Research Journal of Applied Sciences, Engineering and Technology 4(22): 4591-4595, 2012
ISSN: 2040-7467

Submitted: June 07, 2012 Accepted: July 04, 2012 Published: November 15, 2012

Electromyographic Responses during Elbow Movement at Two Angles with Voluntary Contraction: Influences of Muscle Activity on Upper Arm Biceps Brachii

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Abstract: Analysis of Electromyography (EMG) signals generated by individuals is part of human musculoskeletal system research and signals are always influenced by the electrode placement in the muscle. This characteristic is also obvious at Biceps Brachii (BB) muscles during the movement of elbow at different angles. The purpose of this study was to monitor and determine the BB muscle function in 3 conditions: (i) electrodes were placed at 3 locations on the BB, (ii) elbow was fixed at the two angles (90° and 150°) and (iii) isometric contractions were performed to record EMG data. EMG data were obtained from six healthy subjects (n = 6, mean±SD age = 24.4±3.1 years, body mass = 68±6.3 kg, height = 164±4.1 cm, BMI = 21.2±2.3, right arm dominated). A Bluetooth-enabled laptop, wireless EMG sensors, digital dynamometer and angle meter were used for data recording. EMG data were calculated and analyzed by average value, standard deviation, Root Mean Square (RMS) and highest peak of the signal during maximum voluntary contraction. All the dependent variables were calculated using repeated measures Analysis of Variance (ANOVA). The results from the research showed that (i) according to the calculation of average RMS and the maximum peaks of EMG signals, there was a significant difference between 2 angles ($p = 0.047$, i.e., $p<0.05$), but no interaction at the same angles when overall average EMG and standard deviation value are considered and (ii) majority of the outcomes showed that EMG activity is higher in the order of middle, upper and lower BB muscle. It is therefore important that electrical signals generated upon different electrode placements and angles on the BB muscle are used for biceps rehabilitation and other physiological measurements on upper arm.

Keywords: Angle, biceps brachii, electrode, EMG, isometric contraction

INTRODUCTION

Analysis of the electrical signals produced by individuals was originally performed by Murguia *et al.* (2009) and Reaz *et al.* (2006). EMG is one of the basic processing techniques to detect muscle activity using the electrical signal, which emanates from contracting muscle (Di Fabio, 1987; Luca, 1997). In general, EMG signal is generated from the skeletal muscle in the human body because of muscle fiber contraction and these signals are always indiscriminate (Komi and Viitasalo, 1976; Merletti and Parker, 2004). So far, researchers have used invasive (needle) and noninvasive (without needle) techniques to identify and record EMG signals (Merletti and Bonalo, 2008). Moreover, different data acquisition systems such as a sensor for signal recording process or wire or wireless system were employed. In this experiment, a wireless sensor was used, because wireless technology is used in our day-to-day applications due to its lower cost, improved product performance, signal accuracy, portability, robustness and extensibility (Burns *et al.*, 2010).

Upper arm biceps brachii muscle in the human body is normally described as a two-headed muscle that originates proximally through a long head and a short head (Rai *et al.*, 2007). According to the anatomical description (Fig. 1) of human biceps brachii muscle, it extends from the shoulder to the elbow on the front of the upper arm and is responsible for moving the upper arm in different angles due to strong connectivity of two biceps tendons (Naito, 2004). The lower side biceps tendon is called the distal and the upper one is called proximal tendons (Muscle, 2008). Typically, the researcher's preferable location for electrode placement is middle of the biceps brachii muscle or muscle belly.

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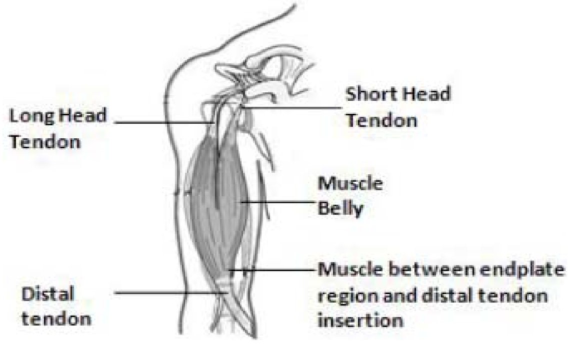

Fig. 1: An anatomical portrait of human upper arm bicep brachii muscle

The next 2 choices for electrode placement are muscle, which is below the proximal tendon (upper part of muscle belly) and upper muscle of the distal tendon (lower part of muscle belly) (Hermens *et al*., 2000; Ollivier *et al*., 2005). In our study we have selected 3 locations for the EMG data recording:

- Middle of muscle belly (M)
- Lower part of the muscle belly, i.e., between the muscle end-plate region and distal tendon insertion (L)
- Upper part of the muscle belly, i.e., over the medial belly of each head (long and short head) parallel to the muscle fibers and below the proximal bicep tendon (U).

The diversity of electromyography recording and processing methods on muscle serves many physiological purposes, such as signal processing, analysis of muscle fatigue, kinesiology behaviour, torque relationship, sports science, study of ergonomics, exercise review and laboratory assessment (Eberstein and Beattie, 1985; Hussain and Mamun, 2012; Jobe *et al*., 1984; Marras, 2000; Ollivier *et al*., 2005; Rainoldi *et al*., 1999; Soderberg and Cook, 1984; Stegeman *et al*., 2000).

Among different types of voluntary muscle contractions, isometric contraction is a stable technique in the physiological measurement process. This type of contraction happens when there is no change in the length of the contracting muscle. In this experiment, subjects were asked to grip a hand-held dynamometer and the data were recorded at 2 elbow angles. There was no movement in the joints of the hand, but the muscles were contracting to provide an adequate force to keep a stable hold on the dynamometer. The quantity of force a muscle is able to produce during an isometric contraction depends upon the length of the muscle at the position of contraction. Biceps muscle has an optimum length at which the maximum isometric force can be produced (contraction). So far, biceps brachii muscle with the isometric voluntary contraction has been used in many studies (Orizio *et al*., 1990; Sakurai *et al*., 1998).

Earlier studies show the effect of surface EMG on different locations of the biceps muscle with the variety of elbow angles and the several muscle contractions (Webber *et al*., 1995; Yamaguchi *et al*., 1997). In this study we measured the electromyographic results using 2 angles. The 2 angles refer to the extent to which a joint or group of muscles can be flexed or extended. EMG values are recorded at the elbow angles of 150° and 90°. An earlier study has demonstrated the effect of EMG on different angles in the biceps muscles (Keenan *et al*., 1990; Leedham and Dowling, 1995). However, we did not find any report that reported the EMG of biceps brachii muscle for electrode placement at different locations, voluntary isometric contraction, different elbow angles and using wireless EMG sensor. In this study, we present and compare the results of muscle strength at 3 locations of the biceps muscles during isometric contraction with the elbow angles of 150° and 90°. Three locations of the biceps muscles were:

- Between the endplate region and distal tendon insertion
- In the midst of the muscle belly
- Above the medial belly of both head parallel to the muscle fibers (long and short head biceps tendon)

We strongly hope that the results are useful for biceps rehabilitation (Ahamed *et al*., 2011).

MATERIALS AND METHODS

Six healthy male subjects (n = 6, mean±SD age = 24.4±3.1 years, body mass = 68±6.3 kg, height = 164±4.1 cm, BMI = 21.2±2.3, right hand dominated) participated in the study. All the subjects were free from any disorder or pain in biceps muscles. A 3-channel wireless EMG sensor was used to detect their muscle activity. Out of these channels, one channel was used as a reference and attached to the bony area. EMG bipolar Ag/AgCl noninvasive surface active electrodes with a diameter of 4 mm were used for data collection. The inter-electrode distance was 2 mm. Data were recorded in triplicate for each location and each angle with 100 Hz sampling rate for 10 s with a 5-min interval. Electrical dynamometer (WCS-1000) and angle level measurement device were used in the study. Subjects were requested to hold the dynamometer with 100% Muscle Voluntary Contraction (MVC). The angle was set 0° when the elbow (shoulder to finger) is straight and 90° when the elbow lies on the table. Average grasping power with the dynamometer was 25 kg. Figure 2 shows the full experimental setup for data collection from the subject right arm BB muscle.

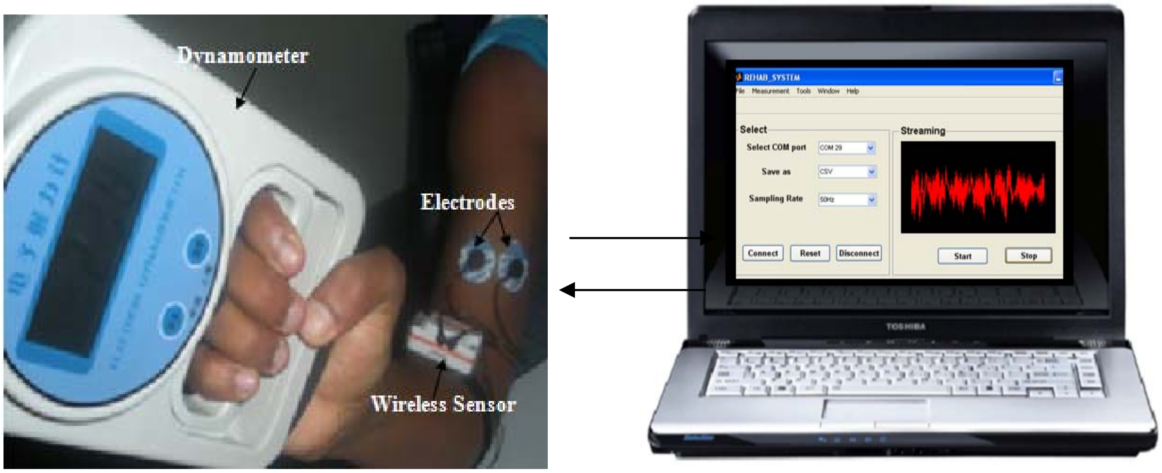

Fig. 2: EMG data were recorded at the 150° elbow angle. Electrodes were placed on the muscle belly with a wireless EMG sensor (left side). Bluetooth-enabled laptop (right) was used to create communication and transfer of signals

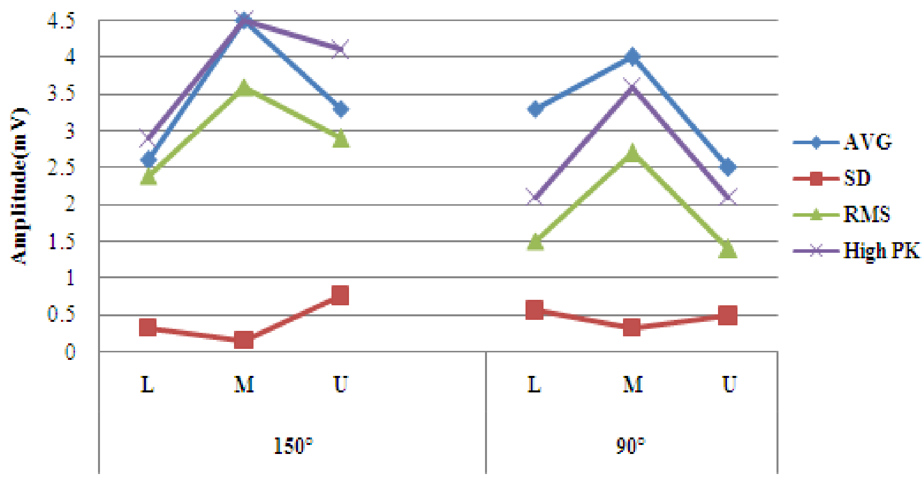

Fig. 3: Comparison effects among two angles and three electrode placement locations

Sensors were attached to a laptop via a Bluetooth device. Electrodes were placed and skin was prepared according to the SENIAM instructions and Hermens *et al.* (1999, 2000) and Zipp (1982). The distance between the sensor (connected to the biceps) placement area on the body and the laptop was 5 feet. As it was a wireless system, the air-conditioning and fan were switched-off to avoid unwanted signals, cross talk and device disconnection. The results were assessed by the 2 -tailed paired *t*-test assuming equal Analysis of Variances (ANOVA) using Minitab statistical software (MINITAB® Release 14.12.0). The level of significance was set at p<0.05.

RESULTS

Results of EMG signals from 2 angles at 3 electrode placements are presented in Table 1. Muscle activity at 2 elbow angles is discussed first. Muscle strength is higher at 150° than at 90° (average EMG is 3.47 and 3.23 mV,

Table1: Results of electromyography signal from biceps brachii muscle during two angles

				RMS		Highest peak	
Angle	EP	Avg.	S.D.				
150°	L	2.6	0.33	2.4	*a**	2.9	*a**
	M	4.5	0.16	3.6		4.5	
	U	3.3	0.76	2.9		4.1	
90°	L	3.3	0.56	1.5	*a**	2.1	*a**
	M	4.0	0.33	2.7		3.6	
	U	2.5	0.49	1.4		2.1	

EP: Electrode placement on the BB; RMS: Root mean square; SD: Standard Deviation; *a**: p<0.05 (confidence level 95%); L: Lower part (between the endplate region and distal tendon insertion location); M: Middle (muscle belly); U: upper part (above the medial belly of both head parallel to muscle fibers)

respectively). Also, similar results are found from RMS and highest peak value calculations. It is noted that there was a significant difference between 150° and 90° for the RMS-derived result and highest peak value (p<0.05). But, there was no effect for the result of average EMG and standard deviation. Now, according to the electrode placement results, muscle belly generates maximum signals than other 2 locations from our analysis. Also, Fig. 3 shows that the middle of the biceps brachii muscle produced more electrical signal than the upper and lower muscles. The upper part produces strong signal than the lowers of BB muscle.

DISCUSSION

It has been reported previously that electromyography signals can be best viewed and recorded during maximum contractions (Akataki *et al*., 1996; Orizio *et al*., 1989). This research study reports analysis of EMG signals from BB at 2 elbow angles and at 3 different electrode placement positions. Isometric contraction was performed during data recording process. Some key findings and comparison results from this study are presented below:

- Muscle activity of BB is higher at the angle of 150° than at 90° during contraction (Table 1 and Fig. 1).
- Calculation of EMG average, RMS and highest peak value at the angle of 150° shows that the electrical signal from the middle of the muscle is higher (4.5, 3.6 and 4.5 mV consecutively) than the upper (3.3, 2.9 and 4.1 mV consecutively) and lower parts (2.6, 2.4 and 2.9 mV consecutively).
- On the other hand, similar results are found at 90° angle. In this angle too, middle of the muscle generates stronger electrical signals than the other 2 parts (4.0, 2.7 and 3.6 mV consecutively). The results for the upper and lower parts are almost same (upper; 2.5, 1.4 and 2.1 mV consecutively and higher; 3.3, 1.5 and 2.1 mV consecutively).
- The most important findings are that there was a similarity between 150° and 90° for the results of EMG RMS and EMG highest peak value ($p<0.05$). But, there was no effect between 150° and 90° for SD and average EMG results.
- All the findings based on EMG data have significant implications for both experimental research and clinical practice, which provide an important clue for electrode placement for appropriate muscle strength of biceps brachii. The study results show that there are effects on BB when elbow is flexed rather than when it is straight.

There were some limitations to the study such as limited subjects (n = 6), only one gender (male) and use of only right arm. Also, the number of angles (2) and kind of muscle contractions (isometric) were few. However, we have successfully investigated and obtained results for the biceps brachii muscle.

CONCLUSION

In summary, muscle characteristics are influenced by electrode placement as well as elbow movement. It therefore suggests that researchers should focus on proper electrode placement during physiological measurements. We hope our research will contribute to further research on biceps rehabilitation, neuromuscular system and other physiological measurements.

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