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Electromyographic Activity of the Lower Limb Muscles during *Salat* and Specific Exercises

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Abstract. [Purpose] This study investigated the activity of the rectus femoris (RF), biceps femoris (BF), tibialis anterior (TA) and gastrocnemius (Gas) muscles of healthy subjects during *salat* and specific exercises using surface electromyography (EMG). [Methods] A group of undergraduates aged between 19 to 25 years voluntarily participated in this study. For the assessment of the RF muscle, the subjects were asked to perform *salat* movement [standing to prostration (STP)] and squat exercise (SE) and for the BF, TA and Gas muscles, subjects were asked to perform *salat* (bowing) and the toe touching exercise (TTE). The electromyograms of the muscles were recorded and analyzed. [Result] The findings indicate that there were contractions of the muscles during the *salat* and exercises with difference EMG levels. Wilcoxon's Rank Sum Test found a statistically no significant differences between *salat* and the specific exercises for RF, BF and Gas. For TA, the test revealed a statistically significant difference between *salat* and the specific exercise with a difference of 5.67%MVC. [Conclusion] S*alat* may be useful in warm up or in rehabilitation programs. This pilot study conducted initial research into the biomechanical responses of human muscles in various positions of *salat*.
Key words: Electromyography, *Salat*, Exercise

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INTRODUCTION

Electrical activity in human muscles can be measured using electromyography (EMG). This allows the measurement of the change in the membrane potential as the action potentials are transmitted along the fiber. The study of the muscles from this perspective can provide valuable information concerning the control of voluntary and reflexive movements. The study of muscle activity during a particular task can yield insight into which muscles are active and when the muscles initiate and cease their activities[1]. EMG is also used to study neuromuscular function, including identification of which muscles develop tension throughout a movement and which movements elicit more or less tension from a particular muscle or muscle group. It is also used clinically to measure nerve conduction velocities and muscle responses in conjunction with the diagnosis and tracking of pathological conditions of the neuromuscular system[2].

Salat is a ritual Islamic prayer that's given by all those practicing the Muslim religion five times a day. *Salat* shows an individual's dedication to God and is considered the most important act of worship. *Salat* has precise steps that all Muslim all over the world must perform. The various motions of the *salat* include standing, bowing, prostration, and sitting. The joints that are involved in the movements are the shoulders, wrists, elbows, metacarphophalangeals (MP), proximal interphalangeals, distal interphalangeals, temporomandibular, vertebral column, hip, knee, ankle, subtalar, metatarsophalangeal, and antanto-axial[3].

A Muslim performing *salat* 1) begins the prayer by standing facing the direction of the Qibla and raises the hands and speaks aloud a phrase called the *takbir*, 2) stands while the hands are placed between the chest and stomach and recites Al-Quran, 3) bows, repeating the *takbir*, 4) returns to the standing position, 5) prostrates, placing the forehead, nose, hand, knee, and toes on the floor, 6) moves to the upright kneeling position, 7) repeats the act of prostration, 8) return to the upright kneeling position while reciting *tashahhud* and 9) concludes *salat* by turning first towards the right and toward the left, the movement called *salam*. These positions and movements involve many muscle contractions and relaxations and is a good exercise activity. Besides, a Muslim is commanded to perform *salat* regularly, five times a day.

Many benefits accrue to the muscles of a person who is always doing exercise or training. During training of the muscular system, a neural adaptation modifies the activation levels and patterns of the neural input to the muscle. In strength training, for example, significant strength gains can be demonstrated after approximately four weeks of training. This strength gain is not attributable to an increase in muscle fiber size but is rather a learning effect in which neural adaptation occurs[4], resulting in increases in factors such as firing, and motorneuron excitability[5]. In addition, strength training is also recognized as an effective form of exercise for elderly individuals[6]. Strength training that is maintained into the later years may counteract atrophy of bone and tissues, and moderate the progression of degenerative joint alteration. Eccentric training also been shown to be effective at developing strength in the elderly[7].

The purpose of this experiment is to identify the muscle potential during *salat's* movement and position that can be one of the daily exercise and training for our muscle. This is because, it is obligatory for Muslim to perform *salat* five prayers during day and night with difference rakat or unit; dawn prayer 2 *rakat*, midday prayer 4 *rakat*, afternoon prayer 4 *rakat*, dusk prayer 3 *rakat* and night prayer 4 *rakat*. Each *rakat* consist a routine start from standing-bowing-standing-prostration-sitting-prostration-standing. Besides the obligatory or prescribed five daily routine (prayers), Muslims are strongly advised to perform the non-obligatory prayers.

SUBJECTS AND METHODS

A total of 14 undergraduates (age: 19.5 ± 5.1 years) with no medical history were recruited as subjects for the study. Seven subjects performed standing to prostration (STP) movement and squat exercise (SE) while the other 7 subjects performed bowing and toe touching exercise (TTE). Subjects were verbally informed about the experimental protocols, and they read and signed a consent form prior to participating in the experiments. Three repetitions were recorded for both the *salat* and exercise protocol.

Disposable bipolar Ag-AgCl disc surface electrodes with a diameter of one cm were affixed over the chosen muscle groups, parallel to their fiber orientation at the muscle belly. The electrodes were attached to the right leg over the belly of the rectus femoris (RF), biceps femoris (BF), tibialis anterior (TA) and gastrocnemius (Gas). The electrodes were placed over the midpoint of the muscle belly. The common-earth electrode was attached to the head of the fibula on the same side. The electrodes were connected to an EMG data collection system (Myomonitor IV Wireless Transmission, Delys) and the signals were collected using customized software (DelysEMGWorks, Boston, MA, USA). The records were then downloaded to a personal computer (Toshiba, Japan). The EMG bandwidth used was 10–500 Hz and the sampling rate was 1500 Hz. The electrodes were placed according to the SENIAM recommendation[8]. The myomonitor was capable of recording 16 muscles simultaneously.

In order to compare the values of muscle activities across subjects it was necessary to normalize the EMG data. To normalize the EMG data, a record was made of the maximum voluntary contraction (MVC) of each of the muscles studied. To obtain stable maximum force prior to formal EMG data collection, sufficient practice was allowed for warming-up and for the subjects to familiarize themselves with the testing procedures. Subjects maintained the same level of contraction for 5 s and the 3 s with the most constant root mean square (RMS) EMG signal were selected and used to represent the normalization value (100% MVC).

To measure MVC of RF, subjects sat on a chair with 90° knee flexion. Then, they extended the knee between 90° and 70° while imagining a large resistance load . For BF, subjects sat on a chair and completely extended the knee. Then, they flexed the knee while imagining a large resistance load. For TA, subjects sat on the edge of a high desk with the knees bent and the ankle in the neutral position. Then, they raised the toes up toward the front of the leg by bending the ankle while imagining a large resistance load. For Gas, subjects sat on a chair with the foot in the neutral position on the floor. Then, they pushed off the floor by lifting the heel off the ground while imagining a large resistance load. Three repetitions were recorded for each muscle.

To assess RF, subjects were asked to perform STP and SE. According to Maior AS et al.[9] SE consists of two phases, an eccentric phase and a concentric phase. We only measured the eccentric phase. Subjects performed 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, they flexed the knee to 90°. For *salat*, subjects started from standing upright, and flexed the knee till the knees, forehead and palms of the hands touched the ground. These movements were done during a period of 5 seconds, starting from standing upright. For the comparison of BF, Gas and TA, subjects performed bowing and TTE. During bowing, subjects bent their trunk to reach 90° of flexion and gripped the knees. While performing TTE, subjects bent their trunk and touched their toes or the ground. The positions were held in duration for 5 seconds.

The EMGs recorded during *salat* and exercises were identically processed. The EMG signals were analyzed using EMG analysis software version 3.5.1.0, (EMGWorks, Delsys, Boston, MA), then the root mean square (RMS) was calculated to smooth the data, producing a linear envelope of EMG activity. The data obtained for each subject were downloaded to a personal computer (Toshiba, Japan). The values of all RMS were averaged and then normalized as % MVC. Then, each position of *salat* and exercise were compared.

Descriptive statistics were used to study the features of the entire signal. The Wilcoxon's Rank Sum test was used to examine the differences between *salat* and exercise in terms of the EMG level. Result were considered significant for values of $p<0.05$. The data was analyzed using the Statistical Package for the Social Sciences (SPSS) software, version 18.0.

RESULT

The experimental results of the EMG signals for all the subjects indicate that there were muscles contractions for all of the muscles during *salat* and exercise. RF, TA and Gas generated almost the same levels of EMG in *salat* and the exercise. The EMG level averages in % MVC for each muscle are shown in Table 1.

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 show that the muscle contractions and stretches are quite the same between *salat* and exercise.

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 exercise (RF p=0.310, BF 0.176 and Gas 0.176). For TA, Wilcoxon's Rank Sum test indicated a statistically significant difference between *salat* and exercise ($p<0.05$) (Table 2).

Table 1. EMG levels

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

DISCUSSION

From this experiment, we can see that muscle contraction appeared during *salat* as well as exercise. The rectus femoris, hamstring and gastrocnemius are the most important muscles during walking. Two-joint muscles that work together in walking are the sartorius and rectus femoris at heel strike; the hamstrings and gastrocnemius at mid-stance; the gastrocnemius and rectus femoris at toe-off; the rectus femoris, sartorius and hamstrings in forward swing; and the hamstring and gastrocnemius in foot descent[10]. Doing exercise for these muscles, it will helps to maintain movements in the lower limbs, especially in the gait cycle.

Muslims perform *salat* regularly. 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[11,12]. 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[13]. Barlet et al. found that a regular program of weight-bearing exercise, such as walking can increase bone health and strength even among individuals with osteoporosis[14].

In this study, we only assessed 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 squat exercise and *salat*, there are also concentric phases to complete the task which would elicit different result[9]. Electromyographic activity of the muscle is different between eccentric and concentric muscle actions[15,16]. 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[17]. However, mean electrical frequencies increase during eccentric actions, which suggests preferential recruitment of fast-twitch motor units[15]. 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[18,19]. 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.

The toe touching exercise is a stretching exercise that helps to stretch the spine and also the muscles of lower back. This exercise causes the hamstring to extend. During flexion movement, abdominal muscles have higher intensity of activation while lying down[20]. TTE is different from bowing because of the degree of trunk flexion. For bowing, subjects needed to flex their trunk to 90°, but in TTE, subjects needed to flex their trunk more than 90° to touch their toes. This difference in degree of flexion has its own inherent workload

Table 2. Results of *salat* and exercise

Posture	Median	Interquartile Range	SD
Rectus Femoris			
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
Tibialis Anterior*			
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

(*$p<0.05$)

because of the fact that body alignment is not in the neutral position where weight is born by the joint[21].

In conclusion, the *salat* positions such as standing to prostration and bowing can be used as exercises to maintain lower limb performance. Every Muslim who performs *salat* 5 times a day is doing exercise for their lower limb muscles especially the rectus femoris and gastrocnemius muscles. Besides, *salat* can also be used as a flexibility exercise for maintaining range of motion (ROM) of the joints. This pilot study may be useful for therapists conducting rehabilitation or exercise programs.

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