BIOMECHANICS ANALYSIS DURING CUTTING OIL PALM FRONDS

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DECLARATION

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

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LIST OF ABBREVIATIONS

IMU	Inertial Measurement Unit
WMSD	Work related Musculoskeletal Disorder
REBA	Rapid Entire Body Assessment
OWAS	Ovako Working posture Assessment System
RULA	Rapid Upper Limb Assessment
3DSSPP	3D Static Strength Prediction Program
MPOC	Malaysian Palm Oil Council
NIOSH	National Institute for Occupational Safety and Health
GRF	Ground Reaction Force
L4/L5	Lumbar Vertebrae 4 / Lumbar Vertebrae 5
L5/S1	Lumbar Vertebrae 5 / Sacrum 1

ABSTRAK

Kajian ini membincangkan mengenai analisis beban lumbar semasa memotong pelepah kelapa sawit. Pada mulanya, pekerja kelapa sawit melakukan banyak kerja di ladang kelapa sawit. Disebabkan kerja mereka memerlukan tenaga kerja yang sengit, pekerja mengalami gangguan dan kecederaan muskuloskeletal. Oleh kerana gangguan ini berlaku semasa bekerja, gangguan dan kecederaan ini dinamakan sebagai Musculoskeletal Disorder (WMSD). Sebelum ini, risiko dan penyebab kecederaan ini diperiksa dengan menggunakan alat penilaian ergonomik seperti Rapid Entire Body Assessment (REBA), Ovako Working posture Assessment System (OWAS) dan Rapid Upper Limb Assessment (RULA). Disebabkan terdapatnya batasan dalam penilaian seperti tidak dapat merekod waktu bekerja dan tenaga pekerja memerlukan untuk menjalankan aktiviti tidak disertakan menyebabkan kaedah penilaian ini kurang cekap. Tambahan pula, kaedah penilaian ini hanya dilakukan berdasarkan pemerhatian. Kemungkinan kesalahan berlaku sangat tinggi. Oleh itu, unit pengukuran inersia (IMU) dan plat kekuatan digunakan untuk mengukur postur badan. IMU yang digunakan adalah Xsens akan dilekatkan pada badan kedua-dua subjek. Tiga ketinggian untuk memangkas menggunakan pahat digunakan dan dua jenis sabit digunakan untuk memotong pelepah. Subjek akan melakukan pemotongan dan pemangkasan dari platform yang mempunyai plat kekuatan. Keseluruhan aktiviti akan dirakam melalui kamera telefon untuk diproses. Setelah data Xsens dan data plat kekuatan diproses, graf REBA dan masa dihasilkan. Berdasarkan graf, postur skor REBA yang tinggi dengan beban tangan yang tinggi dipilih untuk mampatan lumbar dan ricih menggunakan perisian Program Prediksi Kekuatan 3D (3DSSPP). Nilai pemampatan dan ricih lumbar dikenal pasti. Keperluan bio penilaian menggunakan IMU ditentukan.

ABSTRACT

The study discusses about lumbar load analysis during cutting oil palm fronds. Initially, oil palm workers were conducting multiple works in the oil palm field. Due to their labour intense work, workers experience musculoskeletal disorders and injuries. Since these disorders occurs during work, they are called as Work-related Musculoskeletal Disorders (WMSDs) Previously, these risks and cause of injuries were inspected using ergonomic assessment tools such as Rapid Entire Body Assessment (REBA), Ovako Working posture Assessment System (OWAS) and Rapid Upper Limb Assessment (RULA). Due to their limitations in assessment such as not accounting working time and forces workers are dealing, these tools were less efficient. Furthermore, these tools were only conducted assessment based on observation. Possibility of error to occur is very high. Therefore, inertial measurement unit (IMU) and force plate is used to measure body postures. IMU used is Xsens attached to two subject's body. Different height for chisel is used and two types of sickles were used for cutting of fronds. Subject will perform cutting and pruning from a platform which have force plate. The whole activity will be recorded through phone camera for processing. After Xsens data and force plate's data are processed, graph of REBA and time is produced. Based on the graphs, high REBA scored posture with high hand load was opted out for lumbar and shear compression using 3D Static Strength Prediction Program (3DSSPP) software. Lumbar compression and shear values were identified. The necessary of bioassessment using IMU is defined.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF PROJECT

Oil palm tree which is known as *Elaeis guineensis jacq* for its scientific name, originally grown in the West Africa as wild plants[1]. The plant later was developed into agricultural crop. Looking into the potential in it, the British who was ruling Malaysia then introduced it in the early 19th century[2]. Oil palm plantation was opted as agricultural crop after rubber and tin's market in worldwide market sink. The plantation of oil palm later helps rural areas farmers to settle down with decent work. There are two types of trees can be found in oil palm plantation. The first one is the short breed where the height of the tree will not reach more than 3 metres while the second type is tall breed. The tall breeds tree can reach a height of 20 metres.

According to Malaysian Palm Oil Council (MPOC), Malaysia plays a vital role in producing palm oil worldwide. In 2020, Malaysia was responsible for 25.8% of oil production and 34.3% of exports around the world[1]. The process involved in turning raw palm oil fruit to usable oil and vegetable fats involves two types of processes; field processing and company processing. Currently there are 505,972 workers[3] involved under field processing are harvesting palm oil fruit branches, pruning of fronds, collecting and transporting oil palm fruit branches to companies. Whereas under company processing, the fruits will undergo sterilization, purification, refining process and multiple stages of processing to produces various raw output[4].

Even though processes in the company are incorporated with mechanical systems, field works does require more manual works[5]. Currently, harvesting and pruning are done partially automated where certain companies use motorized cutter while others use labours. For pruning of fronds for trees under 2m, a flat triangle shaped cutting tool Chisel is used. For cutting of fronds and harvesting fresh fruit brunches for trees above 2m, semi c-shaped sickle cutting tool is used. The tools will be attached to one end of pole while the other end will be attached with motor as shown in Figure 1.1 (a) and (b). When accelerator knob is pressed, the flywheel connected to engine rotates. The rotary movement will be converted to linear motion through pole attached to the engine and cutting tool[6]. This automation applies to collecting and transporting of oil palm.

Workers in the field are not educated with correct ergonomically harvesting and pruning methods as they are only taught on harvesting the ripe fruits only[7]. This cause them to come out with their own methods which are not researched. Result of this modification, injuries occur among field workers. This injury can be divided into two sections. The first injury is caused by physical actions. This type of injuries usually occurs due to machineries and accidents during working. Physical actions related can be treated with immediate attention given. The second injury is ill health. This type of injury is related to human body. Ill health is called as work related musculoskeletal disorders[8]. These disorders occur due to prolonged work hours, high vibration, unergonomic work postures. Effect of disorders are categorized into three categories; short term risk such as muscle pain, next is long term risk which is permanent disability, wheel chair bounded and lastly is death. It is important to give good attention to work related musculoskeletal disorders.[9]


(a) (b)

Figure 1.1: (a)Sickle and (b)chisel with motor

1.2 PROBLEM STATEMENT

Usually, field processing requires more man power compared to mill processing. It’s because most mill processing is conducted by automated machines while field processing is done partly automated. Till this date, at most Malaysian farms workers mainly men will harvest the fruit brunches from tree and collect them in a place. Only then a loader with automated arm will pick up the fruits from the collection area to be sent to main collection area so that these fruits can be loaded on trailers to be sent for processing. Since early years, cutting of oil palm fruit brunches and fronds are done manually despite having motorized cutter. Manual cutting requires more power compared to motorized cutter. As a result, awkward postures were used in order to cut the manual work. The incorrect postures produce pain and eventually possess harm to workers health.

Initially, oil palm workers were interviewed and answered Modified Nordic Questionnaire. They work activities later were recorded and assessed through ergonomic assessment tools such as Rapid Entire Body Assessment (REBA), Ovako Working posture Assessment System (OWAS) and Rapid Upper Limb Assessment (RULA)[10]. These tools have their own limitations as their assessments are not directed towards any particular work but their purposes are to assess general works only. The limitations are related to process of capturing the postures while a worker performed the task. As an example, instead of taking exact working time, these tools set a limit to the working time such as more than or less than.

Although these tools have limitations, they are still been used for assessments in order to identify the preliminary stage of risk each work possess[11]. Through this project, effects of manual cutting tools for cutting oil palm fronds and fresh fruit brunches are collected through Inertial Measurement Unit (IMU) based motion capture and force plate.

By using IMU based motion capture software, specific postures that causes effects to body postures can be identified and the risk level can be calculated. Automated Rapid Entire Body Assessment (REBA) is used in the study to identify the risk level. Automated Rapid Entire Body Assessment (REBA) is a software that receives data of Inertial Measurement Unit (IMU) and assess the risk at every posture. For instance, during a simple bending automated Rapid Entire Body Assessment (REBA) able to list the risk level at each degree of bending.

1.3 OBJECTIVE

There are few objectives to be achieved at the end of the experiment.

1) Obtain raw results from Xsens for processing and measure work postures during cutting to identify harmful postures.
2) Measure and compare risk level between chisel, intervention and conventional sickle using automated Rapid Entire Body Assessment (REBA)
3) Obtain compression and shear of lumbar L5/S1 using 3DSSPP software.

1.4 SCOPE OF WORK

This study involves experimental study of effects of manual cutting tools for cutting fresh fruit brunches to the whole body posture. There will be two subjects involved in this experiment in order to produce variance in data. In terms of software, motion capture software Xsens will create an avatar to recreate the subject. A camera will be placed on the sagittal view of the subject to capture subject’s movement. Force plates will be used to identify lumbar compression in subjects during the experiment. A series of coding files will be used to process the raw data of Inertial Measurement Unit (IMU) Xsens and force plate. From this software, automated Rapid Entire Body Assessment (REBA) score of each position will be generated. In order to verify the final output, the processed data were inserted in 3DSSPP software. Based on the results generated from the software, compressions and shears of postures can be calculated.

All simulation were conducted in School of Mechanical Engineering and real field experiments were conducted at parking lot, School of Chemical Engineering.

1.5 SUMMARY OF CHAPTERS

This thesis is divided into five chapters which are introduction, literature review, research methodology, results and discussion and lastly is conclusion and future recommendations.

Chapter 1 discusses on the studies background, overview about oil palm plantation and work-related musculoskeletal disorders.

Chapter 2 discusses on the literature review about assessment tools, study about work related musculoskeletal disorders, designs of cutting tools, biomechanical assessment of loads.

Chapter 3 involves participants information, posture analysis methods and tools, experimental setups and post processing methods of data.

Chapter 4 discusses on the raw data obtained from experiment, compression and shear of lumbar L5/S1 and also postures comparison using trunk angles.

Chapter 5 concludes the whole study with comparison of data obtained and future recommendations on the study.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter explains on articles that supports the facts those related to oil palm industry. Main contents of the chapter would be human anatomy, oil palm cutting tools, cutting methods, REBA assessment, oil palm workers back pain, compression and tension on spinal cord.

2.2 WORK-RELATED MUSCULOSKELETAL DISORDERS (WMSDs)

Work related musculoskeletal disorders (WMSDs) are list of disorders that are related to muscle, ligaments, tendons and nerves which are found in human body[12]. Based on study conducted in Great Britain, workers from agriculture, forestry and fishing industries experiences the most work related musculoskeletal disorders (WMSDs) followed by construction, human health and social activities industries[13]. In Malaysia, Work related musculoskeletal disorders (WMSDs) shows a rising trend since 1995 starting from 5 cases [14] till 238 cases recorded in 2010 to National Institute for Occupational Safety and Health (NIOSH)[15]. These disorders are not genetically inherited or caused by sudden activities instead they are developed over time due to certain factors. One of the factors for these disorders to occur is repetitive motions, risk work cultures and prolonged work hours[16]. Common list of disorders of WMSDs are tendon inflammations such as tenosynovitis, nerve compression disorders such as carpal tunnel disorders, osteoarthrosis.

These diseases are not only limited to tendons and muscle but also to body parts such as lower body, neck shoulder, forearm and also hand[17]. Effects of WMSD are not only directed to workers only but also to employers too. It will cause drop in workers efficiency and increase in health care cost[18]. There is a high possibility for employees to be permanently disabled or have long time effect to their body due to WMSDs.

2.3 PREVALENCE OF WORK-RELATED MUSCULOSKELETAL DISORDERS AMONG OIL PALM WORKERS

Oil palm workers conduct multiple tasks in order to bring oil palm brunches from tree top to processing mill. Conducting these jobs requires physical strength of workers. Due to its nature of work, the correct working position is not applied. During working, awkward positions such as prolonged bending, overweight lifting, high force of cutting techniques is applied[19]. Workers from the field are divided into several groups to conduct four main tasks. The first group of workers are cutters as they cut all ripe fresh fruit brunches and prune fronds (Figure 2.1 (a)). The second group are stackers as they would be stacking fruits into groups and fronds in a place (Figure 2.1 (b)). The third group is loose fruit collector (Figure 2.1 (c)). Their job would be mainly collecting loose fruits. Lastly, are the truck drivers (Figure 2.1 (d)). The drivers drive collection lorry at mean time loads the fruits into trucks.

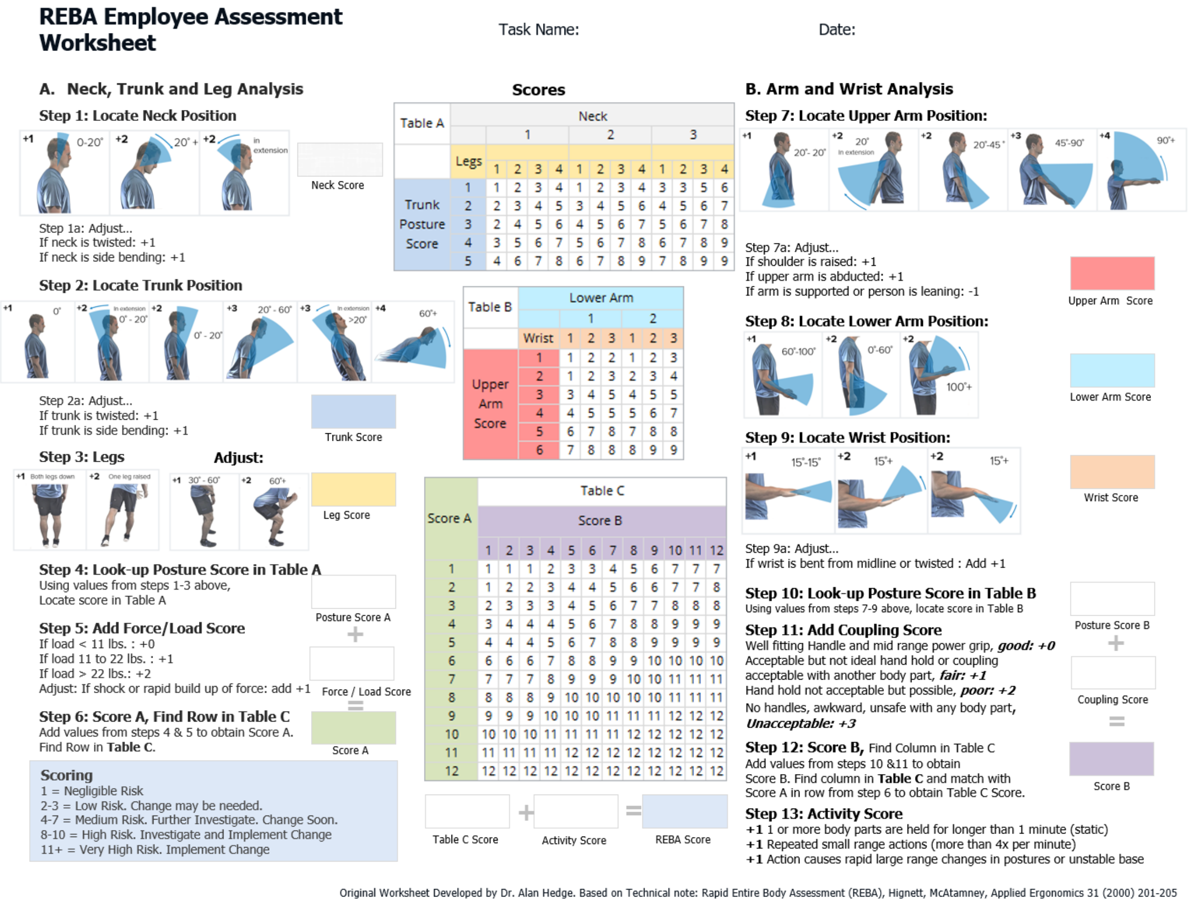
(a) (b) (c) (d)

Figure 2.1: (a)Cutters are harvesting fresh fruit brunches (b)Stackers stacks fruits in groups (c)Loose fruit collectors collecting fruits (d)Drivers driver machineries around plantation.[20]

All this worker would be experiencing upper and lower back pains[21]. Of all this group of workers, cutters experience the highest pain all the time followed by loose fruit collectors [20] This is followed by truck drivers who also works as loaders. The cutters experience lower back pain because of their posture which they bend down in order to pull the sickle down[21]. The drivers experience same lower back pain as they have to lift a heavy fruit from ground into truck causing them to bend down and apply pressure to their lower back[10].

2.4 ERGONOMIC ASSESSMENT TOOLS

REBA and RULA assessment have been the primary tools to measure work posture and their risk levels. A pen and paper in order to conduct the assessment. The scores are obtained through manual assessment which is observations by human observer and scoring based on tables provided. The REBA tool is divided into two sections. Section A is for neck, trunk and leg analysis whereas Section B is based on arms and wrist analysis. The tool will add scores from neck, leg and trunk to form a score. This score will include each parts twisting, bending and external force addition. Then this score is added with section B score which includes bending, twisting, addition of coupling score and activity score [22]. This tool identifies the risk of WMSD by grouping scores in their boundaries. Since the assessment is based on human observer, estimation of risk will vary from person to person[11]. Some observers will find a posture to be scored high value while some will score a posture low value. Reliability concern arise due to different outcomes of multiple observers[23].



REBA Employee Assessment Worksheet

Task Name:

Date:

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position

Neck Score

Step 1a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Step 2: Locate Trunk Position

Step 2a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 3: Legs **Adjust:**

Leg Score

Step 4: Look-up Posture Score in Table A
Using values from steps 1-3 above,
Locate score in Table A

Posture Score A

Step 5: Add Force/Load Score
If load < 11 lbs. : +0
If load 11 to 22 lbs. : +1
If load > 22 lbs.: +2
Adjust: If shock or rapid build up of force: add +1

Force / Load Score

Step 6: Score A, Find Row in Table C
Add values from steps 4 & 5 to obtain Score A.
Find Row in **Table C.**

Score A

Scoring
1 = Negligible Risk
2-3 = Low Risk. Change may be needed.
4-7 = Medium Risk. Further Investigate. Change Soon.
8-10 = High Risk. Investigate and Implement Change
11+ = Very High Risk. Implement Change

Scores

Table A		Neck											
		1				2				3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

Table B		Lower Arm					
		1			2		
	Wrist	1	2	3	1	2	3
Upper Arm Score	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

Score A	Table C											
	Score B											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Table C Score + Activity Score = REBA Score

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position:

Step 7a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

Step 8: Locate Lower Arm Position:

Lower Arm Score

Step 9: Locate Wrist Position:

Wrist Score

Step 9a: Adjust...
If wrist is bent from midline or twisted : Add +1

Step 10: Look-up Posture Score in Table B
Using values from steps 7-9 above, locate score in Table B

Posture Score B

Step 11: Add Coupling Score
Well fitting Handle and mid range power grip, ***good: +0***
Acceptable but not ideal hand hold or coupling
acceptable with another body part, ***fair: +1***
Hand hold not acceptable but possible, ***poor: +2***
No handles, awkward, unsafe with any body part,
Unacceptable: +3

Coupling Score

Step 12: Score B, Find Column in Table C
Add values from steps 10 &11 to obtain
Score B. Find column in **Table C** and match with
Score A in row from step 6 to obtain Table C Score.

Score B

Step 13: Activity Score
+1 1 or more body parts are held for longer than 1 minute (static)
+1 Repeated small range actions (more than 4x per minute)
+1 Action causes rapid large range changes in postures or unstable base

Original Worksheet Developed by Dr. Alan Hedge. Based on Technical note: Rapid Entire Body Assessment (REBA), Hignett, McAtamney, Applied Ergonomics 31 (2000) 201-205

Figure 2.2 : REBA form with guidance [22]

But these assessment tools are found to be less accurate compared to real time body posture assessment tools such as Xsens.[11][23] This is because this tool only measures for a single worker at a time. Furthermore, the actual duration of work is not accounted in the work calculation as only estimation is done on working hours [24]

Xsens is a human motion capturing system which comes with hardware and software. It consists of 17 sensors occupied with inertial and magnetic sensors combined[25]. This tool not limited to human ergonomics, but also for those analyst who are specialized in sports science, ergonomics, rehabilitation, and biomechanics fields[26]. One of the advantages is it does not confine to lab usage only as it can take to real field to experience real life applications.

2.5 MEASUREMENT OF HUMAN MOTION

Measurement of human motion can be done using Xsens software. Xsens uses inertial based motion capture system which will able to create human motion in software (Figure 2.3). One of the criteria that can be measured in the motion is angle of flexion and extension. Other than that, forces exerted on each part of body can be identified. As for example, from lifting above head, amount of force applied on pelvis bones, flexion of spinal cord and joint angles can be calculated[27]. Apart from angles, movement from one place to another can be calculated. This is done by motion sensor attached to sensors.

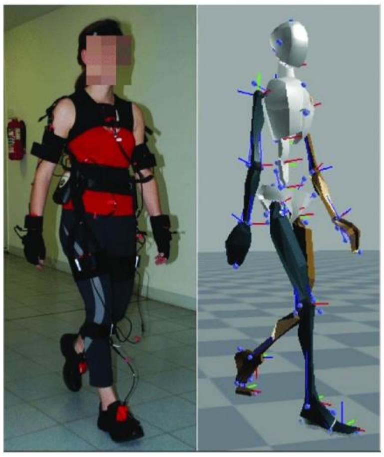


Figure 2.3: Figure of Xsens motion tracker for 3D real time human motion measurement.[28]

2.6 OIL PALM CUTTING TOOLS

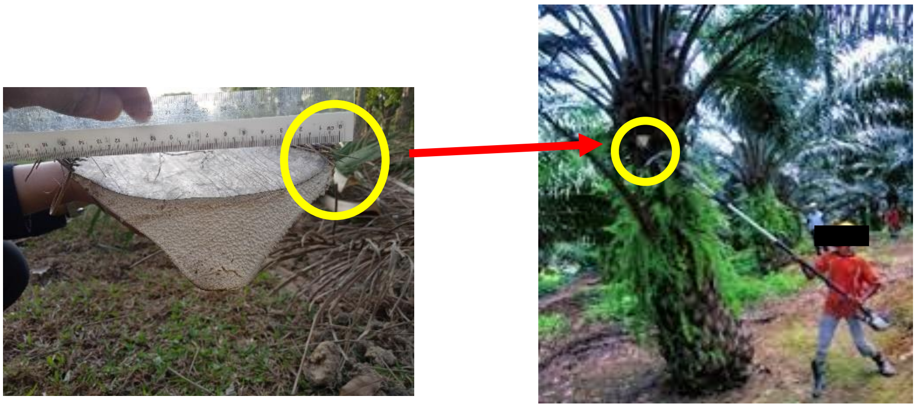
Oil palm workers uses two types of cutting tool for harvesting of fresh fruit brunches and cutting of palm fronds. Chisel is triangle shaped cutting tool while sickle is semi-C shaped cutting tool. Chisel (Figure 2.4(a)) is mainly used for pruning of oil palm fronds and seldom used for harvesting fruit brunches of low height trees while sickle (Figure 2.4(b)) is used for pruning of oil palm fronds and harvesting fruit brunches both short and tall trees.

Intervention sickle is the same design as conventional sickle but modifications are done to cutting tool ending which will be inserted into aluminium pole (Figure 2.4(c)). When workers place intervention sickle on frond to cut and pulled, the pole willed be pulled down followed by sickle. The delay produces a sudden momentum to the cutting tool. This sudden momentum cuts through fronds and brunches very easily[29].

(a) (b) (c)

Figure 2.4: (a)Chisel, (b)Conventional sickle and (c) Intervention sickle.

These tools require certain techniques in order to cut oil palm brunches and fronds. In order to cut oil palm fronds using sickle, the tool should be placed perpendicular to the frond. This will cause the blade to be in contact with frond on the other end (Figure 2.5(a)) and when the worker pulls the cutting tool will slice through the frond (Figure 2.5(b)).



(a) (b)

Figure 2.5: (a)The contact point of sickle before cutting on the left is the enlargement (b)after frond is cut using sickle.

For chisel, the worker should be standing as same as sickle method. During cutting, the tool should be in contact with small thickness frond in order to initiate the cut (Figure 2.6). When chisel is thrown towards the frond, the top section will be in contact first. This point is the weakest point due to its small thickness compared to bottom section.

Figure 2.6: The first touch point of chisel.

In Malaysia, Malaysian Palm Oil Board previously have developed a motorized cutter named as ‘Cantas’[30]. The main reason for this innovation was to reduce labour force in harvesting, increase harvesting efficiency and at the same time reduces cost of production. These motorized cutting tools able to reduce cutting time and increase cutting efficiency. But as it was one of the first kind in Malaysia, it does have certain weakness.

One of the weakness of ‘Cantas’ was frequent breakdown, high vibration and heavy. It also cost a fortune to buy cutting tools for different tree heights[31]. This in terms of economical, not feasible as the maintenance cost and product cost is high when it is compared to manual cutting [32].

2.7 BIOMECHANICAL ASSESSMENT OF LOAD ON THE LUMBAR SPINE

Workers from oil palm field are constantly exposing themselves to the same work pattern over the time they work in the field. This could place a potential hazard to their spinal cord. Previously, when a survey was conducted for oil palm workers discomfort on different body regions, out of 88 respondents 87 pointed out lower back for discomfort[21]. As discussed above, oil palm workers involve lifting, pushing and pulling. These activities put a lot of compression and tension to their spinal cord. Result of the compression and tension is the gradual wear that happens between spinal cords segments.[33]. According to National Institute of Occupational Safety and Health (NIOSH), the allowed compression that lumbar L5/S1 should experience is not more than 3400 N whereas for shear force is not more than 1000N[34]. Any activity that possesses more than recommended compression and shear value is assumed as very risky posture and activity.

2.8 SUMMARY

Overall, this chapter discusses on how work-related musculoskeletal disorders happens to workers, what is the ergonomic assessment tool that is currently used and its disadvantages. It’s also discusses on which oil palm worker experiences high risk of WMSDs. Current cutting tool designs are also discussed in this chapter.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This study uses data collection through experiment set-up in order to obtain forces exerted on lumbar when oil palm fronds are cut. Two subjects were called in for conducting the experiment. The experiment was conducted at parking lot of School of Chemical Engineering.

3.2 PARTICIPANTS

Two male participants were called in for the experiment. Each participant was labelled as subject 1 and subject 2 for identification purpose. Subject 1 is a non-experienced worker in oil palm industry with weight of 69.1 kg and height of 1.71 m. Subject 2 is an experienced worker in oil palm industry with weight of 84.5 kg and 1.65m in height. Subject 2 is a part timer in oil palm field where he will be spending 10 hours per week by working 6 days per week. All participants were in good health and reported no history of musculoskeletal disorders within the previous twelve months. Both workers were equipped with safety equipment’s such as safety hat and covered shoes in order to protect themselves from dangerous materials. Each subject was briefed on the topic’s objective, flow of experiment and possible harms that they could encounter at end of experiment. All participants were provided with written consent before data collection was undertaken. At the end of each day of experiment, subjects were interviewed on their experience of conducting this experiment and their pain levels at each part of body.

3.3 PREPARATION OF CUTTING TOOLS

There are two types of cutting tools used in this study which are chisel and sickle. Sickle is divided into two types. The first one is conventional sickle and the second type is intervention sickle - sickle with ‘pelajak’. Each cutting tool have its own technique in using it. Chisel uses push cutting technique in order to prune fronds. The chisel is aimed at the frond by standing perpendicular to the frond. The chisel then pushed towards the frond where it cut through frond. Sickle uses pull cutting technique. This technique is done by locating the sickle on fronds perpendicularly to the fronds. The sickle is then pulled down causing the sickle to cut the frond[29]. Unlike of chisel which cut from front to behind, sickle cuts from behind to front.

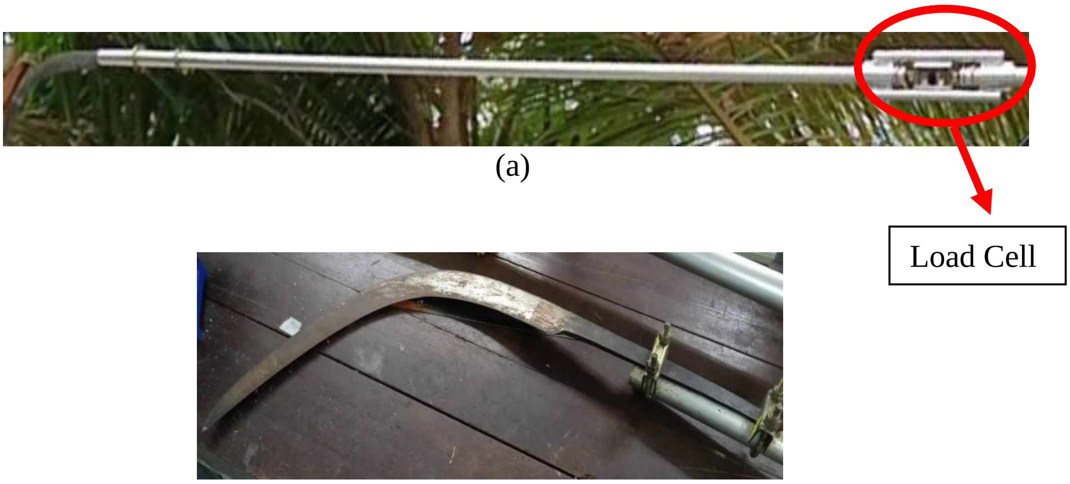
3.3.1 CHISEL

Chisel (Figure 3.1) is a triangle shaped cutting tool. It is made up of 1.64 meters in length and 10.84±0.36 kg in weight. The load cell is located 50 cm from the top end of cutting tool. A load cell is placed 0.54 meters from tip of the cutting tool. The cutting tool is made up of spring steel and connected with a firm pole. The firmness of the pole is very important in order to avoid the pole from bending during push cutting.

Figure 3.1: Chisel attached with load cell

3.3.2 CONVENTIONAL SICKLE

Conventional sickle (Figure 3.2) is a semi c shaped cutting tool which is connected to long aluminium pole. The sickle is 0.62 m in length and 3.67 m in total length with aluminium pole. It weighs about 22.8 ±1.03kg. Load cell is placed 2.19 meters from top of cutting tool. The necessary of load cell to be attached on tool is to measure hand force applied by the worker for each attempt. This aluminium pole is not very stiff compared to chisel but strong and flexible. The flexibility of the pole enables the tool to be placed on top of the frond easily.[35]



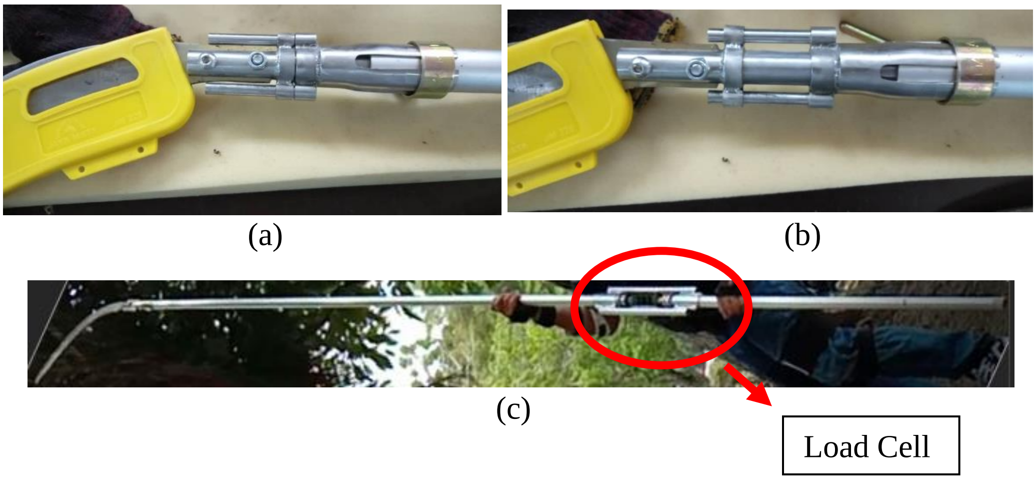
(a)

(b)

Figure 3.2: (b)Conventional sickle attached to (a)aluminium pole with load cell.

3.3.3 INTERVENTION SICKLE

This sickle fitted with an extension (Figure 3.3(a) & (b)) which will extend upon been pulled. The length of this sickle is 3.67 meters and weighs about 22.8 ± 1.01kg. A load cell is also placed 2.19 meters from the top of blade.



(a)

(b)

(c)

Figure 3.3: (a)Before and (b)after the extension of intervention sickle. (c)Intervention sickle attached to aluminium pole with load cell

This tool was selected for assessment due to its innovation which extends when pulled downwards. One of the advantages of this tool is its ability to produce a jerk force during cutting. The jerk force reduces the bending angle of workers in order to pull down technique used for cutting of fronds.

3.4 POSTURE MEASUREMENT

Full-body kinematics were measured using Xsens MVN Awinda wireless motion-tracker (Xsens Technologies BV, Enschede, The Netherlands), which consists of 17 inertial measurement units (IMUs), sampling at 60 Hz. The IMUs were attached to the subjects with the accompanying Velcro straps, headband and a tight-fitting customised t-shirt on the following body segments; one on each foot, shank, thigh, shoulders, upper arm, wrist (lower arm) and hand, as well as one placed on the pelvis, sternum and head.(Figure 3.4 and Table 3.1) The data collected are then transmitted using Awinda station using Wi-Fi connection to the computer. In the computer, MVN Analyze software (version 2020.2) is installed which able to drive a 23-segment kinematic model intimidating acts of real human. An external camera (Vivo Y12, 13megapixels) is used in order to record the movement in sagittal view.


[redacted]
[redacted]

(a) (b)

Figure 3.4: (a) Front and (b) Rear view of subject 1 with labelled Xsens Sensor

Table 3.1 Xsens Sensors Position on subject

No	Sensor Placement	Optimal Position / Location
1	Head	Forehead
2	Sternum	Chest
3	Shoulders	Top of back
4	Upper Arm	Lateral side of upper arm
5	Forearm	Close to wrist
6	Hand	On the wrist
7	Pelvic	Pelvis bone (height of the anterior superior iliac spine)
8	Upper Leg	Lateral thigh
9	Lower Leg	Tibia (close to the knee)
10	Foot	front upper part of the foot

3.5 FORCE MEASUREMENT

Ground reaction force (GRF) was measured using two (60 cm x 40 cm) Bertec triaxial force plates (Bertec Corporation, Columbus, OH). The force-plate data underwent an analog to digital conversion and were stored on personal computer by using excel file. A Bertec amplifier (AM6500 model) low-pass filtered the GRF data with a frequency of 1000Hz.

Hand force was measured using load cell attached to the pole of cutting tools. The load cell is 20.5 cm in length and 8cm in width. The data was processed through LabView (National Instruments, Austin, Texas, U.S) software which uses visual programming. The processing rate of data of LabView is 2000Hz.

3.6 BIOMECHANICAL MODELLING

Biomechanical exposures to the participants were modelled using 3D Static Strength Prediction Program (3DSSPP) (University of Michigan; Ann Arbor, Michigan, USA). The software is a trial version ergonomic software that focuses on lumbar analysis. The data such as hand loads, positions, hand angles, body angles are inserted in each frame in order to imitated the full resemblance of the act and the result panel will show the final result such as level of risk, shear. For each trial, peak spine compression and shear at L4/L5 and L5/S1 were recorded, as well as the minimum percent of population with the shoulder strength capable to perform the task.

3.7 FIELD SETUP

The experiment was conducted behind School of Chemical Engineering, Universiti Sains Malaysia. This location was chosen since it was near to power source and characteristics of tree such as number of palms, height of tree was suitable. The tree chosen for the experiment is shown in Figure 3.5. The height of the tree is approximately 3 meters.

Figure 3.5: Oil palm tree that were chosen for study

MVN Remote application is a remote application to record the scenario using phone camera was downloaded through play store in phone (Vivo Y12 13megapixels). The phone was connected to the same WIFI of Xsens software. The phone was placed on a tripod beside subjects in order to record sagittal view. The application will use handphones camera in order to record the experiment (Figure 3.6). A set of force plate was placed on a flat surface in this case, it was placed on a 1.5m x 1.5m squared platform assuming it the ground due to the irregularity of the experiment place.

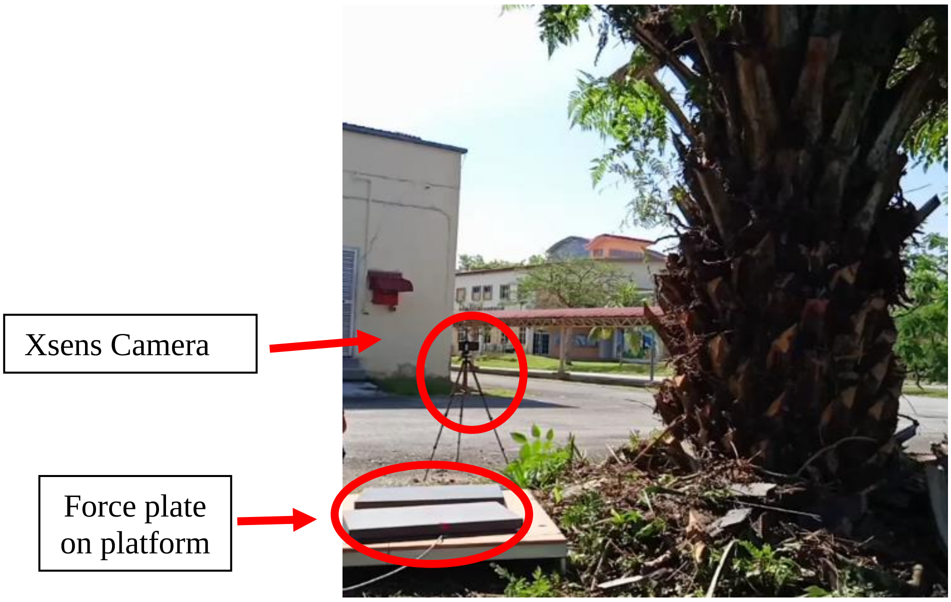


Figure 3.6: Setup of experiment in the field.

3.8 EXPERIMENTAL METHODS

This section will explain on the method each experiment was conducted.

3.8.1 CHISEL

The tree was divided into three sections; below 1 meter, between 1 meter and 2 meter and lastly was above 2 meters marked using spray paint as shown in the figure below. Fronds that need to be cut were identified and marked (Figure 3.7). Steel platform was placed near the tree and force plates were placed on them. Force plate was placed at 30cm spacing to create a big surface area of analysis. Subject was prepared with Xsens sensors and shimmers. Each experiment was conducted for 5 minutes. In between each activity, a 10 minutes break was given for subjects to have rest. All time were monitored using stopwatch. Time was set as constant for all three heights while number of fronds cut were only counted after each experiment. Subject was asked to stand at a reference point so that for every time subject starts experiment, subject will stand on the point and starts from there. When Xsens, force plate and timer was started, subject moved onto platform and starts cutting of fronds (Figure 3.8)(a). When timer stops, subject returns to reference point again. The procedure is repeated for all 3 sections of trees using chisel (Figure 3.8 (b) & (c).

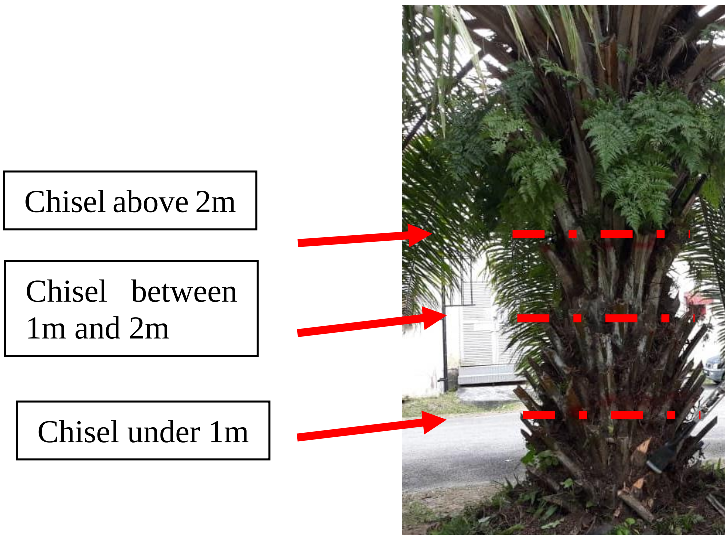


Figure 3.7: Marking on the tree for chisel under1m, between 1m and 2m and above 2m

(a) (b) (c)

Figure 3.8: Subject performing pruning (a) under 1m, (b) between 1m and 2m and (c) above 2m.

3.8.2 SICKLE INTERVENTION AND CONVENTIONAL

The top of tree was divided into four sections based on number of fronds available for cutting; each subject assigned to a pair of sections for intervention and conventional sickle cutting tool. The subject was attached with Xsens sensors. Metal platform was placed 2.5 meters away from the tree in order to give the subject comfort during cutting. Force plate was placed on top of platform. The experiment was conducted for 5 minutes. Subject was asked to stand at pivot point before starting experiment. Subject was asked to cut as many as fronds during the 5 minutes (Figure 3.9). When time started, subject stand on the force plate and started to cut oil palm fronds. When time stops, subject return to the pivot point. A 10 minutes break time was given for the subject to rest. The steps were repeated for conventional sickle too.

(a) (b)

Figure 3.9: Subject 2 conduct cutting of frond using (a) sickle intervention and (b) sickle conventional.

3.9 RAW DATA PROCESSING

The results of the recordings are stored in MVNS format file. These files are then processed using Xsens software by selecting frame that contains experiment actions only. By selecting the frames, unwanted scenes in the recordings such as subject walking towards force plate can be removed so that size of the file will be reduced and noises can eliminate. These selected frames will then be saved as MVNX and Excel format. The saved MVNX file then processed using Automated REBA software. The output of postural analysis will be saved as excel file. All these files will be saved inside a folder for further processing. Command prompt will be used to run phyton coding. Force plate produces forces in the direction of Fx, Fy, Fz and moments in the direction of Mx, My and Mz along a timestamp. This coding will sync automated REBA data with force plate data. The final output of the data will be a colour-based graph which is Figure 3.10 below. The graph will contain REBA level along frame of actions.

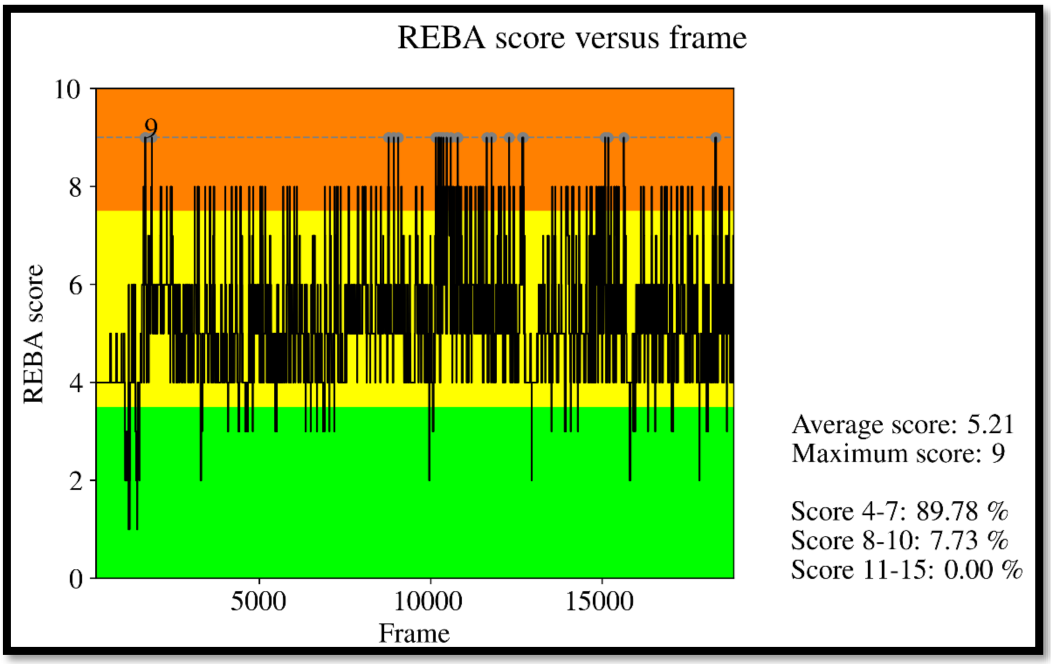


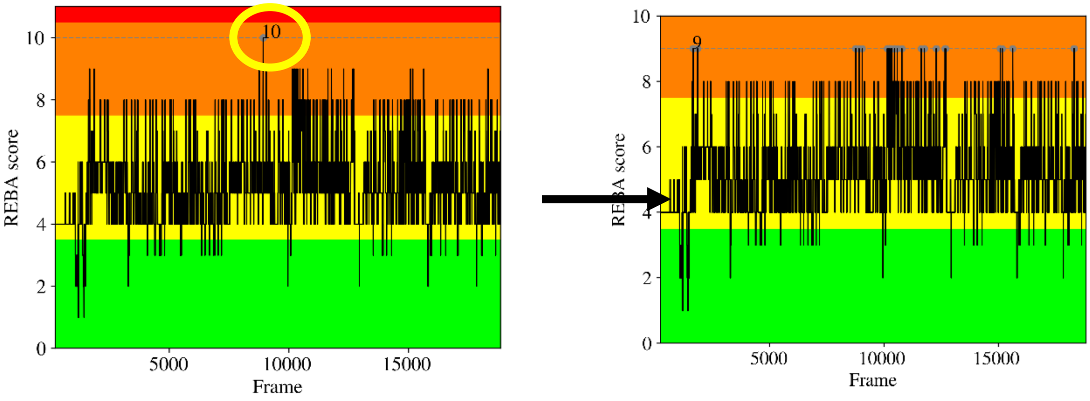
Figure 3.10: REBA score of chisel tool used for cutting under 1m

3.10 DATA VALIDATION

After processing data using Automated REBA tool and Phyton coding, the data is then validated using 3DSSPP software. High score of REBA which is repeatedly recorded from each activity were chosen for validation. The posture of that score will be chosen and complete process including cutting and aiming for sickle while for chisel is aiming, cutting and return posture will be drawn in 3DSSPP software and hand loads for aiming and cutting activity will be inserted. Output of the software will be tabulated inside a table.

3.11 NOISE REDUCTION

Each raw data will have noise during the recording. This noise is created by unintentional act of the subject. Some of the acts that can cause noise in the raw data are sudden lost control of cutting tool, cutting tool hitting force plates and Xsens sensors and not standing in both legs during experiment. These noises can be removed but have to be done manually. Firstly, the raw data will be processed as stated in raw data processing section above and produce REBA graph. Based on the graph identified by a sudden spike in the graph as shown in the picture below. By identifying the sudden spike’s time frame and compare it with actual recording, the noise can be confirmed. By running, Phyton coding again by removing the noise in the sync.csv file during the processing, pure data can be obtained. Removing of noise is very essential in experiment because they can create impurities in the result. In this case, before noise is removed, the highest REBA score is 10 but after noise reduction the highest REBA score was 9. Although REBA 8 till 10 is classified as high-risk section, but each risk level has its own mitigation level and steps.



(a) (b)

Figure 3.11: (a)Graph before noise reduction (b)Graph after noise removed graph.