# Analysis of the Effect on Electrode Placement on an Adolescent^|^rsquo;s Biceps Brachii during Muscle Contractions Using a Wireless EMG Sensor

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# Analysis of the Effect on Electrode Placement on an Adolescent's Biceps Brachii during Muscle Contractions Using a Wireless EMG Sensor

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**Abstract**. [Purpose] Electromyography (EMG) is a random signal recording process that fully depends on proper electrode placement on the active muscle. The present study investigated and analyzed the electrical (amplitude) responses from three different locations of an adolescent's biceps brachii muscle during four contractions (concentric, eccentric, isometric and isokinetic) using a wireless EMG sensor. [Subjects and Methods] One healthy male subject (age: 17 years, weight: 60 kg, height: 171 cm, BMI: 20.7, right arm biceps muscle) volunteered for the study. A Shimmer™ wireless EMG sensor (non-invasive technique) was used in this experiment and MVC% was set to 0% and 100% with a 6-kg load. Electrode placement locations on the biceps were, i) between the endplate region and distal tendon insertion ii) in the midst of the muscle belly, and iii) above the medial belly of both head parallel to muscle fibers (long and short head biceps tendon). Statistical analyses were performed to examine the significant differences among the three electrode placements were determined by ANOVA (analysis of variances). [Results] The muscle belly gave significantly higher EMG activity than the other two locations. The medial belly muscle (long and short head biceps tendon) gave a considerably higher signal than the lower part muscle (near the endplate and tendon region). [Conclusion] The overall outcomes demonstrate that, EMG signals varied among the three electrode placements of an adolescent biceps brachii muscle. Generated results will be useful for adolescent's biceps rehabilitation and any other physiological measurement that concern the upper arm muscles.
**Key words:** Adolescent, Biceps brachii, EMG

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## INTRODUCTION

Electromyography measures the electrical signals that generated in the skeleton muscles of the human body during muscle fiber contraction, and these signals are always stochastic (random)[1, 2)] Electromyograms are the primary means of detecting and analyzing muscle activity from a global perspective and the electrical signals are generated from the contracted muscles. Accurate EMG signal recording depends on proper surface EMG electrode selection, and placement locations on the human body[3–5)]. EMGs are helpful for monitoring the rehabilitation progress of neuromuscular disorder patients[6)].

Researchers have investigated and shown that, recordings of EMGs vary with electrode selection, muscle contraction, age, angle measurement, gender, MVC% (muscle voluntary contraction), and electrode placement. One fruitful research was done by Mercer et al. of the biceps brachii muscle[7)]. They analyzed subjects with a mean age of 27 years using more than two electrodes, a frequency range of 1000 Hz, four common contractions with different MVC%, a wired sensor, and verified their results with statistical analysis. With all these protocols, they showed that, the muscle belly is the most suitable area for electrical signal generation, rather than the medial or lateral part of the biceps muscle. Merletti et al. and Rainoldi et al. indicated that EMGs vary with electrode size, distance, and location[9, 10)]. Wong et al. described the surface EMG recording process of the quadriceps muscles and the influence of the surface EMG signal[11)].

According to several studies of adolescents, between 13 to 19 years of age, the muscle grows progressively[12)]. We found, few researchers have investigated electromyograms of adolescent's upper arm muscles[13, 14)]. One good result was reported by Kirsch et al., who presented their analysis of a teenagers' muscle with EMG biofeedback[15)]. Then, Oksanen et al. discussed about the EMG activity on adolescents neck muscle[8)].

In this study, we investigated the muscle function of an adolescent's biceps brachii with electrode placement at three different locations: near the two tendon zones, and the middle of the muscle. Our research was very specific. Like, we have selected only one subject, because our target was not subject variation, rather it was biceps muscle coordination and the influence of electrode location on EMG signals. Measurements were made at two values of MVC (0% and100%) and a constant load (6-Kg). Our subject was a male healthy adolescent and we measured only the right hand biceps brachii using a sampling rate of 100 Hz, and a wireless EMG sensor with active electrodes.

## METHODS

One healthy male subject (age=17 years, weight=60 kg, height=171 cm, BMI= 20.7) volunteered for the study. EMG activity was recorded by one pair of EMG bipolar Ag/AgCl noninvasive surface electrodes with a diameter of 4 mm. One ground electrode was attached to the bony area near the biceps muscle. Before attaching the electrodes, the skin of the biceps was prepared using skin cleaning gel (sigma gel) and an alcohol swab. Biceps brachii muscle activity was recorded at a sample rate of 100 Hz using a SHIMMER$^{TM}$ wireless EMG sensor. The sensor was connected to a laptop via Bluetooth device. 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 full experiment was conducted within a day. Data were collected three times (three samples) from each electrode location for 10 seconds, and there was a five minutes interval between each muscle action. Four types of muscle contractions were isotonic concentric and eccentric, isometric, and isokinetic. The inter-electrode distances and placements were those suggested by Hermens et al.[3]. The subject was asked to sit on a chair and relax, and the angle of arm movement was within 0° to 90° except for isometric contraction which took place at 90° and a digital inclinometer was used to measure the elbow angle.

Recorded EMG data were processed for the average (mean), standard deviation (SD), root mean square (peak-to-peak value), average root mean square, and highest peak. The differences between the three electrode placement results and the four types of contractions were assessed by the two-tailed paired t-test assuming equal analysis of variances (ANOVA) using Minitab statistical software (MINITAB® Release 14.12.0). Significance was accepted for values of $p<0.05$.

## RESULTS

Table 1 shows the EMG results generated at the three locations of the biceps brachii muscle. Single (*) with alphabet 'a' and 'b' indicate the relation and significance of differences ($p<0.05$) between each location on the muscle. In Table 1, the three locations are indicated as, L (lower part), between the endplate region and distal tendon insertion, M (middle), the middle of the muscle belly and U (Upper), over the medial belly muscle (long and short head biceps tendon). The mean value of the EMG was calculated first within the same data group and tested for their confidence level. It has proved that, all the recorded data are significantly relevant ($p<0.05$). A main effect of location was found for the mean value between L and M, M and U (both $p<0.05$), but not between L and U ($p=0.26$). Comparing the standard deviations (SD) showed that, there were relations between L and M ($p<0.05$), and L and U ($p<0.05$), but not between M and U ($p=0.78$). There was no interaction of the RMS value among L, M and U (all $p>0.05$). On the other hand, there was interaction between L and M, and M and U ($p<0.05$) for average RMS, but not between L and U ($p=0.167$). Some good and fruitful results were found from peak (amplitudes) analysis. The highest pick was 4.09 mV for M during isotonic concentric contraction, and the second highest peak value was for U (3.71 mV). The other three actions also showed that, the EMG was highest in the order

**Table 1.** Results of EMG signal (mV) from different electrode placement on the biceps brachii muscle during muscle contractions

| Electrode Placement | MC | Mean | | Cl (95%) | SD | | RMS | RMS (Avg) | | Max | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| L | A | 2.05 | | 0.01 | 0.22 | | 2.53 | 2.28 | | 3.58 | |
| | B | 2.04 | a* | 0.02 | 0.21 | a* | 2.10 | 1.89 | a* | 2.97 | a* |
| | C | 2.05 | | 0.02 | 0.25 | b* | 2.10 | 1.90 | | 2.98 | |
| | D | 2.05 | | 0.02 | 0.25 | | 2.15 | 1.94 | | 3.04 | |
| M | A | 2.07 | | 0.03 | 0.43 | | 2.53 | 2.61 | | 4.09 | |
| | B | 2.06 | a* | 0.03 | 0.40 | a* | 2.10 | 2.48 | a* | 3.90 | a* |
| | C | 2.06 | b* | 0.03 | 0.44 | | 2.10 | 2.30 | b* | 3.61 | b* |
| | D | 2.06 | | 0.02 | 0.28 | | 2.15 | 2.43 | | 3.81 | |
| U | A | 2.06 | | 0.03 | 0.48 | | 2.62 | 2.36 | | 3.71 | |
| | B | 2.04 | b* | 0.03 | 0.44 | b* | 2.54 | 2.29 | b* | 3.60 | b* |
| | C | 2.05 | | 0.02 | 0.38 | | 2.27 | 2.05 | | 3.21 | |
| | D | 2.05 | | 0.02 | 0.32 | | 2.31 | 2.08 | | 3.27 | |

CL: Confidence level 95% ($p<0.05$) from the same data group; MC: muscle contraction; A: Isotonic concentric; B: isotonic eccentric; C: isometric; D: isokinetic; * is $p<0.05$; L: Between endplate region and distal tendon insertion; M: Middle of the muscle belly; U: Above the medial belly of both head parallel to muscle fibers (long and short head biceps tendon).

of M, U and L. Moreover, in the highest peak analysis, there was an interaction between L and M ($p<0.05$) as well as M and U ($p<0.05$), but not between L and U ($p= 0.162$).

## DISCUSSION

The human biceps muscle undergoes major structural and functional changes in the early years of life. An adolescent's biceps muscle is newly structured in the body and is a relatively new tissue for generating electromyographic signals[12]. Previous studies have reported EMG analysis of the biceps brachii muscle of various age groups (young adults, the elderly, and the middle aged), number of electrode placements, different environment for experiment (lab, air, water, sports ground, and temperature), sampling and frequency range, types of sensors, types of muscle contractions etc[8, 16–20]. However, in our study, we successfully demonstrated the electromyographic signal generated on an adolescent's biceps brachii muscle at different muscle locations using wireless sensor, three electrodes, four basic contractions, a fixed load and a 100 Hz sampling rate. Statistical analysis was performed to analyze the differences.

A previous study successfully showed that muscle contraction is influenced by sensor placement, and that a young adult's (mean age 27) muscle belly is the best location to easily identify the signal. Also the signal peak was higher than at the muscle belly at the medial and lateral locations[8]. Pearce et al. reported EMG results of the muscle belly during eccentric contraction performed by individuals (mean age 63)[21]. In our present study, we found similar results for an adolescent's (17 years) biceps muscle using a different protocol and measurement technique. We showed that the electrical signal was significantly higher ($p<0.05$) at the muscle belly than at the other two muscles locations, for the mean, maximum amplitude, and average RMS. Another important finding was that, the EMG results were higher in most of the cases during concentric contraction than the other three contractions.

There were some limitations to this study. We measured only one subject, because our objective was not subject variation, rather it was biceps muscle coordination and the influences of electrode location on the EMG signal. Also, only two values of percentages of MVC (0% and 100%) and a constant load (6 Kg) were used, and only a male adolescent's right arm was investigated.

In conclusion, these initial results from a single subject suggest that the muscle belly of the biceps brachii is the best location for measuring EMG, followed by the muscle between the endplate region and distal tendon insertion, and over the medial belly of each head. These results will be valuable for adolescent biceps rehabilitation and any other physiological measurement that concern the upper arm muscles. Further studies are required to measure a larger group of adolescents, and both arms (both male and female), and to examine potential applications of the information in rehabilitation and medical science.

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