THE IMPACT OF *SALAT*'S POSITIONS ON THE BIOMECHANICAL RESPONSE OF THE HUMAN MUSCLES

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ABSTRACT

Salat is an Islamic prayer ritual that all Muslims must perform five times a day. The *salat*physical manoeuvres steps include various motions such as standing, bowing, prostration, and sitting. Recently, the study of *salat* movements from the perspective of science has been widely investigated. The current study evaluated the impact of *salat*movements on the biomechanical response of human muscle using electromyography (EMG). The eight upper-bodymuscles involved were the neck extensors (NE), sternocleidomastoideus (SCM), trapezius (TRP), deltoid (DL), bicepsbrachii (BB), triceps brachii (TB), rectus abdominus (RA), and erector spine (ES) and the four lower-body muscles involved were the rectus femoris (RF), biceps femoris (BF), tibialis anterior (TA), and gastrocnemius (GAS) muscles. A group of undergraduates aged between 19 to 28 years voluntarily participated in this study. The subjects were asked to perform*salat* movements(*takbir*, bowing, prostration, sitting, and *salam*) and specified exercises (squat exercise and toe touching exercise). During the experiment, the root mean square (RMS) and maximum voluntary contraction (MVC) for each muscle in every position of *salat*was recorded. The result showed that the muscles produced different EMG levels during each *salat's* positions. For example, the highest EMG level achieved during the *'takbir'*movement was at the TRP (23.11% MVC), followed by DL (10.57%MVC), BB (9.75%MVC), ES (5.50%MVC), NE (3.93%MVC), RA (3.25%MVC), SCM (2.94%MVC), and TB (2.61%MVC). Forstatisticalanalysis, the Wilcoxon'sRank Sum Test was used to compare the neighbouring and antagonistic muscles: NE to SCM, TRP to DL, BB to TB, and ES to RA. The finding showed that there were significant differences in the performances for all the antagonist muscles during each *salat's*position ($p<0.05$). For the comparison between the *salat* and the specified exercises, the test found a statistically no significant difference between *salat*and the specified exercises for the RF, BF, and GAS, but for

the TA, there was significant difference with a difference of 5.67%MVC. Muscle contraction and relaxation that occurred showed an agonist-antagonist response which is good for exercise and strengthening programmes. Hence, the current experiment can be taken as a pilot study on the biomechanical response of the human muscles during the act of performing the *salat*.

ABSTRAK

Solatmerupakanaktivitiibadatbagi Islam dengansemuaorang Islam wajibmelakukannyasebanyaklima kali setiaphari. Terdapatbeberapagerakfizikaldalamsalattermasuklahberdiri, rukuk, sujud,danduduk.Padamasaini, kajianmengenaipergerakansolatdaripada perspective sainstelahberkembangdenganmeluasnya.KajianinimenerangkanmengenaikesanpergerakansolatterhadapresponsbiomekanikalototmanusiadenganmenggunakanElektromiografi (EMG).Lapanotot–ototbahagianbadanatasyang terlibatadalahneck extensors (NE), sternocleidomastoideus (SCM), trapezius (TRP), deltoid (DL), bicepsbrachii (BB), triceps brachii(TB), rectus abdominus (RA), dan erector spine (ES), manakalaempatototbahagianbawahbadan yang terlibatadalah rectus femoris (RF), biceps femoris (BF), tibialis anterior (TA), and gastrocnemius (GAS).Sekumpulanpelajarberumurantara 19hingga 28 tahunsecarasukarelatelahmenyertaikajianini.Subjekdimintauntukmelakukanpergerakansolat(takbir, rukuk, sujud, duduk,dansalam) dansenaman yang telahditentukan (*squat exercise*dan toe *touching exercise*). Semasaeksperimen, telahdirekodkankuasadua min punca (RMS) danpengecutansukarelamaksimum (MVC) padasetiapototdalamsetiapposisisolat.Keputusanmenunjukkansetiapototmenghasilkantahap EMG yang berbezapadasetiapposisisolat.Misalnya, tahap EMG paling tinggisemasatakbirialah TRP (23.11% MVC),diikuti DL (10.57%MVC), BB (9.75% MVC), ES (5.50%MVC), NE (3.93%MVC), RA (3.25%MVC), SCM (2.94%MVC),dan TB (2.61%MVC).Bagianalisisstatistik, *Wilcoxion'sRunk Sum Test*telahdigunakanuntukmembandingkanotot-otot yang berjirandanberantagonis: NE dengan SCM, TRP dengan DL, BB dengan TB, dan ES dengan RA. Keputusanmenunjukkanterdapatperbezaanstatistik yang ketarapadakesemuaototantagonisbagisetiapposisisolat($p<0.05$).Untukperbezaanantarasol

atdengansenaman yang telahditentukanitu, secarastatistiknyakajianmenunjukkanbahawatiadaperbezaan yang berertipada RF, BF, and GAS, manakalabagi TA, terdapatperbezaanberertidenganperbezaan5.67%MVC. Pengecutandanpersantaianototinimenunjukkanrespons yang bersifatagonis-antagonis yangbaikuntuksenamandan program pengukuhanotot.Kajian yang dijalankaninimerupakankajianmulabagiresponsbiomekanikototmanusiasemasamelakukansolat.

ORIGINAL LITERARY WORK DECLARATION

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Title of Project: The Impact of *Salat,s* Positions on the Biomechanical Response of The Human Muscles

Field of Study: Biomechanics

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LIST OF ABBREVIATIONS

ABBREVIATIONS

BB	Biceps Brachii
BMI	Body Mass Index
DL	Deltoid
EMG	Electromyogram/Electromyography
ES	Erector Spine
MVC	Maximal Voluntary Contraction
NE	Neck Extension
RA	Rectus Abdominal
RMS	Root Mean Square
SCM	Sternocleidomastoid
SD	Standard Deviation
SPSS	Statistical Package for the Social Sciences
TB	Triceps Brachii
TRP	Trapezius

CHAPTER 1. INTRODUCTION

1.1. Background

Biomechanicsis defined by Hatze(1974) as "the study of the structure and function of biological systems by means of the methods of mechanics". The word “biomechanics” developed during the early 1970s, describing the application of Engineering Mechanics to biological and medical systems. The international community adopted the term “biomechanics” to describe the science involving the study of biological systems from a mechanical perspective (Nelson, 1980). Biomechanics is a discipline that uses the principles of physics to quantitatively study how forces interact within a living body. In biomechanics, the term “body” is used rather loosely to describe the entire body, or any of its parts or segments, such as individual bones or regions(Shirazi-Adi et al., 2005). Biomechanics also deals with motions of bodies, both translation and rotation (Shirazi-Adi et al., 2005).

Biomechanists use the tools of mechanics, the branch of physical science involving analysis of the actions of forces, to study the anatomical and functional aspects of living organisms. Statics and dynamics are two major subbranches of mechanics. Statics is the study of systems that are in a state of rest (no motion) or moving with a constant velocity. Dynamics is the study of systems in which acceleration is present in their motion. Kinematics and kinetics are further subdivisions of biomechanical study. Kinematics is the description of motion, including the pattern and speed of movement, sequencing by the body segments that often translates to the degree of coordination an individual displays. Kinematics describes the appearance of motion, kinetics is the study of the forces associated with motion(Hall, 2007).

Muscles are the major contributors to human movement. Muscles are used to hold a position, to raise or lower a body part, to slow down a fast moving segment, and to generate great speeds in the body or in an object that is propelled into the air (Hamill & Knutzen, 2009). Because of its important function, it is necessary to make sure that one's muscles are always in good conditionsthrough maintenance programs such as physical exercises. Many research shows that exercises produce muscle health and maintain the muscle in optimum working condition.

Muscle is the only tissue capable of actively developing tension. This characteristic enables the skeletal, or striated, muscle to perform the important functions of maintaining upright body posture, moving the body limb, and absorbing shock. The four behavioural properties of muscle tissue are extensibility, elasticity, irritability, and contractility(the ability to develop tension). These properties are common to all muscles, including the cardiac, smooth, and skeletal muscles of the human beings, as well as the muscles of other mammals, reptiles, amphibians, birds, and insects. There are 434 muscles in the human body, making up 40-45% of the body weight of most adults. Muscles are distributed in pairs on the right and left sides of the body. About 75 muscle pairs are responsible for body movements and posture, with the remainder involved in activities such as eye control and swallowing (Hall, 2007).

Muscle tissue is very resilient and can be stretched or shortened at fairly high speeds without major damage to the tissue. The performance of a muscle tissue under varying loads and velocities is determined by its irritability, contractility, extensibility, and elasticity.

i. Irritability

Irritability, or excitability, is the ability of a muscle to respond to stimulation. In a muscle, the stimulation is provided by a motor neuron releasing a chemical neurotransmitter. Skeletal muscle tissues is one of the most sensitive and responsive tissues in the body. Only nerve tissue is more sensitive than a skeletal muscle. As an excitable tissue, skeletal muscle can be recruited quickly, with significant control over how many muscle fibers and which ones will be stimulated for a movement(Hamill & Knutzen, 2009).

ii. Contractility

Contractility is the ability of a muscle to generate tension and shorten when it receives sufficient stimulation. Some skeletal muscles can shorten as much as 50% to 70% of their resting length. The average range is about 57% of resting length for all skeletal muscles. The distance through which a muscle shortens is usually limited by the physical confinement of the body. For example, the sartorius muscle can shorten more than half of its length if it is removed and stimulated in a laboratory but, in the body, the shortening distance is restrained by the hip joint as well as positioning of the trunk and thigh(Hamill & Knutzen, 2009).

iii. Extensibility

Extensibility is the muscle’s ability to lengthen, or stretch beyond the resting length. The skeletal muscle itself cannot produce the elongation; another muscle or an external force is required. Taking a joint through a passive range of motion, i.e.pushing another’s limb past its resting length is good example of elongation in muscle tissue. The amount of extensibility in the muscle is determined by the connective tissue surrounding and within the muscle(Hamill & Knutzen, 2009).

iv. Elasticity

Elasticity is the ability of muscle fiber to return to its resting length after the stretch is removed. Elasticity in the muscle is determined by the connective tissue in the muscle rather than the fibrils themselves. The properties of elasticity and extensibility are protective mechanisms that maintain the integrity and basic length of the muscle. Elasticity is also a critical component in facilitating output in a shortening muscle action that is preceded by a stretch(Hamill & Knutzen, 2009).

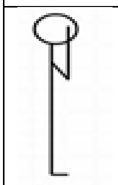
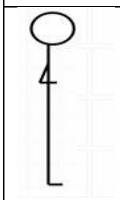
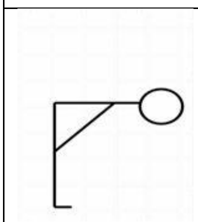
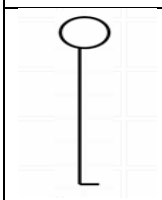
Skeletal muscle performs a variety of different functions, all of which are important to efficient performance of the human body. Three functions relate specifically to human movement, assisting in joint stability, and maintaining posture and body positioning. Besides, muscle action also provides four other functions that are not directly related to human movement. First, muscle support and protect the visceral organs and protect the internal tissues from injury. Second, tension in the muscle tissues can alter and control pressures within the cavities. Third, skeletal muscle contributes to the maintenance of body temperature by producing heat. Fourth, the muscle control the entrances and exits to the body through voluntary control over swallowing, defecation, and urination(Hamill & Knutzen, 2009).

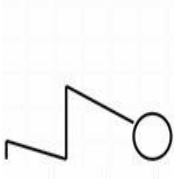
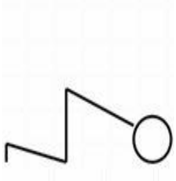
This purpose of the current study was to find out the myoelectric activityduring *salat*. The *salat* is the most important ritual that a Muslim performs every day. Every Muslim performs *salat* 5 times a day, from dawn till night. The various motions of the *sala*t include the "*takbir*", "standing/*qiam*", "bowing", "prostration", "sitting", and "*salam*". The movements and positions of the *salat*are rather similar to other exercises normally performed in the gymnasium. From this experiment, the biomechanical response of human muscle during*salat* is measured.

A Muslim performing the *salat*executes the following actions, as shown in Table 1.1:

1) stands facing the direction of the Kiblah, raises the hands, and utter aloud a phrase called the *takbir*, 2) stands with the hands placed between the chest and stomach, and recites phrases from the Quran, 3) bows at the waist into *rukuk*, repeating the *takbir*, 4) returns to standing position, 5) prostrates into *sajadah*, placing the forehead, nose, hand, knee, and toes on the floor, 6) gets into an upright sitting position, 7)repeats the act of prostration, 8) repeats the upright sitting position while reciting *tashahhud*,and 9) conclude the*salat*byturning the head first towards his right and then toward his left.

Table 1.1: Phases of *salat's*position

Position / phases	**Description**
 (‘*Takbir’*)	• Standing upright. • Both hands raised to level of the ears.
 (Standing/*qiam*)	• Standing upright • Both hands were between chest and stomach. • The eyes looked downward to the ground.
 (Bowing)	• Bent as far as he could to reach 90^0 bending position. • Both hands gripped the knees.
 (Standing/qiam)	• Standing upright • Both hands were in straight position downwards. • The eyes looked downward to the ground

 (Prostration)	• The forehead and palms of the hands touched the ground. • The upper limbs are abducted slightly outward. • The thighs were straight vertically with both knees touching the ground. • The toes were erected during prostration.
 (Sitting)	• Sit on the left leg and the right leg toes are erected. • Both hands are placed between the thigh and knee
 (Prostration)	• The forehead and palms of the hands touched the ground. • The upper limbs are abducted slightly outward. • The thighs were straight vertically with both knees touching the ground. • The toes were erected during prostration.
 (Sitting)	• Sit on the left leg and the right leg toes are erected. • Both hands are placed between the thigh and knee
 (*'Salam'* right)	• Sit on the left leg and the right leg toes are erected. • Both hands are placed between the thigh and knee turns first towards his right.
 ('*Salam*' left)	• Sit on the left leg and the right leg toes are erected. • Both hands are placed between the thigh and knee turns first toward his left.

The *salat* is obligatory on every Muslim above the age of puberty, with the exception of those who are mentally ill, too ill, menstruating, or experiencing post-partum bleeding. The number of *raka`ah* (prayer units) for each of the five obligatory prayers are different: Fajr tworakaahs, Dhuhur four rakaahs, Asar four rakaah, Maghrib threerakaahs, and Isha` fourrakaahs.

1.2. Overview of Research

Nowadays, people are very concerned about health. They want to know about the beneficial effects of any physical activity in the prevention of acquired disease.However, it appears that knowledge does not necessarily influence the behaviours of the vast majority of the population of the world. They need to do exercises or other physical activity to improve or maintain their state of health. One of the factors that influence an individual’s health is his/her muscle health.

Epidemiological evidence supports the importance of regular physical activities in the prevention of many acquired chronic diseases and in the enhancement of overall health (Sothern et al., 1999). Physical inactivity is an independent risk factor for coronary heart disease (Paffenbarger et al., 1993) and regular physical activity has been shown to reduce the risk of hypertension, Type 2 diabetes, and to maintain optimal bone mineral density. Regular physical activity can relieve symptoms of depression and, in the elderlies it may reduce the risk of falling. *Salat* is one of the physical activities that all Muslims are required to perform daily as a religious ritual.

The primary objective of this research is to investigate the impactsof the *salat* movements on the biomechanical response of human muscles. The electromyography (EMG) was used to measure the muscle response during *salat*. The EMG levels of the muscles involved were assessed to identify the muscle contraction during *salat.*

1.3. Objectives of the Research

The objectives of this research are as follows:

1. To identify the muscles those are activated during the*salat.*
2. To measure the EMG level of the muscles those are activated during *salat.*
3. To investigate the connection in terms of antagonistic functionbetween opposite muscles that are involved in*salat.*
4. To identify standard exercise that have similar characteristic to the *salat*movements.

1.4. Hypothesis of Research

To identify the beneficial responses of the human muscle to *salat*, a hypothesis has been formulated. The hypothesis is:

H_0: There is no biomechanical response of the human muscles to*salat.*

1.5. Scope of Research

The study involved myoelectric recordings of eight muscles of the upper body, namely the neck extensors (NE), sternocleidomastoideus (SCM), trapezius (TRP), deltoid (DL), bicepsbrachii (BB), triceps brachii (TB), rectus abdominus (RA), and erector spine (ES) and four lower-body, namely the rectus femoris (RF), biceps femoris (BF), tibialis anterior (TA), and gastrocnemius (GAS) muscles. The myoelectric signals were recorded while the subjects were performing the *salat*movements, starting from *takbir* till *salam*. The myoelectric signals were measured using the electromyography (EMG). After that, the myoelectric signal werebe analysed.

1.6. Organization of Thesis

Chapter 1 is the introductory chapter which describes the background of this research, the reason why this research was initiated, and the objectives of the research.

Chapter 2 covers the literature review related to the study. This chapter reviews the application of biomechanics in a number of fields of research, the electromyography and its application for muscle assessment, the effect of *salat* on the human health, the effect of exercise on the human health, and the benefits of muscle response for the daily living activity.

Chapter 3 describes the measurements of EMG levels on the human muscles involved in this experiment. For EMG measurement, the description includes criteria of subject selection, tasks performed by subjects, apparatus and materials used in the experiment, and the setup procedures. In addition, the steps involved in converting and processing raw EMG data to RMS values, and the statistical analysis method used are covered as well.

Chapter 4 covers the results obtained from the EMG. The results are then analysed and compared by using the statistical analysis.

Chapter 5 presents the discussion of the results, limitation of the conducted experiment, and suggestions for further improvement.

Chapter 6 presents the conclusion, which describes the findings, recommendations for future work, and ethical issues associated with the research.

CHAPTER 2. LITERATURE REVIEW

2.1. Biomechanics and its application

There are a lot of researches that involved the biomechanics concept. For example, zoologists have examined the locomotion patterns of dozens of species of animals walking, running, trotting, and galloping at controlled speeds on a treadmill to determine why animals choose a particular stride length and stride rate at a given speed. They concluded that most vertebrates, including humans, selected a gait that optimizes economy, or metabolic energy consumption, at a given speed (Perry et al., 1988). There are also changes in the energy cost of running and walking among growing children as their bodies undergo developmental changes in body proportions and motor skills. Between early childhood and young adulthood, there is a decrease in the amount of energy required for standing, walking, and running, with children expending 70% more energy to walk at a fast pace than adult (DeJaeger et al., 2001).

Another problem challenging biomechanists who study the elderly is mobility impairment. Age is associated with decreased ability to balance, and older adults both sway more and fall more than young adults, although the reasons for these changes are not well understood (Perrin et al., 1997). Biomechanical research teams are investigating the biomechanical factors that enable individuals to avoid falling, the characteristic of safe landing from falls, the forces sustained by different parts of the body during falls, and the ability of protective clothing and floors to prevent falling injuries (Robinovitch et al., 2000).

Occupational biomechanics is a field that focuses on the prevention of work-related injuries and the improvement of working conditions and worker performances (Chaffin et al., 1999). It is also recognizing how important it is for workers to be both physically and mentally prepared for jobs in industry in order to prevent low back pain (Yamamoto, 1997). Sophisticated biomechanical models of the trunk are now being used in the design of materials-handling tasks in industry to enable minimizing potentially injurious stresses related to the low back pain (Chaffin, 2005).

In sports biomechanics, the laws of mechanics are applied in order to gain a greater understanding of athletic performances and to reduce sports injuries as well. Elements of mechanical engineering (e.g. strain gauges), electrical engineering (e.g. digital filtering), computer science (e.g. numerical methods), gait analysis (e.g. force platforms), and clinical neurophysiology (e.g. surface EMG) are common methods used in sports biomechanics (Bartlett, 2007). Sport biomechanists have also directed efforts at improving the biomechanical, or technique, components of athletic performance. They have learned, for example, that factors contributing to superior performance in the long jump, high jump, and the pole vault include high horizontal velocity going into take-off and a shortened last step that facilitates continued elevation of the total-body centre of mass (Dapena & Chung, 1988; Hay & Nohara, 1990). Other concerns of sport biomechanics relate to minimizing sport injuries through both identifying dangerous practices and designing safe equipments and apparels. In recreation runners, for example, research shows that the most serious risk factors for overuse injuries are training errors such as a sudden increase in running distance or intensity, excess cumulative mileage, running on cambered surface, and improper footwear(O'Toole, 1992).

2.2. Types of Exercise

Exercise is defined as a subclass of physical activity that includes planned, structured, and repetitive bodily movements, which is done to improve or maintain one or more components of physical fitness (ACSM, 2000). There are three types of exercises used in muscle conditioning. They are isometric, isotonic, and isokinetic exercises.

An isometric exercise occurs when a muscle contracts without associated movement of the joints on which the muscle acts. Isometric exercises are often the first form of strengthening exercise used after injury, especially if the region is excessively painful or if the area is immobilized. It is commenced as soon as the subject can perform it without pain (Nelson, 1980).

An isotonic exercise is performed when the joint moves through a range of motion against a constant resistance or weight. It may be performed using free weights, such as dumbbells, or with weight devices. An isotonic exercise may be concentric or eccentric. Concentric contraction is a type of muscle contraction in which a muscle generates enough force to overcome the resistance to joint movement, so it shortens as it contracts. During a concentric contraction, a muscle is stimulated to contract according to the sliding filament mechanism. This occurs throughout the length of the muscle, generating force at the musculo-tendinous junction, causing the muscle to shorten and changing the angle of the joint(Nelson, 1980). An eccentric contraction is a type of muscle contraction in which the resistance (such as a weight carried in the hand) is greater than the force applied by the muscle so that the muscle lengthens as it contracts. An eccentric contraction also occurs when the muscular force is used to brake or slow the opening of a joint. During an eccentric contraction, the muscle lengthens, with the actin and myosin filaments lengthening as the joint opens. In essence, rather than the muscle producing an active force to move a weight, the muscle works to 'brake' or resist the motion, slowing down the opening of the joint. An eccentric contractions is usually used to control the lowering of a load(Nelson, 1980).

An isokinetic exercise is performed on devices at a fixed speed with a variable resistance that is totally accommodative to the individual throughout the range of motion. The velocity is, therefore, constant at preselected dynamic rate while the resistance varies to match the force applied every point in the range of motion. This enables the subject to perform more work than is possible with either constant or variable resistance isotonic exercise(Nelson, 1980).

2.2.1 Benefits of exercises for human health

Recommendations for exercise have moved from emphasising vigorous activity for cardiorespiratory fitness to the option of moderate levels of activity for health benefits. The ACSM (2000)recommended that people of all ages accumulate 30 minutes of moderate physical activity on most, if not all, days of the week. Researchers hypothesize that weight-bearing exercise is particularly crucial during the prepubertal years, because the presence of high levels of growth hormone may act with exercise in a synergistic fashion to increase bone density (Bass, 2000; Kenny & Prestwood, 2000).

The AmericanCollege of Sport Medicine pronouncement on “Physical Activity and Bone Healthy” makes recommendation related to the role of exercise in preventing and treating osteoporosis (Kohrt et al., 2004). In order to maintain bone mass, adults should participate in weight-bearing enduring activities such as tennis, stair climbing, and jogging; activities that involve jumping, such as volleyball and basketball; and resistance exercise. Intensity should be from moderate to high in terms of bone-loading force, and weight-bearing endurance activities should be done 3-5 times per week whilst resistance exercise 2-3 times per week. Jumping on a sport, with 50-100 jumps done in set of 10 with a frequency of 3-5 times per week, is also recommended for maintenance of bone mass (Winter-Stone, 2005).

One of the famous traditional exercises is the *Tai Chi* which is widely accepted ashaving particular benefits for postural stability in older people. A number of studies have shown that *Tai Chi* practitioners have a better balance capacity, proprioceptive function, and muscle strength (Hong, Li, & Robinson, 2000; Xu, Hong, Li, & Chan, 2004). It has been promoted to improve balance and strength, and to reduce falls in the elderly, especially those 'at risk'. Dynamic balance measured by the functional Reach Test was significantly improved following *Tai Chi*, with significant decreases in both mean systolic and diastolic blood pressure(Thornton et al., 2004). The findings reveal that *Tai Chi* exercise programmes can safely improve physical strength and reduce fall risk for fall-prone older adults in residential care facilities (Choi et al., 2005).

2.3. The Human Muscle

Muscle is composed primarily of skeletal muscle fibers but also contains a certain amount of connective tissue and abundant blood vessels and nerves (David, 2009). Muscles exert forces and thus are the major contributor to human movement. Muscles are used to hold a position, to raise or lower a body part, to slow down a fast moving segment, and to generate great speed in the body or in an object that is propelled into the air (Hamill & Knutzen, 2009). All skeletal muscles are composed of one specific type of muscle tissue. However, other types of muscle tissue constitute a few named muscles and form important components of the organs of other systems, including the cardiovascular, alimentary, genitourinary, integumentary, and visual systems (Moore et al., 2010).

A single skeletal muscle cell is known as a muscle fiber. During the development of the foetus in the womb, these fibers are formed via the fusion of a number of undifferentiated muscle fibers. The term 'muscle' refers to a number of muscle fibers bound together by connective tissues and anchored to a bone by bundles of collagen fibers known as tendons. In some muscles, individual fibers extend the entire length of the muscle, although more often the fibers are shorter at an angle to the longitudinal axis of the muscle(John & Juliette, 2005).

There are three types of muscle, namelythe skeletal muscle, smooth muscle, and cardiac muscle. The skeletal muscle, or voluntary muscle, is attached by tendons to a bone. It affects skeletal movement such as locomotion and maintaining of posture. An average adult male is made up of 42% and adult female of 36% of skeletal muscle(Elaine & Hoehn, 2007). It also constitutes, by far, the greatest mass of muscle in the body and is the tissue that, in domestic animals, is usually recognized as meat (David, 2009).The smooth muscle, or involuntary muscle,typically occurs in sheets surrounding hollow viscera, such as the walls of the digestive tract and blood vessels (David, 2009).Another type of muscle is the cardiac muscle. It is confined to the heart and the bases of the great vessels immediately adjacent to the heart. Physiologically, this muscle resembles smooth muscle in that it also is involuntary. However, it differs sharply from skeletal muscle in one regard: its cells branch and are closely united to each other so that contraction starting within one localized region of cardiac muscle spreads widely over the heart through the close contact of the cardiac muscle cells with one another (David, 2009).

The anatomy of muscles comprises gross anatomy and microanatomy. Gross anatomy consists of all the muscles of an organism whilst microanatomy contains the structures of a single muscle. Figure 2.1 and Figure 2.2 show the anatomy of muscles for the anterior and posterior views.

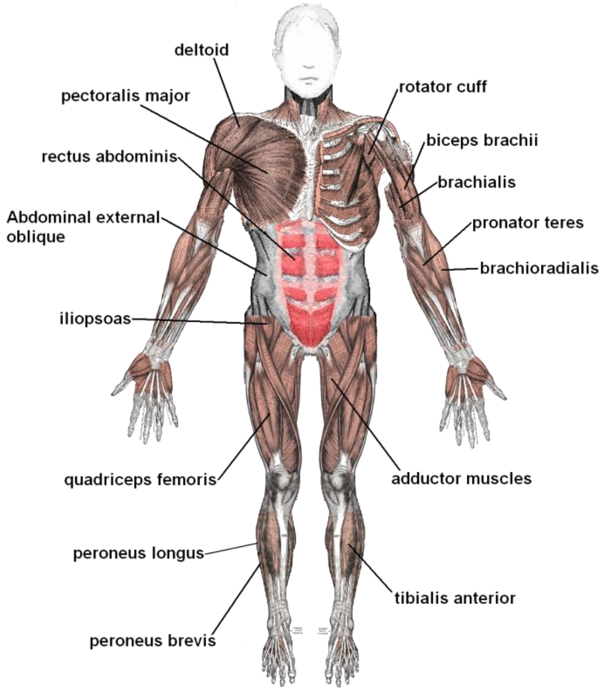


Figure 2.1: Anterior view of human anatomy(Reproduced from Konrad, 2005)

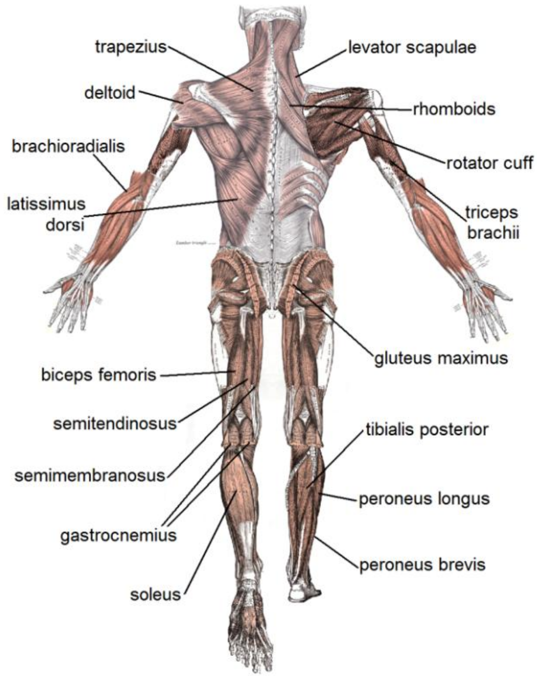


Figure 2.2: Posterior view of human anatomy (Reproduced from Konrad, 2005)

2.3.1. Muscle Selection

In this study, twelve muscles were chosen, namely theneck extensor, sternocleidomastoid,trapezius, deltoid, biceps brachii, triceps brachii, erector spine, and rectus abdominal,rectus femoris, biceps femoris, tibialis anterior, and gastrocnemius.

The muscles play very important roles in the body movements. Their roles are listed in Table 2.1 for the upper body muscles and Table 2.2 for the lower body muscles.

Table 2.1: Muscle's function of upper-body(Moore et al., 2010)

Muscle	**Function**
Neck Extensor	Elevates pectoral girdle, maintains level of shoulders against gravity or resistance, retracts scapula, depresses shoulders, and rotatesspinous process of scapula superiorly.
Sternocleidomastoid	Tilts head to same side and rotates it superiorly towards opposite side, flexes cervical vertebrae and extends superior cervical vertebrae while flexing inferior vertebrae so chin is thrust forward with head kept level. With cervical vertebrae fixed, may elevate manubrium and medial ends of clavicles, assisting pump-handle action of deep respiration.
Trapezius	Elevates pectoral girdle, maintains level of shoulders against gravity or resistance, retracts scapula, depresses shoulder, rotatesspinous process of scapula superiorly, and extends neck.
Deltoid	Flexes and medially rotates arm, abducts arm, and extends and laterally rotates arm.
Biceps Brachii	Contracts to supinate forearm and flex forearm.
Triceps Brachii	Extends the spine and strengthens the back muscle.
Erector Spine	Extend vertebra column and bends vertebra column toward same side (lateral flexion).
Rectus Abdominal	Flexes trunk (lumbar vertebrae) and compresses abdominal visceral, stabilizes and controls tilt of pelvis (antilordosis).

Table 2.2: Muscle’s function of lower-body(Moore et al., 2010)

Muscle	**Function**
RectusFemoris	Extends the leg and medially rotate the thigh.
Biceps Femoris	Flexes leg and rotates it laterally when knee is flexed.
Tibialis Anterior	Dorsiflexes ankle and inverts foot.
Gastrocnemius	Plantarflexes ankle when knee is extended, raises heel during walking, flexes leg at knee joint.

2.4. Electromyography (EMG)

Electromyography is an experimental technique concerned with the development, recording, and analysis of myoelectric signal. Myoelectric signals are formed by physiological variations in the state of muscle fiber membranes(Basmajian& De Luca, 1985).Surface EMG measurement is an experimental technique for recording and quantifying the action potential along the skeletal muscle fiber’s surface (De Luca, 1997; Farina, Merletti, & Enoka, 2004). The action potential is generated during voluntary muscle action. The surface EMG is a compound signal produced by the electrical activities of many motor units(Basmajian & De Luca, 1985).

EMG provides many useful information and applications. It is generally beneficial for various uses in the field of biomechanics and physiological study. Besides, it also plays a major role as an evaluation tool in medical research, sports training, rehabilitation, and ergonomics. In the ergonomics application, it helps to enhance risk prevention, analysis of demand, and ergonomic design. Moreover, EMG allows detection of the muscle activity, analyzing, and then improving the ergonomics design. In sports science, EMG helps in analyzing and improving the sports activities(Konrad, 2005).

Currently, the common applications of EMG signal are as follows: to measure of muscular performance, helps in decision making both before and after surgery, documents treatment and training regimes, helps patients to train their muscles, allows analysis to improve sports activities, and detects muscle response in ergonomic studies (Konrad, 2005).

2.4.1. EMG Guidelines

To measure the EMG signals, a few guidelines and factors must be considered. Among them are raw EMG signal, factors influencing EMG signal, EMG amplification, and computation of EMG signal.

2.4.1.1. Raw EMG Signal

Raw EMG signal is defined as an unfiltered and unprocessed signal from the EMG recording devices. An example is given in Figure 2.3 which displays the EMG recording obtained for three static contractions of the biceps brachii muscle.

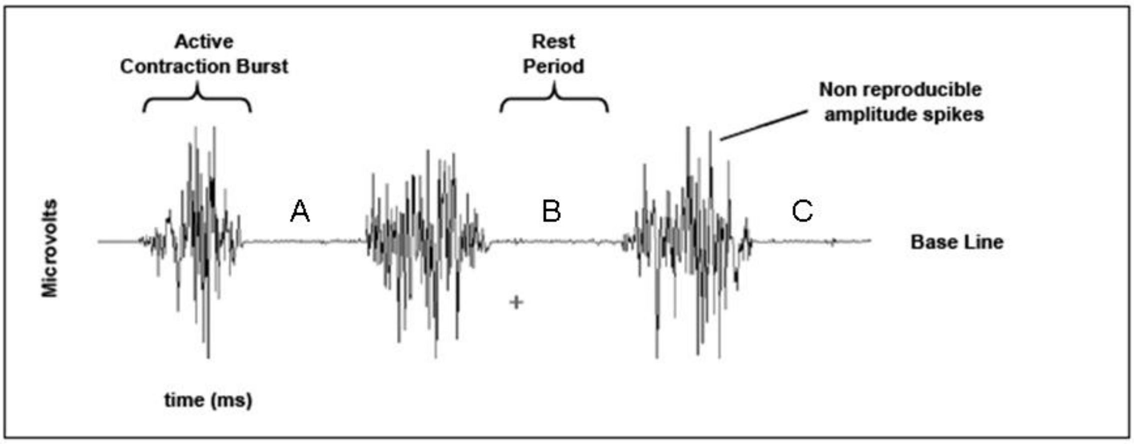


Figure 2.3: The raw EMG recording of three contraction bursts of the biceps muscle (Reproduced from Konrad, 2005)

It can be seenfrom Figure 2.3, theEMG baseline is observable when the muscle is relaxed(marked A, B, and C on the diagram). This EMG baseline depends on many factors such as the quality of the EMG amplifier, the environment noise, and the quality of the given detection condition. The average baseline noise observed is not higher than 3 – 5 µV by for a proper skin preparation and good amplifier performance.

The investigation on the EMG baseline is very important for every EMG measurement. This is because the measurement should not include interfering noise or problem within the detection apparatus. Hence, the base activity of muscle can be analyzed more precisely (Konrad, 2005).

2.4.1.2. Factors Influencing EMG Signal

There are several external factors which influence the EMG signal. These factors change the characteristic and the shape of the EMG signal. However, the effects of some of the factors can be avoided by a proper detection method when using the EMG system efficiently in the experiment. Basically, the external factors can be grouped into several categories, such as external electrical noise, anatomical and physiological crosstalk, geometry between muscle belly, electrode placement, and external noise (Konrad, 2005).

Tissue characteristic is one the main factors that influences the EMG signal. Although the human body is a good electrical conductor, the electrical conductivity greatly varies with the thickness of tissue. Any increase in thickness of tissue can cause a decrease in the amplitude of EMG signal. This is shown in Figure 2.4. In order to minimize the effect of tissue thickness in this research, it was proposed to limit specific criteria of the subject, i.e. the body mass index (BMI) of the subject should be in the range of 18 to 24.5.

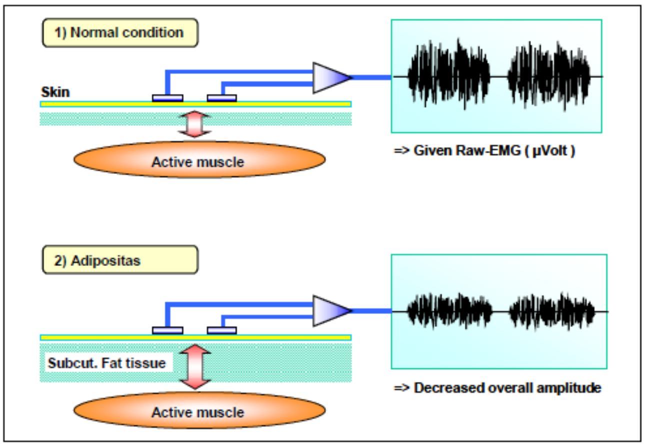


Figure 2.4: Influence of thickness of tissue layers below the electrodes. (Reproduced from Konrad, 2005)

Another factor that influences the EMG signal is physiological cross talk. It refers to a significant amount of EMG which originates from neighbouring muscles but detected at the local electrode site. Cross talk is generally defined as a signal that does not exceed 10 to 15% of overall signal(Konrad, 2005).

Electrical noise may originate from various sources such as inherent noise of the electronics components in the detection and recording equipments. All electronic equipments generate electrical noises that have frequency ranging from zero to several thousand Hz. They cannot be eliminated but they can be reduced by using high quality electronic components (De Luca, 2002).

The factor that influences the EMG signal the most is the surface EMG electrode placement. Muscle is typically located between a motor point and a tendon insertion, or within two motor points (De Luca, 2002; Konrad, 2005). The longitudinal axis of the electrode (surface electrode with two parallel bars) should be placed at the middle of muscle belly, aligned to the length of the muscle fibers.

Reference electrode is a neutral electrode needed to be included whenever recording the EMG signal. This is to provide a common reference to the differential input of amplifier in the electrode. It is typically positioned at a place which is electrically unaffected but nearby to the area being measured, such as joint, bony area, frontal head, and tibia bone (De Luca, 2002; Konrad, 2005). In the experiment of the current research, the targeted area was the forearm muscles. It was decided to place a reference electrode at the joint of the arm of the right hand. This is an area with less muscle distributed within it so as to minimize EMG activity to the reference.

2.4.1.3. EMG Amplification

EMG-amplifiers act as differential amplifiers and their most desirable characteristic is the ability to reject or eliminate artifacts. The differential amplification detects the potential differences between the electrodes and cancels out external interferences. Typically, external noise signals reach both electrodes with no phase shift. These “common mode” signals are signals which are equal in phase and amplitude. The term "common mode gain" refers to the input-output relationship of common mode signals(Konrad, 2005).

2.4.1.4. Computation of the EMG signal

Before a signal can be displayed and analyzed in the computer, it has to be converted from an analog voltage to a digital signal (A/D conversion). The resolution of A/D measurement boards have to properly convert the expected amplitude range. Very small signals may need a higher amplification to achieve a better amplitude resolution(Konrad, 2005).

The other important technical item is the selection of a proper Sampling Frequency. In order to accurately “translate” the complete frequency spectrum of a signal, the sampling rate at which the A/D board determines the voltage of the input signal must be at least twice as high as the maximum expected frequency of the signal.For EMG, almost all of the signal powers are located between 10 and 250 Hz and scientific recommendations (SENIAM, ISEK) require an amplifier band setting of 10 to

500 Hz. This would result in a sampling frequency of at least 1000 Hz (double band of EMG) or even 1500 Hz to avoid signal loss (Konrad, 2005).

2.4.2. Maximal Voluntary Contraction (MVC)

MVC is a method to normalize the recorded data. It is important to rescale data to the percentage of a reference value (100%) in order to standardize all the subjects in the study. It solves the problem of how effective is a muscle in achieving a required task and what capacity level of muscle did the task.Typically, it is performed with a very good fixation and contraction against a rigid resistance (Konrad, 2005).

In order to produce a maximal contraction, a trained subject is required. Logically, patients with injury cannot perform the MVCs test. This is because the maximumcontraction produced would be different compared to a normal subject. However, in the current research, normal subject with no history of chronic musculoskeletal or abdominal pain is the only specific criteria. It is assumed that the maximum contraction force generated by the subject can serve as the reference value.

In the current research, the MVCs test is performed for every muscle to be tested. Each muscle has its own specific action to perform for the MVC test. For example, in order to perform the MVCs test for the forearm, the forearm is prepared by using a stable forearm support. Manual resistance like belt can be used(Konrad, 2005). The subjects were asked to perform their maximum effort, extend and adduct their wrist for the ECU muscle, extend only for the ECRL muscle, flex and adduct their wrist for the FCU muscle, and lastly, flex and abduct their wrist for the FCR muscle(Fagarasanu et al., 2004).

2.4.3. Signal Processing

RMS is used to assess the influence of the arm and wrist support on the forearm during keyboard operation (Nag et al., 2009). Previous study by Cook et al. (2004), investigated the effect of muscle activity on keyboard use. Beside, a study to compare the wrist posture and forearm muscle activities while using alternative and standard keyboards had been conducted (Szeto & Ng, 2000). The effect of key switch stiffness on the development of fatigue during typing had also been investigated(Gerard et al., 1996; Gerard et al., 1999). Additionally, Jack et al. (2002) researched on the wrist and shoulder muscle activities across computer task by using RMS. Apart from that, the RMS is used to indicate the activity level of different tasks in the study of EMG measurement on neck-shoulder for computer worker (Laura et al., 2006).

In order toobtainthe RMS values, the window length and number of window subdivisions of RMS are important. For kinesiological studies, window length of 20ms (fast movements like jump) to 500ms (slow or static activities) are selected(Konrad, 2005). Previous studies analysed the EMG signal in subdivision with intervals instead of taking all recorded EMG data. For example, the RMS values were calculated with a time constant of 55ms(1996; Gerard et al., 1999; Gerard et al., 2002). Besides, 30 s samples were taken for each five minute interval and window length of 65 ms for the RMS was selected (Cook et al., 2004).

In biomechanics, it is often attractive to have means for assessing the fatigue of muscles which are of concern in the performance of a task. The force output of a muscle is used by physiologists to determine the index of muscle fatigue (De Luca, 1997).Typically, fatigue can be detected only after it had occurred.

2.5. Summary

Only a few researches on*salat* movements had been done to date. Most of them cover the joints' range of motion (ROM) for*salat's* positions and brain signals for certain *salat*movements. However, there is no research on the biomechanical response of one's muscles while one is performing the *salat*. This current study will be a pilot study on the myoelectric signals during the *salat* by using the EMG.

CHAPTER 3. METHODOLOGY

3.1. Subjects

A total of 18 undergraduate subjects (average age: 19 ± 5.1 years) volunteered to participate in this experiment. Only subjects that had normal BMI (from 18.5 to 24.9 kg/m^2)(James et al., 2002), no medical history, and no back pain were accepted. 11 of them performed the *salat's* movement and another seven subjects were asked to perform additional task, i.e. performed two *salat* movements (bowing and prostration) and the specified exercises(squat exercise and toe touching exercise). For the comparison between *salat* and specified exercises, only lower-body muscles were assessed. Before that, all the subjects were briefed on and showed the standardized*salat* movement and the specified exercises, so as to make sure that all subjects perform the same movements and protocols. Besides, their muscles were given enough rest (at least 15 minutes) before the measurement were taken.They read and signed a consent form prior to participating in the experiment. A sample of the consent form is given in Appendix A.

3.2. Assumptions

Before the experiment was conducted, some assumptions had been made. The assumptions are as follows:

i. All subjects performed the *salat* in the same protocol according to the Shafei's school of thought(Saqib, 1997). The bone's joints during *salat* movementswere in same range of motion (ROM) and are according to standard *salat* movements that all Muslim in Malaysia practise.

ii. All subjects had enough muscle rest before the experiment begun.

iii. The usable signals that were measured were those with energy above the electrical noise level. The usable energy of the signal is limited from 0 to 500Hz frequency range, with dominant energy being in the 50-150Hz range.

3.3. Space, Equipment, and Material

3.3.1. Room for the Experiment

All experiments were conducted inside one small laboratory room of about $20m^2$. This room is located at the Tissue Mechanics Laboratory, Department of Biomedical Engineering, Faculty of Engineering, University of Malaya, Kuala Lumpur, Malaysia. There is enough space and the floor is covered with carpet for the subject to perform the *salat* in a very comfortable condition.

3.3.2. Electrical noise

In this room, there was no electrical equipment that was turned on during the experiment except the laptop that was connected to the EMG. Meanwhile, during the experiment, the laptop was placed far away from the subjects, about 1.5meter. This could be done because the EMG systemused was a wireless system.

3.3.3. EMG System

The activities of the upper body muscle were measured using the Myomonitor ®III EMG system, Delsys Inc., Figure 3.1. It was an ultra-portable EMG data acquisition system which offered full-bandwidth signal recordings. It had dual mode operation which was either a wireless transmitter or an autonomous data logger. Wireless myomonitor was used in the current experiment where the data was transmitted to a host computer nearby for storage and real-time viewing (Delsys, 2008).

Figure 3.1: Myomonitor ®III EMG system, Delsys Inc. (Reproduced from Delsys, 2008)

The differential electrode unit had two 10 x 1 mm contact surfaces spaced 10 mm apart and coupled with a preamplifier with a gain of 1000 V/V to reduce noise. The recorded signals were amplified with a total gain of 1000. The Myomonitor ®III EMG system was used with a bandwidth of 20 to 450 Hz and the signals were sampled at 1500 Hz using a 16-bit ADC. The Myomonitor ®III EMG system is a medical device approved under the IEC 601 Electromyography standards (CE approved). Subsequently, the digitized signals were acquired using Delsys EMG Works Acquisition Software (Delsys, 2008).

3.4. Task

In this experiment, subjects were asked to perform the standard *salat*movements and specified exercises according to themanualsthat were given to them. For salat's movement, they started with *takbir* and finished with the *salam*. The muscle that were assessed were neck extensors (NE), sternocleidomastoideus (SCM), trapezius (TRP), deltoid (DT), bicepsbrachii (BB), triceps brachii (TB), rectus abdominus (RA), erector spine (ES), rectus femoris (RF), biceps femoris (BF), tibialis anterior (TA), and gastrocnemius (GAS) muscles. The muscles are shown in Figure 3.2. All the muscles were attached with EMG electrodes and their output measured with EMG. In this study, EMG signalswere recorded at sevensalat's positions, namely the '*takbir*', standing, bowing, prostrating, sitting, *salam* (right), and *salam* (left).

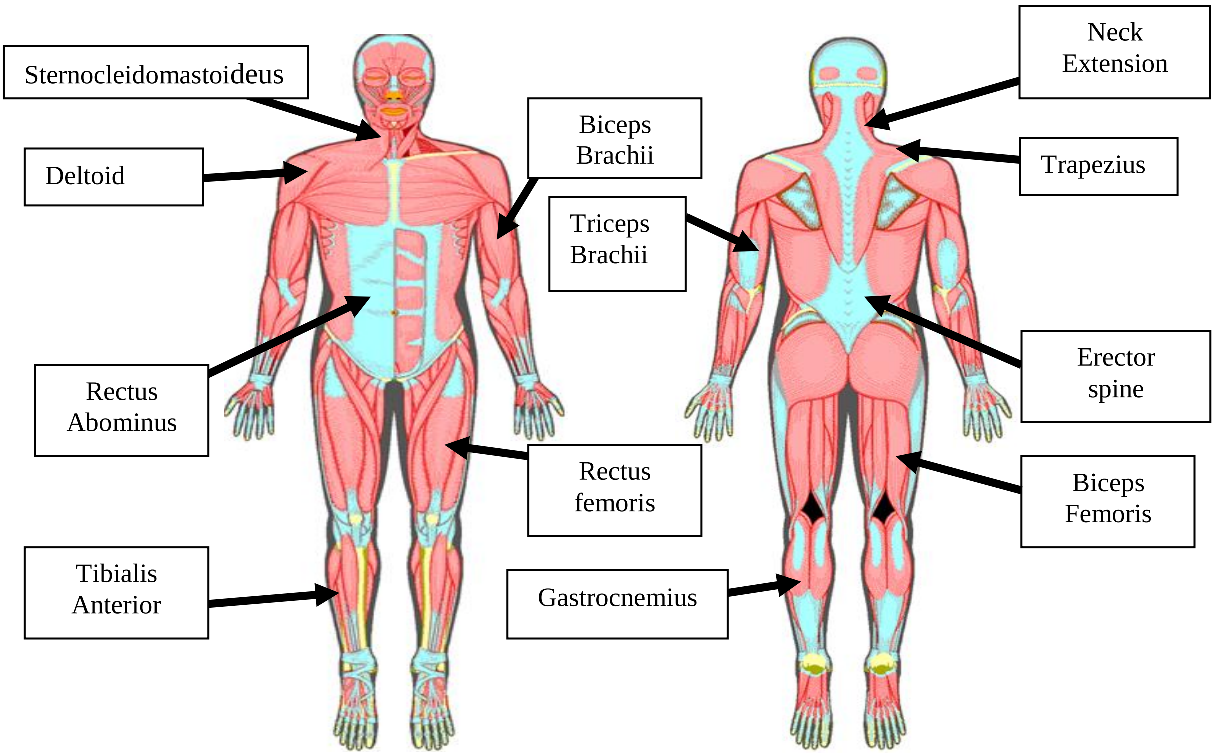


Figure 3.2: The muscle accessed.

3.4.1 The *Salat's* task

In order to ensure the correct movements of *salat*, all subject followed the task that was given to them. All the subjects performed the seven phases of the salat's positions shown earlier in Chapter 1, Figure 1.1.

3.4.2 Electrode positioning

Electrode placement was preceded by palpation and visual inspection of each of the muscles. The positions of the electrodes are given as in Table 3.1. A ground electrode was placed on the tibial tuberosity. Electrode placement was verified by inspection of the signal during voluntary contraction.

Table 3.1: Electrode's position on muscles (Konrad, 2005)

No.	Muscle	Electrode position
1	NE	Bilaterally on the paraspinal muscle at 2 cm lateral of the C4 spinous process
2	SCM	Along the sternal portion of the muscle, with the electrode 1/3 of the distance between the mastoid process and the sternal notch
3	TRP	Halfway between the C7 spinous process and the tip of the acromion on the crest of the shoulder in line with the direction of the muscle fibers
4	DL	3.5 cm below the anterior angle of the acromium
5	BB	Midway between the elbow and the midpoint of the upper arm, centered on the muscle midline
6	TB	Midway between the elbow and the midpoint of the upper arm, centered on the muscle midline
7	RA	On the left aspect of the umbilicus and oriented parallel to the muscle fibers on the right side of the body
8	ES	Bilaterally about 2 cm laterals from the spinous processes between the fourth lumbar (L4) and fifth lumbar (L5) on the right side of the body
9	RF	Over the midpoint of the muscle belly.
10	BF	Over the midpoint of the muscle belly
11	TA	Over the midpoint of the muscle belly
12	GAS	Over the midpoint of the muscle belly

3.5. Measurement Protocol

In this experiment, EMG measurement protocol was used. This measurement protocol allowed the experiment to be conducted smoothly and the resultscan be obtained easily.

3.5.1 Electrode Placement Protocol

Electrode positioning is very important to get the best EMG signals from the muscles. An EMG signal provides a view of the electrical activity in a muscle during contraction. The view is highly dependent on where the electrode is positioned on the muscle of interest. Since electrode placement determines the electrical view of a muscle, it is thus important, in EMG measurements, to be consistent in the placement of the electrodes for a subject (over consecutive recording sessions) and between different subjects. When determining electrode placement, the use of the guidelines set forth in the international SENIAM initiative is highly recommended. The sensor location is defined as the position of the two bipolar sites overlying a muscle in relation to a line between two anatomical landmarks. The goal of sensor placement is to achieve a location where a good and stable surface EMG signal can be obtained. For electrode placement, the protocols described below were followed (De Luca, 2002):

i. The electrode should be placed between a motor point and the tendon insertion or between two motor points, and along the longitudinal midline of the muscle. The longitudinal axis of the electrode (which passed through both detection surfaces) should be aligned parallel to the length of the muscle fibers.

ii. The electrodes should be placed not on or near the tendon of the muscle. As the muscle fibers approach the fibers of the tendon, the muscle fibers become thinner and fewer in number, reducing the amplitude of the EMG signal. Also in this region the physical dimension of the muscle is considerably reduced rendering it difficult to properly locate the electrode, and making the detection of the signal susceptible to crosstalk because of the likely proximity of agonistic muscles

iii. The electrodes should not be placed on the motor point. The motor point is that point on the muscle where the introduction of minimal electrical current causes a perceptible twitch of the surface muscle fibers. This point usually, but not always, corresponds to that part of the innervation zone in the muscle having the greatest neural density, depending on the anisotropy of the muscle in this region.

In the region of a motor point, the action potentials travel caudally and rostrally along the muscle fibers, thus the positive and negative phases of the action potentials (detected by the differential configuration) will add and subtract with minor phase differences causing the resulting EMG signal to have higher frequency components.

iv. The electrodes should not be placed at the outside edges of the muscle. In this region, the electrode is susceptible to detecting crosstalk signals from adjacent muscles. For some applications, crosstalk signals may be undesirable.

v. Orientation of the electrode with respect to the muscle fiber: The longitudinal axis of the electrode (which passes through both detection surfaces) should be aligned parallel to the length of the muscle fibers. When so arranged, both detection surfaces will intersect most of the same muscle fibers.

3.5.2 Reference Electrode Placement

The reference electrode (sometimes called the ground electrode) is necessary for providing a common reference to the differential input of the preamplifier in the electrode. For this purpose, the reference electrode should be placed as far away as possible and on electrically neutral tissue (say, over a bony prominence). Often this arrangement is inconvenient because the separation of the detecting electrode and reference electrode leads requires two wires between the electrodes and the amplifier.

3.5.3 Electrical Safety Concerns

The failure of any electrical instrumentation making direct or indirect galvanic contact with the skin can cause a potentially harmful fault current to pass through the skin of the subject. This concern is less relevant in devices that are powered exclusively by low voltage (3-15 V) batteries. To ensure safety, the subject should be electrically isolated from any electrical connection (to the power line or ground) associated with the power source. This isolation provides the added benefit of reducing the amount of radiated power line noise at the electrode detection surfaces.

3.6. The *Salat's* Protocol

The salat's protocol is illustrated in Figure 1.1. The description of each action is given below.

3.6.1 Takbir

The subject stood upright, with both hands raised to level of the ears. His thumbs touched the same sides ears, and the palms of the hands faced forward. The subject was asked to freeze for about 10 seconds in that position and then moved both hands down to his sides in a continuous motion.

3.6.2 Bowing

The subjectwho was in the upright position flexed his hip to about 90^0 bending position. His hands gripped the same sided knees. He was asked to freeze in this position for about 10 seconds and then extended his hip back to the upright position.

3.6.3 Prostration

The subject in the upright position bent his body at the hip and knees until his knees, forehead, and palms of the hands touched the floor. The upper limbs are abducted slightly outward and the thighs were positioned vertically straight. He was then asked to freeze in this position for about 10 seconds. After that, he moved to the sitting position.

3.6.4 Sitting

The subject was asked to sit on the left leg while the toes were erected. Both his hands were placed on the thigh, near to the same sided knees. The subject freeze in this position for about 10 seconds.

3.6.5 Salam (right)

The subject sat on the left leg with the toes of the right leg erected. Each hand was placed on the respective thigh, near to the knees. After that, the subject turned towards his right and looked over the right shoulder. The subject was asked to freezein this position for about 10 seconds before turning to the left side.

3.6.6 Salam (left)

The subject sat on the left leg with the toes of the right leg erected. Each hand was placed on the thigh near the knees. After that, the subject turned towards his left and look over the left shoulder. The subject was asked to freezein this position for about 10 seconds.

3.7. The Specified Exercise Protocol

The descriptions of the squat exercise and the toe touching exercise are given below.

3.7.1 Squat Exercise

The squat exercise consisted of two phases, an eccentric phase and a concentric phase. Subjects performed only the eccentric phase, starting with the subject standing up with the legs parallel and a small lateral rotation of the feet. With the feet approximately 30-40 cm apart, he flexed the knee to 90^0 of flexion and gripped the knees. He was asked to freeze in this position for about 5 seconds.

3.7.2 Toe Touching Exercise

The subject who was in the upright position, bent his trunk and touched his toes or the ground. He was asked to freeze in this position for about 5 seconds and then extended his trunk back to the upright position.

3.8. Test Procedure

The researcher made an appointment with a subject, depending on the time table that was drawn onto. Normally, every subject spent about an hour to conclude the experiment's protocol. Before the experiment begun, the myomonitor's battery was recharged for two hours. This was because, the lifetime of the battery depended on how long the battery was charged. The subject was asked to rest for about 15 minutes before starting the measurement to make sure that the subject's muscles had enough rest. If the subject still did not have enough rest, he was asked to get more.

Before a measurement session started, subjects were briefed on the study protocol. They were then asked to experience the *salat* protocol. Before application of the electrodes, the area of the skin onto which the electrodes were to be affixed, was shaved using a disposable razor and abraded with a cotton swab and alcohol. Alcohol wipes were used for cleaning the surface of the skin before electrode placement. Then the electrodes were placed on every muscles involved in this experiment, namely the neck extensors (NE), sternocleidomastoideus (SCM), trapezius (TRP), deltoid (DL), bicepsbrachii (BB), triceps brachii (TB), rectus abdominus (RA), and erector spine (ES), rectus femoris (RF), biceps femoris (BF), tibialis anterior (TA), and gastrocnemius (GAS). The reference electrode was placed on the tibial tuberosity. Placement of the surface electrodes on the back of a subject is shown in Figure 3.3.

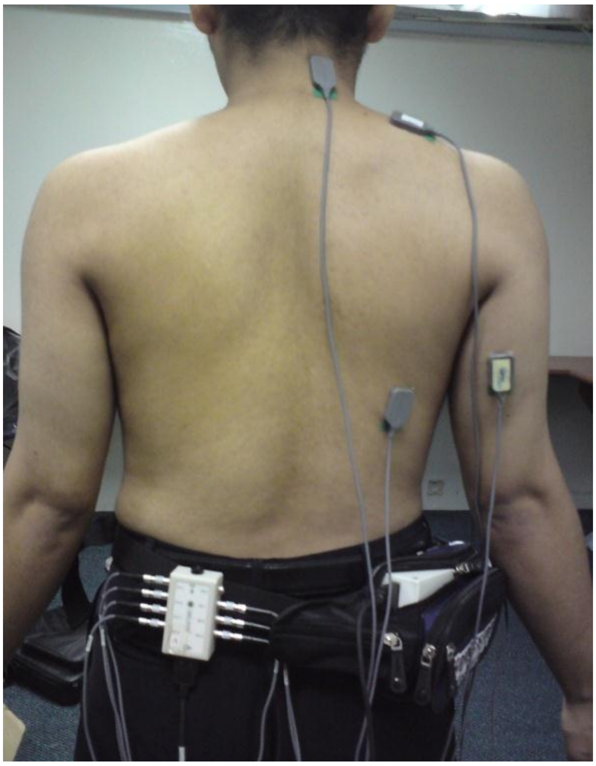


Figure 3.3: Placement of surface electrodes on the back of a subject

3.8.1. EMG Measurement

When all the electrodes had been placed on the muscles, a test run to acquire EMG signals was done to make sure that there was connection between the electrodes and the computer. Then, the experiment started by acquiring the EMG signals from the muscles according to the experiment protocol illustrated in subsection 3.5. Three readings were recorded for every muscle.

3.8.2. MVC Normalization

To normalize the EMG signals, the maximum voluntary contraction (MVC) for each of the 12 muscles involved in this experiment was recorded. To obtain a stable maximum force prior to formal EMG data collection, enough practice warm-up time was allowed. This also made the subject to be familiar with the testing procedures. The EMG reading during the 3 s was used to represent the normalized value (100% MVC).

3.9. Signal Processing

In the current research, the EMG data was digitally filtered by using second order Butterworth band pass filter. The EMG signals from the muscles were in the frequency range of 20 to 450 Hz. This led to using the second order band pass filter of 20 to 450 Hz frequency (Fagarasanu et al., 2005; Szeto & Ng, 2000). Besides, high pass filter of 20 Hz was used to eliminate low frequencyartifacts such as movements during typing activity (Cook et al., 2004; Nag et al., 2009; Szeto et al., 2005).

The digitally filtered EMG signal was processed to calculate the desired parameters which depended on the purpose of research. The parameters could be expressed with respect to various aspects of muscle functions such as frequency, amplitude, and time domains. However, amplitude and frequency domain were focused in this current research. RMS was used to convert the EMG signal to the value that can be calculated.

3.9.1. Root Mean Square (RMS) of EMG Analysis

In order to determine which muscle was on or off, which muscle was more active or less active, and to investigate the degree of activity for each muscle, the amplitude domain of the EMG signal needs to be analyzed. Thus, the possible parameter to answer the entire question in amplitude domain was a RMS (Konrad, 2005).

There were a few steps involved in getting the RMS value, including removing mean, digital filtering, subset (cut into segment with desirable duration), and compute RMS values. This analysis was very important in order to determine the level of the myoelectric activity in a muscle, thus the EMG level of that muscle can be evaluated. For the analysis, each movement or position of *salat*was considered during 10 seconds, than subset for 3 second from the best amplitude. The steps for analysing the data are shown in Figure 3.4. The details are shown in Appendix B.

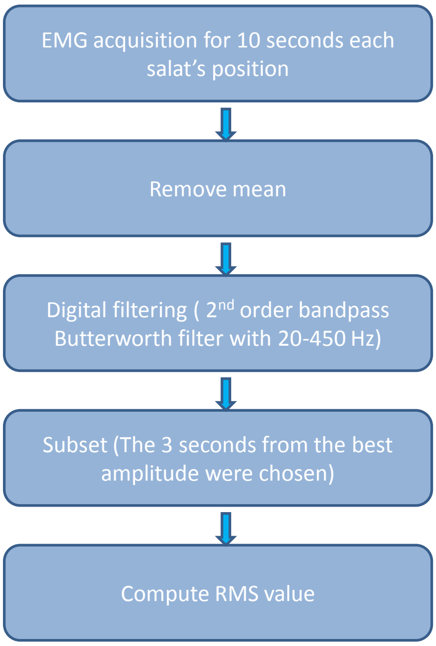


Figure 3.4: Flowchart of RMS computation for EMG analysis

All the readings of themyoelectric activity from each muscle followed the steps analysis shown in Figure 3.3. The normalized EMG value was calculated by dividing the RMS muscle level (mV) with the RMS of MVC (mV). The results were represented in the percentage form. In this study, readings were taken for three times for each position were collected and the averages were used.

3.9.2. MVC for RMS of EMG Analysis

In order to obtain a MVC value, a segment of overall time of the MVC exercise was collected. The same steps of removing mean, digital filtering, getting the subset, and computingthe RMS value were done. Every subject performed repeated an action for three timesfor each muscle and the averages were listed for further analysis statistically.Figure 3.5shows the steps of RMS MVC calculation for the muscle.

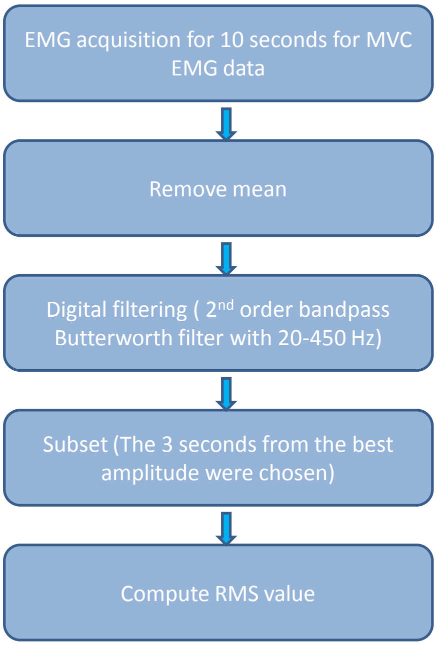


Figure 3.5: MVC for RMS of EMG analysis

3.10.Statistical Analysis

The normalized RMS of EMG data were further analyzed by using the statistical package for the social sciences (SPSS) software to evaluate the difference in muscle activities between pairing muscles during *salat* positions: neck extensor to sternocleidomastoid, trapezius to deltoid, biceps brachii to triceps brachii, and erector spine to rectus abdominal. From that, it was possible to identify whether the pairing muscles underwent the same level of EMG while performing *salat*.

In this test, the Wilcoxon's Rank Sum test was used. This test is a nonparametric test and can be used as an alternative to the paired Student's t-test when the population cannot be assumed to be normally distributed or the data is on the ordinal scale.

CHAPTER 4. RESULTS

4.1. Electromyography Signal

4.1.1 Introduction

20 subjects were involved in this experiment. They were instructed to perform *salat*movements and the myoelectric signals from their muscles were recorded using EMG. However, data of two subjects had been excluded for analysis due to incomplete recording. Therefore, only 18 sets of data from 20subjects (age 23 ± 4 years) were analysed.They were divided into two groups. Group 1 only performed the *salat*protocol (‘takbir’, ‘qiam’, bowing, prostration, sitting and ‘salam’ right and ‘salam’ left) while Group 2performed two *salat*movements (bowing and prostration) and the specified exercises (squat exercise and toe touching exercise).Details of the subjects are shown in Table 4.1.

Table 4.1: Details of subjects (mean ± SD)

	Group 1 (n=11)	Group 2 (n=7)
Age (Years)	24.9 (1.0)	24.1 (1.2)
Gender (M/F)	10/1	5/2
Height (cm)	163.5 (4.9)	162.8 (3.3)
Weight (kg)	56.2 (7.2)	55.7 (6.2)
BMI (kg/cm^2)	21.0 (1.5)	21.0 (1.6)

M, male; F, female.

4.1.2 Raw EMG signal

The raw myoelectric values show that contractions happened for all muscles, both during static positions and during movements from one position to other positions. The EMG produces the raw myoelectric signals. Figure4.1 shows examples of the raw EMG signal obtained from the experiment.

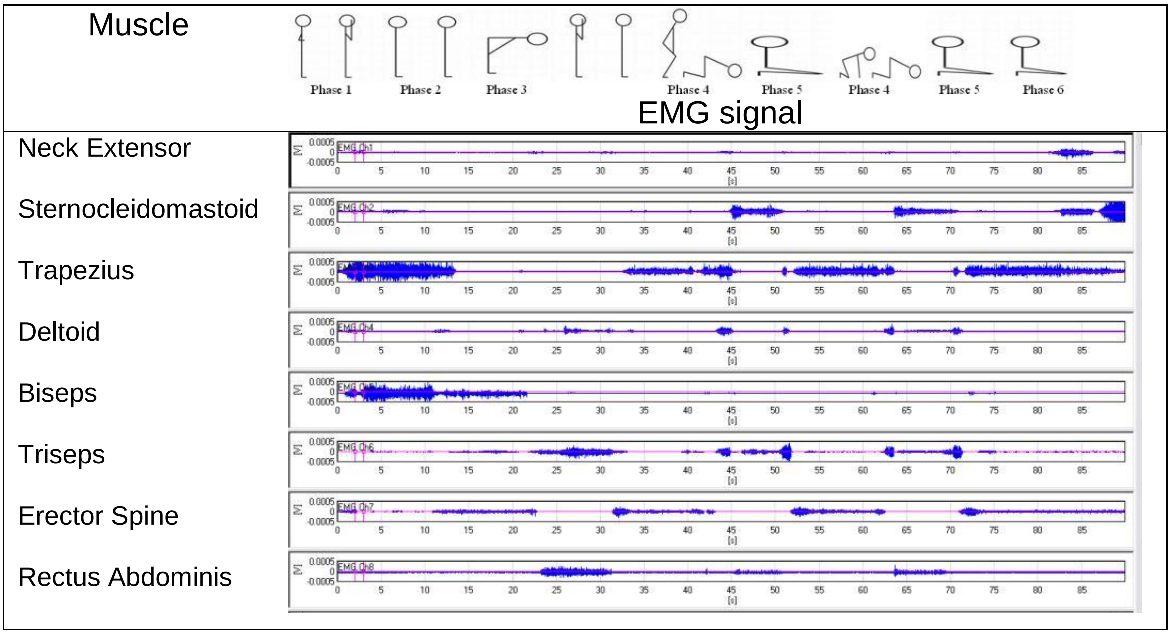


Figure 4.1: The EMG signals (Subject 1)

4.2. Maximum Voluntary Contraction (MVC) in Percentage (%)

4.2.1 Introduction

The raw data obtained from the experiment is normalized to EMG value in percentageof maximum voluntary contraction (MVC). It is important to rescale the data to the percentage of a reference value (MVC) in order to rationalize comparison between subjects. It enables direct comparisons on how effective the muscleswere in achieving a required task and at what capacity level was the task done. Typically, MVC is obtained when a muscle performed a task under a very good fixation and contraction against a rigid resistance (Konrad, 2005).

4.2.2 MVC percentage of each*Salat's* position

After collecting the raw EMG signals for the MVC, the data were analyzed using EMG analysis software version 3.5.1.0 (EMGWorks, Delsys, Boston, MA). Root mean square (RMS) was calculated to smoothen the data, thus producing a linear envelope of EMG activity. Three repetitions were done. The values of all RMS were averaged and then normalized as % MVC. The mean and standard deviation (SD) are shown in Table 4.2.

Table 4.2: EMG level of each muscle during each *salat's* position for group one (mean ± SD)

	'Takbir'	'standing'	bowing	prostration	sitting	Salam right	Salam left
NE	3.9(1.2)	3.9(1.2)	18.4(5.1)	6.2(2.1)	3.9(1.2)	50.6(6.0)	3.9(1.2)
SCM	2.9(0.6)	2.9(0.6)	4.5(1.4)	51.1(7.4)	2.9(0.6)	2.9(0.6)	60.4(5.0)
TRP	23.1(5.2)	1.9(0.1)	2.8(1.4)	3.5(2.0)	1.9(0.1)	1.9(0.1)	1.9(0.1)
DEL	10.6(1.6)	2.0(0.1)	10.5(3.1)	10.4(2.6)	2.0(0.1)	2.0(0.1)	2.0(0.1)
BB	9.8(1.5)	4.4(1.4)	1.4(0.7)	1.4(0.9)	1.2(0.6)	1.2(0.6)	1.2(0.6)
TB	2.6(1.1)	2.4(1.0)	17.9(6.5)	11.0(3.7)	2.4(1.0)	2.4(1.0)	2.4(1.0)
ES	5.5(0.8)	5.5(0.7)	4.7(0.8)	3.7(0.7)	5.3(0.8)	5.3(0.8)	5.3(0.8)
RA	3.3(0.7)	3.3(0.7)	18.7(4.6)	3.2(0.8)	3.2(0.8)	3.2(0.8)	3.2(0.8)

Figure 4.2 shows the EMG level during the "*takbir*". The highest EMG level was that of the TRP muscle (23.11% MVC), followed by DL (10.57% MVC), BB (9.75% MVC), ES (5.50% MVC), NE (3.93% MVC), RA (3.25% MVC), SCM (2.94% MVC), and TB (2.61% MVC).

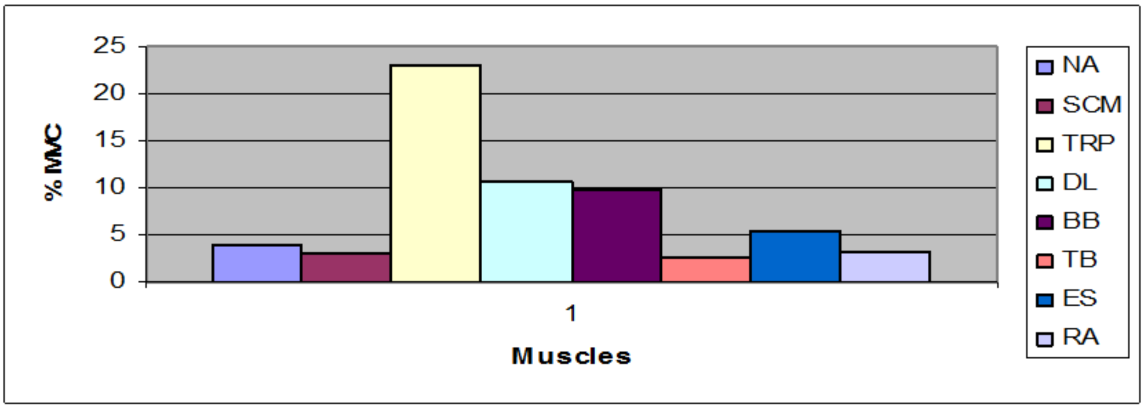


Figure 4.2: The mean of EMG level during *'takbir'*

From the histogram in Figure 4.3, the highest EMG level during "standing/*qiam*" was that of the ES muscle (5.50% MVC), followed by BB (4.43% MVC), NE (3.93% MVC), RA (3.35% MVC), SCM (2.94% MVC), TB (2.42% MVC), DL (2.03% MVC), and TRP (1.88 % MVC).

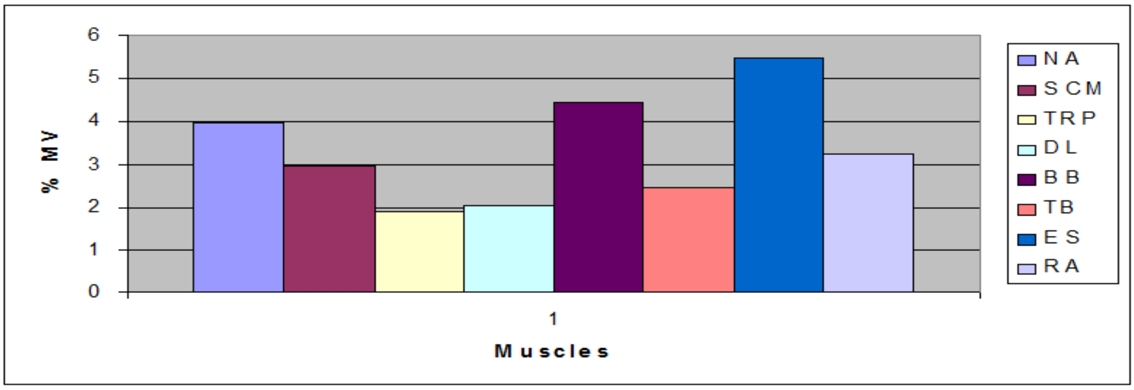


Figure 4.3: The EMG level during 'standing/*qiam*'

Figure 4.4 shows that the highest EMG level obtained during "bowing" was at the RA muscle (18.72% MVC), followed by NE (18.42% MVC), TB (17.92% MVC), DL (10.48% MVC), ES (4.67% MVC), SCM (4.49% MVC), TRP (2.84% MVC), and BB (1.38% MVC).

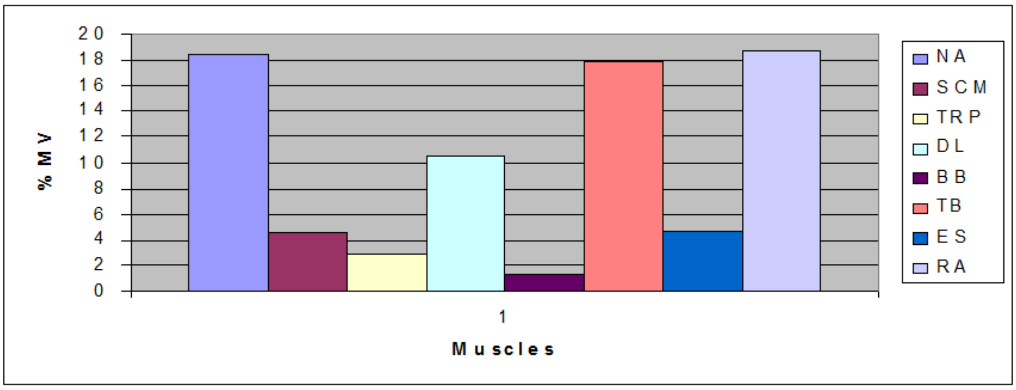


Figure 4.4: The EMG level during bowing

From the histogram in Figure 4.5, it is shown that the highest EMG level obtained during "prostration" was for the SCM muscle (51.05% MVC), followed by RA (12.98% MVC), TB (11.04% MVC), DL (10.35% MVC), NE (6.20% MVC), ES (3.72% MVC), TRP (3.54% MVC), and BB (1.36% MVC).

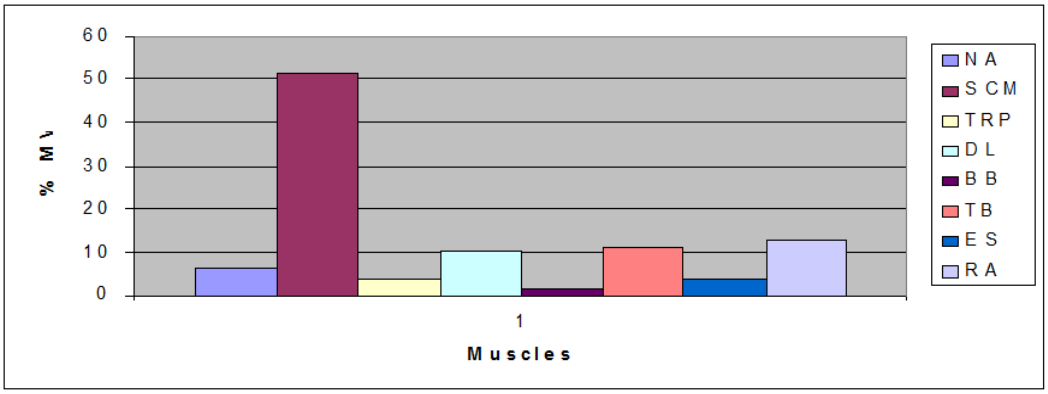


Figure 4.5: The EMG level during 'prostration'

Figure 4.6 shows that the highest EMG level during "sitting" was at the ES muscle (5.33% MVC), followed by NE (3.93% MVC), RA (3.17% MVC), SCM (2.94% MVC), TB (2.42% MVC), DL (2.01% MVC), TRP (1.88% MVC), and BB (1.16% MVC).

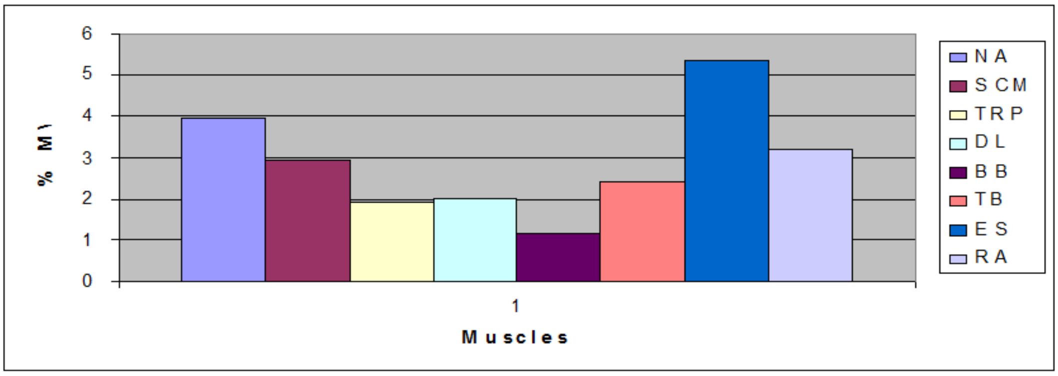


Figure 4.6: The EMG level during 'sitting'

From the histogram in Figure 4.7, it is seen that the highest EMG level obtained during "*salam* (right)" was at the NE muscle (50.55% MVC), followed by ES (5.33% MVC), RA (3.17% MVC), SCM (2.94% MVC), TB (2.42% MVC), DL (2.01% MVC), TRP (1.88% MVC), and BB (1.16% MVC).

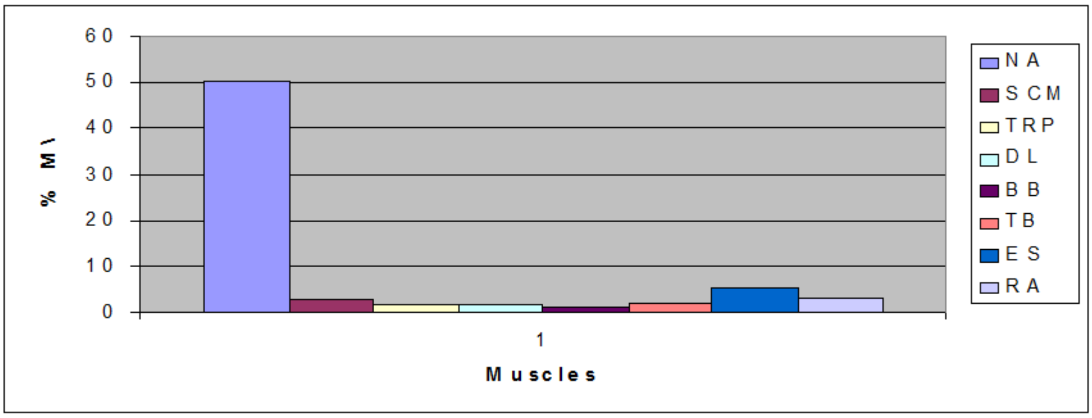


Figure 4.7: The EMG level during '*salam* (right)'

Figure 4.8 showsthat the highest EMG level obtained during the "*salam* (left)" was at the SCM muscle (60.44% MVC), followed by ES (5.33% MVC), NE (3.93% MVC), RA (3.17% MVC), TB (2.42% MVC), DL (2.01% MVC), TRP (1.88% MVC), and BB (1.16% MVC).

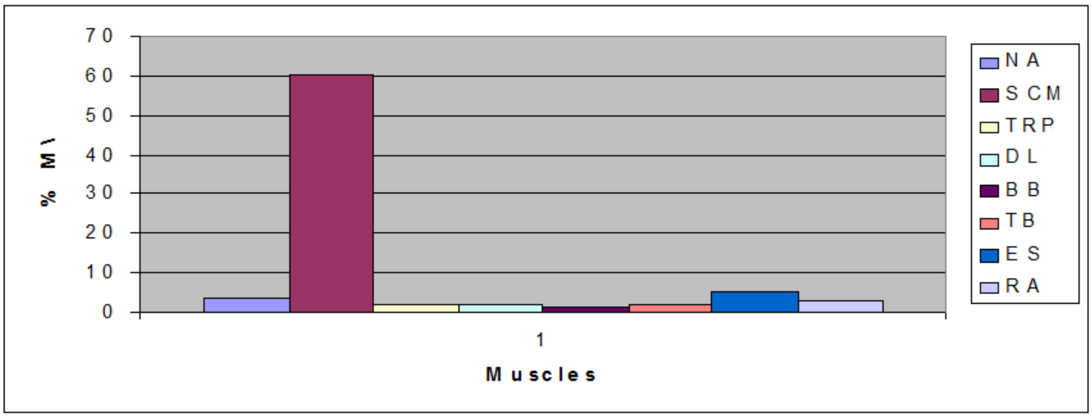


Figure 4.8: The EMG level during 'salam (left)'

The histogram in Figure 4.9 indicates the %MVC level for every muscles during the different solat's positions. It shows the different levels that give the overall comparison for each muscle.

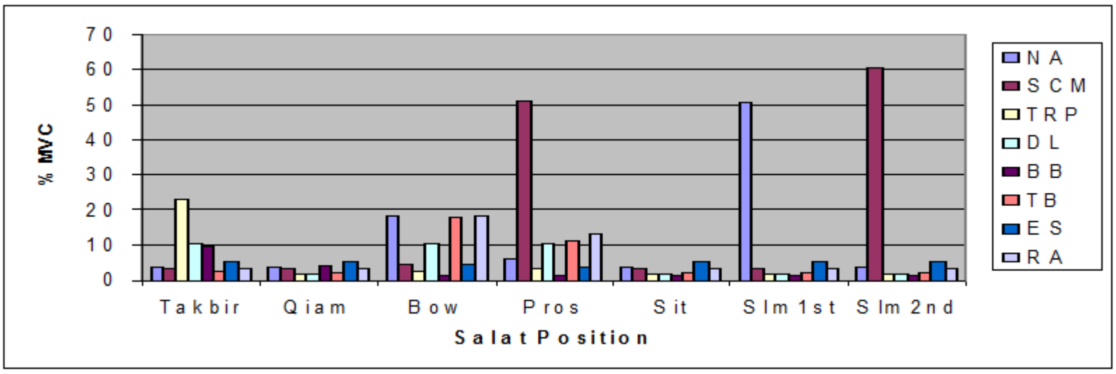


Figure 4.9: The EMG level for each muscle during *salat*

4.2.3 MVC percentage for comparison between Salat's movements and specified exercises

For the comparison of the RF muscle, subjects were asked to performed the prostration and squat exercise whilst for the BE, TA, and GAS, the subjects performed the bowing and toe touching exercise. The EMG average in % MVCis shown in Table 4.3. From the experiment, there were very small differences in EMG levels between *salat* and exercise: RF 1.69%, BF 1.25%, TA 5.67%, and Gas 0.17%. These small differences showed that the muscle contractions and stretches are almost the same between *salat* and exercise.

Table 4.3: EMG level of *salat*and specific exercise

Muscle	EMG average in % MVC	
	Salat	**Exercise**
RF	33.89	35.58
BF	15.13	16.38
TA	15.10	20.77
Gas	21.09	21.26

4.3. Effort Scale (Borg Scale)

4.3.1 Introduction

The level of effort can be subjectively assessed using the Borg Scale. It is important to rate the effort as it is performed to include the influence of posture. The % MVC of Borg's scale is equal to 10 times the scale value or score. Each score describes the condition of the muscle during the activity. Table 4.4 shows the Borg's scale for muscle effort(Borg, 1983).

Table 4.4: Borg's Scale for muscle effort(Borg, 1983)

Score	Description	%MVC
0	Nothing at all 0	0
0.5	Extremely weak (just noticeable)	5
1	Very low (weak)	10
2	Low (light)	20
3	Moderate	30
4		40
5	Strong (heavy)	50
6		60
7	Very strong	70
8		80
9		90
10	Extremely strong (almost maximal)	100

4.3.2 Borg Scale for each*Salat's* Position

EMG's levels in % of MVC obtained from the experiment were transformed to the Borg Scale with the scale from 0 to 10. The score describes the effort of the muscles when performed each *salat's* position. The scores are summarized in Table 4.5.

Table 4.5: Rating Effort Scale (Borg's Scale) for each muscle during each*salat's* position.

Position	Muscle	% MVC	Borg Scale
Takbir	NE	3.93	0
	SCM	2.94	0
	TRP	23.11	2
	DL	10.57	1
	BB	9.75	1
	TB	2.61	0
	ES	5.50	0.5
	RA	3.25	0
Standing/*Qiam*	NE	3.93	0
	SCM	2.94	0
	TRP	1.88	0
	DL	2.03	0
	BB	4.43	0
	TB	2.42	0
	ES	5.50	0.5
	RA	3.35	0
Bowing	NE	18.42	2
	SCM	4.49	0
	TRP	2.84	0
	DL	10.48	1
	BB	1.38	0
	TB	17.92	2
	ES	4.67	0
	RA	18.72	2
Prostration	NE	6.20	0.5
	SCM	51.05	5
	TRP	3.54	0
	DL	10.35	1
	BB	1.36	0
	TB	11.04	1
	ES	3.72	0
	RA	12.98	1
Sitting	NE	3.93	0
	SCM	2.94	0
	TRP	1.88	0
	DL	2.01	0
	BB	1.16	0
	TB	2.42	0
	ES	5.33	0.5
	RA	3.17	0
Salam (right)	NE	50.55	5
	SCM	2.94	0
	TRP	1.88	0
	DL	2.01	0
	BB	1.16	0
	TB	2.42	0
	ES	5.33	0.5
	RA	3.17	0
Salam (left)	NE	3.93	0
	SCM	60.44	6
	TRP	1.88	0
	DL	2.01	0
	BB	1.16	0
	TB	2.42	0
	ES	5.33	0.5
	RA	3.17	0

From Table 4.5, the highest EMG level was produced by SCM during the *salam* (left) motion. According to the rating effort scale (Borg Scale), it scored 6 which was considered as a strong level of intensity of the effort. Besides, SCM also hada score of 5 during prostration which was considered a strong level of intensity of the effort. Another muscle that scored 5 was the NE during *salam* (right). For the TRP, it scored 2 during the *takbir's* position which considered a low level of intensity of the effort.

By position, during the *takbir's*,the TRP scored 2, DL scored 1, BB and ES scored 0.5, and the rest scored 0; during standing, the ES scored 0.5 and the rest scored 0; during bowing, the RA, NE, TB, and DL scored 1 whilst the rest scored 0; during prostration, the SCM scored 5, the RA, TB, and DL scored 1, the NE scored 0.5 whilst the rest scored 0; during sitting, only the NE scored 0.5 whilst the rest scored 0; during the *salam* (right), the NE scored 5, the ES scored 0.5 whilst the rest scored 0; and during*salam* (left), the SCM scored 6, the ES scored 0.5 whilst the rest scored 0.

4.4. Statistical Analysis

4.4.1 Introduction

Descriptive statistics was used to study the features of the entire signal. Statistical analysis was performed with SPSS V18.0. The Wilcoxon's Rank Sum test were used to investigate differences in %MVC strength values between paired muscles during each *salat's*position and to identify the presence of statistically significant differences or imbalances. Normalized mean %MVC of EMG values of each position were analyzed for differences between each pair of muscles. Significance was set at $p<0.05$.

4.4.2 Statistical Analysis for Comparison Between Paired Muscles

Table 4.6 shows the test statistics of the EMG values for *salat's* position of NE and SCM. The test showed that the EMG contraction levels were significant by different between the NE and SCM for all the *salat's* positions.

Table 4.6: Wilcoxon's Rank Sum test for NE and SCM muscles.

Position	Muscle	Medium	Interquartile Range	SD	z	p
Takbir	NE	3.79	0.95	1.17	-1.956	0.05
	SCM	2.78	1.13	0.62		
Standing	NE	3.79	0.95	1.17	-1.956	0.05
	SCM	2.78	1.13	0.62		
Bowing	NE	20.10	7.87	5.08	-2.934	0.003
	SCM	4.25	2.37	1.43		
Prostration	NE	5.94	4.14	2.12	-2.934	0.003
	SCM	51.94	13.02	7.39		
Sitting	NE	3.79	0.95	1.17	-1.956	0.05
	SCM	2.78	1.13	0.62		
Salam (right)	NE	51.29	9.96	5.95	-2.934	0.003
	SCM	2.78	1.13	0.62		
Salam (left)	NE	3.79	0.95	1.17	-2.934	0.003
	SCM	60.03	7.58	4.97		

Table 4.7 shows the test statistics of the EMG values for *salat's* position of the TRP and DL. The result showed that EMG contraction levels were significant by different between the TRP and DL for all the *salat's* positions.

Table 4.7: Wilcoxon's Rank Sum test for TRP and DL muscle.

Position	Muscle	Medium	Interquartile Range	SD	z	p
Takbir	TRP	24.08	8.30	5.16	-2.934	0.003
	DL	10.56	3.08	1.60		
Standing	TRP	1.88	0.26	0.13	-2.492	0.013
	DL	2.03	0.10	0.08		
Bowing	TRP	3.09	1.91	1.39	-2.934	0.003
	DL	10.15	5.34	3.11		
Prostration	TRP	2.42	3.71	2.0	-2.934	0.003
	DL	10.88	4.11	2.6		
Sitting	TRP	1.88	0.26	0.13	-2.193	0.028
	DL	2.03	0.06	0.09		
Salam (right)	TRP	1.88	0.26	0.13	-2.193	0.028
	DL	2.03	0.06	0.09		
Salam (left)	TRP	1.88	0.26	0.13	-2.193	0.028
	DL	2.03	0.06	0.09		

Table 4.8 shows the test statistics of the EMG values for *salat's* position of the BB and TB. The result showed that the EMG contraction levels were significant by different between the BB and TB for all the *salat's* positions.

Table 4.8 : Wilcoxon's Rank Sum test for BB and TB muscle.

Position	Muscle	Medium	Interquartile Range	SD	z	p
Takbir	BB	9.38	1.43	1.48	-2.934	0.003
	TB	2.05	0.92	1.09		
Standing	BB	4.93	2.88	1.38	-2.312	0.021
	TB	1.98	1.45	1.02		
Bowing	BB	1.20	0.92	0.67	-2.934	0.003
	TB	16.11	11.18	6.48		
Prostration	BB	1.04	1.47	0.92	-2.934	0.003
	TB	10.41	6.83	3.75		
Sitting	BB	1.04	0.68	0.62	-2.756	0.006
	TB	1.98	1.45	1.02		
Salam (right)	BB	1.04	0.68	0.62	-2.756	0.006
	TB	1.98	1.45	1.02		
Salam (left)	BB	1.04	0.68	0.62	-2.756	0.006
	TB	1.98	1.45	1.02		

Table 4.9 shows the test statistics of the EMG values for *salat's* position of the ES and RA. The result showed that EMG contraction levels were significant by different between the ES and RA for all the *salat's* positions.

Table 4.9 : Wilcoxon's Rank Sum test for RA and ES muscle.

Position	Muscle	Medium	Interquartile Range	SD	z	p
Takbir	RA	5.57	1.36	0.74	-2.934	0.003
	ES	3.11	1.18	0.73		
Standing	RA	5.57	1.36	0.74	-2.312	0.021
	ES	3.11	1.18	0.73		
Bowing	RA	4.94	0.84	0.77	-2.934	0.003
	ES	19.54	9.48	4.57		
Prostration	RA	3.79	0.60	0.70	-2.934	0.003
	ES	13.02	3.05	1.91		
Sitting	RA	5.43	1.47	0.75	-2.756	0.006
	ES	3.06	1.67	0.75		
Salam (right)	RA	5.43	1.47	0.75	-2.756	0.006
	ES	3.06	1.67	0.76		
Salam (left)	RA	5.43	1.47	0.75	-2.756	0.006
	ES	3.06	1.67	0.76		

4.4.3 Statistical Analysis for Comparison Between Salat and Exercises

According to Table 4.2, although the results show that RF, BF, and Gas had slightly higher EMG activities during exercise than during *salat,* Wilcoxon's Rank Sum test showed no significant difference between *salat* and the exercises (RF p=0.310, BF p= 0.176, and Gas p=0.176). For TA, Wilcoxon's Rank Sum test indicated a statistically significant difference between *salat* and the exercises ($p<0.05$). Table 4.10 shows the test statistics of the EMG values for comparison between *salat* and the exercises.

Table 4.10 : Wilcoxon's Rank Sum test for *salat* and exercises

Posture	**Median**	**InterquartileRange**	**SD**
RectusFemoris			
STP	36.41	8.77	4.96
SE	36.91	7.29	4.27
Biceps Femoris			
Bow	15.23	1.24	1.16
TTE	16.60	2.22	1.27
TibialisAnterior*			
Bow	15.02	1.36	1.39
TTE	20.54	2.83	1.52
Gastrocnemius			
Bow	20.71	4.84	2.53
TTE	21.03	2.29	1.22

CHAPTER 5. DISCUSSION

5.1. Introduction

The aim of this research was to investigate the biomechanical response of the human muscles during*salat's* position by looking at the EMG levels. Beside that, this study also investigates the agonist and antagonist muscle's response during *salat.* It is shown that there were muscle responses during *salat* and that the *salat*produced contraction and relaxation between antagonist muscles.

5.2. Similaritybetween*salat*movement and muscle exercise

The way to make sure that our muscles are healthy is by always doing exercise. Exercise is such a way we contract and stretch the muscles. A good stretching technique for improving the range of motion is static stretching, in which the limb is then maintained in that position for 10 to 30 seconds (Reza et al., 2002). The results of the current study show that, by performing the *salat*, the body muscles produce contraction and stretching responses. During *salat*, each position is performed for about 10 s and these movements can act as the way Muslims do stretching.

Beside that, Muslims perform *salat* regularly. It is similar to exercise that people need to do exercises regularly to get the optimum health conditions. There is a growing realization that regular participation in physical activity endows benefits to our health. For example, regular exercise reduces the blood pressure by reducing body weight and increasing elasticity of the blood vessels(Halbert et al., 1997). Moreover, regular exercise counteracts the effect of habits elevating cardiovascular risk, such as smoking and alcohol consumption, malnutrition, stress, anxiety etc. Regular exercise is quite an effective tool in the prevention and rehabilitation of cardiovascular diseases(Hamer & Stamatakis, 2009). Barlet et al.(1995) found that a regular program of weight-bearing exercise, such as walking, can increase bone health and strength even among individuals with osteoporosis.

In this study, the bowing position is quite similar to the toe touching exercise (TTE). It is a stretching exercise that helps to stretch the spine and also the muscles of the lower back. This exercise causes the hamstring to extend. During the flexion movement, abdominal muscles have higher intensityof activation while lying down(Moraes et al., 2009). TTE is almost the same as bowing because of the degree of trunk flexion. For bowing, subjects needed to flex their trunk to 90^0 and for TTE, subjects needed to flex their trunk 90^o or more than 90^0 to touch their toes.

5.3. Muscle Stretching during*Salat's* Movement

Active stretching of muscles is produced by contraction of the antagonist muscles (those on the side of the joint opposite the muscle, tendons, and ligaments to be stretched)(Warburton et al., 2006). The most effective stretching procedures are known collectively as proprioceptive neuromuscular facilitation (PNF). PNF technique was originally used by physical therapists for treating patients with neuromuscular paralysis (Taylor et al., 2004). All PNF procedures involved some patterns of alternating contraction and relaxation of the agonist and antagonist muscles designed to take advantage of the response of the Golgi tendon organ (GTO). Each phase of contract-relax-antagonist-contract technique is typically maintained for duration of 5 - 10 s, and the entire sequence is carried out for at least four times (Taylor et al., 2004). Muslim is commanded to perform the *salat*five times a day. In the current study, muscles at the upper limb were selected to identify their response during *salat*. From the result, the statistical analysis shows that each pair of muscles produce difference myoelectric responses.

5.4. Normalization RMS with MVC

Normalization allows the results to be compared across subjects, thus compensating for differences in strength, muscle tone, body fat, muscle geometry, and other factors. In order to normalize data for comparison, experimenters get subjects to exert a “maximum voluntary contraction” (MVC) of the muscle being studied (Konrad, 2005). Each subject’s MVC measurement is then considered as a reference point of 100% and the other measurements for that subject are converted to a percentage of their MVC. MVC must be established with the muscle and joint in the same positions as during the experiment. Otherwise, the muscle area under the electrode will change and result in inaccurate data (Konrad, 2005). If the study reports the results in microvolts without normalizing the data, comparison between subjects is impossible due to individual differences as described above. Also, results reported only as microvolts may mask the fact that conditions are either unacceptably high, or so low as to not present a risk.

One important benefit MVC normalized data provides is the estimation of neuromuscular effort “invested” or needed for a given task or exercise. On the microvolt level, it is impossible to estimate the neuromuscular demand because these data are too strongly influenced by the individual signal detection condition. Any “normative” amplitude data published in microvolt values must be used with very special care. MVC normalized data give an understanding at what capacity level the muscles did work, how effective a training exercise “reached” the muscles, or how much demand,ergonomically, a work task is asking from a worker(Konrad, 2005).

5.5. Differences between Concentric and Eccentric Phase during *Salat* and Exercises

In this study, assessments were done only on the squat exercise and *salat* (standing to prostration) during the eccentric phase which is the movement from standing upright of flexing the knee and lowering the body. However, in the squat exercise and *salat*, there are also concentric phases to complete the task which would elicit different results.Electromyographic activity of the muscle is different between eccentric and concentric muscle actions(McHugh et al., 2002; Tesch et al., 1990). Eccentric actions typically result in less EMG amplitude than concentric contractions at the same relative level of force production. A current theory is that motor-neuron-firing rates decrease during eccentric actions, as opposed to a reduction of recruited motor units, resulting in lower EMG amplitude(Coburn et al., 2006). However, mean electrical frequencies increase during eccentric actions, which suggests preferential recruitment of fast-twitch motor units(McHugh et al., 2002). Furthermore, the ability of the muscle to absorb energy during an eccentric contraction can be used to brake a movement and probably serves to protect less compliant elements (e.g., bone, cartilage, ligament) of the neuromuscular system from damage due to high-impact forces and repetitive low-level forces(Wilson et al., 1994) These considerations suggest that the reasons for including an eccentric contraction in a movement may vary across tasks but that the net effect is an enhancement of performance.

5.6. Limitations and Further Improvements

There were several limitations in the current experiment, The EMG is a very sensitive equipment. The researcher had to struggle very hard and always redid the experiment just because of some noise that couldcause errors in the result. To overcome this limitation, researcher must identify the factor that influencing the EMG signal such as tissue characteristics, physiological cross talk, changes in the geometry between muscle belly and electrode site (Konrad, 2005). This entire factor was explained in literature review. To get the best result, all of these factors must be focused. But, in this experiment, the tissue characteristic especially the tissues thickness was not assessed. For further improvement, researchers must identify the thickness of tissues using certain equipment to get the best results (Konrad, 2005).

Besides getting the real raw data of EMG, researcher must eliminate the noises of EMG signal. The electrical equipment also can be one of the external noises. The bigger room is recommended to make sure the electrical equipment can be located as far as possible from the subject to make sure no external noise can disturb the EMG signal. Another limitation was, not many volunteers interested and could give commitment to be involved in the experiment because every session for the test takes about 30 to 60 minutes. To get more volunteers, earlier announcement must be done to arrange the appointment that all volunteers can spend their free time during the test. Honorarium can be one of the attractions to volunteers because this research also takes their working time.

CHAPTER 6. CONCLUSION

6.1. Introduction

This chapter summarizes the finding of this research work and make recommendations for further work in the area.

6.2. The Findings

This study reports effects of *salat's* positions on the biomechanical response of the upper body muscles. Finding shows that by doing *salat*, the muscles contract and stretch in an optimal length of time. Hence,the *salat*can act as one of the daily exercises or warm-up maneuver to enable the muscles perform optimally. Muscle contraction and muscle relaxation that occur show agonist-antagonist response which is good for exercise and strengthening programs. The investigations can be extended to other musclesby involving standing or sitting positions. Hence the current study can be taken as a pilot study for more investigations on the biomechanical response of the human muscles during the act of performing the *salat*.

6.3. Recommendations for Future Work

It is recommended that more subjects be studied and try to compare *salat* with standard exercises that can give a general view on*salat* being one of the moderate exercise that can be of benefit in one's daily life.

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APPENDIX A

SUBJECT’S CONSENT FORM

Appendix A

SUBJECT'S CONSENT FORM

Biceps Brachii

Biomedical Engineering
UNIVERSITY OF MALAYA
MALAYSIA

Title of Project: The Impact Of *Salat*'s Positions On The Biomechanical Response Of The Human Muscles

I subject number__________, I.C number_______________________, give my full consent behalf myself to be the subject for the study of The Impact Of *Salat*'s Positions On The Biomechanical Response Of The Human Muscles. The devices used in this research as following:

1. Myomonitor ®III EMG system, Delsys Inc. (bandwidth of 20 to 450 Hz and sampling rate at 1500 Hz). The EMG system is clinically proven and safe.The Myomonitorsystem is a medical device approved under the International Electrotechnical Commission (IEC).

I have read the information of the research study as stated and have also been given the explanation about purpose of this document. I am understood that no guarantees to me regarding the result from treatments and measurement.I am understood that there are certainrisks involved in participating in this research and I am willing to take responsibility for such risks.I have read and signed this consent statement with my own responsibility and full knowledge of the fact.

Subject Number: ___________ I.C Number:____________________

Subject Signature: _________________Date: ___________________

Researcher Name:__________ I.C Number:_____________________

Researcher Signature: _____________Date: _____________________

APPENDIX B

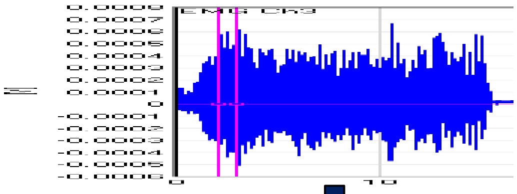
COMPUTING RMS VALUES

FROM RAW DATA

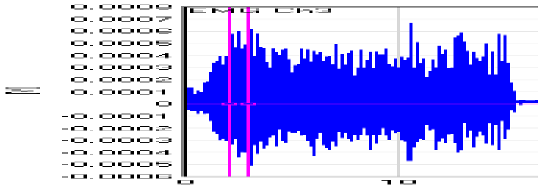
Appendix B

EXAMPLE OF COMPUTATION RMS VALUES FROM RAW DATA

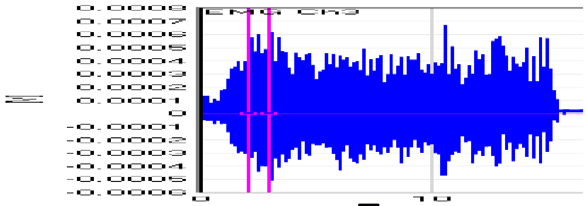
1) EMG acquisition for 10 seconds from a muscle during experiment.



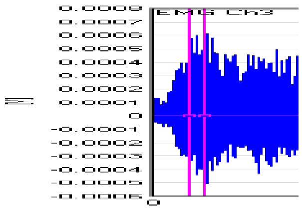
2) Remove mean (the baseline shifted back to zero line).



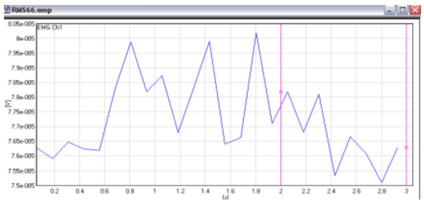
3) Digital Filtering using the 2nd order bandpass Butterworth filter with 20-450Hz.



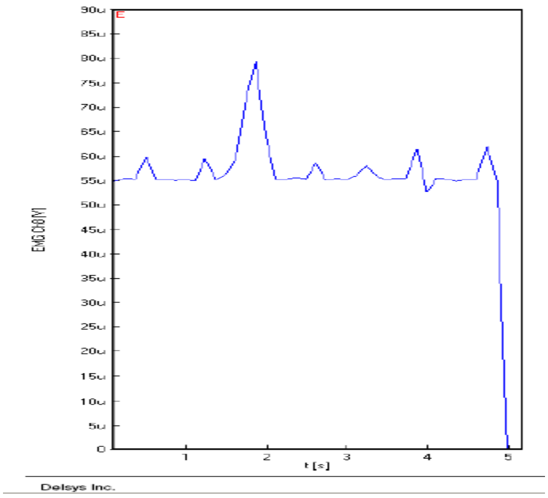
4) The best five seconds amplitude was chosen.



5) Convert into RMS amplitude (all the negative amplitudes are converted to positive amplitudes. The negative spikes are 'moved up' to plus or reflected by the baseline).



6) Compute the RMS value



RMS Value: 56.768µV

APPENDIX C

LIST OF PUBLICATIONS

APPENDIX C

LIST OF PUBLICATIONS

JOURNAL

1. Safee, M.K.M., Wan Abas, W.A.B., Ibrahim, F., Abu Osman, N.A., &Salahuddin, M.H.R. (2012). Electromyographic Activity of the Lower Limb Muscle during Salat and Specific Exercise. Accepted for publication in the *Journal of Physical Therapy Science*, 24(6).(ISI-Cited Publication)
2. Safee, M.K.M., Wan Abas, W.A.B., Ibrahim, F. & Abu Osman, N.A. (2012).Electromyographic Activity of the Upper Limb Muscle during Specific *Salat's* Position and Exercise. Accepted for publication in the International *Journal of Applied Physics and Mathematics* (IJAPM, ISSN: 2010-362X).

PROCEEDINGS

1. Safee, M.K.M., Wan Abas, W.A.B., Ibrahim, F. & Abu Osman, N.A. (2011). Activity of Upper Body Muscle during Bowing and Prostration tasks in Healthy Subjects. 5thKuala Lumpur International Conference on Biomedical Engineering 2011 (BioMed 2011), on 20 – 23 June 2011. IFMBE Proceedings, 2011, Volume 35, 1680-0737, DOI: 10,1007/978-3-642-21729-6. (ISI-Cited Publication).
2. Safee, M.K.M., Wan Abas, W.A.B., Ibrahim, F. & Abu Osman, N.A. (2011). Electromyographic Activity of the Upper Limb Muscle during Specific Salat's Position and Exercise. The 2011 International Conference on Physic Science and Technology (ICPST 2011), on 28 – 30 December 2011. (ISI-Cited Publication).