]
- Body density (D) = 1.1599 – [0.0717 × log of (sum of the four- skinfold thicknesses] [for women]
- Body fat % = [(4.950/D) – 4.5] × 100

Figure 3 Skinfold Caliper
Source: https://www.google.com/lange-skinfold-caliper&psig

Classification of the subjects was done based on the chart given below:

Table 4 Classification according to body fat percentage.

Males	Females	Rating
5 – 10	8 - 15	Athletic
11 – 14	16 – 23	Good
15 – 20	24 – 30	Acceptable
21 – 24	31 – 36	Overweight
> 24	> 37	Obese

Lean Body Mass (LBM)

It is the difference between the total body weight and the total weight of fat. It is calculated using the formula:

- LBM = Body Weight (kg) – [Body Weight (kg) × Body Fat % / 100]

Body Mass Index (BMI)

It is the value derived from the mass (weight) and height of a person, which is defined as the body mass divided by the square of the body height.

The WHO regards a BMI value less than 18.5 as underweight and may indicate malnutrition, an eating disorder, or other health problems, while greater than 25 is considered overweight and above 30 is considered obese. The table given below was used to determine the category to which the sugarcane harvesting field workers belonged.

Table 5 Ranges of BMI values.

Category	BMI (kg metre^{-2})	
	WHO criteria	Asian criteria
Underweight	< 18.5	< 18.5
Normal	18.5 – 24.9	18.5 – 22.9
Overweight	25 – 29.9	23 – 24.9
Pre-obese	-	25 – 29.9
Obese	≥ 30	≥ 30
Obese Class 1	30 - 40	30 - 40
Obese Class 2	40.1 - 50	40.1 - 50
Obese Class 3	> 50	> 50

4.2 Physiological Parameters

Heart Rate

Heart rate is the speed of the heartbeat measured by the number of contractions of the heart per minute (beats per minute). The Heart Rate can vary according to the body's physical needs, including the need to match the body's demand for oxygen.

In this study, the Heart Rate was measured by a Heart Rate monitor (Polar Heart Rate Monitor). Mainly two types of Heart Rate monitors were used, one was a wristwatch type (Polar M200), and the other one was a chest belt type (Polar H10). The devices were mounted (shown in Figure 4) on the subject's wrist and chest respectively, and the readings were taken. Later on, the calculation for the average heart rate for completing each task was obtained, and the classification of workload was done.

Polar M200 Polar H10

Figure 4 Heart Rate Monitor
Source:
https://www.polar.com/sites/default/files/product3/1500x1500/polar-m200-black-1500x1500.jpg
https://www.polar.com/sites/default/files/product3/1500x1500/polar-h10-heart-rate-sensor-black-1500x1500_17.jpg

Energy Expenditure

As the intensity of workload increases, the workload on the heart also increases to meet the body's demand for oxygen. The heart has to pump more blood to fulfill the demands of the system involved. Energy expenditure and Oxygen consumption can be used as parameters to accurately grade the type of work or physical workload while performing a task.

Heart rate recording is a very common method to estimate Energy expenditure because relationship between heart rate and energy expenditure is near-linear at moderate-intensity exercise.

In this study, Energy expenditure was measured directly using a Breath by Breath Oxygen Analyzer (K4b2, manufactured by Cosmed, Italy). The Oxygen Analyzer instrument consists of a telemetric unit and a mask, which is mounted on the subject and is thus used (shown in Figure 5) to measure oxygen consumption and energy expenditure. Later on, a regression equation was generated from the data of the Heart rate and Energy expenditure. The regression equation is in the form of a straight-line equation; $y= mx + c$ where y represents Energy Expenditure (kcal/min), x is Heart Rate (beats/min), m is the slope and c is the intercept. The regression equation was generated based on their work type. After deriving the total Energy Expenditure from the equation, the energy required for

the entire period to complete the task was calculated.

Figure 5 Measurement of Energy Expenditure using K4b2.

4.3 Classification of Workload

Based on the high correlation between physiological work load and perceived exertion, a "Table for classification of jobs ", based on energy expenditure and heart rate response was proposed by Varghese et al (1994) and was used in the present study to classify the workload of both women and men performing the sugarcane harvesting operations. The table for classification of jobs as suggested by Varghese et al (1994) was used to classify the workload and is reproduced below:

Table 6 Classification of Workload (Varghese et al., 1994)

Physiological Workload	Energy Expenditure (kJ/min)	Heart Rate (beats/min)
Very light	up to 5.0	up to 90
Light	5.1 – 7.5	91 - 105
Moderately heavy	7.6 – 10.0	106 – 120
Heavy	10.1 – 12.5	121 – 135
Very heavy	12.6 – 15.0	136 – 150
Extremely heavy	above 15.0	> 150

4.4 Time Motion Analysis

Time motion study is the technique combining the Time Study with the study of elements of the entire work. Frederick Taylor devoted his research to this issue, proposing that the biggest loss in industries due to inefficiencies was not material, but indeed a waste of human effort (https:// www.ncbi.nlm.nih.gov/ pmc/articles/PMC4058370/).

He contributed to the scientific management field with his time study method which involves detailed observation of workers with a stop-watch to determine the time required to accomplish a specific job. Later, Frank and Lilian Gilbreth combined motion study, which sought to make processes more efficient by reducing the motions involved.

A time motion study was used to analyze work efficiency through the observation and timing of tasks. This helps one to understand which part of the job is the most time consuming and causes the consumption of more physical energy. The thorough observation of the whole work procedure also helps to find out the critical postures involved in any part of the work and for how long that posture is maintained by the workers. This analysis later helps in understanding the causes of any work-related musculoskeletal disorders among the workers.

The process of this study involves some steps as follows:

A. Choosing a Data Recording Method

This may be done either by observing the task in real-time or simply by recording a video. In the present study, time-motion analysis was done by recording the different phases of the harvesting procedure throughout the day. Recordings were done using two Sony handicam (model HDR-XR100E) cameras or a mobile phone camera (model redmi2 prime, redmi6). The handicams were mounted on stands and placed in such a way that allowed the capture of many workers in one frame. On the other hand, phone cameras were mainly used to capture one single worker with his/her detailed activities. All of the recordings were about 15-20 minutes duration.

B. Performing the Study

For performing the study, the whole work procedure was first divided into small categories, commonly called as Job Elements. This helps in finding out exactly how much time is spent on each small task. It also helps in finding out the tasks which require critical postures to be maintained for long times. For video analysis, KM Player software was used along with a stopwatch. The timing of each of the elements was done by starting and stopping the stopwatch, calculating the elapsed time, and then noting it down.

C. Analyzing the Results and Making Changes

For the final analysis, the following steps are done:

1. Calculating average time for each element. (viz; cutting the plant from the ground, gathering the trimmed canes, etc.)
2. Calculating the average pause time while performing each element.
3. Calculating the average actual time for the whole task. (viz; cutting, bundling, etc.) [Average Actual Time = (working time + pause time)/ number of cycles observed].
4. Calculating the average pause time in the course of the whole task. [Average Pause Time = (pause time + unavoidable rest time)/number of cycles observed].

Formats for Data Collection and Analysis are given below:

Table 7 Format for cutting phase.

Active elements in 1 complete cycle	**Number of Observations (sec per cycle)**										**No. of cycles in 5 mins**	**Time taken for 10 cycles**
	1	2	3	4	5	6	7	8	9	10		
Cutting the plant from the ground												
Picking up the plant in hand												
Cleaning the dried leaves												
Cutting the green parts from cane												
Throwing the green leafy parts aside												
Total Time												
Average Time												

1. Cutting the plant from the ground.

2. Picking up the plant in hand.

3. Cleaning the dried leaves.

4. Cutting the green parts from cane.

5. Throwing the green leafy parts aside.

Figure 6 Active elements of cutting in a sequential manner.

Table 8 Format for bundling phase.

Active elements in 1 complete cycle	Number of Observations (sec per cycle)							No. of cycles in 5 mins	Time taken for 5 cycles
	1	2	3	4	5	6	7		
Taking two green leafy part									
Placing them on the ground									
Gathering the sugarcanes									
Tying one side of the bundle									
Tying the other side									
Total Time									
Average Time									

1. Taking two green leafy part.

2. Placing them on the ground.

3. Gathering the sugarcanes.

4. Tying one side of the bundle.	
5. Tying the other side.	

Figure 7 Active elements of bundling in a sequential manner.

Table 9 Format for loading Phase.

Active elements in 1 complete cycle	**Number of Observations (sec per cycle)**			**Total distance covered in 5 mins (km)**	**No. of cycles in 5 cycles**
	1	2	3		
Lifting the bundle over the head					
Carrying it to the loading truck					
Transferring bundle to the sitting person					
Going back towards the gathered bundles					
Total Time					
Average Time					

1. Lifting the bundle over the head.	
2. Carrying it to the loading truck.	
3. Transferring bundle to the sitting person in truck.	
4. Going back towards the gathered bundles.	

Figure 8 Active elements of loading in a sequential manner.

CHAPTER 5
RESULTS

According to the study design which has been described in chapter 4 related to methods, the following results have been found and calculated based on formulae and references mentioned in chapter 4. The results are given in a sequential manner, where the physical characteristics of the workers are given at first. After that their physiological parameters, which are heart rate and energy expenditure, are being given in tabulated forms in terms of average and total time to load one tonne of sugarcane. And at the end, the values of time-motion study are given in table format with proper description.

5.1 Physical Parameters of the Workers

Table 10 Physical characteristics of the male population (n=25).

Variables	Mean (±SD)	Range
Maximum Grip Strength (kg)	40 (5.50)	18 - 40
Nutritional Indices		
Waist-Hip Ratio	0.90 (0.04)	0.81 – 0.96
Body Fat%	6.66 (4.02)	2.09 – 17.04
Lean Body Mass (kg)	50.44 (5.16)	37.90 – 58.54
BMI	19.07 (1.91)	15.72 – 23.36

Table 11 Physical characteristics of the female population (n=25).

Variables	Mean (±SD)	Range
Maximum Grip Strength (kg)	27 (5.00)	7 - 27
Nutritional Indices		
Waist-Hip Ratio	0.88 (0.07)	0.70 – 1.10
Body Fat%	17.67 (6.86)	6.12 – 24.69
Lean Body Mass (kg)	37.69 (6.42)	28.42 – 52.92
BMI	19.27 (2.74)	14.07 – 26.13

Maximum Grip Strength

The maximum grip strength for the dominant hand was found to be 40 (±5.50) kg and ranging from 18 to 40 kg in case of male workers, where the average age group is 26.3 (± 7.03) years, which states that the subjects belong to the Normal category, according to Table 2 given in methods. In case of female workers, the maximum grip strength was found to be 27 (±5.00) kg and ranging from 7 to 27 kg, where the average age group is

26.08 (±6.22), which also states that the workers fall under Normal category according to grip strength test (Table 2).

Waist-Hip Ratio (WHR)

The average WHR for male workers was found to be 0.90 (±0.04) and 0.88 (±0.07) in the case of females, which shows that male workers have a Low or Moderate health risk, according to Table 3, given in methods. Where the female workers have High WHR, which indicates that they are exposed to higher health risks than other workers.

Body Fat Percentage

The average Body Fat% in the case of male workers was found to be 6.6 (±4.02) and 17.67 (±6.86) in the case of female workers. The Lean Body Mass was found to be 50.44 (±5.16) and 37.69 (±6.42) in the case of male and female workers. According to the classification present in Table 4 of body fat percentage the male workers have an Athletic body type, that is they have got low body fat percentage. In the case of female workers, the body type falls under Good and Acceptable type according to Table 4, which indicates that they have got a body fat percentage under acceptable range.

Body Mass Index (BMI)

The BMI was found to be 19.07 (±1.91) and 19.27 (±2.74) in case of male and female workers respectively, which states that the workers both from male and female group fall mostly under Normal category according to Table 5 but some are Underweight.

5.2 Physiological Parameters

Average Heart Rate and Energy Expenditure

Table 12.1 Table for cutting for Tukdi.

Cutting (Tukdi)	Average Energy Expenditure (kcal/min)		Average Heart Rate (beats/min)		Total work time (average range) to cut 1 tonne of sugarcane (mins)		Total Energy Expenditure for cutting 1 tonne of sugarcane (kcal/tonne)	
	Male	Female	Male	Female	Male	Female	Male	Female
Actual time	4.23 (±0.58)	5.63 (±0.27)	105 (±5)	118 (±11)	17.35 (17-17.7)		80.37 (71.91 – 80.87)	106.97 (95.71 - 106.65)
Pause time	2.81 (±0.39)	2.53 (±0.56)	93 (±3)	91 (±6)	16.35 (16 -16.7)		49.17 (44.96 – 50.92)	44.27 (40.48 – 45.25)
Total time	3.52 (±0.48)	4.08 (±0.91)	99 (±4)	105 (±8)	33.7 (30.0-36.72)		129.54 (116.16 – 130.08)	151.24 (134.64 – 152.35)

Table 12.2 Table for cutting for Koyta.

Cutting (Koyta)	Average Energy Expenditure (kcal/min)		Total work time to cut 1 tonne of sugarcane for Koyta (mins)		Total Energy Expenditure for cutting 1 tonne of sugarcane (kcal/tonne)		
	Male	Female	Male	Female	Male	Female	Both
Actual time	4.23 (±0.58)	5.63 (±0.27)	136.02 (±0.49)		575.36 (±6.33)	765.79 (±0.03)	1038.49 (±6.78)
Pause time	2.81 (±0.39)	2.53 (±0.56)	126 (±0.49)		354.06 (±4.12)	381.78 (±3.30)	
Total time	3.52 (±0.48)	4.08 (±0.91)	262.02 (±0.70)		929.42 (±5.23)	1147.57 (±5.26)	

Table 12.3 Table for cutting for single person.

Cutting (Single person)	Average Energy Expenditure (kcal/min)		Total work time to cut 1 tonne of sugarcane for single person (mins)		Total Energy Expenditure for cutting 1 tonne of sugarcane (kcal/tonne)	
	Male	Female	Male	Female	Male	Female
Actual time	4.23 (±0.58)	5.63 (±0.27)	266 (±0.49)		1125.18 (±6.33)	1497.58 (±0.03)
Pause time	2.81 (±0.39)	2.53 (±0.56)	245 (±0.49)		688.45 (±4.12)	619.85 (±3.30)
Total time	3.52 (±0.48)	4.08 (±0.91)	525 (±0.70)		1813.63 (±5.23)	2117.43 (±5.26)

Table 13.1 Table for bundling for Tukdi.

Bundling (Tukdi)	Average Energy Expenditure (kcal/min)		Average Heart Rate (beats/min)		Total work time (average range) to bundle 1 tonne of sugarcane (mins)		Total Energy Expenditure for bundling 1 tonne of sugarcane (kcal/tonne)	
	Male	Female	Male	Female	Male	Female	Male	Female
Actual time	4.63 (±0.52)	5.02 (±0.74)	117 (±4)	120 (±6)	4.63 (4.19 - 5.08)		22.61 (19.39 - 23.52)	24.52 (21.03 - 25.50)
Pause time	1.70 (±0.13)	1.19 (±0.01)	94 (±2)	89 (±1)	0.36 (0.31 - 0.42)		0.61 (0.52 – 0.71)	0.42 (0.36 - 0.49)
Total time	4.42 (±0.32)	4.75 (±0.37)	105 (±3)	105 (±3)	4.95 (4.5 – 5.5)		23.22 (19.91- 26.54)	24.94 (21.39 - 28.50)

Table 13.2 Table for bundling for Koyta.

Bundling (Koyta)	Average Energy Expenditure (kcal/min)		Total work time to bundle 1 tonne of sugarcane for Koyta (mins)		Total Energy Expenditure for bundling 1 tonne of sugarcane (kcal/tonne)		
	Male	Female	Male	Female	Male	Female	Both
Actual time	4.63 (±0.52)	5.02 (±0.74)	29.18 (±0.62)		135.10 (±2.92)	146.48 (±3.16)	143.70 (±2.3)
Pause time	1.70 (±0.13)	1.19 (±0.01)	2.02 (±0.07)		3.43 (±0.13)	2.40 (±0.09)	
Total time	4.42 (±0.32)	4.75 (±0.37)	31.20 (±0.63)		138.53 (±3.2)	148.88 (±4.1)	

Table 13.3 Table for bundling for single person.

Bundling (Single person)	Average Energy Expenditure (kcal/min)		Total work time to bundle 1 tonne of sugarcane for single person (mins)		Total Energy Expenditure for bundling 1 tonne of sugarcane (kcal/tonne)	
	Male	Female	Male	Female	Male	Female
Actual time	4.63 (±0.52)	5.02 (±0.74)	58.56 (±0.62)		271.13 (±2.92)	293.97 (±3.16)
Pause time	1.70 (±0.13)	1.19 (±0.01)	4.32 (±0.07)		7.34 (±0.13)	5.14 (±0.09)
Total time	4.42 (±0.32)	4.75 (±0.37)	63 (±0.63)		278.47 (±3.2)	299.11 (±4.1)

Table 14.1 Table for loading (walking phase) for Tukdi.

Loading (Walking Phase)	Average Energy Expenditure (kcal/min)		Average Heart Rate (beats/min)		Total work time (average time) to load 1 tonne of sugarcane (mins)		Total Energy Expenditure for loading 1 tonne of sugarcane (kcal/tonne)	
	Male	Female	Male	Female	Male	Female	Male	Female
Actual time	4.60 (±0.80)	5.13 (±0.78)	109 (±7)	113 (±6)	5.39 (5.20 – 5.58)		24.79 (23.92 - 25.66)	27.64 (26.67 - 28.62)
Pause time	2.38 (±0.35)	2.37 (±0.57)	90 (±6)	89 (±3)	0.41 (0.40 – 0.42)		0.97 (0.95 – 0.99)	0.96 (0.94 - 0.99)
Total time	4.44 (±0.57)	4.93 (±0.67)	99 (±6)	101 (±4)	5.8 (5.6 – 6.0)		25.76 (24.87 - 26.65)	21.75 (27.61 – 29.61)

Table 14.2 Table for loading (walking phase) for Koyta.

Loading (Walking Phase)	Average Energy Expenditure (kcal/min)		Total work time to load 1 tonne of sugarcane for Koyta (mins)		Total Energy Expenditure for loading 1 tonne of sugarcane (kcal/tonne)		
	Male	Female	Male	Female	Male	Female	Both
Actual time	4.60 (±0.80)	5.13 (±0.78)	54.90 (±0.26)		252.54 (±1.23)	281.63 (±1.37)	281.10 (±2)
Pause time	2.38 (±0.35)	2.37 (±0.57)	5.10 (±0.14)		12.13 (±0.02)	12.08 (±0.03)	
Total time	4.44 (±0.57)	4.93 (±0.67)	60 (±0.28)		266.40 (±1.26)	295.80 (±1.39)	

Table 14.3 Table for loading (walking phase) for single person.

Loading (Walking Phase)	Average Energy Expenditure (kcal/min)		Total work time to load 1 tonne of sugarcane for single person (mins)		Total Energy Expenditure for loading 1 tonne of sugarcane (kcal/tonne)	
	Male	Female	Male	Female	Male	Female
Actual time	4.60 (±0.80)	5.13 (±0.78)	109.80 (±0.26)		505.08 (±1.23)	563.27 (±1.37)
Pause time	2.38 (±0.35)	2.37 (±0.57)	10.20 (±0.14)		24.27 (±0.02)	24.17 (±0.03)
Total time	4.44 (±0.57)	4.93 (±0.67)	120 (±0.28)		532.80 (±1.26)	591.60 (±1.39)

Table 15 Table for loading (sitting - standing phase).

Loading (Sitting-Standing Phase)	Average Energy Expenditure (kcal/min)	Average Heart Rate (beats/min)	Total work time (average time) to load 1 tonne of sugarcane (mins)	Total Energy Expenditure for loading 1 tonne of sugarcane (kcal/tonne)
	Male	Male	Male	Male
Actual time	7.45 (±0.63)	133 (±4)	1.48 (1.43 – 1.54)	11.06 (10.65 – 11.47)
Pause time	2.38 (±0.31)	90 (±6)	5.26 (5.07 – 5.46)	12.52 (12.06 – 12.99)
Total time	4.91 (±0.47)	111 (±5)	6.75 (6.5 – 7.0)	33.14 (31.91 – 34.37)

Heart Rate

The values of working heart rate (by heart rate monitor) are given in the above tables. The data are presented based on work type and gender. As described in the time study section, the total time is comprised of the average of actual and pause times.

A. Cutting

For cutting the average heart rate was found to be 105 and 118 beats/min, in the case of male and female workers, respectively. During pause time, the average heart rate was found to be 93 and 91 beats/min in the case of a male and female worker, respectively, and 99 and 105 beats/min for male and female workers for total time, respectively.

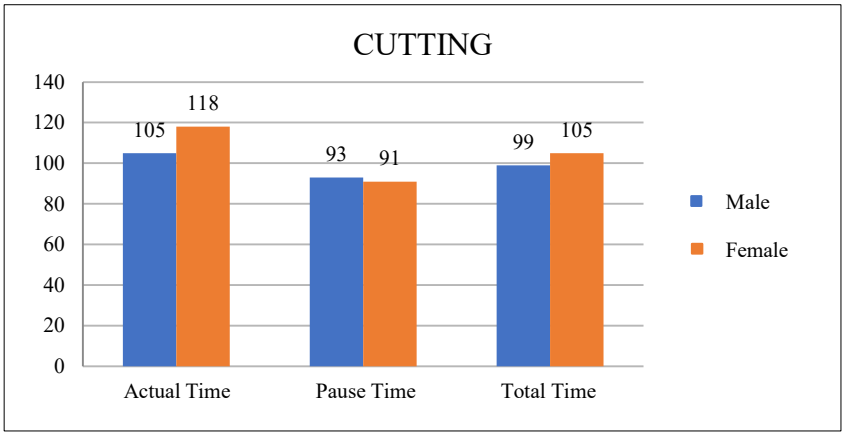

Figure 9 Graphical representation of the average heart rate for cutting in beats/min.

B. Bundling

In the case of bundling the average heart rate was found to be slightly higher than that of cutting. The average heart rate was found to be 117 and 120 beats/min in the case of male and female workers during the actual time, respectively. While in pause time the average heart rate was found to be 94 and 89 beats/min in the case of male and female workers, respectively. For the total time, the average heart rate was found to be same in case of male and female worker, that is 105 beats/min.

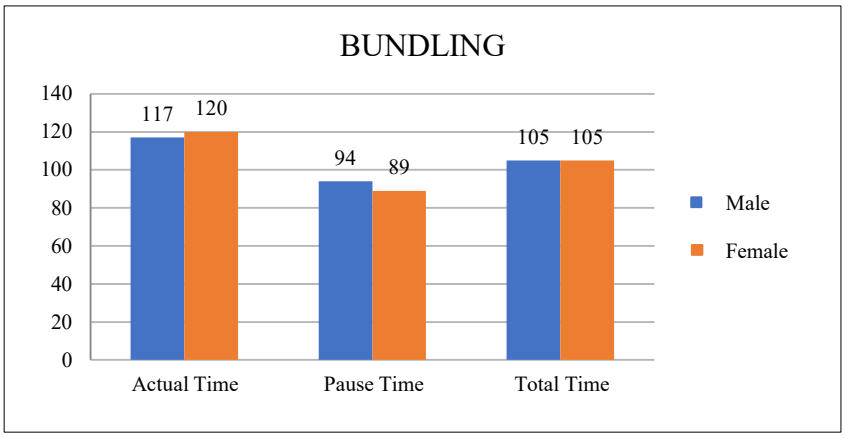

Figure 10 Graphical representation of the average heart rate for bundling in beats/min.

C. Loading

The loading part has two phases; the walking phase and the sitting and standing phase.

In the walking phase, the average heart rate was found to be 109 and 113 beats/min for male and female workers during the actual time, respectively. During the pause time, it was found to be 90 and 89 beats/min for male and female, and 99 beats/min and 101 beats/min during the total time, respectively.

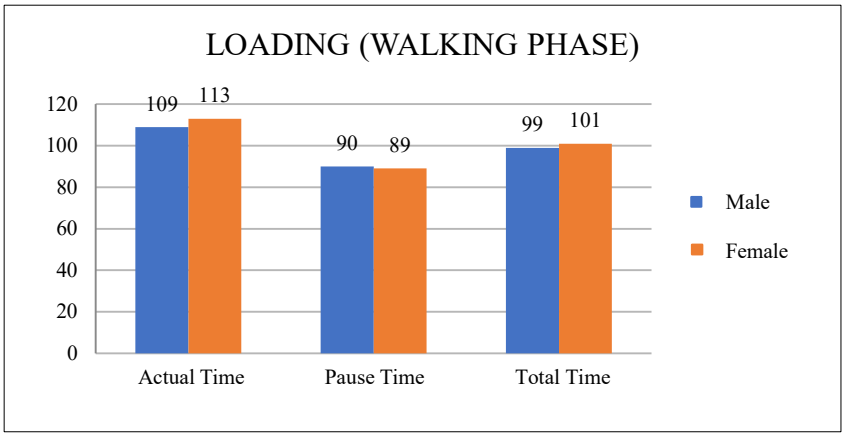

Figure 11 Graphical representation of average heart rate for loading (walking phase) in beats/min.

In the sitting and standing phase only, male workers were engaged in the activity (two at a time), and the average heart rate was found to be 133 beats/min, 99 beats/min and 111 beats/min during the actual time, pause time, and total time, respectively.

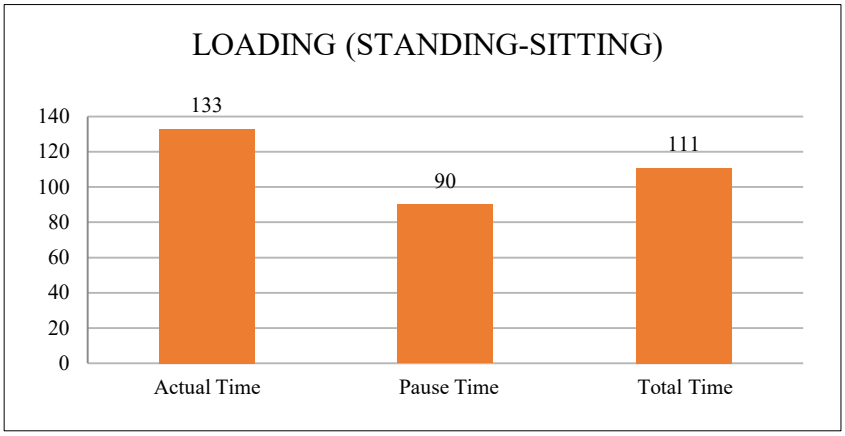

Figure 12 Graphical representation of the average heart rate (males) for loading (sitting-standing posture).

Energy Expenditure

For energy expenditure measurement the following derived regression equation was used; ***Y= 0.116X – 8.10*** for cutting, ***Y= 0.121X – 9.60*** for bundling and ***Y= 0.116X – 8.10*** for loading, where X is the working heart rate in beats/min and Y is the energy expenditure in kcal/min. Using these equations, the following values given in the above tables were calculated.

A. Cutting

The Average Energy Expenditure was found to be 4.23 and 5.63 kcal/min in case of actual working time for male and female worker, respectively, 2.81 and 2.53 kcal/min for the male and female worker, respectively, during the pause time, and 3.52 and 4.08 kcal/min for male and female workers, respectively, during total working time (includes work and pause time).

Tukdi: As the working time for cutting is maximum among the three stages of work, the total energy expenditure for cutting one tonne of sugarcane was found to be highest, which was 129.54

kcal/tonne and 151.24 kcal/tonne in case of male and female workers, respectively.

Koyta: The total energy expenditure during cutting time was found to be 929.42 and 1147.57 kcal/tonne in case of male and female worker individually and 1038.49 kcal/tonne while working as pair or Koyta.

Single person: In case of single person the total energy expenditure was found to be 1813.63 and 2117.43 kcal/tonne in case of male and female worker.

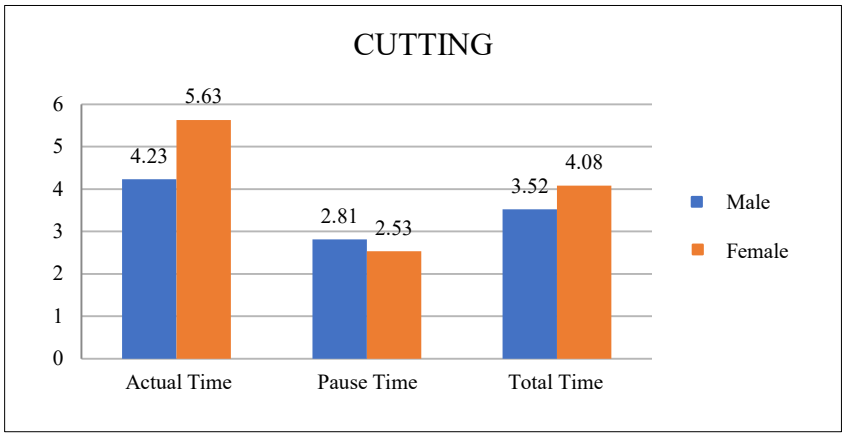

Figure 13 Graphical representation of average energy expenditure for cutting in kcal/min.

B. Bundling

In the case of bundling the average energy expenditure was found to be 4.63 and 5.02 kcal/min during actual work time, 1.70, and 1.19 kcal/min pause time, and 4.42 and 4.75 kcal/min during the total time, in case of a male and female worker, respectively.

Tukdi: As the time required to bundle one tonne of sugarcane is less than that of cutting, the total energy expenditure is less than cutting, which is 23.22 kcal/tonne in the case of male and 24.94 kcal/tonne in case of female workers.

Koyta: The total energy expenditure during bundling is 138.53 and 148.88 kcal/tonne for male and female worker while working individually and 143.70 kcal/tonne while working as a unit or Koyta.

Single person: In case of single person the total energy expenditure for male and female workers are 278.47 kcal/tonne and 299.11 kcal/tonne.

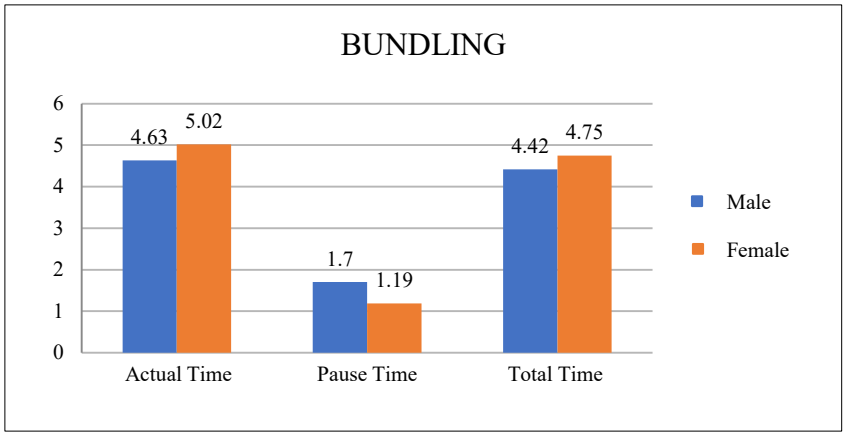

Figure 14 Graphical representation of average energy expenditure for bundling in kcal/min.

C. Loading

As we know that the loading part has two components, the walking phase, and the sitting-standing phase. The average energy expenditures have also been calculated based on the two components.

In the walking phase, the average energy expenditure was found to be 4.60 and 5.13 kcal/min for the male and female worker, respectively, during actual working time, 2.38 and 2.37 kcal/min during the pause time, and 4.44 and 4.93 kcal/min during the total time, in case of a male and female worker, respectively.

Tukdi: As the loading time for one tonne of sugarcane is the lowest among all the other activities, the total energy expenditure was found to be lowest among all the activities, being 25.76 and 21.75 kcal/tonne in case of male and female worker, respectively.

Koyta: The total energy expenditure during loading (walking phase) is found to be 266.40 and 295.80 kcal/tonne for male and female workers individually and 281.10 kcal/tonne while working as a single unit or Koyta.

Single person: In case of single person to load one tonne individually the total energy expenditure is about 532.80 kcal/tonne and 591.60 kcal/tonne in case of male and female workers.

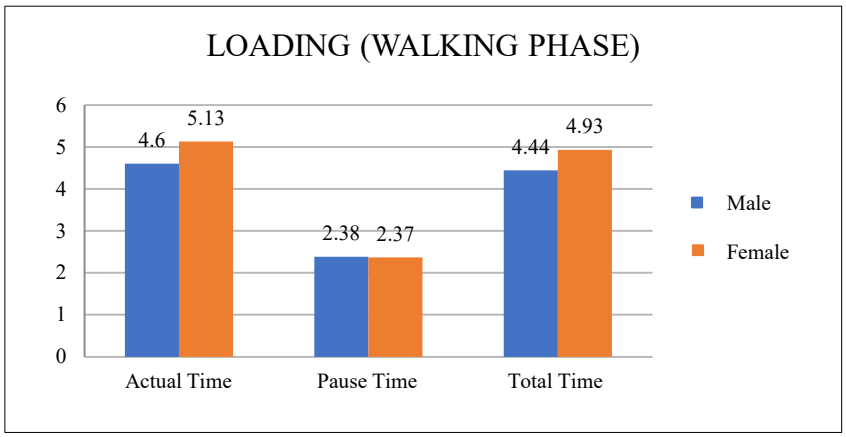

Figure 15 Graphical representation of average energy expenditure for loading (walking phase) in kcal/min.

The figures given below are the comparison between the three groups present while cutting, bundling and loading for walking phase. The figures are given are on the basis of Tukdi, Koyta and Single person, where the total energy expenditure taking place while doing their job throughout the time interval which have been calculated from time motion analysis have been given. There is a gradual change in total energy expenditure while there is change in number of workers.

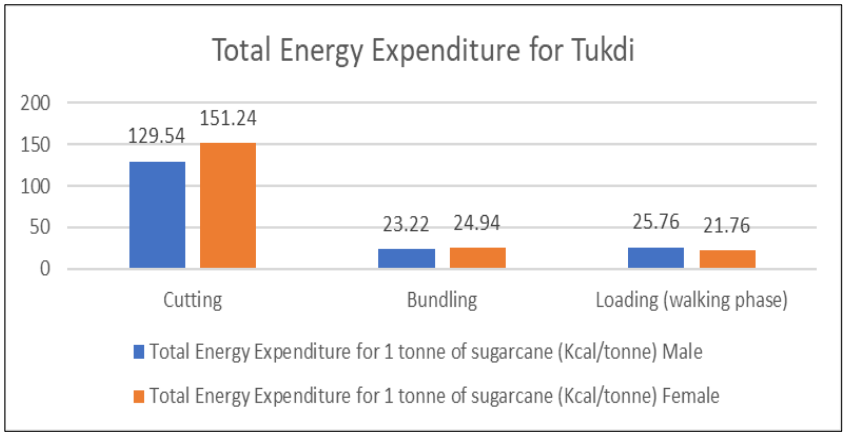

Figure 16 Total Energy Expenditure for cutting, bundling and loading (walking phase) of 1 tonne of sugarcane (kcal/tonne), for Tukdi.

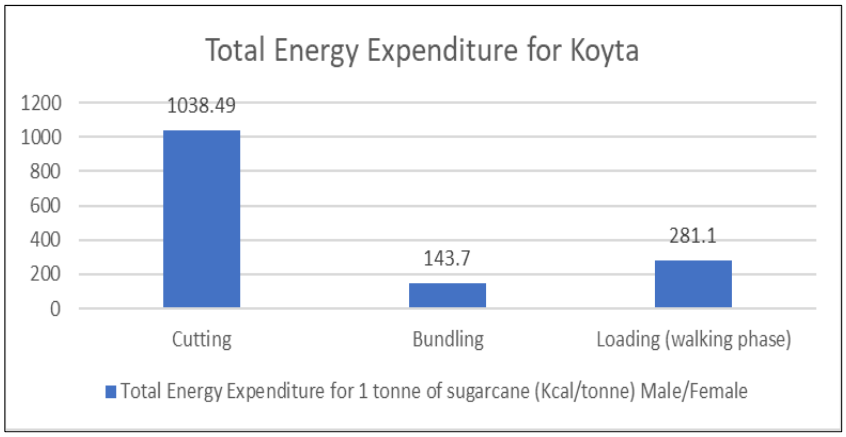

Figure 17 Total Energy Expenditure for cutting, bundling and loading (walking phase) of 1 tonne of sugarcane (kcal/tonne), for Koyta.

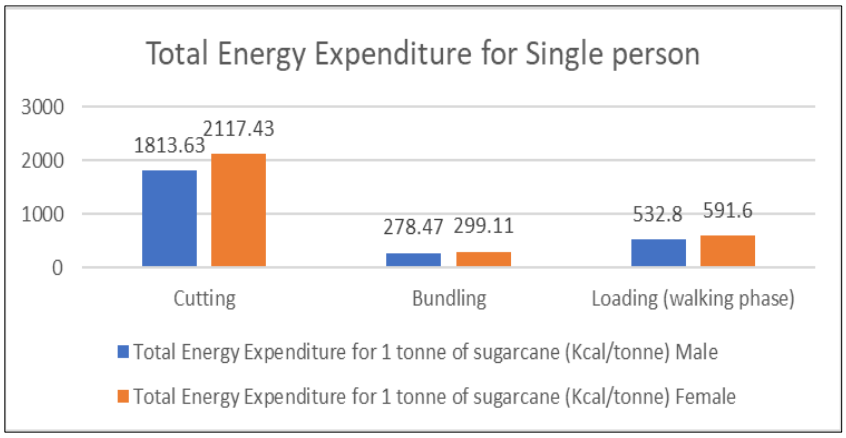

Figure 18 Total Energy Expenditure for cutting, bundling and loading (walking phase) of 1 tonne of sugarcane (kcal/tonne), for Single person.

For the Sitting-standing phase, the average energy expenditure was found to be highest than all the other activities, as it consists of a huge repetitive task component in a short duration of time. The average energy expenditure for this phase was 7.45 kcal/min during actual work time, 2.38 kcal/min during pause time, and 4.91 kcal/min during the total time. However, the total energy expenditure to load one tonne of sugarcane was lower than the other two activities and was 33.14 kcal/tonne in the case of male workers, respectively.

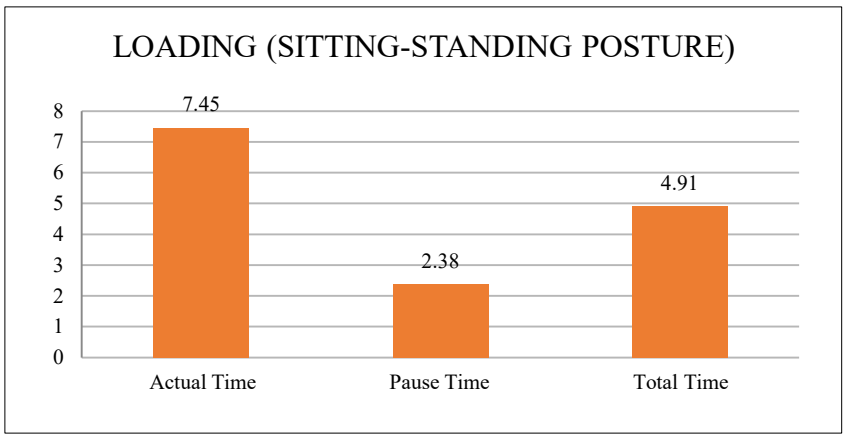

Figure 19 Graphical representation of male's average energy expenditure for loading (sitting-standing phase) in kcal/min.

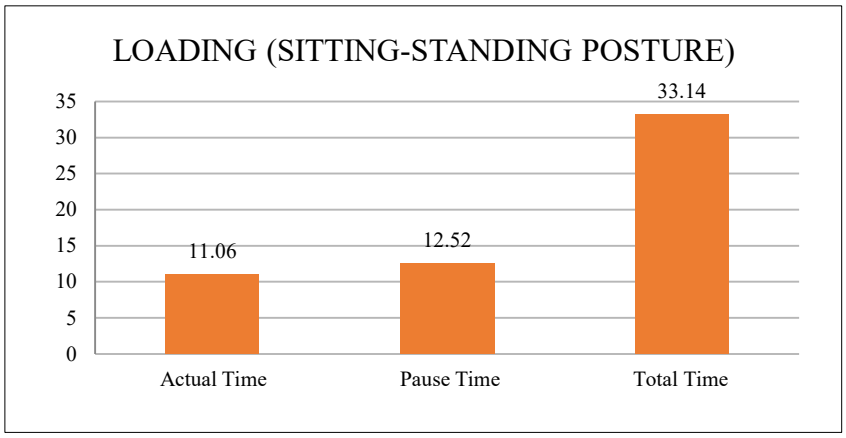

Figure 20 Graphical representation of total energy expenditure for loading (sitting-standing phase) in kcal/tonne.

5.3 Classification of Workload

Classification of workload based on heart rate and energy expenditure (Varghese et al., 1994) for the work tasks are given below:

- Cutting the sugarcane: moderately heavy workload (107 beats/min).
- Bundling the sugarcane: moderately heavy workload (119 beats/min).
- Loading (walking phase): moderately heavy workload (111 beats/min).
- Loading (sitting-standing phase): heavy workload (133 beats/min).

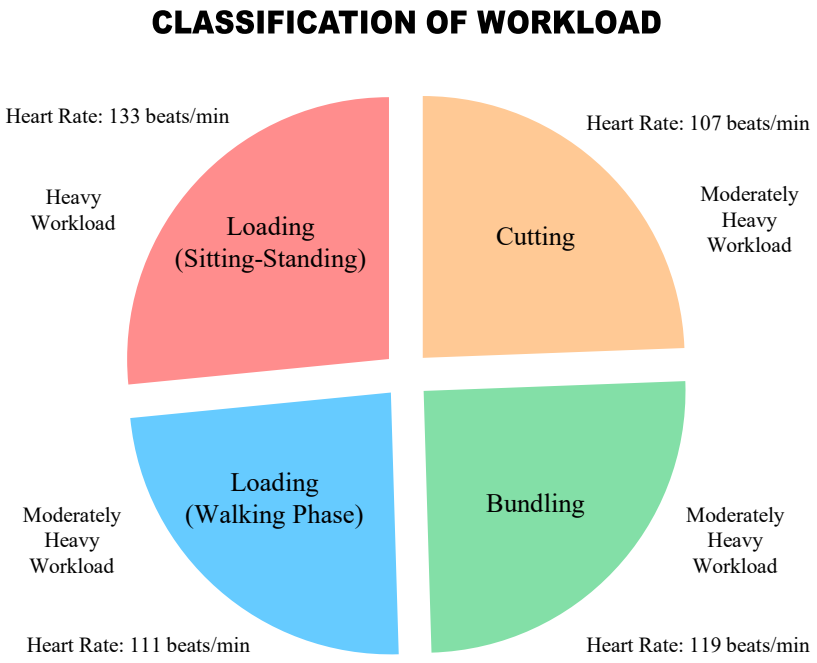

Figure 21 Graphical representation of classification of workload according to energy expenditure and heart rate [M=Male, F=Female]

5.4 Time Motion Analysis

A typical working day starts at about 6'O clock in the morning and lasts up to about 6'O clock in the evening. As stated above, there is neither a fixed working schedule nor a scheduled rest-pause. The cutting and bundling procedures continue throughout the day in different parts of the field. The loading process is done for almost 2 hours, but mainly depends on the availability of empty trucks to be loaded, and involves around 15-20 workers. On average, 12-15 tonnes of sugarcane are loaded in a truck. In this project, time motion study aimed to find the average time taken to cut and load 1 tonne (metric ton, 1000 kg), (https://writingexplained.org/ton-vs-tonnes-difference) of sugarcane in the truck. For this, the average time taken by an individual to perform each element of a cycle is first determined following the format shown above. Time paused during each activity (which may be due to talking, tying bun, taking care of children in between work, waiting in the queue for loading in truck, etc.) was also calculated.

Table 16 Time motion study based on job elements of cutting for one worker.

Observation No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Active Elements in one complete cycle	**Time per cycle (sec)**									
1. Cutting the plant from the ground	2	3	3	4	2	2	2	3	2	2
2. Picking up the plant in hand	1	2	2	3	2	3	2	1	2	2
3. Cleaning the dried leaves	3	4	5	3	2	3	2	2	3	2
4. Cutting the green parts from cane	2	2	2	2	2	2	1	1	2	1
5. Throwing the green leafy parts aside	1	2	2	2	1	1	2	1	1	2
Total time	9	13	14	14	9	11	9	8	10	9
Average cycle time	10.6 sec = 0.18 min									
Average time paused	8.82 sec = 0.15 min									

As illustrated in the above table, the average cycle time and average pause time for a sample of workers were obtained for each operation. The average cycle time and average pause time for cutting operation (based on a sample of 5 workers) are shown below (Table 4).

Table 17 Average time frame for cutting.

Activity	Subject	No. of cycles in 5 min	Time taken for each cycle (secs)	Pause time (secs)
Cutting	Worker 1	20	10.6	8.82
	Worker 2	19	11.7	7.8
	Worker 3	24	10.2	5.52
	Worker 4	22	8.9	10.44
	Worker 5	18	9.2	13.44
Total Values		103	50.6	46.02
Average No. of Cycles - 20				
Average Working Time - 0.16 min (*SD - 0.018 min)				
Average Pause Time - 0.15 min (*SD - 0.04 min)				

*SD - Standard Deviation (± mean)

The above table shows that on an average each of the workers perform 20 cycles in 5 minutes and their average working time = 0.16 minutes, average pause time = 0.15 minutes. The standard deviations for working time and pause time are also shown.

This same process is applied for bundling and loading procedures.

Table 18 Average time frame for bundling.

Activity	Subject	No. of cycles in 5 min	Time taken for each cycle (secs)	Pause time (secs)
Bundling	Worker 1	4	61.71	7.62
	Worker 2	4	72	1.71
	Worker 3	3	92	4.8
	Worker 4	4	62.4	10.08
Total Values		15	288.11	24.21
Average No. of Cycles - 4				
Average Working Time – 1.2 min (*SD - 0.22 min)				
Average Pause Time – 0.10 min (*SD - 0.64 min)				

Table 19 Average time frame for loading (walking phase).

Activity	Subject	No. of cycles in 5 min	Time taken for each cycle (secs)	Pause time (secs)	Distance covered in 5 min (km)
Loading (Walking Phase)	Worker 1	2	146.33	2.6	0.38
	Worker 2	2	120.66	19.6	0.29
	Worker 3	4	77.66	4	0.15
Total Values		8	344.65	26.2	0.82
Average No. of Cycles - 3					
Average Working Time – 1.91 min (*SD - 0.56 min)					
Average Pause Time – 0.14 min (*SD - 0.59 min)					
Average Distance Covered – 0.27 km (*SD - 0.11 km)					

Table 20 Average time frame for loading (sitting-standing phase).

Activity	Subject	No. of cycles in 2 min	Time taken for each cycle (secs)	Pause time (secs)
Loading (Sitting-Standing Phase)	Worker 1	26	2	6.8
	Worker 2	24	2	7.2
Total Values		50	4	14
Average No. of Cycles - 25				
Average Working Time – 0.03 min (*SD - 0 min)				
Average Pause Time – 0.11 min (*SD – 1.48 min)				

Now, using all these data, the total time to cut, bundle, and load 1 tonne of sugarcane is calculated (Table 8).

Table 21 Some information about sugarcane.

Parameters	Average Values
Circumference of a single sugarcane	2.57 cm
Circumference of a bundle	76 cm
No. of sugarcane in each bundle	27-30 canes
Weight of one bundle	20-25 kg
No. of sugarcanes in 1 tonne of sugarcane	1300-1500 canes
No. of bundles for 1 tonne of sugarcane	45-50 bundles

Calculation of Time Required to Cut, Bundle and Load one tonne [metric ton] (1000 kg) of Sugarcane

Table 22 Time calculation for one Tukdi working at a time.

Activity	No. of Workers at a time		Average Time to Cut a Single Cane			Total Time to Cut 1 tonne of Sugarcane (mins)
	Male	Female	Working Time (mins)	Pause Time (mins)	Actual Time (mins)	
Cutting	7	7	0.16	0.15	0.32	33.7 (±3.02)
Bundling	6	6	Average Time for a Single Bundle			Total Time to Bundle 1 tonne of Sugarcane (mins)
			Working Time (mins)	Pause Time (mins)	Actual Time (mins)	
			1.2	0.10	1.3	4.95 (±0.63)
Loading (Walking Phase)	10	10	Average Time to Load a Single Bundle			Total Time to Load 1 tonne of Sugarcane (mins)
			Working Time (mins)	Pause Time (mins)	Actual Time (mins)	
			1.91	0.14	2.05	5.8 (±0.28)
Loading (Sitting-Standing) Phase)	2 (work as a pair)	--	Average Time to Load a Single Bundle			Total Time to Load 1 tonne of Sugarcane (mins)
			Working Time (mins)	Pause Time (mins)	Actual Time (mins)	
			0.03	0.11	0.14	6.75 (±0.35)

From the above data (Table 22), an estimate for the time required (an average) by a Tukdi (group of workers) to cut, bundle, and load 1 tonne of sugarcane can be observed. For each phase, the number of male and female workers working at a time is also given. It is seen that the cutting procedure involves around 14 workers (7 males and 7 females) at a time and about 30-37 minutes to cut 1 tonne of sugarcane. The bundling process requires about 5 minutes and involves not more than 12 workers (6 males and 6 females) for making 50 bundles (approx.). Loading the bundles from the field to the truck and then lifting them to the truck also requires around 6 to 7 minutes. The walking phase of loading is done almost by the whole group and involves about 20 workers (10 males and 10 females), while only 2 male workers (no females are involved in this phase) are involved in lifting the bundles over the truck and always work as a pair.

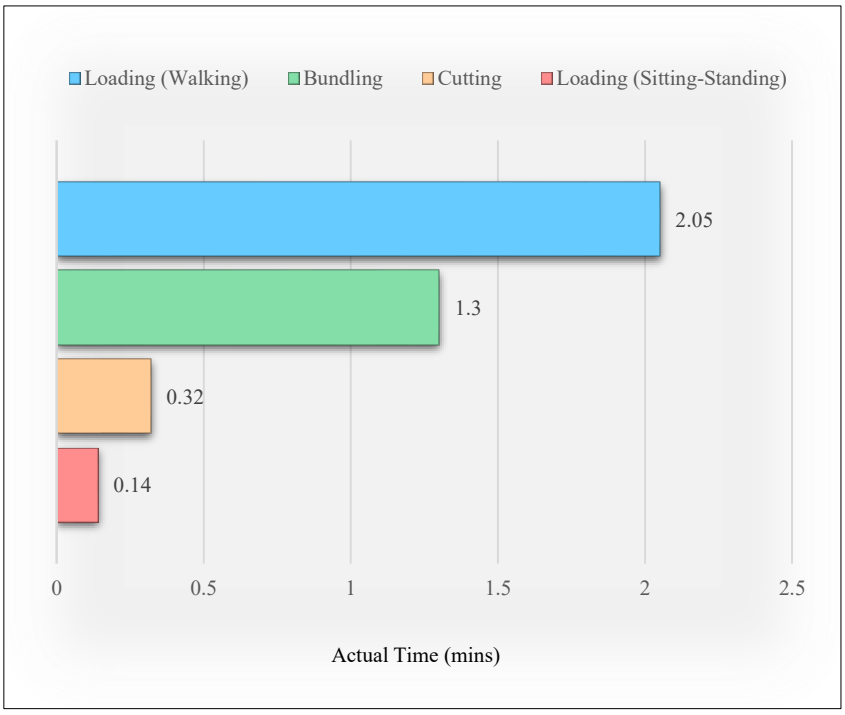

Figure 22 Comparison of the actual time (mins/cycle) for different phases of sugarcane harvesting.

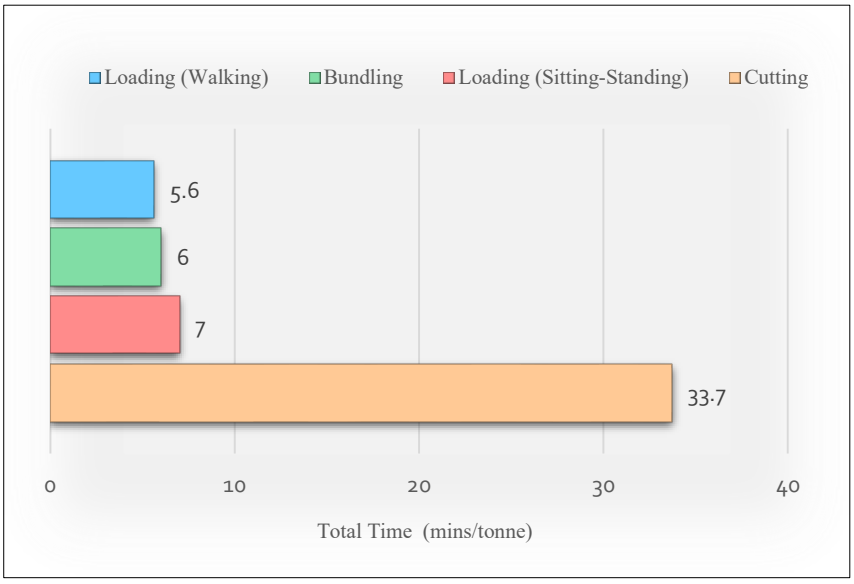

Figure 23 Comparison between the total time (mins/tonne) for different phases of sugarcane harvesting.

From the above Figure 23, it can be observed that the actual time (mins) taken to perform a single cycle is highest in the case of loading (walking phase), while the total time (mins) to cut each tonne of sugarcane is highest than other activities. This is may be due to the fact that, depending upon the size of the field and location of the loading truck, the workers have to travel a long distance to transfer the bundles to the truck, with bundles on their heads.

Table 23 Time Calculation for a single worker (male/female).

Activity	No. of Workers at a time (Male/ Female)	Total Time to Cut 1 tonne of Sugarcane (hrs)
Cutting	1	8.75 (±0.70)
Bundling	1	Total Time to Bundle 1 tonne of Sugarcane (hrs)
		1.05 (±0.63)
Loading (Walking Phase)	1	Total Time to Load 1 tonne of Sugarcane (hrs)
		2 (±0.28)

The above data (Table 23), gives an estimation of total time (hrs) required by a single worker, either male or female to cut, bundle and load 1 tonne of sugarcane. It can be observed that a single person needs around 8.75 hrs, 1.05 hrs and 2 hrs to cut, bundle and load the required amount respectively. This data indicates that cutting performed by a single worker demands maximum time.

The data (Table 24) given below, indicates the total time required by a koyta, which involves a group of two workers – one male and one female (generally husband and wife), working together. This shows that, a koyta takes around 4.37 hrs, 0.52 hrs and 1 hr to cut, bundle and load the required amount.

Table 24 Time Calculation for Koyta (pair of male and female worker).

Activity	No. of Workers at a time (Male & Female)	Total Time to cut 1 tonne of Sugarcane (hrs)
Cutting	2	4.37 (±0.70)
Bundling	2	Total Time to Bundle 1 tonne of Sugarcane (hrs)
		0.52 (±0.63)
Loading (Walking Phase)	2	Total Time to Load 1 tonne of Sugarcane (hrs)
		1 (±0.28)

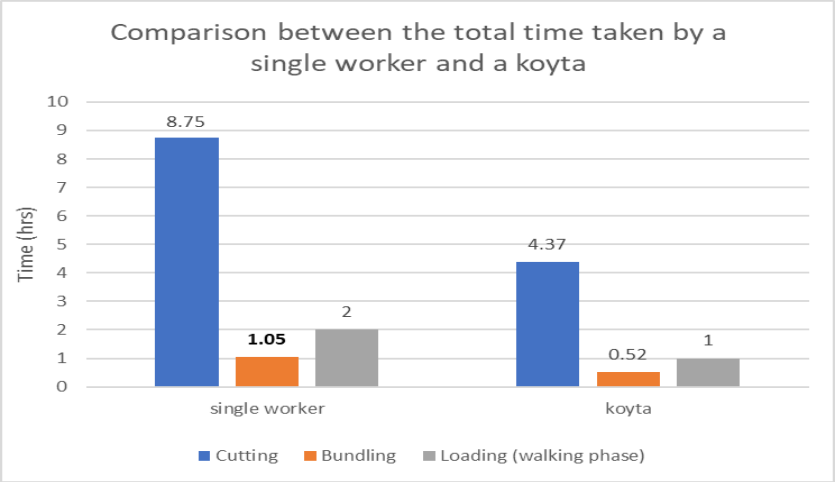

Figure 24 Graphical representation showing the comparison between the total time required by a single worker and a Koyta to cut, bundle and load 1 tonne of sugarcane.

Table 23 and Table 24 along with the above graphical representation (Figure 24) give the data of three phases of sugarcane harvesting, viz; cutting, bundling and the walking phase of loading activity and ignores the data for the lifting phase of loading activity. This is due to the fact that, lifting the bundled cane over the truck is always performed by two male workers and never involves a single worker or any female workers.

Thus, their approximate 12 hours/day working schedule involves – 8.75 hrs of cutting, 1.05 hrs of bundling, and 2 hrs of loading, on an average.

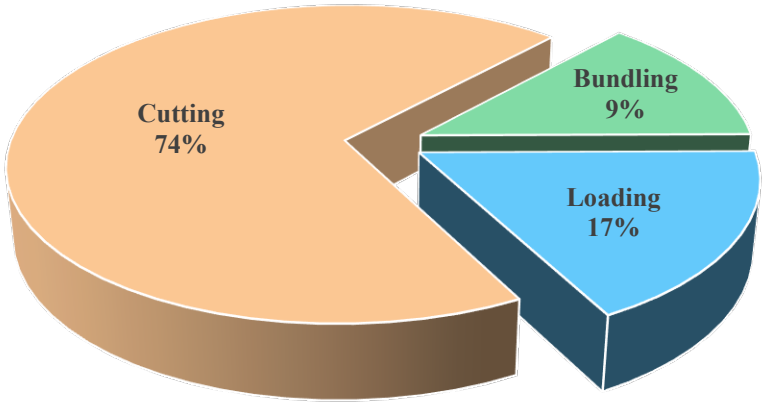

Figure 25 Total time for each activity as a percentage (%) of whole day (12 hours).

The above chart (Figure 25) shows the values of cutting, bundling and loading activities as a percentage of total working hours in a day (approx. 12 hours).

Calculation of time break by a *koyta* throughout the working hours (excluding the calculated Pause Time as mentioned throughout the report):

A typical working day also includes following activities (other than Cutting, Bundling and Loading) mentioned here, such as,

1. Taking care of children (time dedicated only for child care, like feeding etc.)
2. Taking rest - going for toilet, having a short break after working continuously in a particular activity.
3. Waiting for empty truck to arrive in the field, after finishing their cutting and bundling.
4. Having their meal which includes eating, taking rest after meal.

Table 25 Calculation of energy expenditure for break time

Activities of break time	Male (minutes/day)	Female (minutes/ day)	Energy expenditure for Male (kcal/day)	Energy expenditure for Female (kcal/day)
1.	10	15	230.04 (±0.87) (approx)	243.60 (±1.14) (approx)
2.	45	45		
3.	40	40		
4.	20	20		
Total time wasted	115 (approx)	120 (approx)		

Table 25 shows the approximate value of break time and energy expenditure for one work unit '*koyta',* throughout the day excluding their scheduled activity (include cutting, bundling and loading). The numbering of the table is same as that of the break time activities given above the table.

According to the table every day a male worker spends about 115 minutes /day approximately, and the female worker spends about 120 minutes /day approximately. So, in a total, both a male and a female workers working as an unit or 'koyta' spends more than 3 hours approximately per day and an approximate energy expenditure of 230 kcal/day for male and 244 kcal/day for female worker takes place individually.

This break time was not included in the report where time motion analysis and calculation of energy expenditure for throughout the day was calculated and has not been included in their working hour. Also it can vary from person to person where the values can even be higher or lower than the given values in the above table.

CHAPTER 6
DISCUSSION & CONCLUSION

From the overall results of the study, it may be concluded that the workers have to perform strenuous jobs at every stage of sugarcane harvesting. In each stage, there are certain types of difficulties that are dependent on the job type. In the cutting stage, the time duration is much higher than the others, whereas in other stages either the repetitive task is very high or the workers have to carry a huge load on their heads. Thus, there is a lot of variation in task characteristics and difficulties in different stages.

Cutting

For cutting one tonne of sugarcane the time is found to be the highest among the three stages of work.

For Tukdi the time is about 33.7 mins. Accordingly, the Energy Expenditure during this period is also found to be the highest, both in the case of male (129.54 kcal/tonne) and female (151.24 kcal/tonne) workers, which is about five to six times higher than the other stages.

In case of Koyta the Energy Expenditure was found to be 1038.49 kcal/tonne for both male and female working as a unit.

While in case of Single worker the Energy Expenditure was found to be 1813.63 kcal/tonne for male and 2117.43 kcal/tonne for female.

The level of difficulties while doing the work is also much higher than other stages because they often get injured and there is a history of chronic body pain in almost every worker. Injuries such as cuts in hands and fingers are common in the workers.

Bundling

In the case of bundling the time required to bundle one tonne of sugarcane is much lower than that of cutting, which is about 4.95 mins. The time is completely dependent upon the number of workers involved in the activity.

The rate of energy expenditure is also lower than that of other activities; 23.22 kcal/tonne in case of a male, and 24.94 kcal/tonne in case of female workers while working as a group or Tukdi.

While working as a single unit or Koyta the Energy Expenditure was found to be 143.70 kcal/tonne.

While working as Single worker the Energy Expenditure to bundle one tone of sugarcane was found to be 278.47 kcal/tonne for male and 299.11 kcal/tonne for female workers.

The rate of energy expenditure is lower because the work dose not takes for a long period and not as heavy as that of cutting. The movement of the work is not as fast as that of other activities but the chances of injury due to sustained bending postures are almost the same as that of loading postures.

Loading

In case of loading the time required to load one tonne of sugarcane is almost the same as that of bundling, but the intensity of the work is much higher than bundling. The workers

have to carry a huge amount of load throughout a certain distance and give the bundle to the one who is sitting on the truck, and again go back to the origin and again another cycle. So, repetition and intensity are much higher.

There are also two phases present, i.e., the walking phase and the sitting-standing phase. The time required in the two phases is almost the same, which is about 5.8 mins. But there is a difference in energy expenditure. In the case of the walking phase, the energy expenditure is found to be 25.76 kcal/day in the case of males and 21.76 kcal/day in the case of females. In the case of the sitting-standing phase, the energy expenditure is found to be 33.14 kcal/day, which takes place in just about 6.75 mins which is quite higher than all other activities. The reason behind it is there is a maximum number of repetitions taking place in a very short period, and the load they are carrying is much higher.

It is also found that workers do not have any proper schedule. Sometimes they have to perform their work throughout the day, even during night time, especially for loading.

The table given below shows the time to cut, bundle and load 1 tonne of sugarcane and the corresponding energy expenditure for both male and female workers while performing each of those activities on the basis of Tukdi, Koyta and Single worker.

Table 26 Table for energy expenditure and time required.

	Tukdi			Koyta			Single worker		
	Total Energy expenditure (kcal/tonne)		Time Required (hrs)	Total Energy expenditure (kcal/tonne)		Time Required (hrs)	Total Energy Expenditure (kcal/tonne)		Time Required (hrs)
	Male	Female		Male	Female		Male	Female	
Cutting	129.54	151.24	0.56 (±3.02)	1038.49		4.37 (±0.70)	1813.63	2117.43	8.75 (±0.70)
Bundling	23.22	24.94	0.08 (±0.63)	143.70		0.52 (±0.63)	278.47	299.11	1.05 (±0.63)
Loading (walking phase)	25.76	21.76	0.09 (±0.28)	281.10		1 (±0.28)	532.80	591.60	2 (±0.28)
Loading (sitting-standing phase)	33.14	–	0.11 (±0.35)	–	–	–	–	–	–

The table given above is an overall look of the whole study that has been done. For detailed results and values of Table 26, please do follow Table 12, Table 13, Table 14, Table 15, Table 22, Table 23 and Table 24.

Conclusion

Thus, there is a lot of variation of work in every stage.

To figure out all these difficulties, different aspects of nutritional index, working hours and energy expenditure during these hours of 50 workers (25 male and 25 female) belonging to a particular age group and having at least 3years of working experience, were thoroughly studied. Results of our study on this small group of workers revealed the following result.

1. Hand Grip Strength

Among the total studied population, HGS or Hand Grip Strength was found to be more or less balanced. Data from male group shows that 33% of them lie below the normal range and considered to be Weak and 67% to be Normal, while data from female group indicates 40% to be as Weak and 60% within Normal range (referred to Table 2).

2. Waist Hip Ratio

This is one of the measures of nutritional status of a person. Among the workers, 11% and 89% of male workers are considered to be at Moderate and Low Risk, respectively. On the other hand, 32%, 28%, and 40% of female workers indicate Low, Moderate and High Risk, respectively (referred to Table 3). The overall data shows that the female population is within risk zone.

3. Body Fat Percentage

This parameter gives a direct measure of body fat and idea about fitness. The studied population shows that only 23% of male workers and 24% of female workers have very low body fat percentage, which lies even below the Athletic range, while rest of the population belongs to the Acceptable limit (referred to Table 4).

4. Body Mass Index

Body Mass Index or BMI values is another factor to determine the overall fitness level. In this study, BMI values of the studied population are calculated and the workers are categorized based on the Asian criteria (referred to Table 5). According to these criteria, among the male workers - 34.61% are Underweight, 3.84% are Overweight and 61.55% are within Normal category. Data from female workers shows that, 29.16% of them are Underweight, 8.33% are Overweight and 62.51% are within Normal category.

5. Time Requirement

About 74% of the total time of work is spent in cutting, 9% of the time is spent in bundling and rest of the 17% is spend in loading. As a result, the energy expenditure also shows same variation of percentage while comparing with the four type of working group.

6. Energy Expenditure and Heart Rate

In case of female, the energy expenditure have been found to be slightly higher than that of male. The reason behind it is due to the physiological difference between male and female. In case of male the heart size is comparatively bigger than female, as a result they can do a work with a low heart rate than that of female. But in case of female subject the heart size is small, so they have a greater workload than that of male.

As the energy expenditure has got a linear relationship with that of heart rate, and the regression equation have been derived from heart rate and energy expenditure, whenever there is an increase in heart rate, there is an increase in energy expenditure.

In case of Cutting and Loading the working heart rate and energy expenditure of female workers, were found to be significantly high. But in case of loading there was no significant difference. That is simply due to the increasing work load in a specific amount of time in case of female workers. But during bundling the workload and burden is much less and less strenuous than the other two work types. As a result there is no difference in energy expenditure between male and female workers.

In summary, it is recommended that:

- There should be proper wage fixation for the workers, based on their working time and energy expenditure to perform their respective tasks.
- Necessary inclusion must be made to include the energy expenditure as per actual, for the rest of the day while calculated the whole day energy expenditure during fixation of daily wages.

- From the work safety and occupational safety point of view works must be provided with suitable personal protective equipment and scientifically designed hand tools.
- A suitable small cart may be designed and provided for transporting the sugarcanes for loading purpose in the field.
- There also should be a proper schedule for the workers with scheduled rest pauses, so that the load of the whole work is evenly distributed among the workers and the fatigue is reduced.
- A proper job distribution may be attempted so that the peak loads are shared and no worker has to carry an extra burden or load while performing the job.