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Muscle Activation Pattern of Upper and Lower Back Muscles during Islamic Prayer (Salat)

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ABSTRACT

Electromyographic (EMG) activity of muscles can help us to assess the muscular functions during daily activity. In this paper we investigate two major muscles in upper and lower back during movements in Salat. Specifically, the dorsal side of human body has been assessed using EMG activation pattern and muscle co-contraction. Two upper and lower back muscles named as Trapezius and Erector Spinae muscles were investigated during four positions involved in Islamic prayer (Salat). Muscle activation pattern has been elucidated from raw EMG signal after a series of signal processing steps. Next, muscle co-contraction index was calculated from the pattern. Results show that, both muscles maintain a balance in terms of contraction and relaxation during bowing and prostration position of Salat. In addition, there is a clear co-contraction between upper and lower back muscles in two positions during the prayer. The finding of the study may help to develop rehabilitation program for the Muslim population suffering from back pain that restrain them to perform obligatory Salat.

1. Introduction

It is one of the compulsory daily activities to perform Islamic prayer (*Salat*) five times for Muslims all around the world. *Salat* is also known as one of the relaxing physical exercises having therapeutic advantage of meditation [3]. There are four positions include standing, bending upper body (bowing), prostration and sitting to be performed while reading verses from the Holy Quran during the *Salat*. However, many adult Muslim citizens cannot perform *Salat* properly due to back pain and low back pain. Specifically, positions in *Salat* require a constant activity of upper and lower back muscles. For instance, 90^0 lumbar flexion is required in bowing position. Electromyography (EMG) based assessment has become one of the most popular therapeutic process of musculoskeletal system in human body. Any irregularity in muscular functions can be identified more precisely by the EMG assessment. EMG has been used to assess the muscles actions during

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daily life activity involving body movements such as sitting, walking and weight lifting. The body movement during the prayer results a gentle exercise of the muscles in upper-limbs as well as lower-limbs of the body. In this study we investigate the EMG signal activity of two muscles which possesses a great control over the human body during *Salat.*

Previous studies investigated the EMG activity of different muscles during *Salat* by analysing time and frequency domain features to assess muscle functions. For example, the relationship of back pain and these two positions was also investigated by Safee *et al*., [12]. Root Mean Square (RMS) feature has been used to assess EMG activity. Biceps brachii (BB), tibialis anterior (TA), gastrocnemius femoris (GF) muscles during different position of *Salat* [8]. Using integrated EMG (IEMG), this study found the similar amount of muscle activity during *Salat* and some other physical exercise such as bowing and toe touching. Safee *et al*., [12] investigated TA and lower limb muscles during *Salat* [11]. The amount of force and work done by some upper and lower limb muscles was estimated by using surface EMG in a study by Khanam and Ahmad [6] and Khanam *et al*., [7]. In addition, Ibrahim *et al*., [2] studied the muscles activities during specific postures of *Salat* as well as in similar physical exercise [1]. RMS feature of EMG during *Salat* was investigated in both [6] and [1]. Frequency domain features such as mean frequency (MNF) and median frequency (MDF) were investigated in Khanam and Ahmad [6] . Medial and lateral gastronomies muscle activity during *Salat* was investigated by Safee *et al*., [13]. Only RMS feature was investigated in this study. Also, EMG activity during prostration in *Salat* and child's pose was examined and compared by Ibrahim *et al*., [2]. In addition to the above, the EMG activity was investigated for identifying lower back pain in the forward flexion of lumber paraspinal muscles (which is similar to bowing in *Salat*) by Watson *et al*., [15]. Apart from the above, Salleh *et al*., [14] investigated the electroencephalogram (EEG) signal activity during *Salat.* The study demonstrated the EEG spectral analysis on the specific position of *Salat* such as prostration. So far, no study was found to investigate the muscle activation patterns (MAP) of back muscles during *Salat.* MAP can be used to assess the muscle activity during the body movement. The irregularity in MAP may indicate the disorder in muscular functions during a specific task. In this study we investigate the Trapezius (Trap) and Erector Spine (ES) muscles during *Salat*. Results found in this study may be useful to develop rehabilitation program for those who has trouble to perform *Salat.*

In addition to the above EMG features muscle co-contraction is another metric to quantify the joint activity of contracting muscle. Specifically, co-contraction index (CCI) has been used as a measure of co-contraction in a pair of antagonist-agonist muscles around a joint in human body. Previous studies investigated the CCI for knee, ankle and elbow joints for lower and upper limb studies respectively. For example, Iwamoto *et al*., [4], investigated the CCI of soleus and tibialis anterior muscles in ankle joint of young and elderly adults during dynamic posture control. Further, Kiewiet, *et al*., [9], demonstrated the CCI of biceps and triceps muscles in shoulder-elbow joint during cycling tasks. Generally, such pair of agonist-antagonist muscles are examined with EMG to observe CCI which indicates the joint activity of the pair of muscles during a task. In this study we investigate the CCI for upper and lower back muscles. Although Trap and ES muscles are not a pair of agonist-antagonist muscle, but it might provide us an insight of joint muscle activity of the upper and lower back during movements in *Salat.*

2. Subjects and Methods

Five Muslim students participated voluntarily in this study. The mean (±Standard Deviation (SD)) of the subjects was 26.6 (±4.6). No subjects reported in any type of back injury or long-term diseases. All the experiments procedures were conformed to the principles of the Declaration of Helsinki and were approved by the local Human Research Ethics Committee of the University.

2.1 Experiment Protocol

Subject was asked to perform a two-*Rakat Salat* with a fixed amount of time in four positions such as standing, bowing, sitting and prostration. In each position, subject was asked to be steady for 10 sec. and there was an inter-position gap of 5 sec. In addition, an inter-*Rakat* gap of 1 mint. was maintained. EMG data was recorded with three trials including an inter-trial gap of 5 minutes.

2.2 EMG Acquisition and Signal Processing

A two-channel SHIMMER (Model SHIM-KIT- 004) EMG sensor was used to record the EMG signal. This sensor is a touch proof with Bluetooth facility. A sampling frequency of 1 KHz is used for EMG recording which is pre-amplified by a 4^{th} order Butterworth bandpass filter of frequency range 30-400 Hz. Next, the EMG signal was rectified to remove common modes and noises. Finally, a 4^{th} order Butterworth lowpass filter of 6 Hz was applied to achieve the muscle activation pattern by removing the high frequency components. The distance between the EMG sensors and a Bluetooth enabled laptop was three feet. Two silver chloride (AgCl) surface electrodes were used; one for input and another one for reference or ground. The placement locations of electrodes were chosen as Trapezius (Trap) and Erector Spine (ES) muscle to determine the EMG variability. The distance between the electrodes was considered as approximately 4 cm to avoid crosstalk signal coming from neighbouring muscle as shown in Fig. 1.

2.3 Offline Data Processing

After the acquisition, the EMG data was processed offline by windowing and filtering the extracted signal. Signal processing was performed using MATLAB® software. The normalized EMG. amplitude was calculated for further analysis of mean and SD values. After recording, statistical analysis was performed using Minitab® software. Significance differences in the EMG amplitude were detected through repeated-measures analysis of variance.

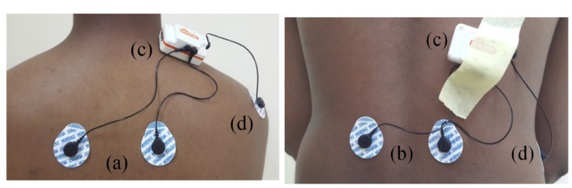

Fig. 1. Protocol setup. Electrodes placed on (a) Trap and (b) ES muscle, (c) EMG wireless sensor, (d) reference electrode Example

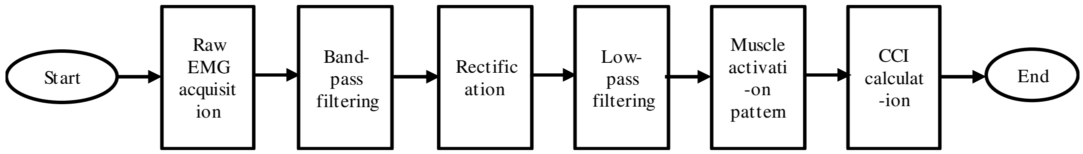

Fig. 2. Work flow of the muscle activation pattern and CCI calculation

3. Data Analysis

In this study we investigate muscle activation pattern and co-contraction of the Trap and ES muscles during four positions in *Salat*.

3.1 Muscle Activation Pattern

The raw EMG were pre-processed as mentioned in Section-II(C). Fig. 2 presents the signal processing steps to obtain muscle activation pattern from raw EMG signal. MAPs were time normalized to one second to compare among trials. The MAPs were averaged over trials of all subjects. MAPs from two muscles were recorded separately for four different positions to quantify the muscles activity during the positions of *Salat.*

3.2 Co-Contraction Index

Muscle co-contraction index (CCI) for two muscles was calculated from the MAPs for different positions of *Salat*. CCI was calculated similar to Iwamoto *et al*., [4] as follows.

$$CCI_{Trap} = 2\frac{\alpha_{Trap}}{\alpha_{Trap} + \alpha_{ES}} \quad (1)$$

and

$$CCI_{ES} = 2\frac{\alpha_{ES}}{\alpha_{Trap} + \alpha_{ES}} \quad (2)$$

with α_{Trap} and α_{ES} being the normalized MAPs of Trap and ES muscles respectively. Note that, although CCI is usually calculated with agonistic and antagonistic muscles, here we considered Trap and ES muscles which are not such muscle pair. However, the CCI from these two muscles would give us an idea of joint muscle activity during different position of *Salat.*

3.3 MAP Analysis

Muscle activation pattern of ES muscle has been shown in Fig. 3 (a). As demonstrated in the figure, there is a fluctuation in the EMG activity in all positions except for sitting where the activation remains almost constant. Note that, EMG activity during prostration position found to be more relaxed compared to the other positions. The average EMG-MAP amplitude is 0.01 volt in this position whereas in other positions it is 0.025 volt and 0.02 volt for Trap and ES respectively. MAP of Trap muscle has been shown in Fig. 3(b). As depicted in the figure, the muscle activity during standing and bowing is almost same while another similar MAP has been found during sitting and prostration. While comparing the muscle activity between the upper and lower back muscle, it has been found that, the ES muscle is more active than the Trap muscle overall positions of the *Salat*. Similar result was found in the previous study [10] where the MAV and IEMG activity of the upper and lower muscles where compared during four positions of *Salat*. Note that, the ES muscle activity during standing and bowing position is quite opposite. On the other hand, Trap muscle activity patterns during those two positions are almost same. In Fig. 4 we demonstrate the Root Means Square (RMS) values of EMG recorded from two muscles during four positions of *Salat*. As depicted in the figure there is an opposite muscle activity during all positions except sitting. Also, there was a significant correlation found for RMS feature in four positions (r=0.87, p<0.05). This implies that, the EMG activity of ES and Trap muscles are highly correlated during *Salat* performance.

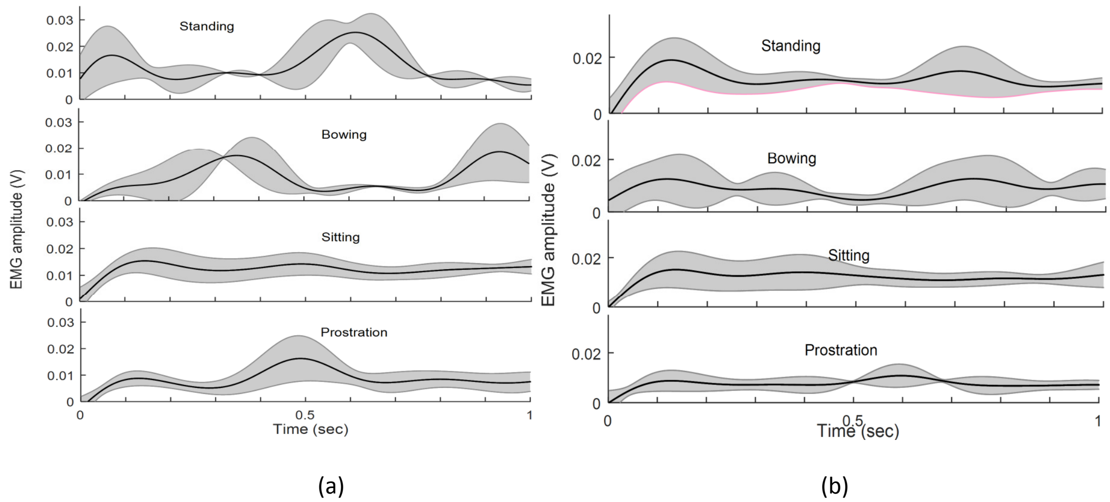

Fig.3. Muscle activation pattern of (a) ES and (b) Trap muscle during four positions of *Salat.* Shaded regions and solid line indicate the standard deviation mean activation respectively

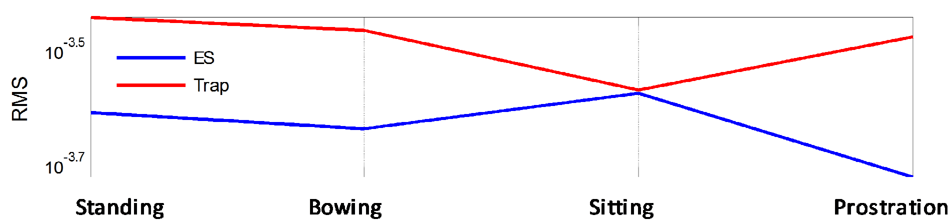

Fig. 4. RMS values of EMG during four positions of *Salat*

3.4 Muscle Co-contraction Analysis

Muscle co-contraction index for Trap and ES muscles was calculated using (1) and (2) respectively. The CCI has been demonstrated in Fig. 5. As depicted in the figure, there is a clear co-contraction in standing and bowing positions. The CCI_{Trap} and CCI_{ES} intersect each other during these two positions. This implies that, during standing and bowing positions the upper and lower back muscles jointly contract to keep a balanced posture of the body. other positions, CCI_{Trap} and CCI_{ES} have almost similar trend *i.e.* both are either more than 50% or less than 20%. This indicates that, during sitting and prostration upper and lower back muscles are active independently. Note that, we found an exceptional In CCI value at the beginning of each time. This might be due to the noise introduced in EMG during the transition of different positions.

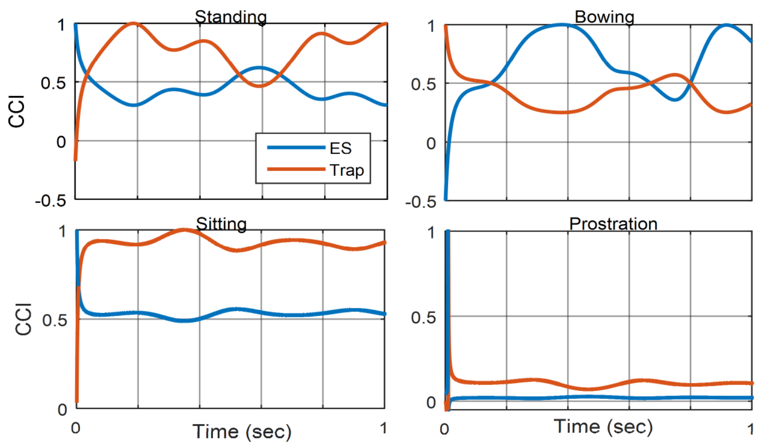

Fig. 5. Muscle co-contraction index of Trap and ES muscles in four positions of *Salat*

4. Findings and Discussion

In this study, it has been found that the activity of the upper back muscle has a strong correlation with that of the lower back muscle during *Salat* performance. The activity of the upper back muscle is stronger than that of the lower back. However, the shoulder muscle (Trap) remains more stable than lumbar muscle (ES). This implies that, the lower back has a greater risk of fatigue than upper back during longer version of prayer such as, *Tarawih* prayer. Extra caution is advised for elderly population. Secondly, co-contraction of shoulder and lumbar muscles has been found explicitly during standing and bowing positions. Although, Trap and ES muscles are not a pair of agonist-antagonist muscle, the co-contraction of these two muscles is apparent and can be taken into consideration. Also, the CCI indicates that, both muscles have almost similar activity during sitting and prostration positions. Either they exhibit high (>50%) or very low (<20%). Therefore, the contraction and relaxation of two back muscles is occurred during beginning and end of each *Rakat* during *Salat*. Due to this alternate fashion of contraction the total activity of prayer is very relaxing for whole body. This has also been demonstrated by qualitative as well as quantitative assessment in previous studies [3,5].

Despite our rigorous effort, there are few limitations of the study. For example, the subjects of the study are young adults. The investigation on the elder subjects would give more insightful findings of the study. To understand the co-contraction of low back a pair of agonist-antagonist muscles could be considered. For instance, the opposite side of the ES muscle is lower abdominal muscles (e.g. rectus abdominis) which act as antagonistically to keep balance of the back. However, back pain is one of the common muscular complications among the senior Muslim citizens which often restrain them to perform *Salat* in ideal approach. The findings of the study may be useful to assess the back pain and to develop rehabilitation program for the population who are suffering from the back pain but wish to perform *Salat* in appropriate manner.

5. Conclusion

In this paper, we investigated the muscle activation pattern and co-contraction of a lower back and an upper back muscle in different positions of *Salat*. It has been found that, the lower back muscle tends to fluctuate during the movement while the upper back muscle is comparatively more stable. However, the shoulder muscle showed higher EMG activity than lumbar muscle. Both muscle exhibit co-contraction during standing and bowing positions. Overall, the shoulder and lumbar muscles make balanced activity throughout the *Salat* performance. Therefore, there is a very low probability to have muscle fatigue during the prayer. Our findings match with the findings of previous studies. The findings of the study may contribute to the further investigation and development of rehabilitation program for back pain.

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