BIOMECHANICAL ANALYSIS OF WEIGHTLIFTING

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project report and in my opinion, it is fully adequate in terms of language standard, and report formatting requirement for the award of the degree of Bachelor of Mechanical Engineering with "specialization".

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EXAMINER'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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Name of Examiner :
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Date :

STUDENT'S DECLARATION

I hereby declare that the work in this report is my own except for quotations and summaries which have been duly acknowledged. The report has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

Weightlifting is a sport that requires good strength and appropriate technique to make a weightlifter success in its lift. Weightlifting contains two main technique which are snatch technique and clean-jerk technique. Both techniques have six phase and the phases are, first pull; transition from first to second pull; second pull; turnover under the barbell; catching phase; rising from squat position. This project is about the biomechanical analysis on the weightlifting and the result from the experiment will be compared with other researcher. This experiment is only for preliminary study for this thesis. The objectives for this experiment are to investigate the force exerted, observe the muscle activity and study the angle of joint on the subjects while lifting the barbell for both techniques. In force distribution and muscle activity analysis, only one subject is selected to do the comparison as all subjects shows almost same pattern of graph in the experiment. From the result of angle of joint, all the subjects is compare with each other's and only one subject is selected for comparison with the professional athlete. From the result shown by the subject and comparison with the professional athlete, the technique shown by the subject is not much different. Analysis on weightlifting also important as it can reduce the injuries and increase the performance for the lifter.

ABSTRAK

Angkat berat adalah sukan yang memerlukan kekuatan dan teknik yang betul untuk membolehkan ahli angkat berat berjaya dalam dalam angkatannya. Angkat berat mempunyai dua teknik utama iaitu teknik “snatch” dan teknik “clean-jerk”. Kedua-dua teknik mempunyai enam fasa utama iaitu, angkatan pertama; peralihan dari angkatan pertama ke angkatan kedua; angkatan kedua; pembalikan besi pengangkat; fasa tangkapan; bangun dari keadaan mencangkung. Projek ini adalah berkenaan dengan analisis biomekanikal pada angkat berat dan hasil daripada eksperimen akan dibandingkan dengan kajian yang lain. Eksperimen ini adalah untuk kajian awal dalam thesis ini. Objektif untuk eksperimen ini adalah untuk, mengkaji agihan daya, aktiviti otot dan sudut antara anggota badan pada subjek semasa mengangkat barbell untuk kedua teknik. Untuk analisis agihan daya dan aktiviti otot, hanya satu subjek juga dipilih untuk dibuat perbandingan dengan atlet professional kerana semua subjek menghasilkan bentuk graf yang agak sama ketika eksperimen. Keputusan sudut antara anggota badan dari eksperimen akan dibandingkan antara subjek dan hanya satu subjek dipilih untuk dibuat perbandingan dengan atlet professional. Keputusan dari subjek dan perbandingan dengan atlet professional menunjukkan teknik yang dilakukan oleh subjek tidak banyak bezanya. Analisis untuk angkat berat adalah penting kerana ia boleh mengurangkan kecederaan dan menambahkan prestasi ahli angkat berat.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

This study is mainly about weightlifting technique in a sport and the effect of weightlifting technique from the distribution force, angle of joint and muscles activity produce by the lifter. Biomechanics in this project is the study and analysis about the weightlifter and the activities of weightlifting in general. Weightlifting consists of two main technique which are snatch technique and clean-jerk technique. Snatch technique is lifting the barbell from the platform and locked arms overhead in a smooth continuous movement. A lifter then will pull the barbell as high as he or she can. In this technique, power and strength is very important to the athlete but the technical skills, excellent balanced, speed and shoulder flexibility cannot be put aside as all of it also can affects to a good technique during the lifting. Clean-jerk technique is another technique in weightlifting where it is the part when the lifter explosively pulling the weight from the floor to their racked position and the barbell is across the shoulder. After that, the lifter will do some flips and the barbell will be on the overhead which this part is called jerk technique.

Effect of weightlifting in this study contains three main parts which are distribution force produce by the lifter, angle of joint on lifter's body during the weightlifting and the muscle activity uses in weightlifting. The distribution force will be determined from the experiment measured by using a plantar force in a laboratory. During the experiment run, effect of muscle activity is determine by using electromyography (EMG) to know the most active muscle involve in weightlifting.

Angle of joint is taken from the lifter's body with a digital camera at the certain point. Then, the final report can be done according to the result.

1.2 Problem Statement

In this experiment, the distribution force produce by weightlifter during lifting the barbell is determined at each phase. Each phase will produce different distribution force due to the different style perform by the lifter. Different technique also will result in different distribution force for each lifter and this is important as the lifter has their owned style. From this experiment, each distribution force produce will be compare with another journal.

During the lifting process, the muscles activity also needs to find through the different weightlifting technique because muscles play an important role in weightlifting. Muscles that show the most activity have a higher potential to fatigue early and it can affect the lifter's performance. There are many muscles that can be investigated but only two muscles that will be used in this study.

Last problem statement in this study is to determine the angle of joint from the lifter's body. Angle of joint can prove the correctness of weightlifting technique. It also will be compare between the subject and professional athlete to see whether subject in the experiment has the correct technique.

1.3 Objective

i) To investigate the force exerted during the weightlifting technique.
ii) To observe the muscle activity in weightlifting.
iii) To study the angle of joint during weightlifting.

1.4 Project Scope

i) Determine the maximum force occur while a lifter lift a weight base on the technique phase.
ii) Find the most active muscle between two muscles during the weightlifting.
iii) Study the angle of joint at hip, knee and ankle in a weightlifting technique.
iv) Determine the barbell kinematics during the experiment.

1.5 Organization of the report

This study involves of five chapters in the report. For PSM 1, this report only include until chapter 3 which are introduction for chapter 1, literature review for chapter 2 and methodology for chapter 3. For chapter 1, the introduction involve of project background of the study which is about the weightlifting and its technique. It also include with the objective, problem statement and the project scope of the study.

Chapter 2 of the report consists of the literature review relating to the title of the study which is the biomechanics analysis of weightlifting. Source of literature review is taken from the journal, article, and book or from the internet. In this chapter, it tells about the weightlifting and the overall information of weightlifting technique which are snatch technique and clean-jerk technique. Besides that, the biomechanics and injury in weightlifting also is in this chapter where it shows that weightlifting consist of many information about it. Furthermore, the muscle involve during the weightlifting also explain in this chapter and also the force produce during the weightlifting technique.

Meanwhile, in chapter 3 of this report, it explains about the methodology for the experiment, the subject, equipment use and the procedure. Briefly explanation about the both snatch technique and clean-jerk technique also include in this chapter. A flowchart for the experiment also can be seen in this chapter where it can give more understanding on how the experiment going.

Chapter 4 for this report is about the result and analysis from the experiment. Result in chapter 4 is divided into four main parts which are distribution of force, angle of joint, barbell kinematics and muscle activity. Meanwhile, chapter 5 in this report explains about the overall conclusion for the experiment and recommendations to improve the experiment in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This literature review is about the weightlifting and it has two technique which is snatch technique and clean-jerk technique. Besides, it also include the muscle activity involve in weightlifting and other sport for additional information and also the injuries produce in weightlifting. This chapter also discuss about the force distribution that produce during the experiment.

2.2 Weightlifting

Weightlifting is a sport that requires strength and technique to make a lifter success and it is also can be as an exercise to the athlete. Weightlifting sport has two types of technique which are snatch and clean-jerk. In the Olympic competition, each weightlifter can did three attempts for each technique, and combination of two highest successful lifts determines the overall result within a bodyweight category (BBC Sports Olympic, 2012). Bodyweight categories are different for different genders. A lifter who fails to complete at least one successful snatch and one successful clean and jerk also fails to total, and therefore receives an incomplete entry for the competition (BBC Sports Olympic, 2012). Olympic weightlifting tests include in the aspects of human limits strength and therefore implemented faster with more movement and a greater range of motion during their implementation compare

to the other lifts. If the technique is properly implemented, the snatch and the clean and jerk are both dynamic while appearing smoothly, especially when viewed from a slower speed recorder.

Each technique has different phase and different angle in lifting the barbell. In competition, snatch technique will be the first for the competitors to do follow by the clean-jerk technique. Load of the barbell lift by the weightlifter is not the same as each person have different strength and different technique in lifting.

2.2.1 Snatch technique

For the overall view of snatch technique, the lifter will start by setting the position to lift the barbell from the platform. The barbell then will be lift to the mid chest of the lifter and at the certain point, it will be flipped overhead. Some lifter had been done a power snatch which means during the lifting, the lifter does not need to bend their knees because the load of the barbell is currently light (BBC Sports Olympic, 2012). For a clearly understanding, **Figure 2.1** is showing the progress of snatch technique.

Figure 2.1: Snatch technique in a competition

Source: Mike stone, 2012

2.2.2 Clean-jerk technique

Clean and jerk is the combination of two technique which is clean technique and jerk technique. These two techniques are continuous between each other as shown in the **Figure 2.2** and **Figure 2.3**.

i) Clean technique

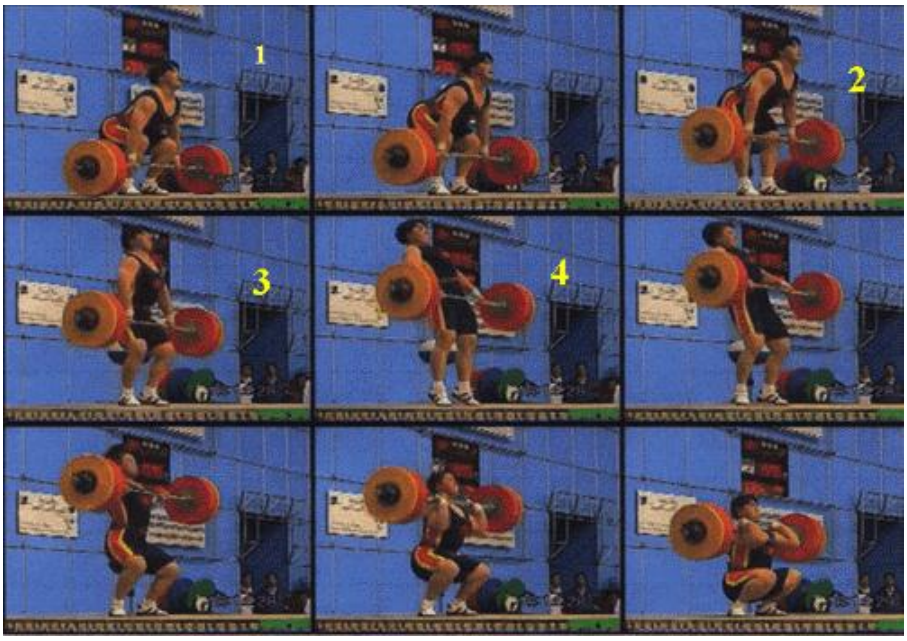


Figure 2.2: Clean technique in a competition

Source: Mike stone, 2012

During this technique, the athlete will begin the lifting in a squat position. Then, the athlete will do hook grip which mean the position of the hand and the hips is only a thumb distance and this hook grip require an athlete grasping the bar so the fingers will go over the thumb. This hand position will make the lifter not easily lose their grip while lifting the barbell. After that, the lifter will pull the barbell upward as high as his shoulder through the quick triple extension of hips, knees and ankles. The lifter then will be pulled under the bar and into a deep front squat position. Finally, the lifter then will stand to continue the second phase which is jerk technique (Mike stone, 2012).

ii) Jerk technique

Figure 2.3: Jerk technique in a competition.

Source: Mike stone, 2012

From the standing position, the lifter then will bend their knees a little bit about 145 degree and push the barbell upwards with their arms while jumping a little until the barbell is above their head. In **Figure 2.3** above, the lifter perform a split jerk where one of the legs is move forward while another leg is move backward. The lifter will stop for a moment at this position to make sure their position with the barbell is stable and finally jump into a standing position (Mike stone, 2012).

2.3 Muscle activity

Term of the muscle is derived from the Latin word '*musculus*' which mean "little mouse". It is call like that because some of the shape of our muscle is small like a mouse and probably the contracting muscles just like a mice moving under the skin (Andrew Charniga, Jr, 2001). Muscle in our body is important if we are active in sport because if our muscle is strong, our ability in sport will be more power and success. Function of our muscle in our body is to produce force and cause motion to

move our body. These muscles are mainly responsible for preservation and changes in posture, locomotion of the organism itself, as well as movement of internal organs.

Normally in weightlifting, there are eight muscles that had been investigated in the experiment. These muscles are three muscles from the back muscle which are deltoideus muscle, latissimus dorsi muscle and trapezius muscle as shown in the **Figure 2.4** below (Xueling Bai, 2008).

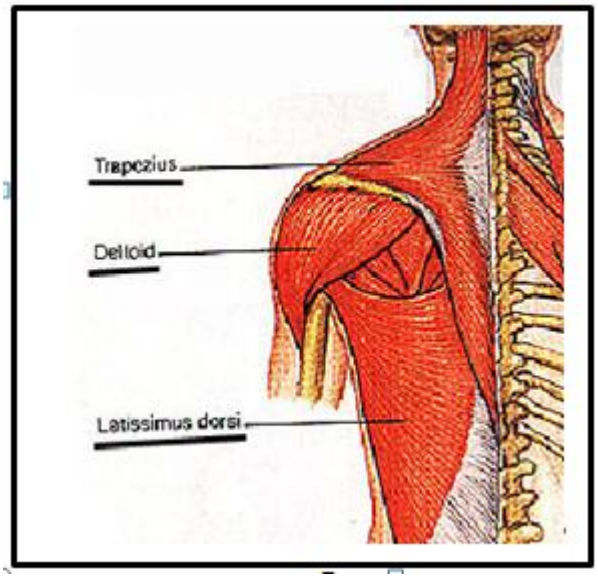


Figure 2.4: Back muscles

Source: Warren, 2012

Another muscle include is at the hand muscles which are triceps brachii muscle and biceps brachii muscle in **Figure 2.5** below:

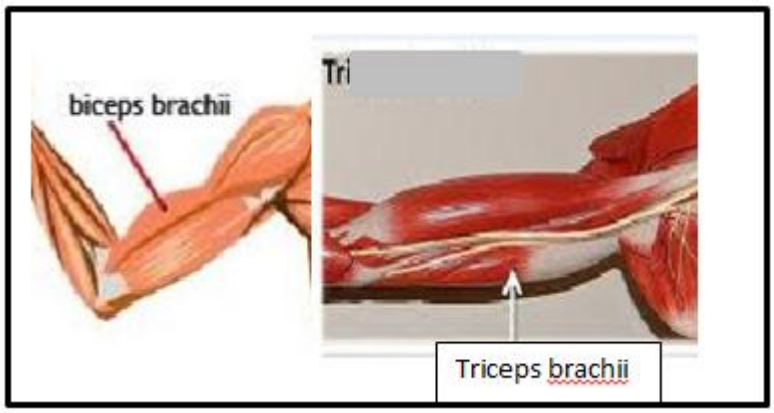


Figure 2.5: Hand muscles

Source: Webstock.com

Leg muscles also important in weightlifting because the starting pull of weightlifting require a power leg muscle to stand up while lifting the barbell. Legs muscles involve are rectus femoris muscle and tibialis interior muscle as shown in **Figure 2.6** below.

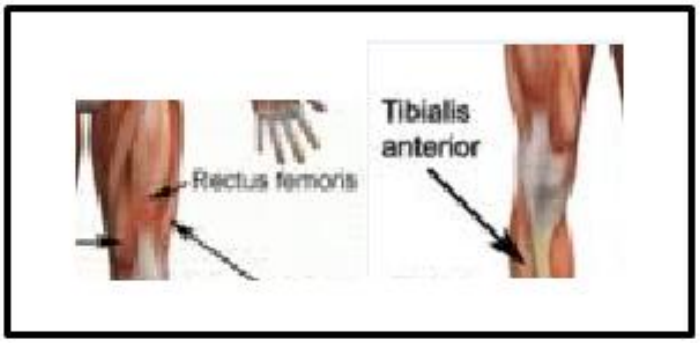


Figure 2.6: Leg muscles

Source: Physio Advisor.com

Another sports also have use many leg muscle as an example water rowing. In this sport, rectus femoris will be use when the rower pushes the canoe (A. Guével, 2011). This leg muscle and hand muscle both play important role during rowing because only both anatomical mainly use while rowing.

Muscle activities had been investigated by using the electromyography (EMG) in the experiment and each muscle gives different result at different phase of weightlifting in the two technique of weightlifting which are snatch and clean-jerk. The EMG is used to calculate the magnitude or the velocity for exerting of a muscle, where exists qualitative but not quantitative relation(Xueling Bai, 2008). **Figure 2.7** shows the example of muscle activities during the snatch technique after the experiment.

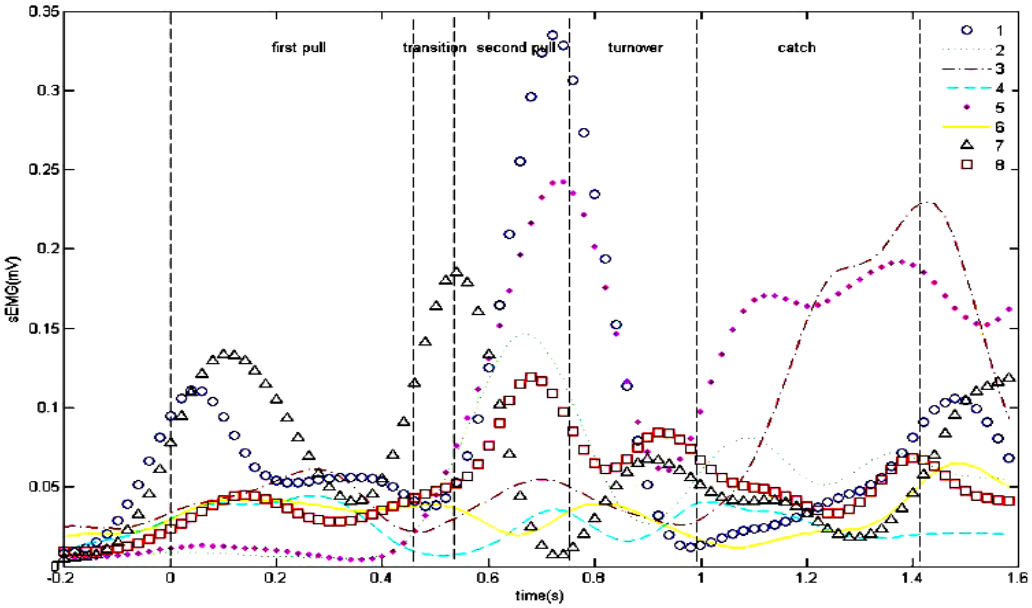


Figure 2.7: Example of 8 muscle activities graph during the snatch technique. 1: M. deltoideus; 2: M. biceps brachii; 3: M. triceps brachii; 4: M. latissimus dorsi; 5: M. trapezius; 6: M. erector spinaeta; 7: M. rectus femoris; and 8: M. tibialis anterior. Source: Xueling Bai, 2008

Another sport also will use EMG to investigate the muscle activity such as the shoulder muscle during playing baseball. Overhead baseball pitch has six phases which are: 1) wind up 2) stride 3) arm cocking 4) arm acceleration 5) arm deceleration 6) follow through (Rafael F. Escamilla, 2009). In this experiment, activities of shoulder muscle increase and decrease at certain phase as shown by the EMG. EMG detects all the movement of muscle during the process and the phases which use more energy on the shoulder muscle will be detected.

2.4 Force distribution

A force is the effect that produces by an object to experience a certain change, either relating to its movement, direction, or geometrical construction. Force also can be described from natural concepts such as a push or pull. A force has both magnitude and direction, making it a vector quantity. Usually, weightlifting will produce force below the lifter because the weight of the barbell and the lifter is

combining to produce a different force at the different phase of lifting technique. Experiment that related to force in weightlifting will use the plantar force as the instrument and it can provide accurate amount of force for each phase in weightlifting technique. Example of force produce is shown in the graph of force versus time below.

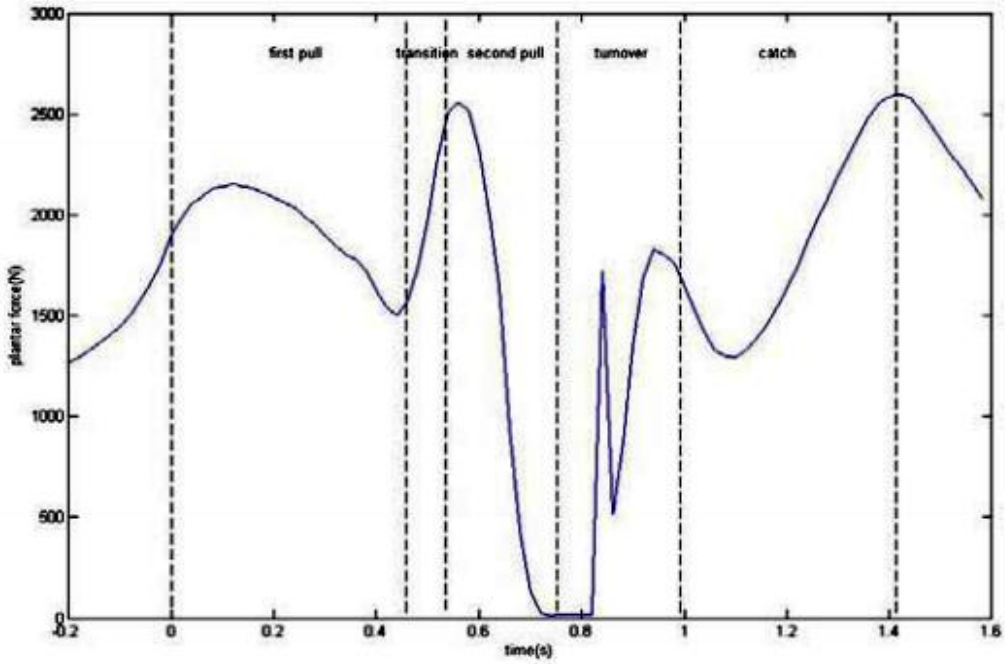


Figure 2.8: Example of force graph result during snatch technique.
Source (Xueling Bai, 2008)

2.5 Injuries in weightlifting

Injuries in sport commonly will occur whether it is bad or not because many factors can produce injuries such wrong technique use, hurt by another player and others. In a research, the overall rate of injury for weight training and weightlifting was 0.0012 per 100 participants (Brian P. Hamill, 1994). This mean a lifter do not have higher rate of having injuries because learning weightlifting require high profile coach. New lifters also learn with light weight until they become familiar with the technique. In this case, injuries happen to weightlifters will be reducing.

From a research, Kotani said that 31% of weightlifters having spondylolysis injuries which mean a disabling spinal degenerative syndrome. From his 26 Olympic weightlifters sample, present of lifters that having spondylolysis is about 7% (Brian P. Hamill, 1994). Other than that, high risk injuries in weightlifting and other sports occur at three anatomical areas which are the shoulder, the knee and low back. Furthermore, weightlifting injuries not only occur at soft tissue muscle but also meniscal injuries and spondylolysis (Gregg Calhoon, 1999).

Clean and jerk technique is the easiest phase where a lifter can get injuries and the result from the research showed that the area of a lifter can get common injury is at the low back where spondylolysis occur (Gregg Calhoon, 1999). Part of the body that also can produce injury to the lifter is at the knee and it is the second critical part compare to the low back. Injuries at knee are mainly the chronic inflammatory problems such as patel-lofemoral osteoarthritis and not the traumatic stability problems from the other sports because in weightlifting, a lifter knee moves in a controlled range of motion (Gregg Calhoon, 1999).

Shoulder of a lifter also has injury that related to the instability which is having extremly lordotic position when pressing motion during clean lift and press lift. Heavy weightlifters are at the highest risk for shoulder injuries such as extreme flexion and abduction (Gregg Calhoon, 1999).

With biomechanical research also injuries can be prevented because with the appropriate technique, less force will be produce at the spine and therefore less the cause of injuries can be avoid (Fortin and Falco, 1997). In the Olympic style of weightlifting, after the second pull when the lifter lift the barbell overhead do not require balancing of large moments but rather tremendous neuromuscular coordination in controlling moments near to the zero(Fortin and Falco, 1997). There are some syndrome and injuries that happen to the lifters such as tired neck syndrome, thoracolumbar syndrome, extremity injuries, sacroiliac joint dysfunction, cardiovascular consequence, spondylolysis, and the most common problem is low back pain (Fortin and Falco, 1997). If this research is followed, all the injuries can be preventing early and all lifters do the correct technique before it getting worst (Fortin and Falco, 1997).

Figure 2.9: Example of spondylolysis injuries.

Source (Pediatric Orthopaedic Department Massachusetts General Hospital)

CHAPTER 3

METHODOLOGY

3.1 Introduction

This methodology is about the setup of the experiment and the process on how this experiment going and the technique of weightlifting. This chapter also include with on how the subject is selected, the equipment that will be use and its function and the flowchart of the experiment. In this chapter also, briefly explanation about the both technique which are snatch technique and clean-jerk technique is being included.

The weightlifting experiment is done only on the plantar force to find the force exerted with the digital camera and electromyography (EMG) also been used. Digital camera is use to capture the picture of lifters in their lifting progress. Then, the result from the experiment will be analyzed for further study.

3.2 Flowchart

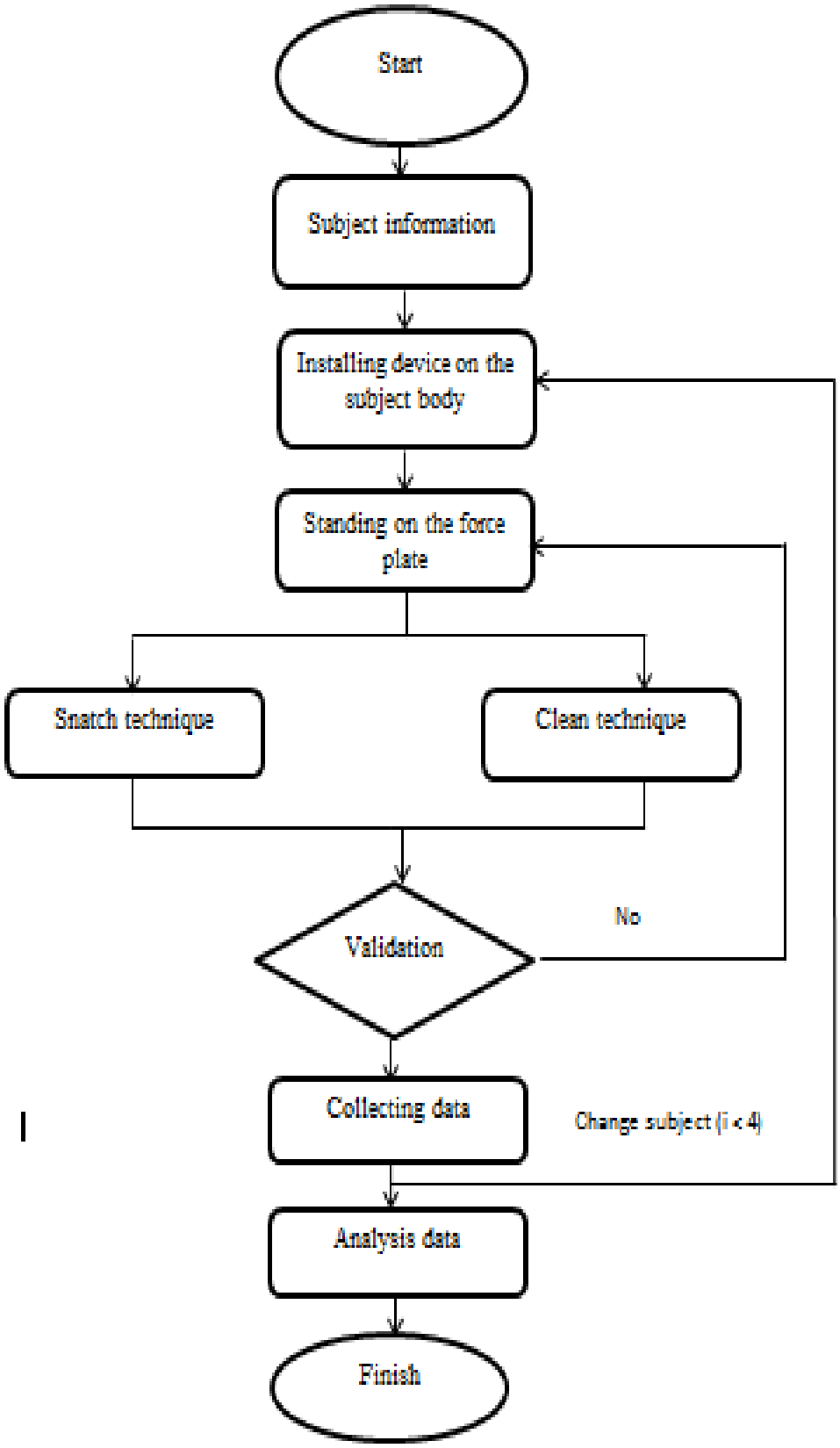


Figure 3.1: Flowchart of experiment

The flowchart showed how the experiment had been done followed all the aspect that need. Subject information in the flowchart refers to the height, weight and experience of a lifter. Different lifter will result to the different technique and skill when lifting the barbell. After getting the information, all devices that need in the experiment must be install to the body which are electromyography (EMG), accelerometer and marker to get the correct data when the lifter lift the barbell.

When finish the installing process, a lifter must stand on the force plate to begin the experiment and perform two technique of weightlifting which are snatch technique and clean technique. After the lifting is done, the result need to going validation process to make sure the result same as in other journal such as the graph in **Figure 2.8**.

If the result is not valid, the lifter must perform the lifting technique again by standing on the force plate until the result is valid and the result of the lifter can be collected. This experiment will continue until the five subjects. After finish the experiment, all the data collected will be analyze to get the proper result and will be compare with the other journal whether this experiment is good or not.

3.3 Participants

In this experiment, four healthy subjects will be chosen with no historical injury create from weightlifting sport. The average of weight and height for the lifters are 80±5 kg and 170±5 cm. One subject for all participants already has the basic knowledge about weightlifting technique which are snatch and clean-jerk technique. Before the experiment, all participants must wearing proper attire and need to warm up to make sure no side injury will occur during the weightlifting experiment.

3.4 Instrumentations

3.4.1 Plantar force

The experiment will be done on plantar force to calculate the force exerted through the lifting phase. This force plate contain sensor in it which allow it to measure accurate force produce from the lifter for every phase. Each subject will perform the technique on the force plate from the start until the end of technique process. The graph produce will be analyzed with the graph from the other research or journal. Each subject will done three try for both technique.

Figure 3.2: Force plate

3.4.2 Digital camera

Digital camera in this experiment is use to capture the movement of lifter's body to study the angle of joint at the hip, knee and ankle at the point with a marker. Before the experiment start, the marker will be attached at shoulder, hip, knee and ankle. The camera will capture each phase of the subject.

Figure 3.3: Digital camera

3.4.3 Electromyography

Electromyography (EMG) signals of two representative muscles also used in this experiment to determine the muscle activities during the weightlifting process. Each muscle that will be analyzed will contain different result for different technique. In this experiment, two EMG will be used because only two parts of muscles that will be analyze which are at the right hand muscle, biceps brachii and left leg muscle, tibialis anterior. The EMG will be attaching to the subject's body by using tape. During the experiment running, EMG must be checked always to make sure part of body that had been attached with EMG not sweats. If this condition happens, EMG will not be detected.

Figure 3.4: EMG at subject's body

3.4.4 Accelerometer

Accelerometer is a device that use to measure acceleration and velocity of a movement. Accelerometer will be put at the side of the barbell to see the acceleration and velocity of the barbell during the lifting technique. Data for the accelerometer will be taken from the start of subject trial until the subject put down the barbell again. Tape is used to attach the accelerometer with the barbell.

3.5 Procedure

Before the experiment run, all the subject need to be ensure that they had do a warm up and wearing a proper attire. After that, a marker will be used to mark point at their hip, knee and ankle for the observation of angle of joint with a digital camera. Marker at the lifter's body will be put at the feet, knee, hip and shoulder. A mark also will be put at the barbell to identify the barbell trajectory. EMG also needs to be stick to a lifter before the experiment to the muscle that want to observe which are trapeziuses, triceps brachii, and rectus femoris muscle. The accelerometer will be put

at the barbell to estimate the velocity of the barbell lift. Height and weight for each subject also need to record to make sure the result can be differentiating easily.

After all the setup is complete, first subject will start the experiment with 30kg load on a force plate by using the snatch technique. The load then will be lift by the first lifter in 3 attempts for both techniques which are snatch technique and clean technique. The experiment continues with next subject until all five subjects follow the sequence made by the first subject.

When all the attempts for both techniques are done, the data then will record and the result for each technique will be analyzed. The result after the analysis will be compare between the two techniques and with another journal. Each result for force, angle of joint and muscle activities is different for each technique.

Brief explanation about the snatch technique and clean-jerk technique is shown. The explanation is about the phase occurring during each technique which there are a little different for clean technique and snatch technique.

3.5.1 Snatch technique

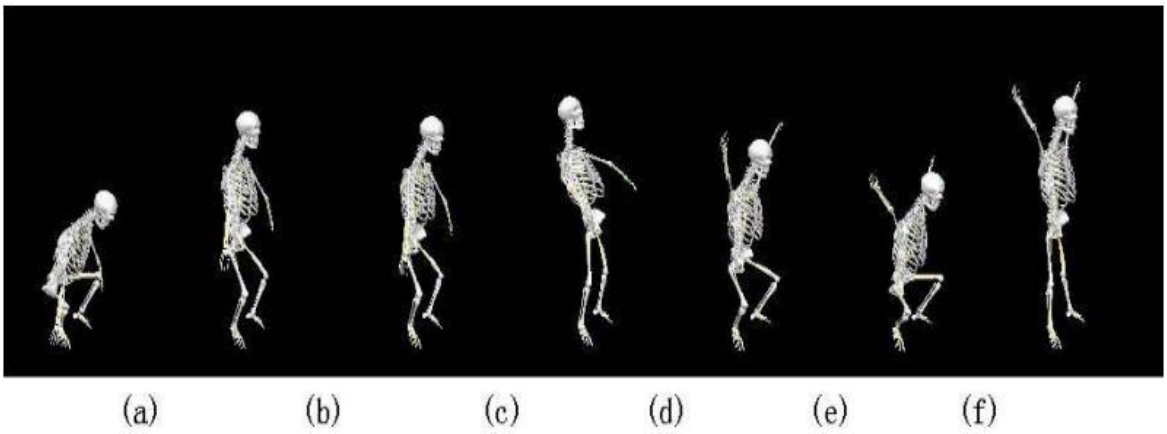


Figure 3.5: Phase of snatch technique

Source: Xueling Bai 2008

Snatch technique can be divided into 6 phase:

(a) The first pull is the process where a lifter must lift the barbell until the first maximum right-knee extension. (Xueling Bai 2008)

(b) This is the transition from first to the second pull is the lifter pull from the first maximum right knee extension until the first maximum right knee flexion (Xueling Bai 2008). The velocity of lifter is started to increase during this phase.

(c) Second pull of the phase is from the first maximum right knee flexion until the second maximum extension of the right knee(Xueling Bai 2008) and the barbell can be pulled by the lifter as high as he can.

(d) Turnover under a barbell is from the second maximum extension of the right knee until the achievement of the maximum height of the barbell (Xueling Bai 2008). Maximum velocity will be done by the lifter as he tries to lift the barbell upwards upon his head.

(e) The catching phase is the achievement of the maximum height of the barbell until stabilization in the catch position with the barbell overhead and during this time also the lifter is flipping the weight so it moves in an arc directly overhead to locked arms.

(f) Rise from the squat position is the final phase after the lifter is secure from the previous phase and the snatch technique is complete (Xueling Bai 2008).

3.5.2 Clean-jerk technique

i) Clean technique

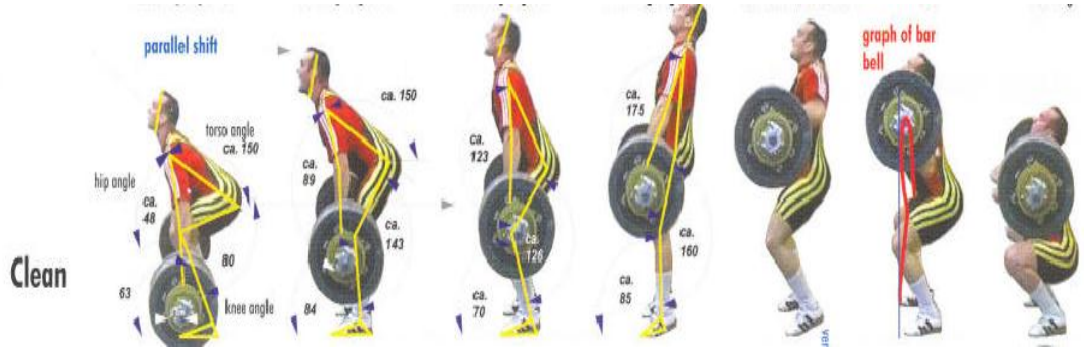


Figure 3.6: Clean technique phase

Source: Martin Zawieja-Koch 2005

This clean technique has 6 phases according to the figure 3.4 above:

(a) The first picture is a lift-off phase where the lifter is in squatting position and their hand are positioned approximately a thumb's distance from hips using what is known as a hook grip. The hip of a lifter is higher than the knee, their arm is straight and the head is slightly raised position with their back is neutral to slightly hyper extended.

(b) Second phase of clean is when the barbell is at the lifter's knee. This is the point where the velocity is starting and the movement of the bar to the upward is performed by the extension of lifter's knee.

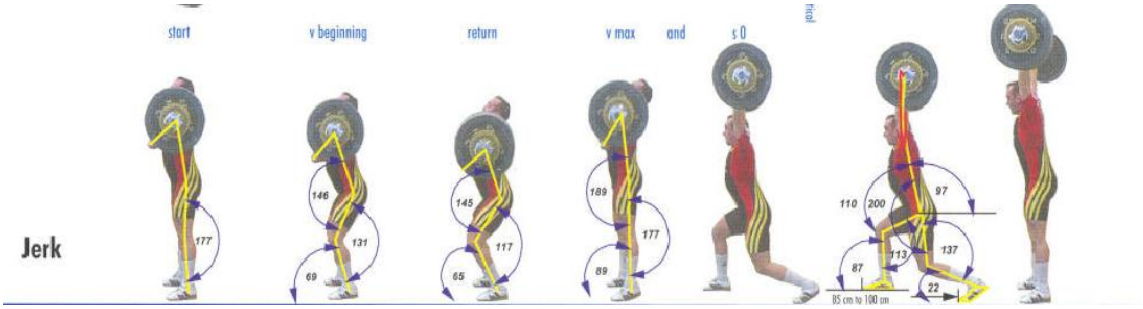
(c) Next is the position when the barbell is at the mid-thigh of a lifter which both knees is bending forward and this is actually called "double-knee bend" (DKB). It is largely a result of the backward-upward movement of the trunk during the transition.

(d) Second pull is the phase where the velocity of a lifter to lift the barbell is at maximum. The lifter's hip will move into extension and the shoulder will move into shrug. The lifter also will use more energy at this phase because the barbell needs to lift upward.

(e) When the barbell is at the chest of a lifter, it is the time a lifter needs to rearrange the position of the barbell to make sure the catching phase will succeed.

(f) The last phase of the clean technique, referring to two last picture in Figure 2, it is called the catching phase. Unlike snatch technique, catching phase in clean technique only at the shoulder of a lifter and in a squat position. From this position, it will continue into the jerk technique when the lifter is rising from the squat position.

(ii) Jerk technique



(a) (b) (c) (d) (e) (f)

Figure 3.7: Jerk technique phase

There are 6 phase of jerk technique:

(a) The first phase is where the lifter bending their knee in order to get the power to make the jump.

(b) This phase showed that the lifter is ready in his position to make a powerful jump and in a stable position.

(c) During this phase, the lifter will straighten their knees in other to drive the barbell upwards. At this time, the velocity of a lifter will be at the maximum as the strength of lifter also increases.

(d) The barbell will be pull upwards with lifter's arm at this phase and the lifter will done a split jerk after that is normally used by all the weightlifter. One of the legs is move forward and the other leg is move backward.

(e) At this phase the lifter must hold the barbell overhead, keep the arms locked, and move the legs directly underneath the trunk so that the entire body lines

up in a single plane. The lifter need to hold the barbell for a few second before the next phase.

(f) Last phase of this technique also can be called a push jerk which the lifter keeps both legs in position, bends the knees and jumps into lockout position. Then the jerk technique is complete.

CHAPTER 4

RESULT AND DISCUSSION

In the experiment, both clean and snatch technique is divided into six phase. Both phase have a little different after the experiment is done. Results and analysis is divided into four main categories which are the force distribution produce by lifter, muscle activities on the lifter's body, angle of joint from the lifter during the lifting and barbell kinematics.

4.1 Force distribution

Force distribution on the lifter is calculated from the force plate and the time capture for the data analysis is two second for each technique. Time of the data is analyzed from the video that had been recorded. All subjects had almost the same pattern of graph and subject 1 is chosen as the distribution force is better compare with another subjects.

4.1.1 Snatch technique

Force use in this analysis is the resultant force. Resultant force is the amount of force at three axes which are axis x, y and z. Amount of resultant force is taken because the movement of subject is not only at one direction and the subject also not very stable while lifting the load. Weight for the subject is 82.3 kg and the barbell load is 20 kg. The amount of subject's weight and barbell weight is added with the amount of resultant force which gives result for the total force distribution produce by the subject.

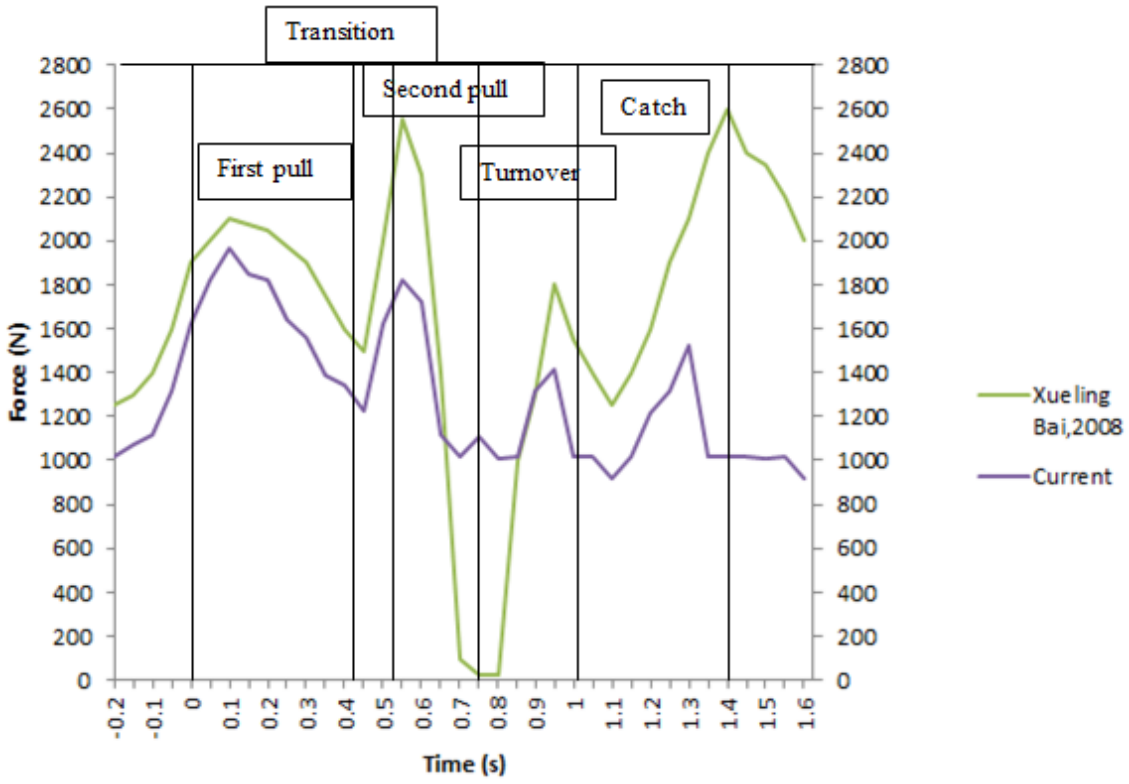


Figure 4.1: Comparison of force distribution graph between Xueling Bai and current subject from experiment in snatch technique

Figure 4.1 shows the comparison between professional athlete from the journal and subject one from the experiment. During the first pull, the subject achieves a maximum force because the subject is on his first time lifting the loads of 20kg compare to the professional athlete who always training to lift a heavy load of a barbell. Then, force is decrease when the lifter is on the transition from the first pull

to the second pull phase. At the transition phase, both subject 1 and professional athlete have an increasing force. This is happen because both lifter use more force on the leg to push downwards as their hand will pull the barbell upwards.

Professional athlete achieves the second highest force in snatch technique during the second pull phase. Distribution force for the subject also increases during second pull phase same as professional athlete. During the change from second pull phase to the turnover phase, professional athlete has a minimum distribution force which is nearly to the zero. This value occurs when the professional lifter only tiptoed while turning the barbell over. Meanwhile, subject 1 is not in tiptoed condition during the change from second pull to turnover phase which made the value of force is not the lowest in the experiment.

In the turnover phase, force produce by professional athlete is highly increased before going down again in catching phase. Subject in the experiment shows same pattern of graph in turnover phase and also going down in catching phase. Professional athlete achieves his maximum distribution force at the end of catching phase because the load support is bigger and the movement of force is going down. Subject in the experiment also has an increase in the catching phase but not at the end of the phase. This happen because subject catches the barbell in a short time and the subject is not stand properly during the turnover phase. When the subject is not stand properly at the turnover phase, his body posture will bend a little which result in the shorter time of lifting process.

Table 4.1: Maximum and minimum force produce by the subject in snatch technique

	Force (N)	**Time (s)**
Maximum	1970.86	0.1
Minimum	1018.87	1.4

Table 4.1 shows the maximum and minimum force for subject 1 during snatch technique. Maximum force is 1970.86 N at 0.1 seconds during first pull phase while the minimum force is 1018.87 N occur at the end of the lifting at 1.4 seconds during catching phase. Data from the Table 4.1 is taken from the graph constructed in Figure 4.1.

4.1.2 Clean technique

The amount of resultant force in this technique also had been calculated from the amount of resultant force such as in snatch technique. Three early phases in clean technique is same as in snatch technique and it can be compare with the journal. The remaining phase in this clean technique cannot be compare because the position of barbell is different. For clean technique, the subject will lift the barbell until it reaches at the shoulder.

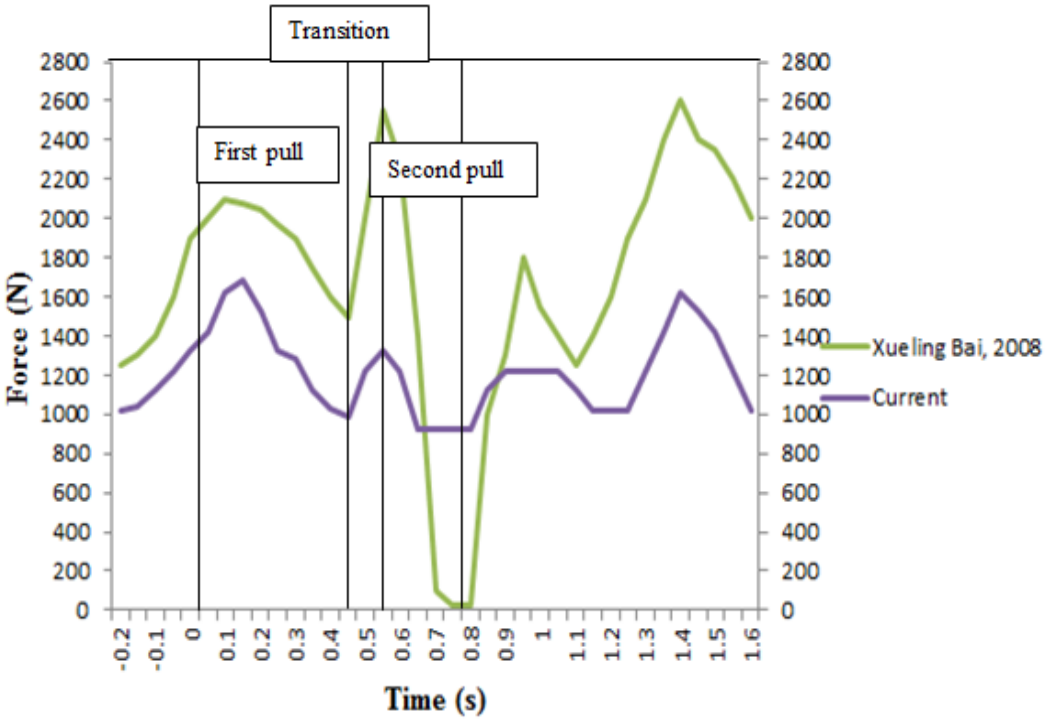


Figure 4.2: Comparison of force distribution graph between Xueling Bai and current subject from experiment in clean technique

Figure 4.2 above shows about the force pattern produce by the subject during the clean technique experiment and the comparison of graph between subject and professional athlete. During the first pull of clean technique, subject reach the maximum force same as in snatch technique experiment because subject has a lack of practice. In transition phase, the force produces by the subject increases as it reach the second pull same as professional athlete but in this phase, force produce by the professional athlete is higher than its first pull phase. During the second pull phase and turnover phase, force is decrease or both lifters.

Subject one has lower force in this experiment because the load use and the subject's weight are lighter compared to the professional athlete in the journal. There are many different occur for both comparison because subject use in the experiment is only a beginner athlete. Subject also needs a lot of practice to increase the performance. The position of barbell also can influence for the force distribution produce. When the position of barbell is higher, the center of gravity for the subject become higher, then the force produce is less compare with the lower position of barbell which have the lower center of gravity.

Table 4.2: Maximum and minimum force produce by the subject in clean technique

	Force (N)	**Time (s)**
Maximum	1681.719	0.15
Minimum	921.413	0.75

In this technique, the barbell weight remains constant which is 20kg. From Table 4.2, the maximum force for this technique is 1681.719N at 0.15 seconds during first pull phase. The maximum forces occur at the early phase for this experiment same as snatch technique experiment before. Meanwhile, the minimum force in this experiment is 921.413N at 0.75 seconds during second pull phase. Time taken in this experiment also analyzed based on the video capture during the experiment.

4.2 Muscle activity

Muscle activity in this experiment is determined by using the electromyography (EMG) and it can show the changing of velocity and the magnitude of muscle. Muscle that had been analyzed in the experiment is right biceps brachii and left tibialis anterior. Both muscles are important to the lifter in completing the technique. In this analysis, subject 1 had been selected as the subject in a healthy condition and has experience on performing the technique of weightlifting. Result for muscle activity from subject 1 also is almost same with professional athlete and both muscles is significant with each other's.

4.2.1 Biceps brachii muscle

This muscle plays important role when a lifter needs to lift barbell upward and balancing the position of the barbell. Result from the experiment is compared with professional athlete to see the activity of muscle.

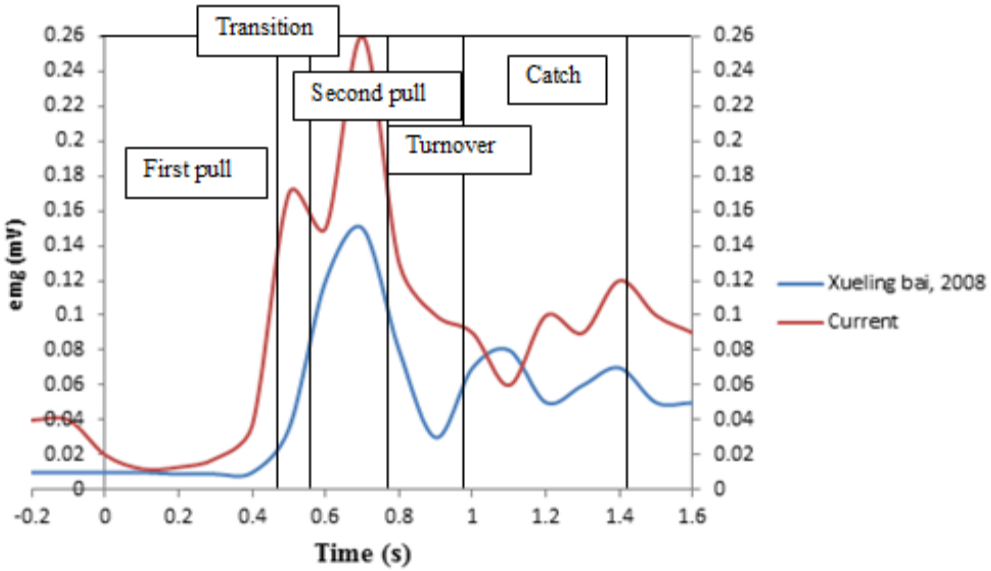


Figure 4.3: Comparison of biceps muscle activity in snatch technique between Xueling Bai, 2008 and current experiment

Figure 4.3 shows the comparison of graph for biceps muscle activity in snatch technique between professional athlete and subject 1. The activity of biceps muscle is at the lowest during first pull phase for both professional athlete and subject because biceps muscle is only function as a support to another muscle. Biceps muscle in professional athlete graph is increasing during transition phase because this muscle is use a lot to make the barbell going upward.

Subject from the experiment has different activity compare to the professional athlete. This happens because subject has stop for a moment before going into second pull phase which make the muscle activity has a little drop. Biceps muscle activity is at the highest during second pull phase for professional athlete and subject because biceps muscle is important to lift the barbell upward. Subject has higher value compare to professional athlete as subject do not receive continuous training in lifting heavy load.

During turnover phase, professional athlete has a decreasing of activity because biceps muscle is relaxing in this phase before the activity is increase in catching phase. Subject has a late decrease of activity in turn over phase because subject use all his hand muscle to stable the barbell. Biceps activity is various during catching phase for both professional athlete and subject because in this phase, lifter need to control and balance the barbell.

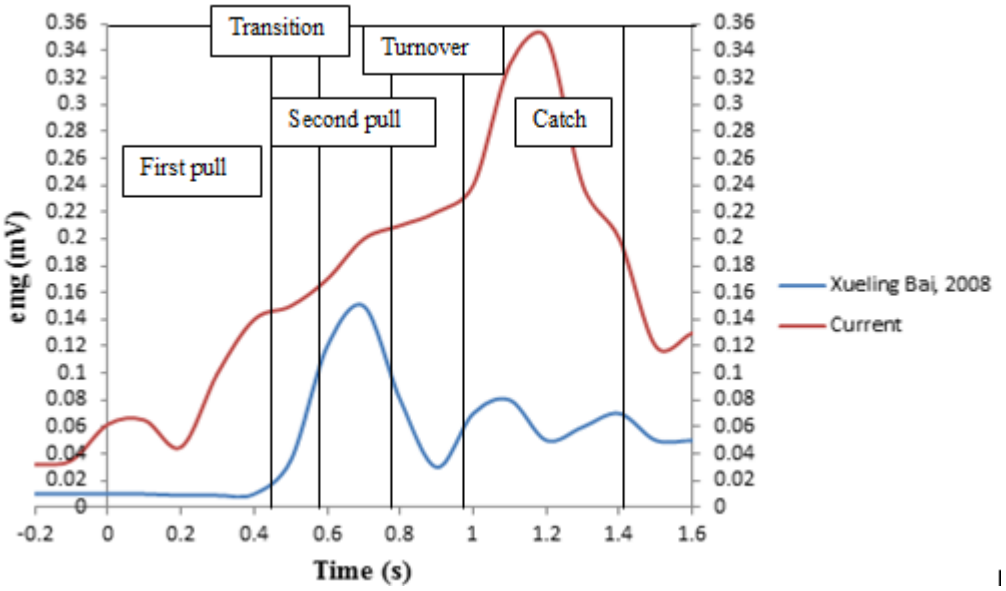


Figure 4.4: Comparison of biceps muscle activity in clean technique between Xueling Bai, 2008 and current experiment

Meanwhile Figure 4.4 is the comparison of biceps muscle activity in clean technique for professional athlete and subject from the experiment. In this clean technique; subject in the experiment will be compare in first three phases only as the graph for professional athlete is done in snatch technique. First three phases in clean technique is same with first three phases in snatch technique. During the experiment, subject has a little increase and decrease during the first pull compare to the professional athlete because subject's muscle is having a little fatigue after many tries. During the transition phase, muscle activity is increasing same as happen to the professional athlete.

In clean technique, biceps muscle activity for subject is increasing on the second pull phase but not having a maximum value as professional athlete. Muscle activity for subject is still increase during the turnover phase because the subject need to control the barbell to make sure the barbell is not far from his shoulder in clean technique.

Highest muscle activity achieved in catching phase because the movement of biceps muscle is compressed due to flexion movement of subject's hand. The muscle activity is then decreasing in squat position because the load of barbell is supported by the shoulder.

Table 4.3: Maximum and minimum value for biceps muscle activity in the experiment

Technique	EMG (mV)	
	Maximum	Minimum
Snatch	0.26	0.12
Clean	0.35	0.032

Table 4.3 shows the maximum and minimum value for biceps muscle activity from the experiment. The value is taken from the graph in Figure 4.3 and Figure 4.4 that had been normalized. The maximum value of biceps muscle activity in snatch technique is 0.26 mv during second pull phase while the maximum value in clean technique is 0.35 during catching phase. The value is different because in clean technique, biceps muscle is compressed more compare in snatch technique.

Minimum value for this muscle activity in the snatch technique is 0.12 mV during first pull phase while in clean technique, the value is 0.032 mV during first pull phase. During this phase, biceps muscle in both techniques is on relaxing condition because this muscle is less involve when the barbell is still lower on the ground. For overall discussion from this experiment biceps muscle is important when the subject need to pull the barbell upwards and stop the barbell from moving.

4.2.2 Tibialis anterior muscle

Tibialis anterior muscle is located at the leg of human body. This muscle is important in balancing the body and support the weight of the body. Tibialis muscle activity is observed during the experiment and the result is compare with professional athlete.

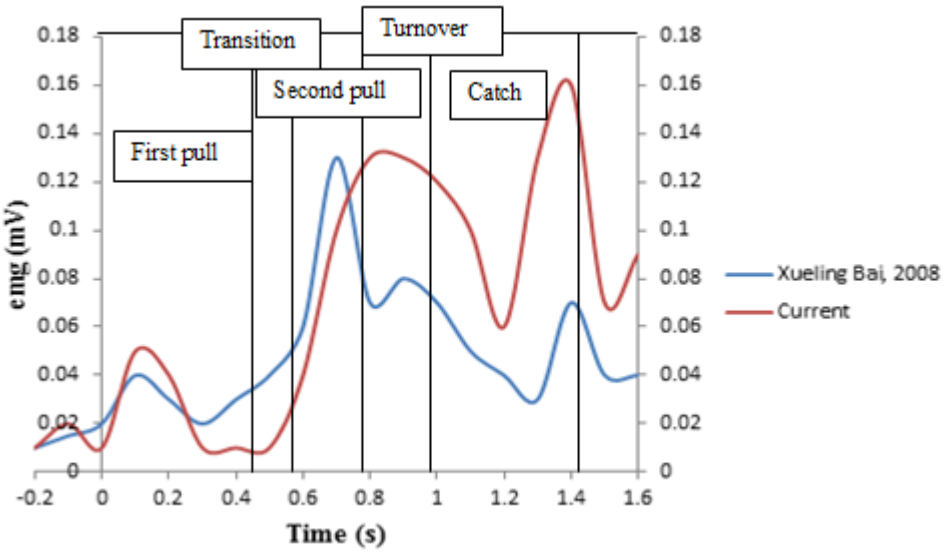


Figure 4.5: Comparison of tibialis muscle activity in snatch technique between Xueling Bai, 2008 and current experiment

Figure 4.5 shows the comparison of tibialis muscle activity in snatch technique between professional athlete and subject from experiment. During fist pull phase the pattern of graph between professional athlete and subject is almost same where the activity of muscle has a little increase. This happen because leg of the subject and professional athlete is push downwards to help the body lift up the barbell and the muscle is said to be compress at this phase.

During transition phase, activity muscle for professional athlete is increasing constantly but muscle activity for the subject has a late increase in transition phase. Muscle activity for professional athlete is increasing during second pull phase and achieved the maximum value. This is happen because the lifter's leg is pushing downward hardly to lift the barbell upwards. Muscle activity for subject also increase during second pull phase but it reach maximum value at the turnover phase because technique perform by the subject is not exactly correct. At the turnover phase, muscle activity for the subject also must decrease as professional athlete.

In catching phase, the muscle activity is decrease for professional athlete and subject. It happens because tibialis muscle is not compressed or extends at the early catching phase. At the end of catching phase, professional athlete and subject have increases their muscle activity because the muscle is extending to balance the body

of the lifters during squat position. At this phase, subject has reached it maximum value of muscle activity.

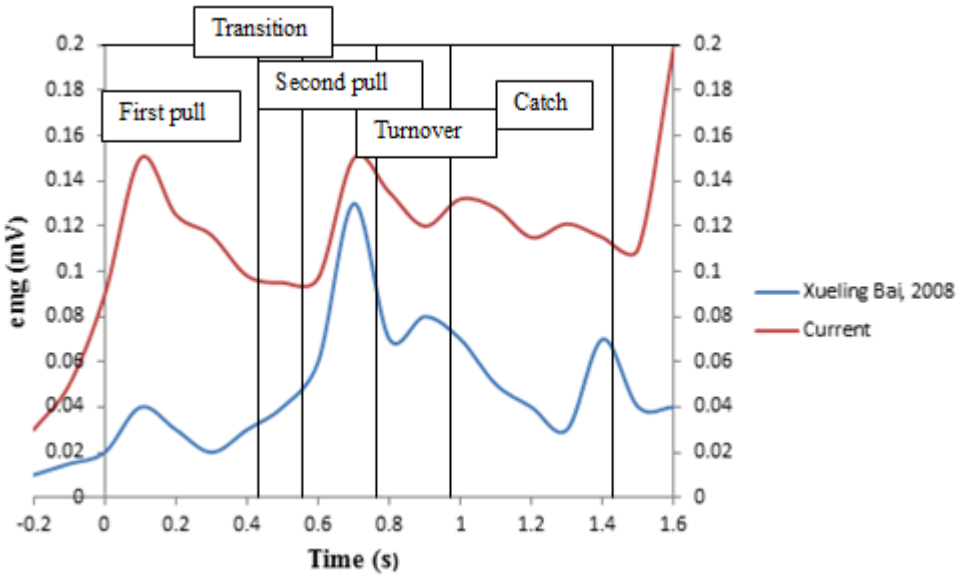


Figure 4.6: Comparison of tibialis muscle activity on clean technique between Xueling Bai, 2008 and current experiment

Figure 4.6 shows the comparison of tibialis muscle activity in clean technique between professional athlete and subject from experiment. In this technique, only first three phases of graph compare with the professional athlete because the graph produce from professional athlete is in snatch technique. For clean technique, tibialis muscle is higher during first pull phase of the subject. It is different compare to the professional athlete where it only increases a little during this phase. Subject has higher increase of muscle activity because his muscle is fatigue after several tries during snatch technique.

During the transition phase, muscle activity of the subject is not increase compare to the professional athlete. This happens because technique perform by the subject is not good enough. In this technique, the activity of muscle does not have a lot different with snatch technique as it also increasing during the second pull phase. During this phase, the tibialis muscle is compressed to make sure lifter's body is in balance position while making the barbell upwards.

Subject's muscle activity is decrease during turnover phase because tibialis muscle does not involve in this part but it increase when it reach the catching phase. This muscle activity is various at the catching phase where the body of a subject need to be balance while holding the barbell.

Table 4.4: Maximum and minimum value for tibialis muscle activity in the experiment

Technique	**EMG (mV)**	
	Maximum	Minimum
Snatch	0.16	0.01
Clean	0.15	0.03

Table 4.4 shows the maximum and minimum value for tibialis anterior muscle activity from the experiment. The value is taken from the graph in Figure 4.5 and Figure 4.6 that had been normalized. The maximum value of tibialis muscle activity in clean technique is 0.16 mv during turnover phase while the maximum value in clean technique is 0.15 during first pull and second pull phase. Maximum value of muscle activity in snatch technique higher compare to the clean technique because the tibialis muscle is compress more in order to lift the barbell higher.

Minimum value for this muscle activity in the snatch technique is 0.01 mV during first pull phase while in clean technique, the value is 0.03 mV during first pull phase. Value of muscle activity in clean technique is higher than snatch technique because subject is fatigue after several tries. A good technique with less muscle activity for certain phase can save the subject energy can increase the performance.

4.2.3 Statistical data

One way analysis of variance (ANOVA) is did from the result in the experiment to get the statistical data. This analysis is use for a comparison of means between the samples. First analysis is done for biceps brachii muscle from both techniques. Second analysis is for tibialis muscle from both techniques.

Table 4.5: Statistical data for biceps muscle

	Mean square	**F value**	**P value**
Overall ANOVA	6.99019E-4	0.05185	1
Homogeneity of variance test	0.01331	2.14258	0

Table 4.5 is the statistical data for biceps muscle from the experiment. P value or probability value set in this analysis is 0.05. For overall ANOVA data, the p value for biceps is 1 which is higher than 0.05. Hypothesis made for this statistical analysis is when p value is below or equal to 0.05, the mean of biceps muscle for both techniques are not significantly different. In this case, when p value is more than 0.05 the mean of biceps muscle is significantly different for both techniques. From the homogeneity of variance test, p value shown is 0 which is lower than 0.05. Meanwhile, hypothesis for variance test is different from the overall ANOVA hypothesis. If the p value is below or equal to 0.05, the variance is significantly different. It means that, the variance of biceps muscle for both techniques also significantly different.

Table 4.6: Statistical data for tibialis muscle

	Mean square	**F value**	**P value**
Overall ANOVA	0.00128	2.50226	1.50302E-12
Homogeneity of variance test	4.46314E-4	2.38171	2.40409E-11

Table 4.6 is the statistical data for tibialis muscle from the experiment. The hypothesis set for this analysis is, when value of p is below or equal to 0.05, the mean of tibialis muscle for both techniques are significantly different. Same goes to the hypothesis for the variance test, when it is lower than or equal to 0.05, the variance is significantly different. P value from the table shows that the value is below 0.05 which indicate that the tibialis muscle mean follow the hypothesis. Variance test analysis from the table also shows that the tibialis muscle variance is significantly different for both techniques.

4.3 Angle of joint

From the experiment, the angle of the lifter only measured at the three phase in the beginning because the next phase of the lifter or the next movement of the lifter cover the marker at the shoulder's lifter, so the angle cannot be calculated. From this angle also, it can show whether the movement part of the body is in flexion or extension. The first three phases are the first pull, transition from first to the second pull and the second pull. These phases are important to the lifter because all these early phase will be resulted to the success of a lifter in lifting the barbell.

4.3.1 Snatch Technique

The result of the subjects on this technique is compared with the other journal result. All the subjects are the beginner's athlete in weightlifting. The angle is measured by using screen protector software. Result for all subjects in the experiment is shown in appendix. From all the subjects, subject 1 had been selected as their result in the experiment is almost the same with the result of professional athlete from the journal.

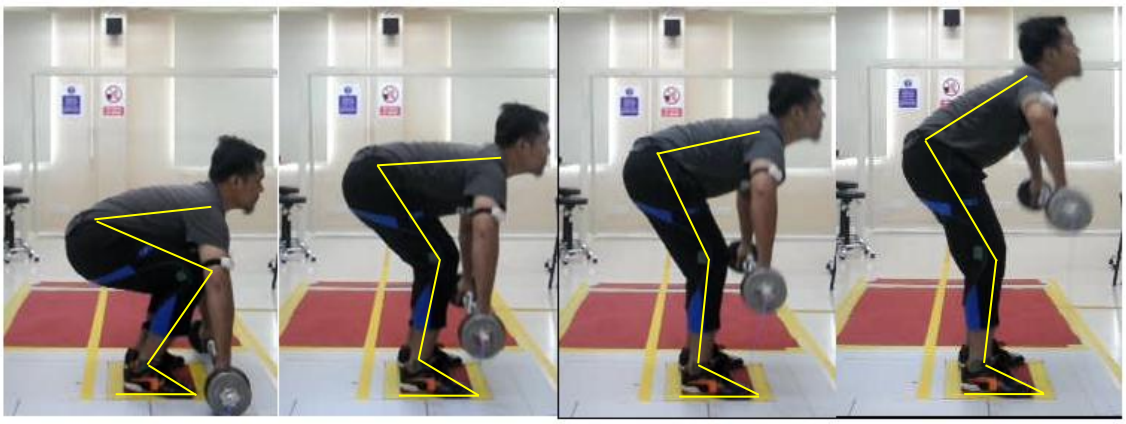
Table 4.7: Comparison of angle of joint between subject and professional athlete

Joints	Phase	Professional angle (°)	Subject 1 angle (°)	Error (%)
Ankle	1	**65**	52	20
	2	**88**	78	11.36
	3	**70**	79	-12.86
	4	**87**	81	6.89
Knee	1	**75**	78	-4
	2	**143**	129	9.79
	3	**130**	141	-8.46
	4	**170**	140	17.65
Hip	1	**47**	38	19.15
	2	**90**	61	32.22
	3	**125**	79	36.8
	4	**190**	93	51.05

Source: Martin Zawieja-Koch 2005

Table 4.5 shows the comparison of angle of joint between subject and professional athlete. Large errors occur at hip joint as shown at the Table because the subject body is too bent while lifting the barbell especially during phase two and phase four. Meanwhile, knee joint shows the smallest errors occur because the movement of knee is limited. Negative sign in the Table shows that, the angle produce by subject is exceeding the angle produce by professional athlete.

There are a lot of factor that can be relate with the differentiation of angle of joint between subject and professional athlete. One of the reason is the subject is lack of training on weightlifting technique which can make their lift is inconsistent. In order to get good technique and good angle of joint, subject need to practice more with consistent weight.



1 2 3 4

Figure 4.7: Early phase in snatch technique from experiment

Figure 4.1 shows that the angle measure from the line that had been joining from a marker to another.

4.3.2 Clean technique

Angle of joint for this technique is different from the snatch technique before because the style performs by the lifter is different.

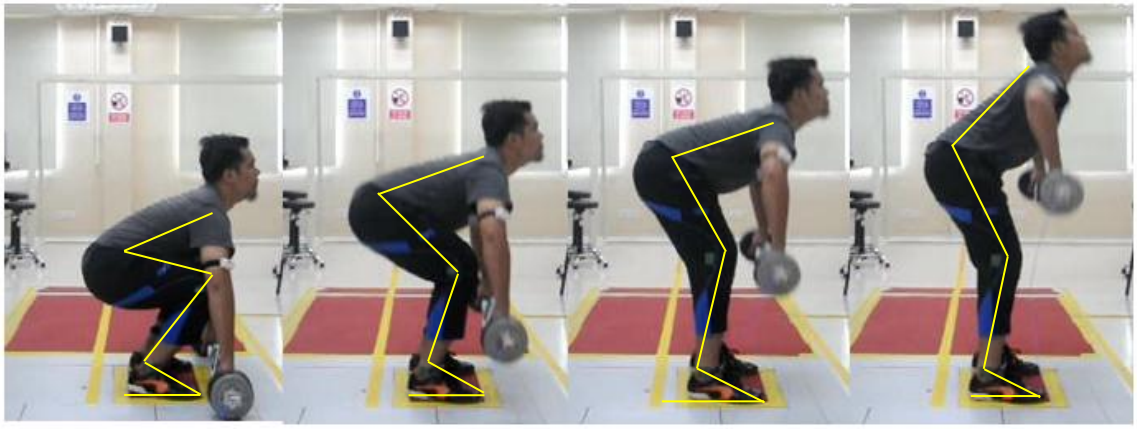
From the result and analysis that had been done, subject 1 had a good result compare to the other subjects as the knowledge between the subjects is different where subject 1 has a basic knowledge about weightlifting technique. Table 4.10 shows the comparison angle of joint between subject 1 and professional athlete.

Table 4.8: Comparison angle of joint between subject and professional athlete

Joints	Phase	Professional angle (°)	Subject 1 angle (°)	Error (%)
Ankle	1	**63**	58	7.94
	2	**84**	75	10.71
	3	**70**	79	-12.86
	4	**85**	81	4.71
Knee	1	**80**	73	8.75
	2	**143**	115	19.58
	3	**126**	130	-3.17
	4	**160**	141	11.87
Hip	1	**48**	41	14.58
	2	**89**	60	32.58
	3	**123**	80	34.96
	4	**175**	105	40

Source: Martin Zawieja-Koch 2005

Large errors in Table 4.10 occur at hip joint same as in the snatch technique experiment. During this technique, the subject still bends a lot because the barbell load is heavy for a beginner's athlete. During this technique, the lowest error can be seen at the ankle joint as the subject improves his lifting after several trials.



1 2 3 4

Figure 4.8: Early phase in clean technique from experiment

As conclusion, the angle of joint is different because the technique applied between the beginner lifter and the professional lifter is different and professional athlete had been train and practice for a long time. From the angle of joint also, it can prove that a correct angle made the lifter performance increase and the lifter can lift the barbell easily compare to the lifter which has very different angle.

4.4 Barbell kinematics

Barbell kinematics also an important analysis on the weightlifting to see how powerful is the lifter during lifting the barbell. In this experiment, both velocity and acceleration of the barbell is analyzed because both data is important in assessing lifting technique. Figure 4.6 and 4.7 shows the comparison between the graph of acceleration and velocity from the experiment and graph from the journal. Based on the result and the research, barbell is rising continuously in velocity and large acceleration during the first pull phase, transition phase and second pull phase. For the barbell kinematics analysis, subject 4 had been chosen because the graph result of the barbell is almost the same with the professional athlete compare to the other subjects.

4.4.1 Acceleration

Acceleration from the experiment is the resultant acceleration by adding the axes in fx, fy and fz. The resultant acceleration need to find because barbell holds by the subject is not in a constant movement.

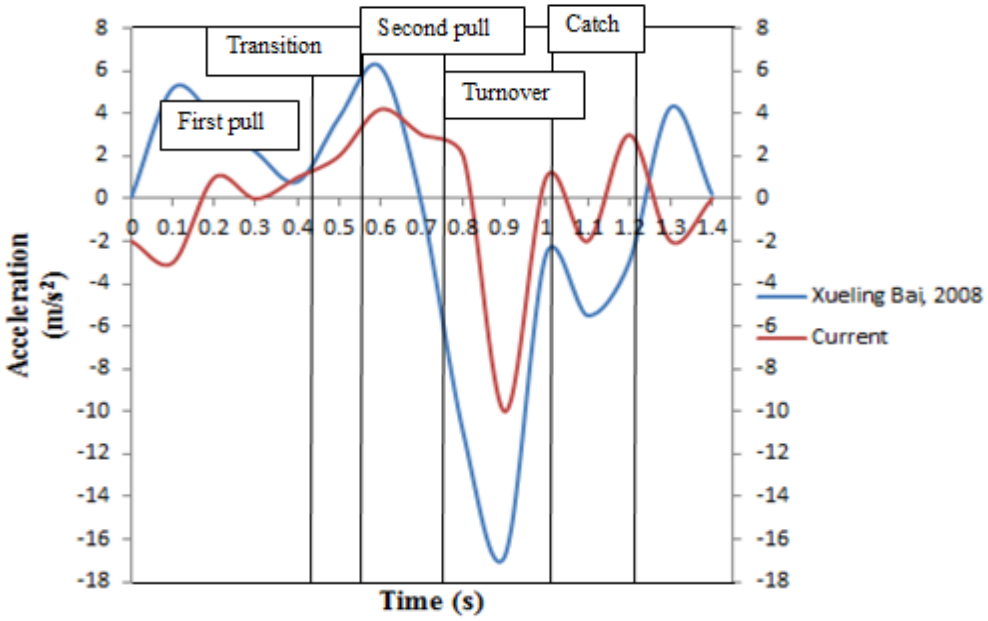


Figure 4.9: Comparison of barbell acceleration graph between current subject from experiment and Xueling Bai.

Figure 4.6 shows the comparison between professional athlete and subject in the experiment. During the first pull, barbell acceleration for professional athlete increase at the starting while the subject has a little decrease in barbell acceleration. The acceleration has a little drop in subject's graph because subject is not familiar with the technique of weightlifting. Acceleration for professional athlete decrease at 0.4 seconds before enters the transition phase and increase constantly in transition phase. Meanwhile, subject has an early decrease at 0.3 seconds because the subject cannot withstand the load of the barbell.

Both professional athlete and subject have maximum acceleration of the barbell during second pull phase. At this phase, the barbell achieves high acceleration because the subject and professional athlete trying to pull up the barbell upwards in the shortest time. Meanwhile, barbell acceleration is drop drastically during the turnover phase as the barbell is stop moving and the velocity is change in direction. At this phase, subject shows positive result because the pattern of graph is equal to the professional athlete's graph.

The acceleration of barbell increase again as it reaches the catching phase because the barbell is moves in a fast velocity. During this phase, pattern of graph produce by the subject is equal to the professional athlete. Time taken for this analysis also refers to the video capture during the experiment.

Highest acceleration in the experiment occurs at the second pull phase from the graph in Figure 4.6 and has a value at 4.2 m/s^2. From the experiment, the lowest acceleration is -3 m/s^2 during the first pull phase. Table 4.6 shows the maximum and minimum acceleration with time during the experiment.

Table 4.9: Maximum and minimum acceleration during the experiment

	Acceleration (m/s^2)	**Time (s)**
Maximum	4.2	0.6
Minimum	-3	0.1

4.4.2 Velocity

Result for the velocity of barbell also taken from the subject 4 to make the result and analysis synchronized. Resultant velocity also needs to be calculated in this analysis to ensure the amount of velocity is valid.

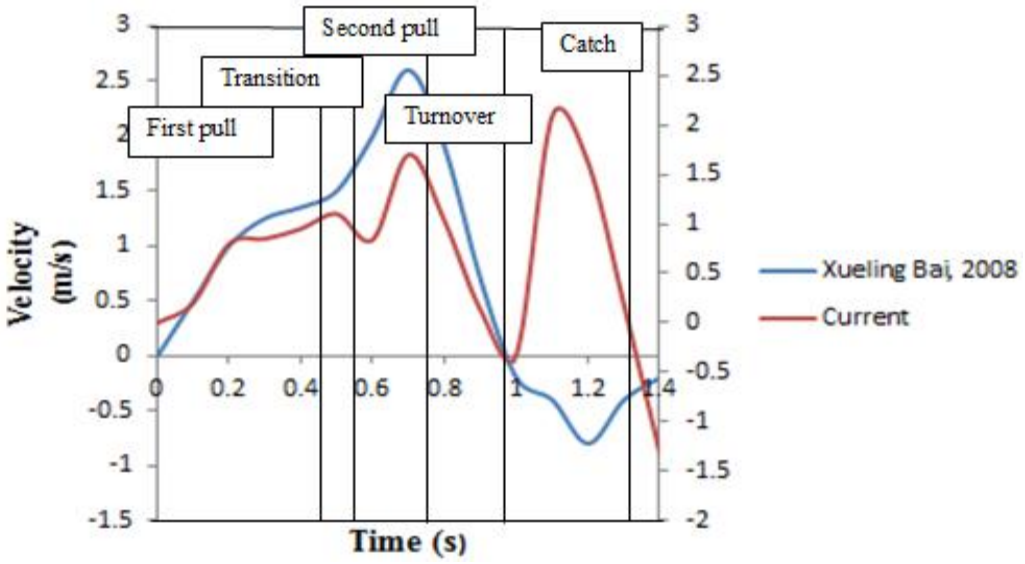


Figure 4.10: Comparison of barbell velocity graph between current subject from experiment and Xueling Bai.

Figure 4.7 shows the comparison of the graph between the subject and professional athlete. There is not much different at the first pull phase of the graph where the barbell velocity is starting to increase. Different can be seen at the transition phase where the barbell velocity is having a little drop compare to the professional athlete. The situation happens because subject gathers the energy before trying to pull up the barbell.

Barbell velocity for both subject and professional athlete increases at the second pull phase. Velocity of barbell increase at this phase because the barbell need to pull up faster to make sure less energy use and get a stable condition. The velocity then decrease constantly during turnover phase for subject and professional athlete.

In catching phase, barbell velocity for professional athlete is decreasing as the barbell stop moving. Meanwhile, subject in the experiment has achieved the maximum barbell velocity during this phase. It occur because barbell hold by subject have many movement in axes x, y and z. Therefore, the resultant velocity showed an increasing of barbell velocity.

Table 4.10: Maximum and minimum velocity during the experiment

	Acceleration (m/s^2)	Time (s)
Maximum	2.09	1.1
Minimum	-1.32	1.4

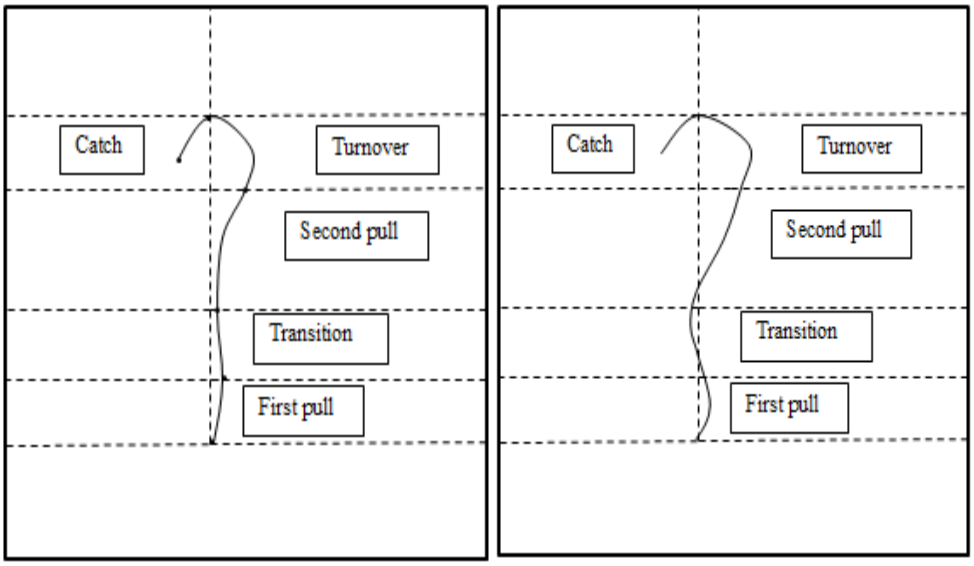
Table 4.7 shows the maximum and minimum barbell velocity and its time period from the experiment. Maximum barbell velocity is 2.09 m/s at 1.1 seconds and it occurs during the catching phase as shown in Figure 4.7. The value of the minimum velocity is -1.32 m/s at 1.4 seconds during catching phase. Minimum barbell velocity occurs at the end of the technique.

4.4.3 Barbell trajectory

Barbell trajectory is observed to understand how the barbell moves in weightlifting. Movement of barbell also can tell how hard a lifter pulls the barbell. This trajectory detected by using a marker attached to the right side of the barbell.

4.4.3.1 Snatch technique

Figure 4.11 shows the barbell trajectory during snatch technique. The trajectory is almost on the straight line from starting point until the end of transition phase. During second pull phase, the barbell is moving forward a little in order make the barbell easier to pull upward. At the turnover and catching phase, the barbell reaches it maximum height before stop moving during catching phase.



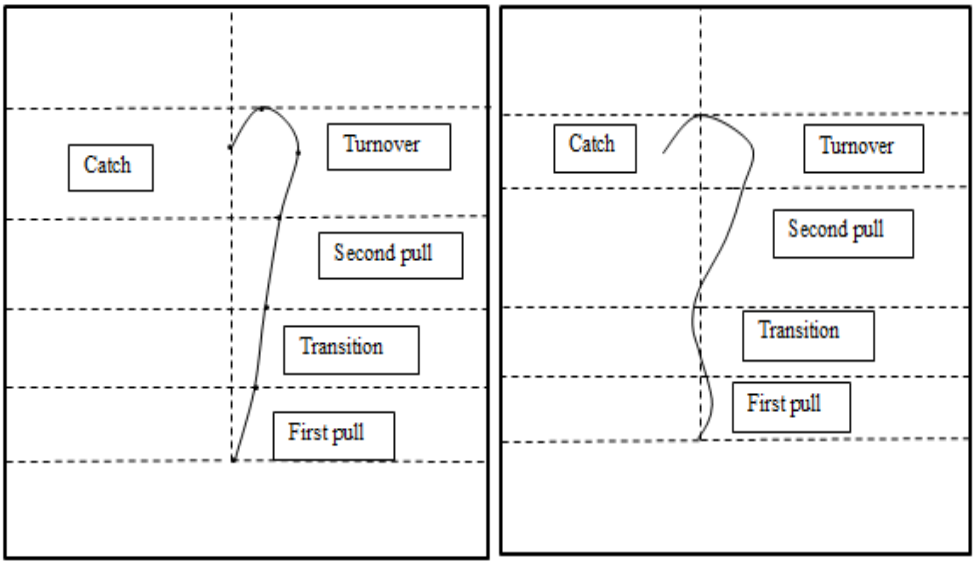
(a) From experiment (b) Xueling Bai, 2008

Figure 4.11: Comparison of barbell trajectory in snatch technique

The barbell trajectory is compared between professional athlete (b) and subject from experiment (a). Barbell trajectory for professional athlete crossed the vertical line three times during transition phase, second pull phase and turnover phase. Meanwhile, barbell trajectory for subject only crossed vertical line during turnover phase. This mean, the techniques perform by the subject while lifting the barbell is totally different.

4.4.3.2 Clean technique

Figure 4.12 shows the barbell trajectory in clean technique. The trajectory is different from snatch technique in **Figure 4.11** because this technique is easier compare to snatch technique. Barbell trajectory is constantly moving forward during lifting from first pull phase until second pull phase. Barbell trajectory in second pull phase has no bending because in this technique, subject will lift barbell until his shoulder. Therefore, the height of trajectory for this technique is lower than snatch technique. Pattern of trajectory in turnover and catching phase is same with the pattern in snatch technique.



(a) From experiment (b) Xueling Bai, 2008

Figure 4.12: Comparison of barbell trajectory in clean technique

Meanwhile in Figure 4.12, comparison only made until second pull phase because the techniques perform by the subject is different. First three techniques perform by the subject should be the same as because the style to lift the barbell is same. Barbell trajectory for the subject is increasing or moving forward until it reaches the turnover phase. When subject trajectory is moving forward, difficulties to lift the barbell is increase. However, the barbell trajectory also related to the weight of lifter and gravity. The barbell moves forward because lifter needs to stabilize the barbell from the gravity below.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

As the conclusion for this experiment, the biomechanical analysis on weightlifting technique is important to see how well and correct the technique of a lifter. All the result can be conclude into four main categories which are the angle of joint, force distribution, barbell kinematics and muscle activity produce.

From all the result in the experiment and comparison with another research, the angle of joint play an important role in weightlifting as a proper angle can reduce or prevent injuries that can happen to the lifters. All the subjects in the experiment produce smaller angle compare to the professional athlete. Between all the subjects, subject 1 shows the most good angle and almost similar with the professional athlete. It is because subject 1 already has a basic knowledge on weightlifting technique.

Another analysis is on force distribution produce during the lifting. All subjects produce almost the same pattern of graph in the experiment and from all the subjects, subject 1 also have a good force distribution pattern of graph. All the subjects in the experiment are in first time experience in lifting the load of 20kg. That is why the maximum value of the subject 1 is different from the professional athlete. From the force distribution also, the phase can be determined and analyze.

Barbell kinematics in weightlifting also an important analysis as it affects the technique in weightlifting. If the acceleration and velocity is not have sequences between each other, then the technique perform by the lifter is not good enough. The

increasing and decreasing of the barbell can also predict from the video and after the result taken, each phase can be determine. Both techniques will have the same pattern of graph for acceleration and velocity because the graph moving in the same direction.

Muscle activity also can be determined from the experiment by using electromyography. All subjects in the experiment have excessive use of their muscle in this experiment because all of them experience a first time experiment by lifting 20 kg load. The distribution in the graph from the experiment also show the activity of the muscle is not very smooth as the professional athlete as the subject's muscle does not train to lift such a heavy weight. Both muscles in this experiment are important while the barbell is needed to pull upwards and it is same from the graph of professional athlete.

Professional lifter and beginner lifter have a big different of their technique. This can be shown from the result of the experiment where there are many different can be found and compare. A beginner lifter must have a good coach and practice more to improve their technique on weightlifting. If good technique is applied during the lifting, amount of injuries happen can be reduce or prevented.

5.2 Recommendations

Some recommendation may apply in this system to make it reliable thus improve the result of the experiment. Below are some recommendations that can be applied in this experiment:

i. The size of force plate use in the experiment. Current force plate in the lab is too small for weightlifting experiment because subjects cannot spread their leg bigger to make they lift the barbell more comfortable. Therefore, a bigger force plate needs to be used to ensure the subject is more comfortable while during the experiment. By using bigger force plate also, jerk technique can be done by the subject who completes the analysis on weightlifting.

ii. Barbell use in the experiment also needs to be improve or following the standard in the competition. In this experiment, only a training barbell had been use because of some problem occur while borrowing the actual barbell from the administration. Training barbell is not straight and bends at the middle of it which makes the subject having some difficulties while performing the technique. When a subject using a straight barbell, the technique can be improve as the subject can grip the barbell more tight and comfortable.

iii. Besides that, subject also must be choose based on their knowledge and experience for a more good result. Beginner lifter has many different from the professional lifter as the result will not be perfect and take longer time to analyze. Before using professional lifter as the subject, all the condition and equipment must be prepare in excellent condition such as the force plate, barbell and instrument that need to attach at subject's body.

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APPENDIX A

Angle of joint in snatch technique

Angle for subject 2 in snatch technique

Phase	Ankle (°)	Knee (°)	Hip (°)
1	44	48	31
2	69	71	52
3	72	122	78
4	71	139	128

Angle for subject 3 in snatch technique

Phase	Ankle (°)	Knee (°)	Hip (°)
1	51	69	41
2	56	86	49
3	62	70	72
4	59	111	98

Angle for subject 4 in snatch technique

Phase	Ankle (°)	Knee (°)	Hip (°)
1	51	68	140
2	71	118	62
3	68	112	73
4	62	98	88

Angle of joint in clean technique

Angle for subject 2 in clean technique

Phase	Ankle (°)	Knee (°)	Hip (°)
1	48	61	28
2	68	104	55
3	71	121	88
4	68	119	110

Angle for subject 3 in clean technique

Phase	Ankle (°)	Knee (°)	Hip (°)
1	58	69	31
2	65	95	57
3	69	109	79
4	60	105	114

Angle for subject 4 in clean technique

Phase	Ankle (°)	Knee (°)	Hip (°)
1	71	119	49
2	68	107	66
3	69	112	87
4	68	112	102