

# Investigation of the EMG-time relationship of the biceps Brachii muscle during contractions

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**Abstract.** [Purpose] This study investigated the changes in the slope of EMG-time curves (relationship) at the maximal and different levels of dynamic (eccentric and concentric) and static (isometric) contractions. [Subjects and Methods] The subject was a 17 year-old male adolescent. The surface EMG signal of the dominant arm's biceps brachii (BB) was recorded through electrodes placed on the muscle belly. [Results] The results obtained during the contractions show that the regression slope was very close to 1.00 during concentric contraction, whereas those of eccentric and isometric contractions were lower. Significant differences were found for the EMG amplitude and time lags among the contractions. [Conclusion] The results show that the EMG signal of the BB varies among the three modes of contraction and the relationship of the EMG amplitude with a time lag gives the best fit during concentric contraction.

**Key words:** EMG, Biceps brachii muscle, Contraction

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## INTRODUCTION

Electromyography (EMG) is a recognized recording tool that is commonly used for measuring the electrical activity of a contracting muscle<sup>1)</sup>. A number of research studies have investigated the relationships between EMG and other parameters. Before conducting this study, we conducted a review of the literature concerning relationships regarding EMG activities of the upper limb muscles. Commonly assessed relationships are those of: EMG-force, EMG-torque, EMG-time, EMG-angle and EMG-other parameters. For example, Munteanu et al. studied the relationship between EMG and muscle temperature during dynamic contraction of the forearm muscles<sup>2)</sup>. Rantalainen et al. examined the EMG-force/torque relationship in the BB. These researchers found that the disruption of the physiological signal (EMG) caused by the innervation zone alters the reliability of the force-EMG relationship on a single bipolar channel level<sup>3)</sup>. Roman-Liu et al. investigated how altering the wrist posture influences the relationship between the time and frequency measures of the surface EMG signal of the wrist muscles. Their results suggested that changes in the relationship between the time and frequency measures should be considered in studies using EMG with different wrist postures<sup>4)</sup>.

A previous study of the biceps brachii (BB) tested the relationship between the EMG median frequency and the low-frequency-band amplitude of the surface EMG profile as a representation of muscle fatigue. The results showed that there is a relationship between the median frequency shift and the amplitude of the 15- to 45-Hz bandwidth and the high-low frequency amplitude ratio<sup>5)</sup>. Similarly, Doheny et al. examined the effect of the joint angle on the relationship between the force and EMG amplitude and the median frequency in the BB, brachioradialis and triceps brachii muscles<sup>6)</sup>. Some other EMG studies have also examined force, exercise and movement. According to the definition by previous gerontological studies, the age range of adolescence is 13 to 19. In the literature we reviewed, most of the previous studies had investigated the EMG signal of subjects older than 20 years of age. We could not find any report of the EMG-time relationship during MVC of adolescent's muscle. The major goal of this study was to fill this gap by analyzing this relationship in order to characterize the BB muscle activity of adolescents. In other words, to investigate the EMG-time relationship in order to evaluate the endurance time of an adolescent's BB using EMG under three contraction conditions.

## SUBJECTS AND METHODS

A male adolescent (age=17 years, weight=60 kg, height=171 cm) participated in this study and provided written informed consent prior to the experiment. All of the experimental procedures conformed to the principles of the Declaration of Helsinki and were approved by the local Human Research Ethics Committee of the University. Be-

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fore the test, the subject was told to sit in a chair and relax as much as possible. Dynamic (concentric (up) and eccentric (down)) contractions were then induced by lifting and lowering a weight. During the dynamic contractions, the subject was instructed to move his forearm between elbow angles of 0° and 90°. In contrast, during static (isometric) contractions, the subject was instructed to hold the same load with an elbow angle fixed at 90°. Three trials of each type of contraction were performed for 10 s with a rest period of 5 min provided between each trial.

A wireless sensor was used to record the EMG signal at the belly of the BB muscle using two foam adhesive electrodes (Ag/AgCL). The inter-electrode distance, electrode placement procedure and skin preparation followed the descriptions of SENIAM<sup>7)</sup>. The raw signals were recorded at a sampling rate of 1 kHz before analog to digital conversion. Fourth-order bandpass Butterworth filter was used to remove skin movement artefacts and high-frequency noises (cutoff frequency between 10 and 500 Hz). The digitized EMG datasets were processed offline (filtering, windowing, and signal extraction) using Matlab software. The EMG signals were divided into four parts and analyzed as 2,500-ms time windows. EMG amplitude data were normalized to the root mean square (RMS) values: i.e., the individual RMS values during the contraction were considered 100% MVC. The filtered EMG activity was normalized by dividing the observed EMG value by the maximum value recorded during the three MVC trials. The mean (RMS) normalized EMG activity was then calculated as the mean of the sum of the normalized EMG percentages during each contraction. The EMG associated with MVC was designated 100% and fractions thereof. The maximum peak-to-peak value of the EMG was considered a relative measure of the motor activity. The statistical analyses were performed using Minitab™ software. Significant differences in the time lag and the EMG amplitudes (RMS) between the three contractions were detected using repeated-measures analysis of variance and post-hoc tests were applied to test the significance of differences of the variables at a significance level of  $\alpha=0.05$  and 95% ( $p<0.05$ ) confidence intervals. Linear regression ( $r^2$ ) analysis was used to analyze the relationship among the variables.

## RESULTS

The results show that the regression slope of EMG versus time was very close to 1.00 during concentric contraction:  $r^2 = 0.93$ , F-value = 456.7. In contrast, a significant decrease in the EMG signal was observed during eccentric contraction in terms of the time lag:  $r^2 = 0.69$ , F-value=77.5. The slope of the regression line between EMG and time decreased during isometric contraction, and the predictability under this condition was poor:  $r^2=0.24$ , F-value=10.46. Significant differences ( $p<0.05$ ) existed between the EMG amplitude and the time lag during concentric, eccentric and isometric contractions.

## DISCUSSION

It is important to analyze the firing rates of the BB muscle during voluntary contractions at different time intervals<sup>8)</sup>.

In this study, three types of contraction were selected, and the duration was sliced into time windows to determine the relationships of EMG with contractions. The time series of the measurable tension after the onset of electrical activity gradually increased during concentric and eccentric contractions, and this increase is collated with EMG as a function of the endurance time. The findings of our present study agree with the results reported by Komi et al<sup>9)</sup>. Prior to this study, no research study had investigated the EMG-time relationship of an adolescent's BB muscle during contractions.

The results of this study will be value to researchers who are interested in EMG analysis over time during contractions. In addition, our results could be used in various practical applications associated with the non-invasive evaluation of the BB muscle. This study characterized the EMG responses, which may aid further research and demonstrate the clinical importance of predicting the EMG-time relationship. Our most significant contribution to research is that our findings note the differences between the three types of contraction in terms of EMG-time relationships of the muscle during the early stage of the contraction. This study had some limitations. Like, only a single muscle was selected, and the EMG data were recorded from a single subject. Future research should focus on defining the relationship between the EMG-moment, EMG-force and other parameters of the BB muscle of individuals in different age groups.

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