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Surface Electromyography Assessment of the *Biceps Brachii* Muscle between the Endplate Region and Distal Tendon Insertion: Comparison in Terms of Gender, Dominant Arm and Contraction

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Abstract. [Purpose] In some earlier studies of electromyography (EMG) of the upper arm *biceps brachii* (*BB*), researchers preferred to place the electrodes on the middle of the biceps muscle to analyze its function. This study investigated the *BB* muscle activity between the region of the endplate and distal tendon insertion (electrode placed on lower part of the *BB* muscle belly). [Subjects and Methods] Six right-arm dominant Asian subjects (n=6, 3 males and 3 females), age range 20–30 years, who were free from any musculoskeletal disorder in *BB*, participated in this study. EMG signals were recorded from 12 *BB* muscles (6 subjects × 2 arms) during two types of muscle contraction (concentric and eccentric). Mean ± SD was calculated and analysis of variance (ANOVA) was performed. [Results] The results indicate that, the dominant right arm (R) of both males (M) and females (F) showed significantly higher activity than non-dominant left arm (L). In addition, there were interactions between M(L) and M(R), F(L) and F(R), M(L) and F(L), M(R) and F(R), and both male *BB* and both female *BB*; but, no interactions were found between M(L) and F(R), and M(R) and F(L). We also discovered that eccentric contraction generates higher EMG signals than the concentric contraction of that muscle region. [Conclusion] These findings suggest that EMG data are random on the *BB* muscle area we investigated during arm movement. These results should be considered in biceps tendonitis rehabilitation, muscle coordination and other physiological measurements of the upper limb muscles.
Key words: EMG, Biceps brachii, Muscle contraction

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INTRODUCTION

Electromyography (EMG) has been used to measure muscle functions for the last three decades[1, 2)]. Moreover, it is one of the fundamental recording processes that detects the exact muscle strength, coordination and function from a global perspective. EMG recording is only possible when tiny electrical signals emanate from a contracted muscle[3, 4)]. An important feature of EMG is that it can easily capture and measure the electrical movement and changes of muscle electric potential making it possible to investigate muscle synergies and predominance in specific patterns of movement[5, 6)]. There are two types of EMG electrodes: invasive and noninvasive. The non-invasive electrode is using massively due to no pain to apply on a subject's skin, widely available, and is preferred by the subject[7)].

It is well-established in electromyography that the placement of surface, or non-invasive, EMG electrodes influences the recorded signal characteristics[8)]. The variations in EMG signal characteristics are detectable in the upper arm *BB*. Muscle activity in the lower part of the biceps muscle (between the region of the endplate and the distal tendon insertion) is essential in several features and research areas, such as sports science, human ergology, rehabilitation, clinical activities, neuromuscular system, and other biomedical study areas. Researchers have reported that electromyography (EMG) characteristics are influenced by electrode placement on the *biceps brachii* muscle[8, 9)]. In many studies, they chose the middle of the *BB* muscle for electromyographic analysis[10–14)], and only a few previous studies have investigated surface electromyography of the *BB* muscle in the lower part of the muscle belly[15–17)]. Lowery et al. investigated cross-talk in this muscle zone[18)] and Merletti et al. investigated the detection of sEMG in the innervation zone of *BB*[19)]. Nishihara et al. analyzed the effect of the position of electrodes relative to the innervation zone (IZ) of the *biceps brachii* muscle during isometric contraction using an eight-channel surface array electrode[20)]. Moreover, early research in this muscle area was performed with different protocols and systems: variation of the subjects as a volunteer (age, sex etc.), different muscle contractions, different sensors (wireless/wired), recordings at different levels of contraction (%MVC) and angle, different positions of the electrodes on the muscle and inter-electrode distances and different statistical analyse, signal processing techniques and fatigue analyse[21–23].

We could not find any studies which had investigated the EMG signal recording process in the lower part of *BB* in terms of contraction, gender and the differences between right and left arms. Accordingly we investigated the electromyographic activity on lower part of the *BB* muscle with: subjects from a specific region (Asia) who had normal BMI, age-paired subjects of different gender, eccentric and concentric muscle contraction with a standard load, a constant data sampling frequency (1 KHz) and a three-channel wireless EMG data acquisition system, and non-invasive electrodes placed according to SENIAM (Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles) recommendation (horizontally with a center-to-center inter-electrode distance of 20 mm). Our main findings were: generated EMG signals were higher in male *BB* than in female *BB*, both genders dominant right arm produced higher EMG signals than their non-dominant left arm, some significant as well as non-significant results were found among the muscles, and differences of mean amplitude are more easily detected and they are higher in eccentric contraction than in concentric contraction. Lastly, our study succeeded in verifying that two non-invasive sensors can be used to differentiate between muscle contraction conditions in the *biceps brachii* muscle between the endplate region and distal tendon insertion.

SUBJECTS AND METHODS

Six healthy and right arm dominant Asian subjects (n=6: 3 males and 3 females) volunteered for the study. They were physically sound according to their written statements. Also, none of them had any neuromuscular (particularly of the biceps brachii muscle and tendon) disorders or symptoms. Anthropometric characteristics of the participants (males and females) are presented in Table 1. The twelve arms of the six subjects were examined by EMG signals. All the participants gave their written consent to participation.

EMG signals were sampled at 1 KHz using the data acquisition system SHIMMER™, Model SH-SHIM-KIT-004 (Real-time Technologies Ltd., Ireland). Off-line EMG data analysis was completed using a computer. EMG signals were recorded using three active surface electrodes connected to three wired channels. Two electrodes were attached to the biceps muscle near the distal tendon region and the reference electrode was placed over the anterior distal end of the forearm between the styloid process of the radius and ulna. Sigma electrode gel was used to clean the skin and to mediate the EMG signal. The inter-electrode distance and other data collection protocols followed those suggested by Hermens et al.[24] and SENIAM: two electrodes were placed horizontally with center-to-center inter-electrode distance of 20 mm. The distance between the muscle belly and the present electrode location was 25 mm.

Two types of muscle contraction (isotonic concentric and eccentric) were performed with a standard 6-kg load (manual process with a dumbbell), and a five minute rest between each EMG recording. EMG signals were recorded for 90 second for each contraction by the subject. According to the system configuration, the maximum EMG signal is ±4.5mV which was not exceeded during this experiment. Each subject was requested to remove their wrist watch, accessories or any other equipment from the arm to avoid signal interference. In this study, traditional and descriptive statistics were used and the results are stated as mean ± standard deviation (mean±sd) for the parameters of importance in each experimental condition. During the tests, the subject sat relaxed on an examination chair. EMG data were collected during elbow movement within 0° to 90° (concentric and eccentric). The angle was assumed and set to 0° when the elbow (shoulder to finger) was extended towards the ground, and 90° when the elbow was flexed. A Goniometer was used to measure the angle. A test was performed to determine the confidence level among the intra- and inter-*BB* muscle activities, the two genders and both arms. The confidence limit was kept at 95%, hence the significance level was defined at $p < 0.05$. Differences were assessed by the two-tailed t-test for paired values, assuming equal analysis of variances (ANOVA) using Minitab statistical software (MINITAB® Release 14.12.0).

Table 1. Characteristics of the subjects

Factor	Subjects (n=6)	Male (n=3)	Female (n=3)
Age (years)	24.5 ± 1.6	25.3 ± 1.5	23.6 ± 1.5
Weight (kg)	64.0 ± 7.4	70.0 ± 5.0	58.0 ± 2.6
Height (cm)	164.2 ± 8.2	170.4 ± 7.4	158.1 ± 1.4
BMI (kg/height²)	23.5 ± 1.0	24.1 ± 0.4	22.8 ± 1.1

BMI: body mass index

RESULTS

The statistical results are organized by gender, arm and contraction with a summary of significance in Table 2. Significant differences were found for the intra- and inter-muscle EMG activities of both genders' right and left arm *BB*. Here, male's muscles showed higher EMG amplitudes than the female one during both contractions (total EMG_{AVG} 4.1±0.6 mV and 3.1±0.5 mV respectively). In the individual results for muscle strength: male right *BB* EMG was 4.2±0.6 mV, and left BB was 3.6±0.5 mV; on the other hand, female right *BB* EMG was 3.2±0.5 mV and left was 2.9±0.6 mV. For the two types of contraction, eccentric contraction showed a maximum average amplitude (3.6±0.5 mV) that was greater than that of concentric contraction (3.4±0.6 mV) in both genders. The variations of the result for male and female *BB* were similar: male EMG was 4.1±0.5 mV during eccentric contraction of both BB, whereas during concentric contraction it was 3.7±0.6 mV; similarly, female EMG was 3.06±0.5 mV during eccentric contraction of both BB, while during concentric contraction it was 3.03±0.6 mV.

Some significant differences were observed between male

Table 2. Electromyographic results (mean ± SD, mV) for both genders' left and right arm BB muscles during eccentric and concentric contractions

Subjects	Left arm BB (L)		Right arm BB (R)	
	CC	EC	CC	EC
Male (M)	3.1 ± 0.2	3.8 ± 0.5	3.7 ± 0.8	4.2 ± 0.4
	3.1 ± 0.6	3.6 ± 0.7	4.2 ± 0.8	4.3 ± 0.6
	3.8 ± 0.5	4.1 ± 0.3	4.3 ± 0.5	4.5 ± 0.7
Total (EMG_{AVG})	3.3 ± 0.4	3.8 ± 0.7	4.1 ± 0.7	4.4 ± 0.6
	3.6 ± 0.5 (a*, d*)		4.2 ± 0.6 (a*, e*)	
	4.1 ± 0.6 (c*)			
Female (F)	2.3 ± 0.3	2.8 ± 0.6	3.1 ± 0.7	3.2 ± 0.4
	3.4 ± 0.5	2.8 ± 0.6	3.2 ± 0.9	3.1 ± 0.2
	3.1 ± 0.4	2.9 ± 0.6	3.1 ± 0.9	3.5 ± 0.2
Total (EMG_{AVG})	2.9 ± 0.4	2.8 ± 0.6	3.2 ± 0.7	3.3 ± 0.3
	2.9 ± 0.6 (b*, d*)		3.2 ± 0.5 (b*, e*)	
	3.1 ± 0.5 (c*)			

CC: concentric contraction, EC: eccentric contraction, values are expressed as mean ± standard deviation (SD), *=p<0.05, a*: interaction between M (L) and M(R), b*: interaction between F (L) and F(R), c*: interaction between M (both BB) and F (both BB), d*: interaction between M (L) and F (L). e*: interaction between M(R) and F(R).

and female of both sides arm muscles, (for that particular electrode placement) when they were performing eccentric and concentric contractions. According to the intra-muscle results EMG activities of both arm and muscles of both males and females are significantly different (p<0.05). Five results were found for the inter-muscle differences. There was a main effect between both *BB* of males and females (p<0.05). Also, significant differences existed between male left and female left, as well as male right and female right *BB* (both p<0.05). No significant differences were found between male right and female left, and the male left, and female right *BB* (both p>0.05).

DISCUSSION

Electromyography is a compound signal processing technique that presents information regarding both the central and peripheral properties of the neuromuscular system[25]. In this study, both biceps brachii muscles (near the biceps endplate zone and the distal tendon insertion) of males and females were chosen to evaluate the electromyographic signals of isotonic (eccentric and concentric) contraction. The main focus was to find the muscle strength of *BB* in terms of gender, contraction and the dominant arm. We strongly believe that, the findings of our present study are as reliable as those of earlier studies on *BB* for measuring surface EMG. For example, DeFreitas et al. reported a comparison of the two genders in the innervations zone (IZ) of the *biceps* muscle during isometric contraction[26]. Many researchers investigated EMG during eccentric and concentric contractions on *BB* muscle[27–29]. Merletti et al. studied the variations in the surface EMG signal aiming to elucidate a method for determining muscle fatigue in the dominant *biceps brachii* muscle[30]. Dimitrova et al. tested the *biceps* muscle fatigue through EMG signals by placing electrodes from the endplate to the upper portion of the *BB*[31]. Gabriel and his team mates were measured the EMG results on that specific location of *BB*[32]. Moreover, some other studies examining inter-electrode distance, have reported results which are different parameters and protocols consistent with our current results[33, 34]. There have also been some electromyographic comparisons of gender and dominant and non-dominant arm *BB*[35–38].

However, we could not find any previous study which had investigated EMG signals from the combined aspects of the following issues: gender, the dominant and non-dominant arm, electrode placement on the specific part of the BB muscle (near the endplate region and the distal tendon insertion), types of contractions with a standard load, and all subjects from a specific region. Our major finding are: electromyography signals are random in the upper arm *BB* of both genders; muscle activity of the dominant arm is higher than that of the non-dominant arm (Table 2); there are significant differences between males and females in the BB muscle on both sides (p<0.05); in intra muscle coordination, there is interaction between male left and right *BB* as well as between female left and right *BB* (p<0.05); there are significant differences between male left and female left arms, and between male right and female right arms (p<0.05); there are no significant differences between male left and female right and male right and female left arm muscle (p>0.05); and differences of mean amplitude are most easily detected and higher during eccentric contraction than during concentric contraction. There were some limitations to our study: the number of subjects were relatively few, the selected subjects were very young, there was no comparison between normal and abnormal subjects, and only the biceps brachii muscle near the distal tendon was evaluated.

In conclusion, the results of this study indicate that electromyography signals generated in *BB* are higher in the dominant arm than in the non-dominant arm. Also, it revealed that males *BB* produced higher EMG than females *BB*. These findings may help us to discover novel physiological measurements and rehabilitation issues in the upper limb muscles. Our future work will evaluate the EMG analysis of BB full muscles of normal and abnormal subjects dominant and non-dominant arm.

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