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Age Related Differences in the Surface EMG Signals on Adolescent's Muscle during Contraction

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Abstract. The aim of this study was to investigate whether there are differences in the amplitude of the EMG signal among five different age groups of adolescent's muscle. Fifteen healthy adolescents participated in this study and they were divided into five age groups (13, 14, 15, 16 and 17 years). Subjects were performed dynamic contraction during lifting a standard weight (3-kg dumbbell) and EMG signals were recorded from their Biceps Brachii (BB) muscle. Two common EMG analysis techniques namely root mean square (RMS) and mean absolute values (MAV) were used to find the differences. The statistical analysis was included: linear regression to examine the relationships between EMG amplitude and age, repeated measures ANOVA to assess differences among the variables, and finally Coefficient of Variation (CoV) for signal steadiness among the groups of subjects during contraction. The result from RMS and MAV analysis shows that the 17-years age groups exhibited higher activity (0.28 and 0.19 mV respectively) compare to other groups (13-Years: 0.26 and 0.17 mV, 14-years: 0.25 and 0.23 mV, 15-Years: 0.23 and 0.16 mV, 16-years: 0.23 and 0.16 mV respectively). Also, this study shows modest correlation between age and signal activities among all age group's muscle. The experiential results can play a pivotal role for developing EMG prosthetic hand controller, neuromuscular system, EMG based rehabilitation aid and movement biomechanics, which may help to separate age groups among the adolescents.

Introduction

Analysis of muscle function is one of the key elements of human body movement, rehabilitation and ergonomics studies as well as survival in different tasks in daily life. Usually, electromyographic (EMG) signal is used to measure muscle activeness, and is an essential tool in rehabilitation, biomechanical and biomedical investigations [1]. For more than a decade, surface EMG has been a challenging field of scientific experiment from human skeleton muscle which is used in areas of human movement studies, rehabilitation system and neuromuscular diagnostics, it can be generated by voluntary muscle contraction and it has better properties of high amplitude as well as signal to noise ratio (SNR) [2-4]. Since, the rehabilitation sciences are the major area of kinesiology where EMG is used, the analysis of EMG signals from different age groups of Adolescent's muscle is one of the important issues to resolve [5].

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This paper did a systematic review to identify the research gap on adolescents muscle activity and to address the most recent research work based on, i) different age related muscle activity, ii) only adolescents muscle activity, iii) calculated EMG feature to analysis the muscle function, and iv) types of protocols used for the experiment. For example, Boccia *et al.*, investigated on two muscles activity of lower limb (namely, vastus lateralis and vastus medialis obliquus) among elderly men (age 69) and young men (age 23) during isometric knee extension using conduction velocity methods [6]. Arjunan *et al.*, investigated the age related changes among younger (20-29 years) and older (61-69) age group's biceps muscle using Fractal dimension (FD) to measure the complexity of a signal [7].Then, one research by Anna *et al.*, investigated the electromyography and mechanomyography signal affect from young and old women subject's triceps and biceps brachii, and brachioradialis muscles during isometric elbow extensions [8]. They normalized the EMG amplitude with RMS calculation. From the previous research on EMG it has been highlighted that different attempts have been made by researchers to identify muscle functions using time domain and frequency domain analysis, such as root mean square (RMS), zero crossing, mean frequency, median frequency, integrated EMG (IEMG), average-rectified value (ARV), mean absolute value (MAV), normalized spectral moments, wavelet transforms, increase in synchronization (IIS) index, and fractal dimension [7. 9-12].

However, there is limited evidence about the age related differences among the adolescents muscle during different movement using the RMS and MAV signal analysis techniques. Thus, this research work has inspired to analysis of EMG from different age groups (13, 14, 15, 16 and 17 years) of adolescent's Biceps Brachii (BB) muscle using two computational feature analyses techniques, namely RMS and MAV during dynamic contractions.

2. Materials and Methods

Fifteen healthy adolescents participated in this study and they were divided into five age groups (13, 14, 15, 16 and 17 years). It is notable that, adolescent (denarian or teenager), one who is between the age of 10 to 19 [13]. No subject is known to have symptoms of neuromuscular diseases. They gave their informed and written consent prior to the beginning of the experiment, and fulfilled a questionnaire describing their pre-test health condition. All experimental procedures conformed to the declaration of Helsinki and were approved by the Human Research Ethics Committee at the University.

Before the test, the subject was told not to move and to stand as relaxed as possible. Then dynamic (up and down) contractions were performed by lifting and lowering a standard 3-kg weight dumbbell. During dynamic contractions, the subject was instructed to move his forearm between elbow angles of 0 ° and 90°. This angle measurement was consider as, from the shoulder to elbow and then elbow to palm which was calculated by a digital inclinometer. Three trials for each contraction were performed for 10 s and a rest period of 5 m was provided between each trial. Figure 1 shows the EMG signal recording protocols from the subject. Here, A) Electrode placed on BB muscle, B) wireless EMG sensor for data recording, C) dumbbell lifting for performing the dynamic contraction.

A wireless, named Shimmer™ (Real-time Technologies Ltd., Ireland) was used to record the signal (in microvolts (mV)) where the two inputs (negative and positive) were used for the EMG recording, and a third was used as the reference channel. Three silver-silver chloride (Ag-AgCL) surface electrodes were used to record EMG signals from the muscle. The recording electrodes were placed over the belly of the BB muscle as well as on their position in relation to muscle fibre orientation. The ground electrode was on the lateral epicondyle of the humerus of the right arm (approximately 1 inch on the olecranon of the elbow). The electrode placement and other protocols of measurement obey the SENIAM recommendations [14]. The raw EMG signals were recorded at a sampling rate of 1 KHz before their A-D conversion and stored on a compatible computer. Then the fourth-order band-pass Butterworth filter was used to remove any skin movement artifacts as well as high-frequency noises (cutoff frequency between 10 to 500 Hz). After that the recorded digitized EMG data sets were processed offline by filtering, windowing, and extracting signal. These signal processing was performed with the Matlab (the Math-works, USA) software.

Figure 1: Experimental protocol setup.

The analysis of the recorded EMG in this study is based on two features namely, root mean square (RMS) and the mean absolute values (MAV). RMS is obtained by calculating the mean value of the square of all values of the EMG signal and dividing it by the length of the vector N and then the root of this result was calculated using the following formula;

$$\mathrm{RMS} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} x_i^2} \quad (1)$$

Then the absolute value of a number in mathematics means the distance of the number form zero. As distance can never be negative, mean absolute value is calculated by dividing the summation of absolute value to the length of the vector EMG and the formula is;

$$\mathrm{MAV} = \frac{1}{N}\sum_{i=1}^{N} |x_i| \quad (2)$$

The statistical analysis was performed using the Minitab™ (version 13.32) software. Significant differences between the age of adolescents and EMG feature (RMS and MAV) were detected using repeated measures with the analysis of variance (ANOVA), and post hoc tests were applied to test differences with the significance level set at $\alpha = 0.05$, 95% ($p < 0.05$) confidence intervals for all variables. EMG signal steadiness or muscle activity variation was characterized by the coefficient of variation (*i.e.* the ratio of their standard deviations divided by their means, Coefficient of Variation (CoV) = σ/μ) from the RMS value. The linear regression (r^2) analysis was used to analyse the relationship between age and the EMG variables. In addition, the null hypothesis of linearity of each regression was tested by means of the F-test. Finally, each individual data set from the trial was calculated to fit with a linear regression line in the logarithmic curve fitting form of $y = a + bx$.

3. Results

Table 1 and Table 2 highlighted the overall results from the calculation of RMS and MAV respectively. The results based on the individual subject among each group shows that the values differ from one subject to another in all groups. For instance, in 13-years old group the RMS was 0.35, 0.28 and 0.14 mV for the three subjects. Then the results from RMS and MAV indicate that, subjects from 17-years group generated maximum signal (0.28 and 0.19 mV respectively), compare to other groups (13-Years: 0.26 and 0.17 mV, 14-years: 0.25 and 0.23 mV, 15-Years: 0.23 and 0.16 mV, 16-years: 0.23 and 0.16 mV respectively).

Results from RMS analysis shows poor regression accuracy between the EMG and age where r^2 value of 0.004, a level of significance is higher than 0.05 (0.82) and an F ratio is 0.061. Similarly, the linear regression results from MAV value shows a low correspondence between EMG and age where, r^2 = 0.003 and F = 0.037. Likewise, no significant difference was found between EMG and the age (P =0.85) from the calculation of MAV values. Finally, Based on the analysis of the steadiness of the signals (with EMG RMS analysis), the subjects belonging to the '15-years' group generated steadier signals (20.53%) than those of the 13-,14-,16- and 17-years groups (41.41%, 24.61%, 49.58% and 26.44%, respectively).

Table 1. Summarised results from the analysis of RMS feature

Age Groups (years)	Mean±SD	R^2	P	F-Ration	CoV (%)
13	0.26±011				41.42
14	0.25±07				24.62
15	0.23±0.05	0.004	0.82	0.061	20.53
16	0.23±0.12				49.58
17	0.28±0.08				26.44

Table 2. Summarised results from the analysis of MAV feature

Age Groups (years)	Mean±SD	R^2	P	F-Ration
13	0.17±0.07			
14	0.18±0.05	0.003	0.85	0.38
15	0.16±0.04			
16	0.16±0.08			
17	0.19±0.05			

4. Discussion

Adolescence is a stage where the transition from childhood to adulthood occurs and the muscle grown up gradually. EMG has an important role in the evaluation of muscle activity and signal variability to detect accurate neurogenic dysfunction among different age groups. Thus, this is the first attempt to identify and compared the EMG results from the adolescents muscle based on the different age groups. The RMS and MAV are the two important and relative measures to identify the muscle function during dynamic movement. Therefore, after calculating these two values, the results show higher activity on older age (17-year) subjects compare to early aged groups. But, the signal steadiness was better in the mid age groups (15 years) compare to younger and elder groups. Also, this study shows weak correlation between EMG and age among different groups of adolescents muscle. Another interesting observation in this study is the signal steadiness using RMS CoV analysing technique.

Only one article reported the EMG response patterns from the four different age groups (15-, 16-, 17- and 18-years) lower limb muscle during sports performance [15]. Except this, no article reported the age-related activity on adolescents muscle. But the effect of muscle age on EMG signals has been investigated in several studies. For example, Merletti *et al,.* found that the EMG signal activity is statistically higher in young subjects compared with elderly subjects, but no significant differences in the variance were found between the groups [16]. Yamada *et al.*, showed that the EMG values are lower in older (mean age: 70 years) compared with younger (mean age 21 years) subjects during MVC in the tibialis anterior muscle [17]. In another study, researchers showed that old men are less physically active (based on the EMG measurement) compared with young men [18]. Gerasimova *et al.*, who showed that the EMG amplitude (RMS) decreased with age with individuals [19]. However, these data failure in support of the hypothesis, which show that muscle activity is greater in older ages of adolescents compared with early ages. An important reason may be the EMG activity is less active on early aged adolescents muscle due to less motor unit recruitment. There are possible clinical significances from the outcomes; like, recurring dynamic contractions on BB muscle can facilitate to clarify the maximum occurrence of shoulder pain as well as biceps tendonitis those are medically observed in adolescents muscle, and treatment methods with specific injury prevention programmes should focus on the different movement phases with the maximum muscle effect. Finally, these considerations will be of particular importance in assessing different physical therapy on adolescent's muscle which can improve the movement performance and stability

5. Conclusion

The paper concludes with a view on future guidelines in research, development and applications of scientific study of surface Electromyographic signal in adolescents muscle based on different age groups. The findings can be applied in biomedical engineering applications for the analysis and control of the neuromuscular system, ergonomics research, rehabilitation engineering, and movement biomechanics. Our future research activities will therefore, analyse the EMG signal with more computational features like mean frequency, median frequency, zero crossing and integrated EMG.

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