BIOMECHANICAL ANALYSIS ON ARCHERY ATHLETES

NUR SYAZWANI BT MOHD NOOR

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UNIVERSITI MALAYSIA PAHANG

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ABSTRACT

Biomechanical is the most important matter in analysis the human movement. In sport, Biomechanical analysis becomes crucial in order to get the best practice to make sure there are no injury occurs during training. This study will focus on Biomechanical analysis to the archery athletes. From this research, the best position of archers elbow was obtained and the best practice in archery is proposed in order to reduce the force on muscle. When the athletes used the incorrect elbow position, the muscle force will increase and the muscle will becomes fatigue. The archery game required repeat action. When the athletes need to repeat the same movement, the muscle will become fatigue easily and will give bad effect to the archer performance. For this present study, the experiment was run together with archery athletes from Majlis Sukan Negeri Terengganu (MSNT). The athletes were categorized to elite, intermediate and beginner. The comparison was made between the athletes and differentiates between genders. From the experiment, the elbow positions of the archers were observed and compare the muscle activation of the archers from the EMG signal. Most of the athletes unable to get the same peak EMG signal due to incorrect position of elbow and muscle fatigue. From the EMG signal obtained from the experiment prove that the most active muscle is deltoid muscle which is shoulder muscle. Basically, when the muscle activation is higher, the muscle force produced also will be higher as muscle force and muscle activation is assumed to be linear.

ABSTRAK

Biomekanikal adalah suatu perkara penting di dalam menganalisa pergerakan tubuh badan manusia. Dalam arena sukan, analisa biomekanikal sangat penting untuk mendapatkan teknik yang terbaik di samping mengelakkan kecederaan yang dialami oleh atlet. Kajian ini akan focus kepada analisa biomekanikal kepada atlet pemanah. Kajian ini dijalankan untuk mendapatkan posisi siku yg terbaik untuk pemanah dan sekaligus mencadangkan praktis yang terbaik bagi mengurangkan beban kepada otot. Hal ini kerana apabila pemanah mempunyai kedudukan siku yang salah maka beban ke atas otot akan meningkat dan akan menyebabkan otot letih. Sukan memanah memerlukan pergerakan yang berulang. Apabila atlet banyak melakukan pergerakan yang mengulang maka otot akan menjadi lebih cepat letih dan akan mengganggu prestasi atlet tersebut. Kajian ini adalah kerjasama dengan Majlis Sukan Negeri Terengganu (MSNT). Atlet-atlet ini dibahagikan kepada tiga kategori iaitu elit, pertengahan dan pemain baru. Kajian ini turut membuat perbandingan antara kesemua atlet. Melalui eksperimen yang dijalankan, perkara yang diberi perhatian adalah kedudukan siku atlet pemanah dan membandingkan pengaktifan otot daripada isyarat Electromyogram (EMG). Kebanyakan atlet gagal memperoleh pengaktifan yang sama kesan daripada kedudukan siku yang tidak betul dan juga kesan daripada keletihan otot. Melalui kajian yg dijalankan, otot yang paling aktif semasa sukan memanah ialah otot bahu atau dikenali sebagai deltoid. Secara keseluruhannya semakin tinggi pengaktifan otot semakin tinggi beban yang dikenakan ke atas otot.

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LIST OF SYMBOLS

N	Newton
mV	Millivolt
F	Force
Hz	Hertz
m	Meter
sec	Second
u(t0	Neural activation
a(t)	Muscle Activation
fps	Frame per second

LIST OF ABBREVIATIONS

UMP	University Malaysia Pahang
MSNT	Majlis Sukan Negeri Terengganu
CenSE	Centre of Sport Engineering
EMG	Electromyogram
COP	Center of Pressure
CNS	Central nervous system
MVC	Maximum voluntary contraction

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Biomechanics is the science that applies the laws of mechanics and physics to human performance. Through the understanding of biomechanical analysis, a researcher can examines the internal and external forces acting on the human body and the effects produced by these forces. It will involve anatomy foundation of the human body including muscles and bones. In archery shooting, there is a fixed sequence of very accurate movements that the shooter performs which are bow holding, drawing, full draw, aiming, release and follow through stage (Haywood, 1989). All sequences of movement in archery will have forces that act on the body that will transfer along the bones and through the joints as well. Application of biomechanics in archery is very useful. It helps in controlling the movement of muscles and reducing the fatigue effects that may occur which causes serious injuries in the long term (L. Jim, 2007). Alignment of bow arm is important as it will produce certain angle and if the alignment is incorrect the force applied to muscles may increase. Forces that act on archer may be differing as the skill and technique are different from each other. In order to analyse the force that acting on muscles and bones, several devices may be used where electronic devices involve.

The study of this project will focus on the forces acting on the archer body during drawing bow activities and shooting activities. By using different position of elbow give effect to the forces acting on the body especially shoulder muscles in drawing the bow. The relationship between drawing shoulder and draw force line also prove that there is an effect of forces acting on the shoulder (S. Ellison, 1999).

Biomechanical analysis is the study of how parts of the human body moves, bears weight and how the various parts of the extremities move. The study of biomechanics is important in determining the causes of injuries and therefore finds the method of prevention of the injuries from occurring or re-occuring. The biomechanic analysis is important in elite athletes but can be a major cause in recurrent injuries faor amateur athletes. Biomechanical analysis also important in order to make improvement on the athlete performance (R.Bartlett, 2007).

1.2 PROBLEM STATEMENT

According to the Biomechanics law applied in archery, the forces acting on the bones should be maximized while force acting on muscles should be minimized in order to reduce the injury impact to the archer (S. Ellison, 1999; L. Jim, 2007). It is important to apply good practice in order to prevent serious injury if the archer practices archery in long period. To reduce the injury during archery practice, one must know how to reduce the force exerted by the body especially forces use by muscle. From this study, the result obtained should include best practice, position and mechanical analysis for archery activity in reducing the injury to the archer.

1.3 OBJECTIVE

The aim of this research is to study the Biomechanical analysis on the archery athletes. The specific objectives of this study are as follows

i. To study the relationship between drawing shoulder and draw-force line.
ii. To determine the force of muscle from EMG signal using mathematical equations.

1.4 SCOPE OF PROJECT

The scope of this project can be narrowed down into three points. They are as the following.

i. Determine a good alignment during shooting that will concentrate on the “Line of Force”
ii. The calculate the muscle force will be taken from the EMG signal
iii. Compare the relationship between elbow position and muscle force

1.5 ORGANIZATION PART

Chapter 1 of this thesis is about the background of the project which is to explain about the different position of the elbow of archery athletes. Then it includes the problem statement that happens to occur during archery games that affect the athletes’ performance. The objective is to optimize the best position of the elbow to the athletes during the archery games. The scope of this project is to find how the elbow position gives effect to the athletes and to determine which position is better for the athletes.

Chapter 2 presents literature review that will focus on recent studies or research by authors related to the biomechanics that apply in archery games to the athletes. Besides that, the literature explains about the methods that need to do in the experiment. The literature review can be approximately close to the titles of the project also. From this chapter, the author will get more knowledge about the results of the previous researches and can predict the result of the project then compare the results with current study.

Chapter 3 is the overview the methodology for the research. This chapter gives information about the study that currently running and how is the study running from the experiment. For this research, the experiment needs real athlete in order to fulfil the requirement of the research. The experiment uses Electromyogram (EMG) to determine

the muscle activation and high speed cameras to record the motion of athletes started from setting the bow until releasing of the arrow. After getting the data from the experiment, the calculation will take place to find the force from the signal of EMG.

Chapter 4 focuses on the outcomes of the research and discussion. From the image captured by the high speed camera, "Line of Force" can be obtained at a full draw position of the athletes and find differences between original draw force line and shoulder line . Besides that, after the experiment the data of muscle activation of athletes were obtained. From the raw data of the EMG, the data are rectified and filtered. Then, the data are converted to force by using an equation. The result for each athlete is analysed and compare between the athletes to compare the result of force.

Chapter 5 focuses on the conclusions of the project and recommendations for future work. This chapter also will summarize both the results and objectives of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is discussing on some literature review which related to the Biomechanics analysis on the human body during sport activities. This chapter also focuses on recent studies or research by the authors regarding to the activities on archery especially in Biomechanics analysis that related to the title of the project given including analysis on forces acting to the arm, position of the elbow and alignment of the arm during drawing the bow.

2.2 DRAW FORCE LINE

Archery required discipline, skills and techniques. Of those three, the most essential is the techniques of the athlete itself where the essence of the perfect techniques can be divided into four. The techniques include constant length of draw, a constant line of force, balanced control and economy of effort. To fulfill those requirements, the athlete should have an ideal position at full draw where it will involve stance of the athlete should be upright, balanced and in a comfortable position. The athlete should can produce constant draw length and control the balancing where it needs to be maintained by the balanced forces from the forward pressure of the bow arm and the equal traction (pull) through the drawing hand. Besides that, the alignment of the hand should be ideal. The ideal alignment of hand means the nock of the arrow, the bow and drawing hand, and elbow of the drawing arm in the same straight line which known as “Line of Force”(J. Larven, 2007).

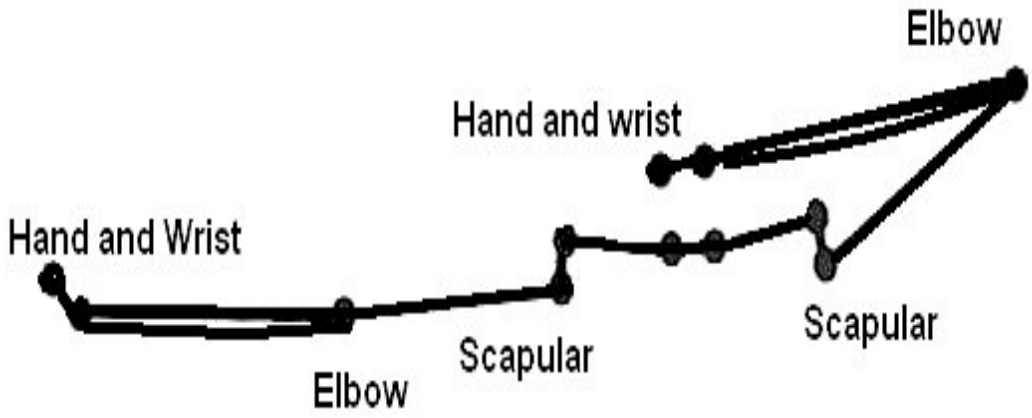

Figure 2.1: Joint involve in shooting of archery

Source: Archery Australia: Shooting Technique/ Biomechanic (2007)

The figure 2.1 illustrated the structure of human shooting machine that involve during archery which mean the part of body that involve. As labeled in the figure, the part involve are hand, wrist, elbow and scapula (shoulder part).

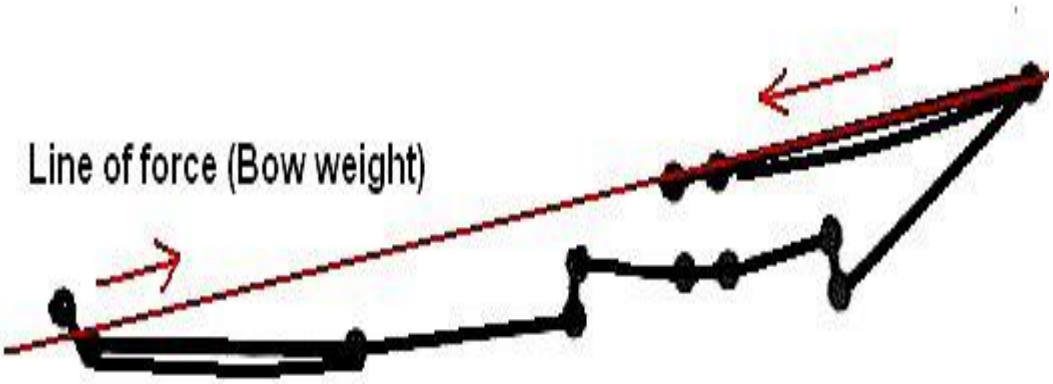

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Figure 2.2: "Line of Force"

Source: Archery Australia: Shooting Technique/ Biomechanic (2007)

To get a good "Line of Force", the line should pass through the bow hand to the drawing hand and drawing elbow which is important as it will give effect the muscle if the athlete has poor force line. The figure 2.2 shows how to determine the correct "Line

of Force". The poor alignment of "Line of Force" will cause the force on muscle will be higher thus the muscle will be fatigue after several repetition which cause the athlete cannot get the good performance.

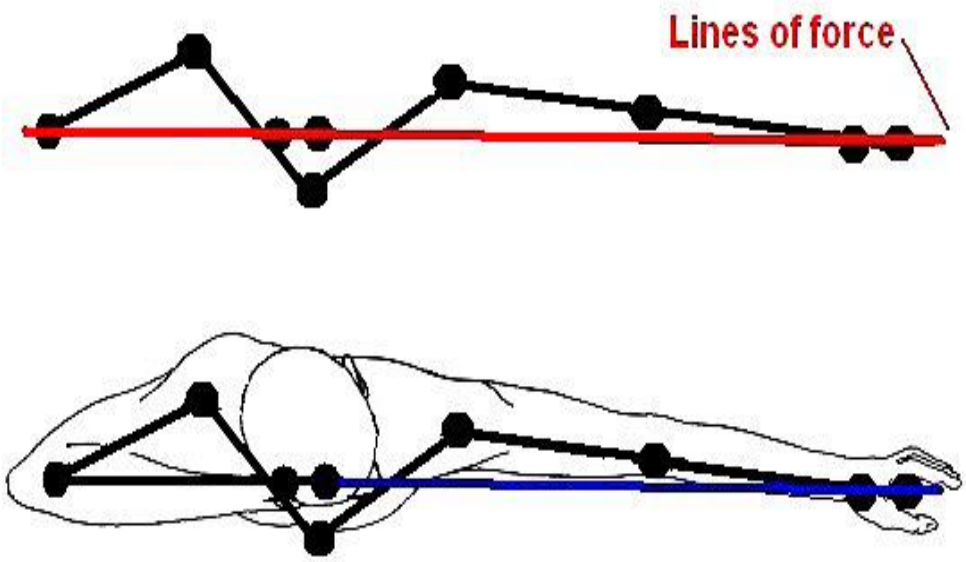

Figure 2.3: Correct Alignment of "Line of Force"
Source: Archery Australia: Shooting Technique/ Biomechanic (2007)

Based on the figure 2.3, the red and blue lines indicate the "Line of Force". The line clearly shows where the line should lie. The "Line of Force" obtained only when the athlete is in full draw condition where we could clearly see the point of joint.

2.3 ELBOW POSITION

Elbow position is one of the important elements that need to take seriously by the athletes. The best elbow position is when the elbow is in line with the "Line of Force" (S. Ellison, 1999, K. Bearman, 2011). Elbow position can be classified into three which are high elbow, in line elbow and low elbow. Incorrect elbow position can produce more force compare to the elbow position that in line with "Line of Force". A rough calculation suggests that for moderate displacements, the bicep needs to generate a lateral force at the string of about 5% of the draw weight for every inch the elbow is out of line (S. Ellison, 1999).

The elbow position can be viewed from both top view and front view. The elbow position also can be related to the drawing shoulder. When the elbow position change, the distance between “Line of Force” and the shoulder muscle will be different and it will definitely affect the forces that act on the muscle (S. Ellison, 1999).

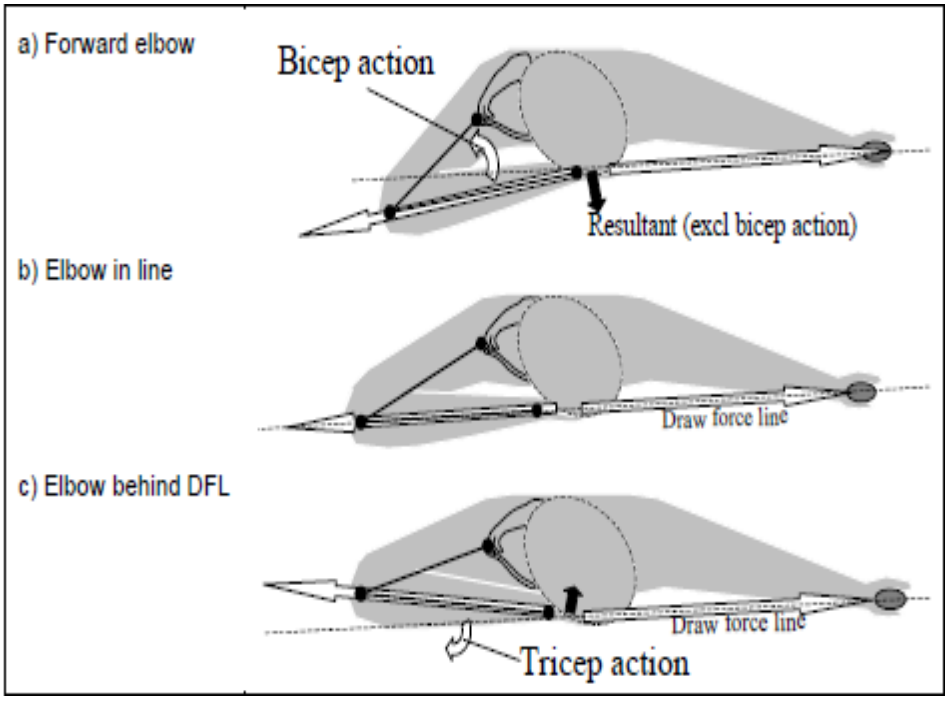

Figure 2.4: Elbow position from the top view

Source: Element Form of Drawing Arm (1999)

The figure 2.4 shows the elbow position from the top view. As the position of the elbow change, the distance of the “Line of Force” and the drawing shoulder also change. During the draw and shot, the main active muscle is the deltoid. However, nearly all the muscles in and around the shoulder are needed to control the movement and stabilise the joint. Lower arm and wrist muscles may also stabilise the elbow joint and wrist, but the forces required are small unless a high wrist position is used, when the wrist joint needs additional stabilization (S. Ellison, 1999).

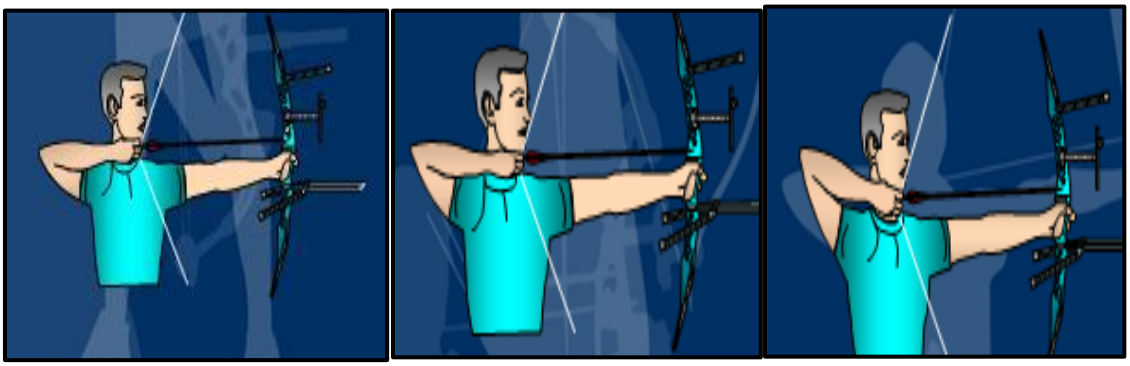

Figure 2.5: Elbow position from the front view

Source: World Archery Coaching Seminar (2011)

The figure 2.5 shows the elbow position from the front view which indicated the low elbow, in line elbow and the high elbow. Besides that, the incorrect position of elbow cause muscle action to maintain the lever draw force. If it happens continuously, it may cause injury. So, the angle between forearm and draw-force line should be minimized so that the lateral forces can be minimized as well.

Not only the position of the elbow, the alignment of overall arm also give effect in order to prevent or eliminate the injury. It proof from the uses of the muscle. As mentioned, muscle action should be less than bones action. It can help the archer to stand the pressure in repeatable techniques (L. Oliver, 2011).

2.4 ELECTROMYOGRAM (EMG)

Electromyography (EMG) is the technique for evaluating and recording the lectrical produced by muscle. EMG technique is used in the study of muscle function through analysis of the electrical signals emanated during muscular contractions. EMG measures the electric signal in muscle that associated with the activation of muscle (G.S. Rash). The measurement includes voluntary or involuntary muscle contraction. The EMG activity of voluntary muscle contractions is related to tension. The functional unit of the muscle contraction is a motor unit, which is comprised of a single alpha motor neuron and all the fibers it enervates. This muscle fiber contracts when the action potentials (impulse) of the motor nerve which supplies it reaches a depolarization threshold. The depolarization generates an electromagnetic field and the potential is

measured as a voltage. The depolarization, which spreads along the membrane of the muscle, is a muscle action potential.

Regarding to the biomechanical aspects, there is positive relationship in increasing the tension with respect to the isometric contractions. During movement, there tends to be a relationship with EMG and the velocity of the movement (G.S. Rash). There is an inverse relationship of strength production with concentric contractions and the speed of movement, while there is a positive relationship of strength production with eccentric contractions and the speed of movement.

According to the G.S. Rash in his paper electromyography fundamental stated the correct ways on EMG usage. The EMG usage includes the correct method of using the EMG and how to process the signal obtained. There are many ways that are being used in processing the EMG data. To filter the data, there are three main types that commonly used by researcher which are high pass, low pass and notch filters. The filters also can be found in many types that can be applied such as Butterworth, Chebyshev, etc. Regarding to the other study, the most common filter used is fourth order Butterworth high-pass (K.G. Keenan et.al, 2007, T.S. Buchanan et.al, 2004). The filter is used 10-15 Hz cut-off but it is depend on the activity that being analyze (10 Hz for walking and 15 Hz for rapid movements) to remove movement artifacts.

EMG can be variable from task to task because of the normal redundancy, velocity or cadence changes or little movement pattern even though the observation might look the same. In that case, one should understand that in EMG data there is a large variety of signal. Sometimes, the combination of muscle activity can produce same movement as in the neuromuscular system there are presence of redundancy. EMG can be differed from task to task because of normal redundancy, velocity, or cadence changes, or slightly different movement patterns even though under same observation. Interpretation of EMG might be also difficult because of cross talk which is the interference of EMG signals from adjacent muscles or deeper muscles that are within the area of the electrode. For the time being, there are no fixed solutions as the size of the patient and the size of the electrode lead are an important matter with the ability to decrease or increase the cross talk (H.U. Kuriki et.al, K.G. Keenan et.al, 2007)

2.5 RELATIONSHIP BETWEEN EMG AND MUSCLE FORCE

Physical movement generation will involve the activation and the control of muscle forces. Knowledge of the contribution of muscle forces to joint position and movement is a great importance for the study of the study of muscle activity during exercise and also for understanding the coordination of muscle activation during functional movement. The generation of the force of muscle is related with the generation of the electrical signal that be observed by placing the electrodes on the skin surface to detect electrical activity underlie that display the waveform. The process uses electromyogram (EMG) which known as electromyography process and the waveform of the EMG (H.U. Kuriki et.al).

Some case studied that there are linear relationship between force and the EMG but the relationship not always simple and linear. In detecting and processing EMG signal, there are many improvements to better equipment, tools, mathematical analysis, statistical, and computational techniques. However, the determination of muscle strength using EMG not fully exploited the technology's potential.

The term of the muscle strength refers to the ability of a muscle generate tension. The generation of muscular force that produces mechanical work, the most important condition is nerve stimulation that triggers the process. Sensory input from muscles travels via afferent pathways to the central nervous system (CNS), where it promotes the recruitment of motor neurons that stimulates muscle fibers and results in the generation and demonstration of the muscle strength. Muscles forces act through a bone system that depends on nervous, muscular and biomechanical factors.

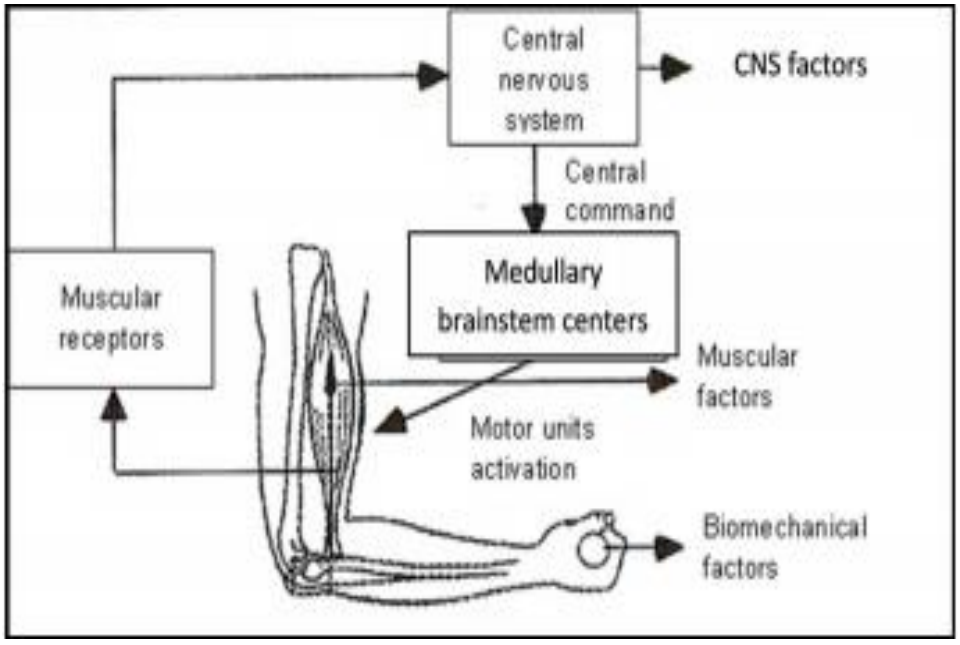

Figure 2.6: Muscular system

Source: The Relationship between Electromygram and Muscle Force (2007)

To do the comparison between muscle force and EMG signal, most of the previous study stated that the magnitude of EMG signal is directly proportional to muscle strength for isometric and/or isotonic contractions (H.U. Kuriki et.al). The measured force of muscle contraction is the result of the global activity of the muscle fibers, and surface near the electrode that attached to the skin. In the most cases, the catchment area of the electrode does not extend sufficiently to detect that signal generated across the entire muscle volume. The equation that can prove the EMG-force is linear

$$EMG=a.FORCE$$

To improve the relationship between EMG-force, the muscle chosen should be the muscle uniquely responsible for generating the muscle measured. The relative location of fast and slow muscle fibers in the muscle, and their distribution and location relative of the electrode are the factors that need to be taken into account.

2.6 EMG PROCESSING

In order to determine each muscle's activation profile, the EMG signal processing is important. A raw EMG signal is a voltage that is both positive and negative, whereas muscle activation is expressed as a number between 0 and 1, which is smoothed or filtered to account for the way EMG is related to force. The first task is to process the raw EMG signal into a form that, after further manipulation, can be used to estimate muscle activation. The first step is to remove any DC offsets or low frequency noise. With low quality amplifiers or movement of the electrodes, it is possible to see the value of the mean signal of the raw EMG change over time. It can be corrected by high-pass filtering the EMG signal to eliminate low-frequency noise (allowing the high-frequency components to pass through, thus the term high-pass filter). This must be done before rectifying and the cutoff frequency should be in the range of 5–30 Hz, depending on the type of filter and electrodes used. This filter can be implemented in software and, if this is the case, one should use a filter that has zero-phase delay properties (e.g., forward and reverse pass 4th order Butterworth filter), so filtering does not shift the EMG signal in time.

The simplest way to transform rectified EMG to muscle activation is to normalize the EMG signal, which is done by dividing it by the peak rectified EMG value obtained during a maximum voluntary contraction (MVC), and then applying a low-pass filter to the resultant signal. Normalizing can be tricky because true maximum EMG values can be difficult to obtain. The rectified EMG signals should then be low-pass filtered because the muscle naturally acts as a filter and we want this to be characterized in the EMG-force transformation. That is,although the electrical signal that passes through the muscle has frequency components over 100 Hz, the force that the muscle generates is of much lower frequency (e.g., muscle force profiles are smoother than raw EMG profiles). This is typical of all mechanical motors. In muscles there are many mechanisms that cause this filtering; for example, calcium dynamics, finite amount of time for transmission of muscle action potentials along the muscle, and muscle and tendon viscoelasticity. Thus, in order for the EMG signal to be correlated with the muscle force, it is important to filter out the high-frequency components. The