EFFECTS OF OIL PALM PLANTATION TASKS ON SKELETAL MUSCLE ACTIVITIES

MUHAMMAD NOR AKMAL BIN NORDIN

UNIVERSITI SAINS MALAYSIA

2022

EFFECTS OF OIL PALM PLANTATION TASKS ON SKELETAL MUSCLE ACTIVITIES

By:

MUHAMMAD NOR AKMAL BIN NORDIN

(Matrix no: 141293)

Supervisor:

Dr. Mohamad Ikhwan Zaini bin Ridzwan

July 2022

This dissertation is submitted to
Universiti Sains Malaysia
As partial fulfilment of the requirement to graduate with honors degree in
BACHELOR OF ENGINEERING (MECHANICAL ENGINEERING)

School of Mechanical Engineering
Engineering Campus
Universiti Sains Malaysia

DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidate for any degree.

Signed………………………………………… (Muhammad Nor Akmal Bin Nordin)

Date……………………………………………………………….... (12/7/2021)

STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by giving explicit references.

Bibliography / references are applied.

Signed…………………………………………... (Muhammad Nor Akmal Bin Nordin)

Date……………………………………………………………….... (12/7/2021)

STATEMENT 2

I hereby give consent for my thesis, if accepted, to be available for photocopying and for interlibrary loan, and for the title and summary to be made available outside organizations.

Signed………………………………………….. (Muhammad Nor Akmal Bin Nordin)

Date……………………………………………………………….... (12/7/2021)

ACKNOWLEDGEMENT

The completion of this project would not have been possible without the help of others. First of all, I would like to extend my sincere thanks to the School of Mechanical Engineering, especially to the Vibration Lab, for providing the equipment and resources needed to complete this Final Year Project (FYP). The opportunity to conduct research allowed me to gain knowledge in using various biomechanical related technologies, which exposed me to new experiences that will be remembered forever.

This is where one of the most important people, where without his enthusiasm and guidance, the success of completing this research is far from possible. Dr Mohamad Ikhwan Zaini Ridzwan, a great supervisor who will always be there whenever I need him and willing to spend his precious time discussing any research related issues. His consistent support and motivation has helped me in conducting research to the best of my ability. I learned a lot from it, not only about research but also the broader scope of biomechanical engineering. I am forever indebted to the knowledge he has given me as well as the life and project advice he has provided to me, and the trust he has given me in planning and deciding for this project.

In addition, I would like to thank my project team, Mohd Nazhan Bin Mohd Shaberi, and Muhammad Adib Haikal Bin Awang Mansor, for their highly motivated attitude, ideas, and support to run some real field trials and tests together. Sincere thanks to Mitchelle Law Jyy Jinn and Nadiah Aqilahwati Binti Abdullah for their guidance and technical advice in using various research -related sensors. Without them, the project would have taken longer to complete. In addition, many thanks are also extended to the coordinator of FYP, Dr. Muhammad Fauzinizam Razali, who has devoted his full energy to structuring this course to help us achieve our targets and give his opinion on the research. My infinite thanks to the assistant engineers, Mr. Baharom Awang, and Mr. Wan Mohd Amri Wan Mamat Ali, who have provided invaluable insights and expertise to complete this research. Finally, I would like to express my appreciation to my family for their continued understanding and moral support even as the Covid-19 pandemic has prevented us from constantly seeing each other throughout this final year's degree.

TABLE OF CONTENTS

ACKNOWLEDGEMENT **3**

TABLE OF CONTENTS .... **v**

LIST OF TABLES .... **vii**

LIST OF FIGURES .... **viii**

LIST OF ABBREVIATIONS .... **xi**

LIST OF APPENDICES .... **xii**

ABSTRAK .... **xiii**

ABSTRACT .... **xiv**

CHAPTER 1 INTRODUCTION **1**

1.1 Brief Overview 1

1.2 Problem Statement 3

1.3 Research Objectives 4

1.4 Scope of Work 5

1.5 The Organization of the Thesis 5

CHAPTER 2 LITERATURE REVIEW **7**

2.1 Musculoskeletal Disorders and Work-Related Musculoskeletal Disorders 7

2.2 Risks of Musculoskeletal Disorders in Harvesting Oil Palm 9

2.3 Risks of Musculoskeletal Disorders in Collecting FFB 11

2.4 Surface Electromyography 13

2.5 Maximum Voluntary Contraction 14

CHAPTER 3 METHODOLOGY **16**

3.1 Introduction 16

3.2 Participants 17

3.3 Field Setup 18

3.3.1 Palm Pruning/Harvesting 18

3.3.2 Collecting FFB. 19
3.4 Placement of Surface Electromyography (EMG) Electrodes 21
3.5 Design of Stimuli 24
3.6 MVC Protocol 25
CHAPTER 4 RESULTS 27
4.1 Introduction 27
4.2 Maximum Voluntary Contraction 27
4.3 Muscle Activation of Pruning Tasks 29
4.3.1 Chisel with Height below 1 meter 29
4.3.2 Chisel with Height between 1 meter to 2 meters 32
4.3.3 Chisel with Height above 2 meters 35
4.3.4 Pruning Using Conventional Sickle 38
4.3.5 Pruning Using Intervention Sickle 42
4.4 Muscle Activation of Collecting FFB Tasks 46
4.4.1 Manual Loading 46
4.4.2 Loading Spike with Wheelbarrow Height 49
4.4.3 Loading Spike with 0.8 meters Height 52
4.4.4 Loading Spike with 1.6 meters Height 55
4.5 Reported Body Pain 58
4.5.1 Pruning Task with Different Height of Oil Palm Tree 58
4.5.2 Pruning Task with Different Types of Sickle Tool 60
CHAPTER 5 CONCLUSION AND FUTURE RECOMMENDATIONS 62
5.1 Conclusion 62
5.2 Recommendations for Future Research 63
REFERENCES 64

APPENDICES

LIST OF TABLES

Page

Table 3.1: Demographic and basic information of the subjects 17

Table 3.2: Label of equipment for pruning task 18

Table 3.3: Label of Experimental Tools 19

Table 3.4: FFB mass recorded for two weeks 20

Table 3.5: Electrodes placement on investigated muscles based on SENIAM 22

Table 3.6: Stimuli for pruning task using Sickle with fronds located higher than 3 meters 24

Table 4.1: MVC value for all subjects during pruning tasks......................................28

Table 4.2: MVC value for all subjects during collecting FFB tasks 28

Table 4.3: p-value between All Selected Muscles during Task 1(a)..........................31

Table 4.4: p-value between All Selected Muscles during Task 1(b)..........................34

Table 4.5: p-value between All Selected Muscles during Task 1(c)..........................37

Table 4.6: p-value between All Selected Muscles during Task 2(a)..........................41

Table 4.7: p-value between All Selected Muscles during Task 2(b)..........................45

Table 4.8: p-value between All Selected Muscles during Manual Loading Task......48

Table 4.9: p-value between All Selected Muscles during Loading Spike with Wheelbarrow Height Task...51

Table 4.10: p-value between All Selected Muscles during Loading Spike with 0.8m Height Task 54

Table 4.11: p-value between All Selected Muscles during Loading Spike with 1.6m Height Task 57

LIST OF FIGURES

Page

Figure 2.1: FFB cutter; (a) stooping during harvesting, (b) oil palm tree canopy layout impacting posture, (c) harvesting task with head tilted forward and both hands above shoulder, (d) balancing and manipulating long sickle to raise pole for harvesting task 10

Figure 2.2: FFB collector; (a) raising FFB with a single hand from the ground to load onto wheelbarrow, (b) lifting FFB with both hands to load into wheelbarrow, (c) lifting FFB with metal pole to load onto wheelbarrow, (d) lifting and transporting FFBs across a distance to where wheelbarrow is left. ...12

Figure 2.3: FFB collector; (a) and (b) sweeping loose fruit scattered on the ground while stooping, (c) pushing completely loaded wheelbarrow with back bent forward, (d) emptying wheelbarrow at truck collection path point....12

Figure 3.1: Arrangement of equipment for pruning task..18

Figure 3.2: Arrangements of experimental tools...19

Figure 3.3: The FFBs used to be lifted by the subjects 20

Figure 3.4: (a) i. Acromion, ii. Middle Deltoid, iii. Olecranon. (b) i. Biceps Brachii. (c) i. Upper 23

Figure 3.5: MVC exercise for (a) RB, (b) LB, (c) RMD, (d) LMD, (e) UT, (f) MT, (g) ES and (h) RF...26

Figure 4.1: Muscle Activation for All Subjects during Pruning Task (Below 1 Meter Height)...29

Figure 4.2: Average %MVC for All Subjects on Right Biceps during Task 1a 30

Figure 4.3: Extreme work posture during Task 1a 31

Figure 4.4: Muscle Activation for All Subjects during Pruning Task (Between 1 Meter and 2 Meters Height)..32

Figure 4.5: Average %MVC for All Subjects on Left Middle Deltoid during Pruning Task 33

Figure 4.6: Extreme work posture during Task 1b..34

Figure 4.7: Muscle Activation for All Subjects during Pruning Task (Above 2 Meters Height)..35

Figure 4.8: Average %MVC for All Subjects on Left Biceps during Pruning Task..36

Figure 4.9: Extreme work posture during Task 1c..37

Figure 4.10: Muscle Activation for All Subjects during Pruning Task (Using Conventional Sickle)..38

Figure 4.11: Average %MVC for All Subjects on Right Biceps during Pruning Task39

Figure 4.12: Extreme work posture during Task 2a..40

Figure 4.13: Muscle Activation for All Subjects during Pruning Task (Using Intervention Sickle)..42

Figure 4.14: Average %MVC for All Subjects on Right Middle Deltoid during Pruning Task 43

Figure 4.15: Extreme work posture during Task 2b..44

Figure 4.16: Boxplot of muscle activation for all subjects during collecting FFB task (manual loading)..46

Figure 4.17: Average %MVC for All Subjects on Middle Trapezius during Manual Loading task 47

Figure 4.18: Extreme work posture during Manual Loading task 47

Figure 4.19: Boxplot of muscle activation for all subjects during collecting FFB task (loading spike with wheelbarrow height)..49

Figure 4.20: Average %MVC for All Subjects on Erector Spinae during Loading Spike with Wheelbarrow Height Task 50

Figure 4.21: Extreme work posture during Loading Spike with Wheelbarrow Height task 50

Figure 4.22: Boxplot of muscle activation for all subjects during collecting FFB task (loading spike with 0.8m height)...52

Figure 4.23: Average %MVC for All Subjects on Erector Spinae during Loading Spike with 0.8m Height Task 53

Figure 4.24: Extreme work posture during Loading Spike with 0.8m Height task ...53

Figure 4.25: Boxplot of muscle activation for all subjects during collecting FFB task (loading spike with 1.6m height)...55

Figure 4.26: Average %MVC for All Subjects on Upper Trapezius during Loading Spike with 1.6m Height Task 56

Figure 4.27: Extreme work posture during Loading Spike with 1.6m Height task ...56

Figure 4.28: Average Pain Score from all Subject during Pruning by using chisel in different height 58

Figure 4.29: Average % MVC from all Subject during Pruning by using chisel in different height 59

Figure 4.30: Average Pain Score from all Subject during Pruning by using different types of sickle 60

Figure 4.31: Average % MVC from all Subject during Pruning by using different types of sickle 61

LIST OF ABBREVIATIONS

3D	3-Dimensional
EMG	Electromyography
FFBs	Fresh Fruit Bunches
GRF	Ground Reaction Force
IMU	Inertial Measurement Units
MSDs	Musculoskeletal Disorders
MVC	Maximum Voluntary Contraction
MTw	Motion Tracker
NIOSH	National Institute for Health and Safety
REBA	Rapid Entire Body Assessment
RULA	Rapid Upper Limb Assessment
OWAS	Ovako Working Posture Analysis System
sEMG	Surface Electromyography
SENIAM	Surface Electromyography for the Non-Invasive Assessment of Muscles
WHO	World Health Organization
WMSDs	Work-related Musculoskeletal Disorders

LIST OF APPENDICES

Appendix A	
Appendix B	
Appendix C	

KESAN TUGASAN PENANAMAN KELAPA SAWIT TERHADAP AKTIVITI OTOT RANGKA.

ABSTRAK

Tujuan kajian ini adalah untuk melihat dan membentangkan risiko gangguan muskuloskeletal yang berkaitan dengan pekerjaan (WMSDs) dalam aktiviti mengumpul dan juga aktiviti pemangkasan pelepah kelapa sawit. Lapan orang subjek dengan pengalaman yang berbeza dalam mengumpul dan pemangkasan sawit telah direkrut untuk melakukan tugasan ini dengan alatan yang berbeza seperti pahat, sabit serta alatan tradisional untuk mengangkat buah sawit. Eksperimen dijalankan dalam pelbagai jenis teknik iaitu memuatkan buah sawit dengan menggunakan cara manual dimana ia terbahagi kepada dua kategori iaitu badan berpintas dan badan bengkok ke hadapan. Alat tradisional digunakan untuk menilai pengaktifan otot badan dalam aktiviti memuatkan pada ketinggian yang berbeza. Tugas memangkas pelepah kelapa sawit pada tiga ketinggian berbeza dan juga memangkas pelepah kelapa sawit dengan menggunakan dua alatan berbeza. Dalam menganalisis gerakan subjek, Unit Pengukuran Inersia (IMU) daripada Xsens digunakan. Sensor elektromiografi (EMG) daripada iMotions digunakan untuk menganalisis pengaktifan otot bahagian atas badan. Elektrod EMG dalam susunan bipolar dipasang pada lapan otot badan (trapezius atas, trapezius tengah, bisep brachii kiri dan kanan, deltoid tengah kiri dan kanan, ereksi spinae longissimus dan rektus femoris). Setiap subjek mengalami kesakitan di sesetengah bahagian badan yang disiasat. Penambahbaikan dalam persekitaran kerja diperlukan untuk mengurangkan risiko WMSDs dan keletihan di kalangan pemotong sawit. Kajian lanjut dengan lebih ramai pekerja di ladang kelapa sawit disyorkan untuk pengukuran kesan yang lebih baik dalam menerangkan pendedahan kepada WMSDs dan penggunaan otot.

EFFECTS OF OIL PALM PLANTATION TASKS ON SKELETAL MUSCLE ACTIVITIES

ABSTRACT

The purpose of this study was to look at and present the risk of work-related musculoskeletal disorders (WMSDs) in collecting activities as well as oil palm fronds pruning activities. Eight subjects with different experience in collecting and pruning oil palm were recruited to perform this task with different tools such as chisels, sickles as well as traditional tools for lifting palm fruit. Experiments were conducted in various types of techniques, namely loading the oil palm fruit by using manual methods where it is divided into two categories, namely the body is twisted and the body is bent forward. Traditional tools were used to assess body muscle activation in loading activities at different heights, the task of pruning palm fronds at three different heights and also pruning palm fronds using two different tools. In analyzing the subject's motion, the inertial measurement units (IMU) from Xsens was used. Electromyography (EMG) sensors from iMotions were used to analyze upper body muscle activation. EMG electrodes in the bipolar arrangement were installed on eight body muscles (upper trapezius, middle trapezius, left and right biceps brachii, left and right middle deltoids, erector spinae longissimus and rectus femoris). Each subject experienced pain in certain parts of the body investigated. Improvements in the work environment are needed to reduce the risk of WMSD and fatigue among oil palm workers. Further studies with more workers in oil palm plantations are recommended for better effect measurement in explaining exposure to WMSD and muscle utilization.

CHAPTER 1

INTRODUCTION

1.1 Brief Overview

The agriculture sector, particularly the oil palm industry, is critical to the success of developing countries like Malaysia. As a result, increasing agricultural productivity in the oil palm sector is critical for economic growth and development. Oil palm has the potential to be one of the greatest solutions for meeting rising food and energy demands. The fresh fruit bunch (FFB) harvesting procedure must be effective and beneficial in order to develop the oil palm source. However, many FFB harvesters suffer from work-related musculoskeletal disorders (WMSDs), which can lead to a loss of productivity. In the realm of worker health, WMSDs are one of the most commonly addressed topics. FFB harvesters experience weariness and discomfort in their body parts during the oil palm harvesting process, which includes swelling, joint pain, and tingling. Designers want extensive data in order to create systems that can prevent WMSDs while having no negative influence on quality or productivity. Furthermore, even when machines are used during the FFB harvesting process, FFB harvesters still encounter WMSDs difficulties. Walking, standing, and bending are unavoidable labour factors that have a negative impact on the FFB harvester's health. Despite the development of various automated harvesting instruments, manual harvesting techniques are still frequently employed to collect oil palm FFB due to their cost effectiveness.

During the FFB harvesting operation, oil palm harvesters often employ a pole, chisel, and loading spike. The human body is required to use manual equipment in the FFB harvesting process, which often entails lifting, manipulating, placing, pushing, tugging, carrying, and moving the fresh fruit bunch (FFB). The FFB harvester's body is subjected to possible ergonomic dangers such as physical stress and mental weariness when these labour elements are repeated over lengthy periods of time. Face-to-face interviews were conducted with Thai oil palm harvesting workers in Krabi Province, Thailand, using a questionnaire, to evaluate the prevalence of musculoskeletal disorders (MSDs) and risk factors related with MSDs. The questionnaire was divided into four sections, each of which contained data on demographics, work-related variables, job stress, and MSDs. The current study included a total of 334 oil palm harvesting workers. MSDs were found to be prevalent in 88.0 % of people in the previous year. Lower back MSDs were the most common (59.0 %) among oil palm harvesting workers over a 12-month period, followed by shoulder (37.1 %) and neck (27.2 %) [1]. The type of task, heavy lifting, and job stress were all linked to lower back MSDs. Furthermore, shoulder and neck MSDs were linked to work type, repetitive movement, and job stress. The cutters were at a higher risk of shoulder and neck MSDs, given the fact that their job required them to cut FFB from high up in the trees. Due to the rigorous lifting, the collectors had greater back problems. As a result, utilizing Rapid Upper Limb Assessment (RULA), this research focuses on determining which area of the human body experiences stress and difficult postures. Researchers have employed a variety of ways to analyze how the design of oil palm harvesting tools leads to muscular fatigue and WMSDs. Rapid Upper Limb Analysis (RULA), Rapid Entire Body Analysis (REBA), Electromyography (EMG), and software simulation were among the tests used. Depending on the desired objective and the working conditions, multiple ways may be used.

In order to estimate the WMSDs, RULA employs body posture targeting. The FFB harvesters' posture is assessed using the RULA method in a systematic and rapid manner. The RULA assessment is critical for identifying the damaged area and demonstrating that the improvement reduces the risk of injury. A worker's body posture is examined and assessed by segments in the RULA method. Green (scoring 1–2) indicates no risk, yellow (score 3–4) indicates low risk, orange (score 5–6) indicates medium risk, and red (score 7 +) indicates high risk.

The Rapid Entire Body Assessment (REBA) is an upgraded version of RULA that uses body posture targeting to estimate WMSDs. With the addition of a complete body evaluation, the features are similar to RULA. A camera was used to capture the harvesters' working postures during the FFB harvesting procedure. The task was used to analyse REBA scores and posture. A harvester must use a lot of force to push and pull to cut the oil palm fruit bunches when using a tool during the harvesting process. As a result, the harvester was more likely to suffer from WMSDs.

Electromyography (EMG) is a signal-based method for determining muscle load. The EMG signal is an electrical output of neuromuscular activation that is triggered by muscle contraction. The signal is a current created by ionic flow across the membrane of the muscle fibres. The signal travels through intervening tissue to an electrode's detecting surface on the skin. Different genders have different effects on EMG signals, with females having higher muscular activity than males and being more susceptible to muscle exhaustion. In a recurrent light assembly work, Dawal and Santy (2010) investigated the time to fatigue for upper body muscles dependent on gender. To calculate the percentage of muscular activity while working, the EMG signal is rectified to root mean square (RMS) and normalised to maximum voluntary contraction (MVC).

1.2 Problem Statement

In this study, many oil palm workers faced many health hazards and musculoskeletal problems. This is because many oil palm workers are exposed to hazardous outdoor manual occupations, work-related musculoskeletal disorders (WMSDs), and injuries. Besides that, most of them prefer to use manual tools like chisel and sickle for pruning oil palm fronds and harvesting fresh fruit bunches (FFB). Muscle activation patterns and postural angles of subjects performing collecting and pruning activities were measured and analysed in this study using iMotions surface electromyography and Inertial Motion Unit from Xsens Awinda for direct measurement of biomechanical loads. So, in this study, we will evaluate the risk of WMSDs and quantify the activation muscles when the subject performs the collecting of FFB task and also the pruning and harvesting task.

1.3 Research Objectives

The main objectives of this study were to:

1. Identify the awkward posture at work while performing activities at an oil palm plantation.
2. Analyse muscle electromyography (EMG) patterns during pruning/harvesting using sickle and chisel, and correlate the results with the pain scores perceived by the worker.

1.4 Scope of Work

First, in this study, experimental work will be done where 8 subjects will be recruited to do the task of pruning/harvesting and collecting fresh fruit bunches (FFB). The subject’s body will be fitted with an EMG sensor as well as an Xsens sensor. During the experiment, bipolar iMotions EMG electrodes were mounted on the subjects' muscles to measure their activation patterns and determine the intensity of muscular activity. For the collecting FFB and pruning tasks, the muscles investigated were the biceps brachii, middle deltoid, middle trapezius, upper trapezius, erector spinae, and rectus femoris. The results of muscle contraction while performing pruning/harvesting and collecting (FFB) tasks can be obtained through iMotion software.

1.5 The Organization of the Thesis

Introduction, literature review, methods, results and discussion, and conclusions are the five chapters of the thesis. The first chapter opens with a summary of oil palm plantation employment, WMSD in FFB collection, and oil palm harvesting, as well as the limits of current methods for determining them. The research's objectives and scope are then highlighted. The importance of the study is discussed at the end of this chapter.

The ideas, facts, and information relevant to this study are discussed in Chapter 2. The human musculoskeletal system, the mechanism of muscle contraction, human movement measurement, risk of WMSD in palm collection and harvesting, ergonomic assessment tools, principles of surface electromyography, maximum voluntary contraction, and detection in dynamic contraction are all covered in this chapter. Facts and findings from past studies are addressed in each subsection.

The methods employed in this study is described in full in Chapter 3. The subject entrance requirements and the method for selecting the investigated muscles are highlighted in the first subsection. Equipment organisation and cutting tool preparation are covered in field preparation. The third paragraph provides a quick overview of the motion capture features of Xsens and iMotions sEMG, including positioning, setup, and calibration. The maximum voluntary contraction (MVC) procedure for EMG, the research protocol including precautions, and the employee's subjective assessment of pain were all explained during data collection. In the fifth subsection, methods for analysing data from all trials and signal processing for all sensors are outlined in order to achieve the study's objectives. Finally, descriptive and inferential statistics are provided for statistical analysis.

The outcomes of the study's objectives are presented and discussed in Chapter 4. At the beginning of this section, the muscular activation and ergonomic risk score are presented. The chapter continues with an examination of all subjects' muscle activation patterns and muscular exhaustion. The effect of collecting FFB and pruning activities on the risk of WMSDs, including muscle effort and the trend of muscle tiredness in all activities, is discussed at the end of this chapter. The findings' conclusion is presented in Chapter 5. The chapter concludes with several recommendations and ideas for future research to improve the proposed technique's quality

CHAPTER 2

LITERATURE REVIEW

This chapter analyses the available literature, which focuses on the study's overview and fundamental principles. It starts by looking at the prevalence of musculoskeletal disorders (MSD) and work-related musculoskeletal disorders (WMSD) in different industries. The topic then shifts to the risks of WMSD during oil palm collecting, harvesting and pruning. It went on to apply design technologies to identify human movement and ergonomic assessment tools to figure out how often MSD is in certain difficult postures. A summary of surface electromyography and maximum voluntary contraction is also provided. This chapter finishes with such a review of the review literature.

2.1 Musculoskeletal Disorders and Work-Related Musculoskeletal Disorders

Work-related musculoskeletal disorders (WMSDs) are a group of diseases that affect muscles, nerves, tendons, ligaments, joints, synovial sacs, cartilage, fascia, and spinal discs, and are caused or exacerbated by poor working conditions or work practises [12, 46, 50]. WMSD is one of the most common disorders impacting employee occupational health, and it frequently causes a decrease in job performance and quality [3, 9, 33]. As a result, WMSD has a detrimental influence on organisational performance, leading to higher health-care expenses and post-retirement illness. Diseases of the musculoskeletal system accounted for 20% of sick pay and disability retirement grants in Brazil between 2012 and 2016. In this regard, it is critical to comprehend the potential risk factors for the onset of this condition in various professional categories in order to build strategic actions and prevent musculoskeletal problems [16]. WMSD has a complicated history since it is the result of direct and indirect actions from a variety of sources, including individual, biomechanical, psychological, and occupational factors [27, 33]. The majority of WMSD research has focused on the lumbar and upper limb regions, but the lower limbs can also be impacted. Previous research on healthcare professionals [3, 4, 31], industrial workers [56, 58], teachers [12, 59], and the general population [25] has shown that WMSD is common in the lower limbs. Age, gender, and body mass index (BMI) have all been linked to symptoms affecting the knees, legs, ankles, and feet [55, 58]. Similarly, occupational factors have been linked to WMSD symptoms in the thighs, legs [56], and knees [6]. Importantly, biomechanical risks like repetitive movement, heavy load handling, and work pose have been related to symptoms in the lower limbs [18, 33, 43, 58], particularly in the thighs, knees, leg, ankle, and foot areas [23]. Furthermore, the amount of research on the role of work-related psychological factors on musculoskeletal illnesses has risen significantly. The presence of symptoms in the thighs [50], knees [2], foot [44], and ankle/foot area has been observed to be influenced by factors such as social support, work satisfaction, high perception of physical and psychological needs, and low job control, among others [9, 58]. High physical and psychological demands, as well as a lack of job control, may contribute to the development of symptoms, whereas social support and job satisfaction may contribute to the absence of WMSD symptoms.

2.2 Risks of Musculoskeletal Disorders in Harvesting Oil Palm

The harvesting steps can be classified according on the tools applied at each stage. A chisel linked to a hollow metal pole (generally galvanised iron—GI) is used to harvest the FFB in the early stages of harvesting, typically during the first three years of hand harvesting (young palm trees between 34 and 67 years old). The chisel produced from GI is predicted to weigh between 2 and 3 kg, depending on the length of the pole, which is decided by personal desire. A chisel or sickle is used for two main tasks: cutting the mature oil palm fruit and pruning (Figure 2.1). The FFBs are separated from the oil palm tree by removing the exposed bunch stem, and the oil palm frond at the base of the stem is pruned. However, the height of the FFB limits the usage of a chisel; normally, it is utilised at a height of 0.5 to 3 metres above ground (Figure 2.1a, 2.1b). When a mature FFB is identified early in the harvesting process, an FFB cutter reaches the tree containing the mature oil palm fruit. They create a firm foothold and shift their body into a favourable position by aligning their body in a horizontal orientation with the stem of the mature FFB while seeking for a strategic place based on the fruit's stem. Then, by continually applying push and pull forces, cuts are generated. The height where the FFBs are positioned rises in lockstep with the height of the oil palm trees. The palm tree's fruits are around 3 metres above the ground at 6 years old. Currently, the FFB cutter employs either a chisel or a sickle, rotating between the two based on which is more convenient for the task. The FFB cutter will use a sickle on trees older than 7 years. They typically tilt their heads forward when they reach this age to seek fresh fruits. At 25 years old, oil palm trees can reach a height of 20 metres. The height of the fruits rises in lockstep with the height of the trees. When a result, the FFB cutter must keep their head tilted upward as they cut the stems of FFBs on the trees, even during pruning (Figure 2.1c). With the growth in tree height, the sickle's length must be increased in order to reach the fruit stalks and tree fronds. As a result, the length will be increased by physically tying more poles together (Figure 2.1d).

Figure 2.1: FFB cutter; (a) stooping during harvesting, (b) oil palm tree canopy layout impacting posture, (c) harvesting task with head tilted forward and both hands above shoulder, (d) balancing and manipulating long sickle to raise pole for harvesting task

Oil palm harvesters are exposed to several ergonomic risk factors for acquiring MSDs, according to the activity breakdown study. Stooping appears to be the most important posture for FFB cutters during the early stages of harvesting (Figure 2.1). Furthermore, as the hand was strongly pushing-pulling/swinging the chisel outside then across the body midline, the trunk and neck were observed to be slightly twisted and bent forward during cutting. The harvester's height, the position of the FFBs on the palm trees, and the work environment all influence the degree of trunk flexion [32]. The fronds of immature oil palm plants branch out in a canopy structure in terms of working environment (Figure 2.1). Harvesters avoid the pointed and sharp leaves of the palms, which could cause cut-type damage to the skin, which encourages more bending. In an attempt to cut an FFB, the author (who had no prior expertise) discovered that the energy required is intensive, counter to the visual perception (in Figure 2.1). Furthermore, in addition to physical strength, accuracy and stability of the chisel, which are developed through experience, are required to conduct a good cut of the FFB stem at the base of the oil palm trunk. FFB cutters must tilt their heads upwards when the oil palm trees reach a specific height, which correlates to their age. FFB cutters must detect mature FFBs before removing them from the trees, as required by the task. FFB cutters will next balance the sickle and raise it to the proper height to cut the FFB stem with their arm extending forward and over their head (Figure 2.1c). FFB cutter will have to tilt his head upwards to the duration of the workday in order to meet both work criteria.

2.3 Risks of Musculoskeletal Disorders in Collecting FFB

An FFB collector, on the other hand, will pierce the disconnected FFB on the ground with a hook or metal pole and load them into a wheelbarrow (Figure 2.2). Following that, the FFB collector will sweep up a loose fruits just on ground (Figure 2.3a, 2.3b). The FFB, on the other hand, will have to be carried a longer distance if the wheelbarrow is left far away from the fruit to be picked. The FFB collector will move the wheelbarrow to the side of the entrance truck route and unload it when it is full (Figure 2.3c, 2.3d). Following that, loaders, who are frequently also truck drivers, will stop at every collection station along the main road to load all of the fruits, even loose fruits, for delivery to the oil palm factory.

Figure 2.2: FFB collector; (a) raising FFB with a single hand from the ground to load onto wheelbarrow, (b) lifting FFB with both hands to load into wheelbarrow, (c) lifting FFB with metal pole to load onto wheelbarrow, (d) lifting and transporting FFBs across a distance to where wheelbarrow is left.

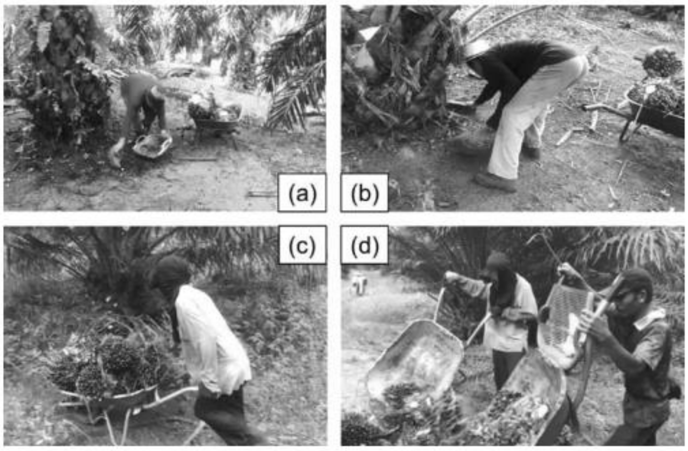


Figure 2.3: FFB collector; (a) and (b) sweeping loose fruit scattered on the ground while stooping, (c) pushing completely loaded wheelbarrow with back bent forward, (d) emptying wheelbarrow at truck collection path point.

In the same way, collecting FFBs is a time-consuming operation. An FFB can weigh up to 5 kg in the early stages of harvest. However, as the trees mature, the size and weight of FFBs become larger and heavier, with FFBs from oil palm trees over 15 years old weighing up to 50 kg [42]. The repeated vigorous manual collections of the FFBs are normally carried out alone, regardless of size and weight. As shown in Figure 2.2, raising and loading FFBs as from ground with either a hook or a metal pole often requires the FFB collector to bend forward as well as twist during the lifting process (Figure 2.2a, 2.2c). When lifting bigger FFBs and maintaining the position while loading FFBs into wheelbarrow, the posture becomes harsher to avoid any collision that could perhaps detach or scatter loose fruit, as well as affect the quality of the fruit. The collecting of scattered loose fruits, on the other hand, was done manually by sweeping beyond a large area. As the FFB collectors extends their arms and hands to sweep fruits that are spread beyond the area within arm's length reach area, this task indirectly causes a stooping posture as well as overreaching. Despite the fact that this activity is completed in a short amount of time, it is performed on a daily basis with a high frequency.

2.4 Surface Electromyography

The ability to record biological signals is a key to knowing how the body behaves in normal and sick settings. The variation in electrical potential between the two appropriate spots on the body's surface, for example, might be used to study the heart's rhythmical activity. Similarly, specialised equipment can be used to measure body temperature and metabolism. These biological signals must be properly treated once they have been gathered in order to reveal useful information. The conditioning, collection, and processing of biological signals have been condensed into widely used measuring techniques [1, 39, 49].

In sports science and rehabilitative medicine, the ability to analyse the activation of muscle tissue by recording electrical potentials generated during muscular contractions (the electromyography [EMG]) is particularly useful. Professional skaters, for example, accomplish graceful spins and jumps by giving appropriate orders to skeletal muscle groups. Rowers, on the other hand, use their skeletal muscles to produce explosive leg flexion that are followed by a hard oar pull. The EMG provides a window into the regulation of the stresses exerted over the body joints by scaling the intensity and velocity of muscle contraction [20, 21, 39].

Electromyography is a method for detecting and analysing EMGs [5]. It is feasible to analyse how controlling commands produced by rowers or figure skaters translate into muscle activation using electrodes put on the skin's surface or introduced into muscle tissue [51, 52]. Surface electrodes have become increasingly widely used in clinical and biological applications for obvious reasons. The analysis of surface EMGs, on the other hand, requires caution. "EMG is too easy to utilise and, as a result, too easy to abuse," De Luca [15] sensibly stated.

2.5 Maximum Voluntary Contraction

The technique of electromyography (EMG) is used to measure muscle activation. The amplitude of EMG signals is regulated by a variety of causes, is extremely variable among individuals, and requires normalising for comparisons between subjects or groups [13]. Peak activity during one dynamic work [54], maximum voluntary contraction (MVC), and artificial stimulation (e.g. M-wave) have all been considered as normalisation factors [8, 13]. Although all of these tactics have been used to standardise inter-subject and intra-session variation for comparison [8, 13, 54], there is no consensus on which methodology is best, and the best strategy is likely context dependant.

The MVC or the peak EMG during a task giving the maximum theoretical intensity of activation during a muscle contraction. It is frequently used to normalise EMG signals, although there are a number of issues with this approach. Normalizing to an MVC is a typical practise in healthy people, but it may have drawbacks or be impossible in injured people. In the early stages of recovery, maximum contraction of a muscles may not even be safe in some pathological circumstances. A failure to fully activate the muscle, referring to as an activation deficiency, was already found to interfere with gaining an accurate picture of the muscle recruitment capability, in terms of safety concerns [10, 35, 40]. This raises concerns that disparities in activation deficit may distort the interpretation of data when comparing normalised EMG signal among limbs or even to a treatment group when comparing normalised EMG signal.

Peak MVC also represents the maximal amplitude of electrical impulses inside a muscle from a conceptual approach. It's not uncommon for the muscular activity recorded during the kinetic task to exceed that of the peak MVC when utilising it to normalise a ballistic contraction [54]. This makes evaluating this data from a physiological viewpoint be difficult.

CHAPTER 3

METHODOLOGY

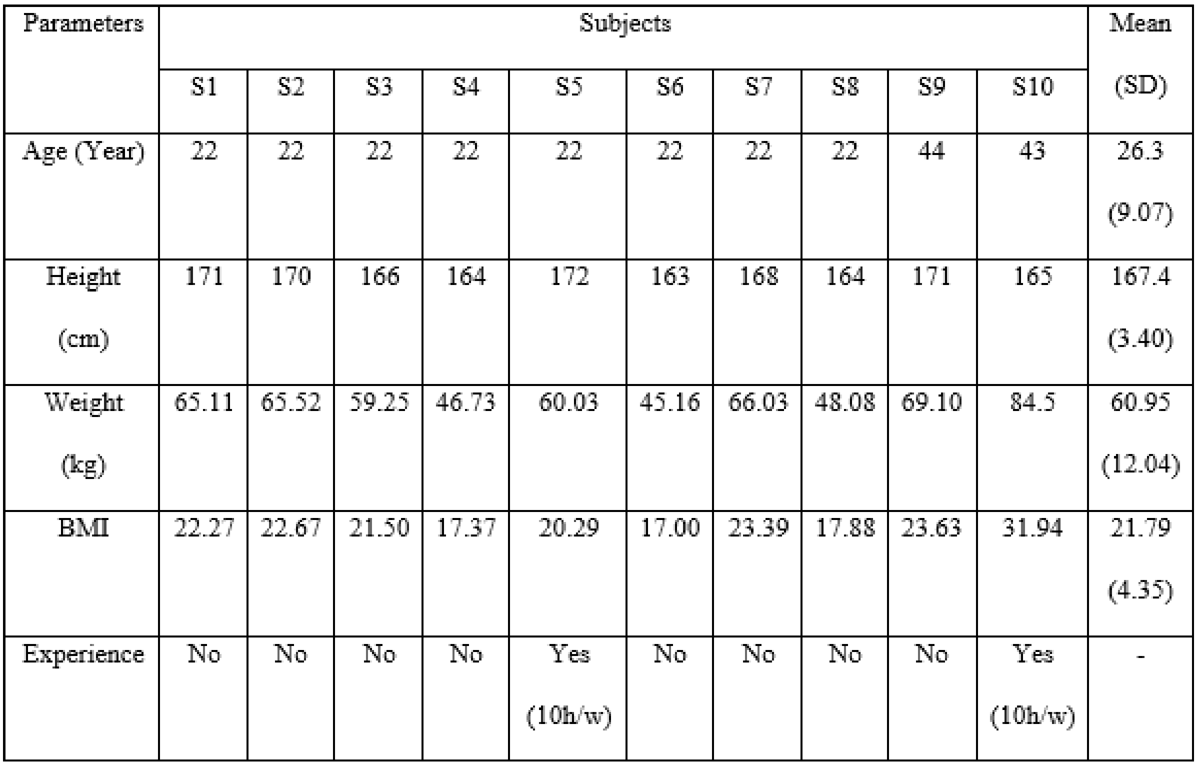
3.1 Introduction

To achieve the study objective, this study merges quantitative and qualitative assessment with direct and indirect measurements. The study started with subject selection, loading spike, cutting instruments, and field preparation, and then moved on to electromyography preparation for biomechanical assessment during FFB collection and palm pruning. This chapter explains in detail all of the gear and software used across the research. The MVC protocol, collecting FFB and palm trimming techniques, and an ergonomic evaluation process were all used to collect data. Following that, signal processing and data analysis are performed, followed by statistical analysis.

3.2 Participants

For this study, eight healthy male subjects (S1 - S8) were recruited and combined with data from previous FYP (S9 & S10). They all meet all of the admission requirements. Two person with experience collecting oil palm fruit, palm pruning and harvesting. But, eight others with knowledge but no experience collecting oil palm fruit, palm pruning and harvesting were involved in this study. There were no severe health or surgical issues, and all components of the study protocol were agreed upon and followed. Table 3.1 displays demographic and subject-based data.

Table 3.1: Demographic and basic information of the subjects



Parameters	Subjects										Mean (SD)
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	
Age (Year)	22	22	22	22	22	22	22	22	44	43	26.3 (9.07)
Height (cm)	171	170	166	164	172	163	168	164	171	165	167.4 (3.40)
Weight (kg)	65.11	65.52	59.25	46.73	60.03	45.16	66.03	48.08	69.10	84.5	60.95 (12.04)
BMI	22.27	22.67	21.50	17.37	20.29	17.00	23.39	17.88	23.63	31.94	21.79 (4.35)
Experience	No	No	No	No	Yes (10h/w)	No	No	No	No	Yes (10h/w)	-

3.3 Field Setup

3.3.1 Palm Pruning/Harvesting

The experiment was carried in a real oil palm harvesting and pruning environment, with equipment placed around selected oil palm trees. The oil palm tree was chosen because it is close to the source of electricity, which benefits in the usage of our electronic equipment, and it is located near the School of Chemical Engineering, Universiti Sains Malaysia (USM). Furthermore, the area surrounding the chosen oil palm trees has a flat soil topography and adequate soil moisture for this experiment. Figure 3.1 gives a visual representation of the experiment's fields.

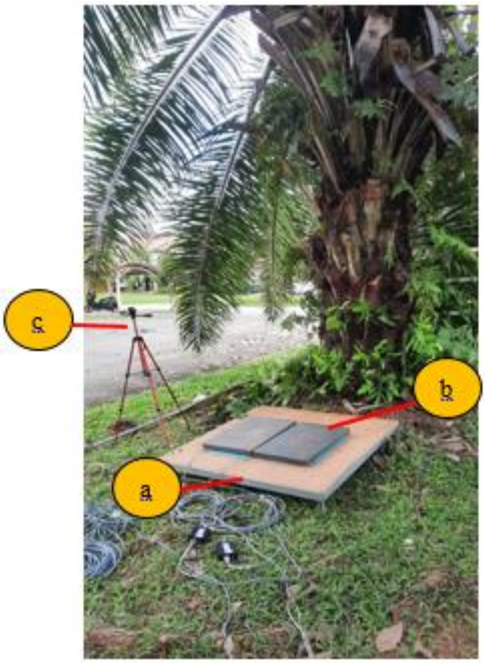


Figure 3.1: Arrangement of equipment for pruning task

Label	Item
a	Platform
b	Force Plate
c	Environmental Camera

Table 3.2: Label of equipment for pruning task

3.3.2 Collecting FFB.

Experiments to collect FFBs were carried out in a vibration laboratory. Because this experiment did not require oil palm trees, but only the fruit, this location was chosen. Furthermore, the vibration lab provides a climate-controlled environment where these studies may be carried out regardless of the weather. Figure 3.2 and Table 3.3 illustrates the locations and labels of the equipment, cameras, and laptops involved in this experiment.

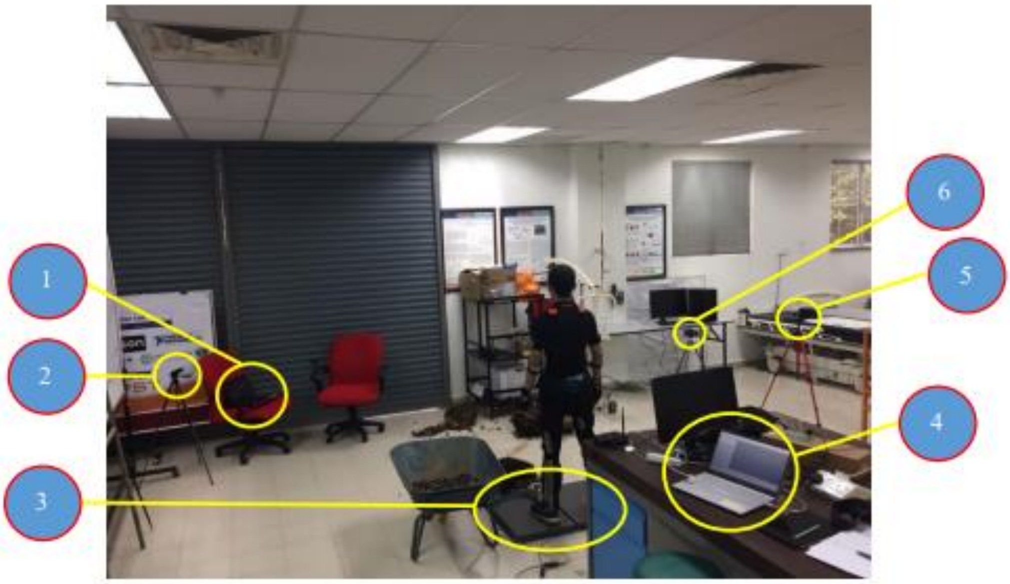
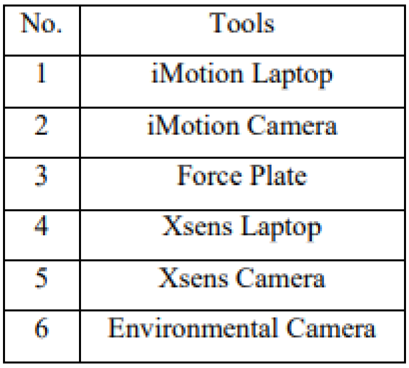


Figure 3.2: Arrangements of experimental tools

Table 3.3: Label of Experimental Tools



No.	Tools
1	iMotion Laptop
2	iMotion Camera
3	Force Plate
4	Xsens Laptop
5	Xsens Camera
6	Environmental Camera

Each person's technique for loading FFB differs according on the situation and setting. Several strategies were examined in this study, including manual loading procedures and three loading techniques that used common instruments (loading spikes). Therefore, five FFBs extracted from the some tree which all have different masses were selected for use in this experiment.

The experiment lasted for two weeks and this situation caused some changes in the mass of FFB used. Table 3.4 shows the change in FFB mass during the two weeks.

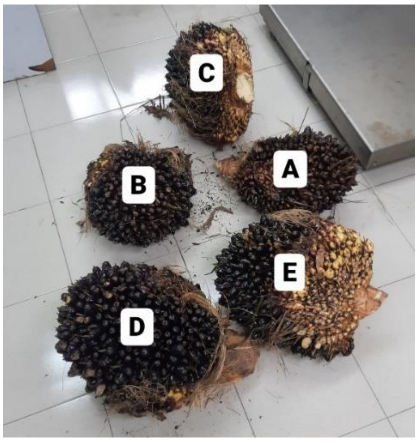
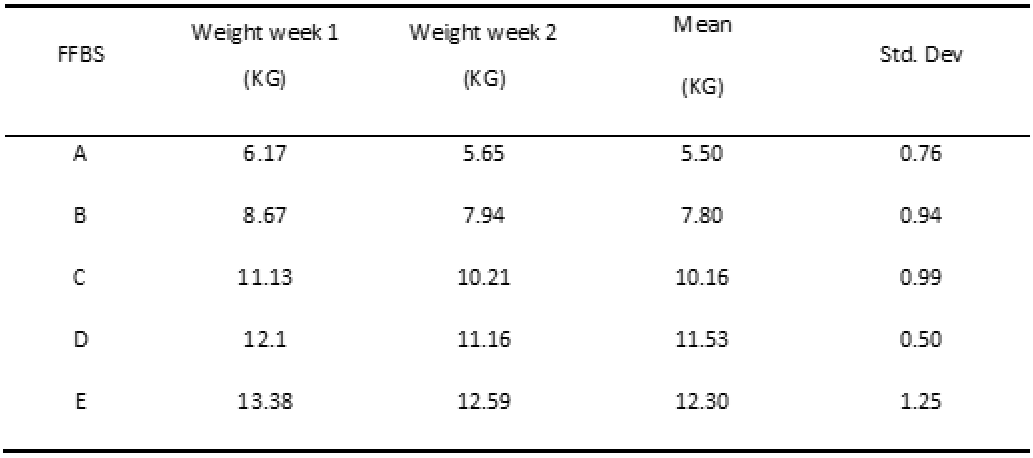


Figure 3.3: The FFBs used to be lifted by the subjects

Table 3.4: FFB mass recorded for two weeks



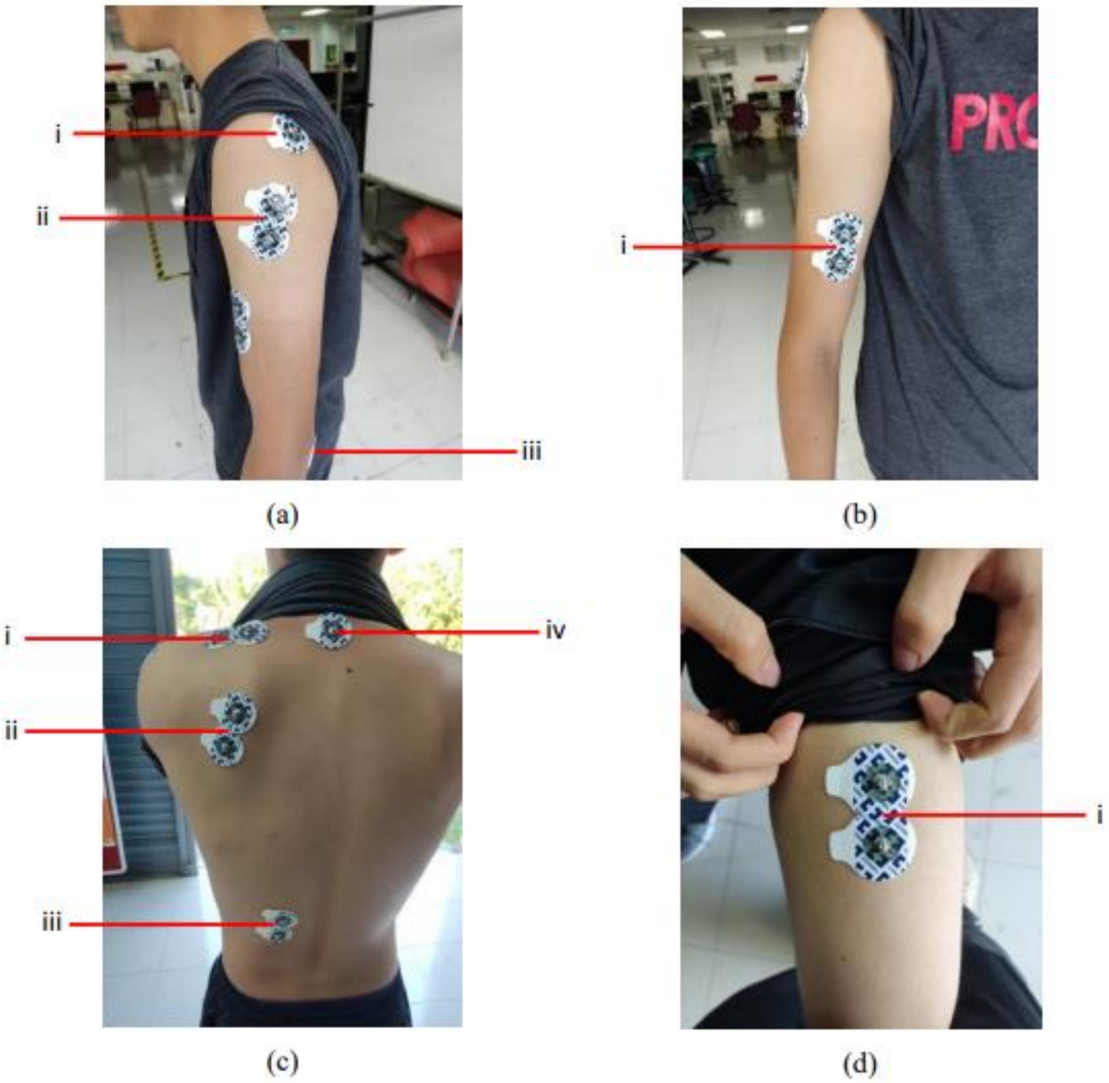
FFBS	Weight week 1 (KG)	Weight week 2 (KG)	Mean (KG)	Std. Dev
A	6.17	5.65	5.50	0.76
B	8.67	7.94	7.80	0.94
C	11.13	10.21	10.16	0.99
D	12.1	11.16	11.53	0.50
E	13.38	12.59	12.30	1.25

3.4 Placement of Surface Electromyography (EMG) Electrodes

The 1024 Hz sampling frequency electrodes placed bilaterally over the muscles on the myofibril with an electrode spacing distance of 20 mm, and away from other muscle groupings, as recommended by Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) [22] for muscle action detection in this study. On the body part, there are twenty electrodes, four of which are reference electrodes. Sixteen of them are located in the biceps brachii (RB and LB), right and left middle deltoid (RMD and LMD), upper trapezius (UT), middle trapezius (MT), erector spinae (ES), and rectus femoris (RF) muscles. Meanwhile, the left and right olecranon (O), acromion (A), and C7 vertebrae serve as reference electrodes. The biceps brachii muscle has been one of the key arm muscles that can function on both the shoulder and elbow joints, which is why it is involved in certain arm actions like pruning/harvesting and lifting the FFB [28]. The brachii biceps muscle is one of the major arm muscles that can function on both the shoulder and elbow joints, which is why it contributes in some arm movements [28] whereas the deltoid muscle can extend and externally rotate the arm [47] during pruning/harvesting and lifting the FFB. Because they are heavily engaged in shoulder girdle movement [36], the upper and middle trapezius were chosen for electrode placement. The erector spinae are responsible for moving the vertebral column. During the experiment, they also assist in maintaining posture by stabilising the spine on the pelvis [26]. One of four quadriceps muscles is the rectus femoris. It is the major muscle that can flex the hip and is responsible for knee extension and thigh flexion [48].

Table 3.5: Electrodes placement on investigated muscles based on SENIAM

Muscle	**Bipolar Electrode**	**Reference Electrode**
Biceps Brachii	Electrodes need to be placed on the line between the medial acromion and the fossa cubit at 1/3 from the fossa cubit.	Olecranon
Middle Deltoid	Electrodes need to be placed from the acromion to the lateral epicondyle of the elbow. This should correspond to the greatest bulge of the muscle.	Olecranon
Upper Trapezius	The electrodes need to be placed at 50% on the line from the acromion to the spine on vertebra C7.	Acromion
Middle Trapezius	The electrodes need to be placed at 50% between the medial border of the scapula and the spine, at the level of T3.	Acromion
Erector Spinae	The electrodes need to be placed at 2 finger width lateral from the proc. spin. of L1.	C7
Rectus Femoris	The electrodes need to be placed at 50% on the line from the anterior spina iliaca superior to the superior part of the patella	C7

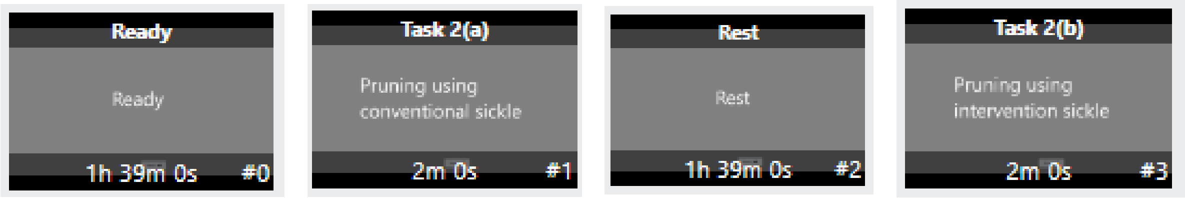


(a) (b) (c) (d)

Figure 3.4: (a) i. Acromion, ii. Middle Deltoid, iii. Olecranon. (b) i. Biceps Brachii. (c) i. Upper Trapezius, ii. Middle Trapezius, iii. Erector Spinae, iv. C7 bone. (d) i. Rectus Femoris

3.5 Design of Stimuli

A research file was made in the iMotions 9.0 programed before any Shimmer3 EMG measurements were carried out. Basic subject data (name, age, and gender), video recording settings, and stimulus production were all included in the study file. Stimulation is a crucial phase in a study since it allows for the storage and processing of recorded EMG signals in relation to the stimulus while measuring muscle activation is being done. Additionally, slide stimuli were developed to guide the subject and tester throughout the experiment. According to the task's suitability, a certain duration was assigned to each stimulus. The stimuli for one of the pruning activities, for instance, are shown in Figure 3.4 on four slides, labelled Ready, Task 2 (a), Rest, and Task 2. (b). The highest time period is given for Ready and the same time period is specified for Rest so that any issues with sensors or other factors can be fixed before the subject moves on to the next task. This allows subjects and testers to be fully prepared. The main stimuli, Task 2(a) and 2(b), were provided for two minutes each. According to the requirements of the study, stimuli were created for MVC as well as other pruning tasks and collecting tasks.



Ready
Ready
1h 39m 0s #0

Task 2(a)
Pruning using conventional sickle
2m 0s #1

Rest
Rest
1h 39m 0s #2

Task 2(b)
Pruning using intervention sickle
2m 0s #3

Table 3.6: Stimuli for pruning task using Sickle with fronds located higher than 3 meters