The Effects of Rest Interval on Electromyographic Signal on Upper Limb Muscle during Contraction

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Abstract— **In this paper, the Electromyographic (EMG) signal was investigated on the Biceps Brachii muscle during dynamic contraction with two different rest intervals between trials. The EMG signal was recorded from 10 healthy right arm-dominant young subjects during load lifting task with a standard 3-kg dumbbell for 10 seconds. Root mean square (RMS) has been used to identify the muscle function. The resting period was 2- and 5-minutes between each trial. The statistical analysis techniques included in the study were *i*) linear regression to examine the relationship between the EMG amplitude and the endurance time, *ii*) repeated measures ANOVA to assess differences among the different trials and *iii*) the coefficient of variation (CoV) to investigate the steadiness of the EMG activation. Results show that EMG signal is more active after 5 minutes rest period compare to 2-minutes gap. On the other hand, EMG signals were steady during 2-minutes rest (7.59%) compare to 5-minutes resting interval (16.14%). Results suggest that moderate interval between each trial is better to identify the muscle activity compare to a very short interval. The findings of this study can be used to improve the current understanding of the mechanics and muscle functions of the upper limb muscle of individuals during a contraction which may prevent from muscle fatigue.**

Keywords— EMG, RMS, Rest interval, Muscle, Contraction.

I. INTRODUCTION

Analysis of EMG signal has been given a lot of attention in the last few decades since the investigation and processing of the signal have a huge influence in developing adaptive control of prosthetic devices in the rehabilitation program as well as in diagnosis of neuromuscular diseases. Generally, EMG signal is used to identify the electrical activity from the skeletal muscles during contraction and body movement and, it provides the detail information about the structure and function of these muscles [1]. One of the major issues reported in recent years is the signal effect on muscle during inter-trial rest intervals [2, 3] while recording the EMG signal. The reason is, lack of proper knowledge of the approximate time duration, between each trial, may result in muscle fatigue, soreness, stiffness and even muscle cramp.

Usually, researchers prefer different time duration as rest interval between each trial during EMG recording. For example, 5 seconds [4], 1 minute [4-6] and 5 minutes [7]. However, few studies have shown the significance of same time duration between each experimental trial. For example, Maia et al., investigated EMG signals from lower limb muscle with a rest interval of 30 seconds, 1 minute, 3 minutes and 5 minutes [8]. Authors found that no rest or relatively shorter rest intervals (30 seconds and 1 minute) might be more effective to stimulate greater agonist repetition enhancement and muscle activation. Furthermore, Pincivero et al. examined the effects of rest interval (5, 40 and 160 sec) on quadriceps femoris muscle activation [17]. The effects of rest interval length on bench press performance with an interval of 1, 2 and 3 minutes were investigated in [19]. In this consequence, the effect of rest interval for muscle characteristics identification during different contractions (isometric, eccentric, concentric and isokinetic) and from different muscles (upper- and lower-limb) were investigated in [9-11].

Moreover, having the significant effect of rest interval on EMG activity, a number of feature extraction methods have been used to investigate the muscle functions. For example, root mean square (RMS), zero crossing, mean frequency, median frequency, average-rectified value (ARV), integrated EMG (IEMG), mean absolute value (MAV), normalized spectral moments, wavelet transforms, increase in synchronization (IIS) index and fractal dimension are more frequently used time and frequency domain techniques. However, no study has been found investigating muscle activity as well as the signal variation on Biceps Brachii (BB) muscle during two rest interval period of 2 and 5 minutes. Also, RMS feature extraction technique has not been given much attention in such kind of investigation. In this study, we investigated the muscle activity during specific rest interval period using RMS feature extraction method. We investigated the effects of two different rest intervals on EMG activity in upper limb muscle during dynamic contraction. Specifically, 2 min and 5 min rest

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interval were considered as a short and a long resting period respectively. Results found in this study may be useful for further investigation on muscle fatigue during contraction.

II. Subjects and Methods

A. Subjects

Ten right-hand dominated subjects (8 males, mean age: 23.25 yrs, weight: 64.88 kg, height: 16.75 cm; and 2 females mean age: 23.12 yrs, weight: 54.5 kg, height: 151.2 cm) voluntarily participated in the study and gave their written informed consent. Subjects did not have any history of disorder or pain in biceps muscles. Note that, the subjects were treated in accordance with the ethical standards of the Declaration of Helsinki.

B. Testing Procedures

At first, each subject was asked to stand straight holding the weight handle bar while it was resting. Then dynamic contraction was performed by lifting a standard 3-kg weight dumbbell. During the arm movement the elbow was swung (flexion and extension) almost at the same speed and generates pendulum arm motion within 0° to 90° angles. The angle was measured using a goniometer at shoulder-to elbow and elbow-to-palm respectively. Each subject underwent two sessions for 10 sec and each session consisted of three trials. There was 2 min rest interval between each trial of the first session and then 30 min break before starting the second session. In the second session, there was 5 min rest between each trial. Note that, EMG signal was recorded after each trial. Fig. 1 depicts the experimental protocol from the subject while lifting the load to generate the dynamic contraction.

Fig 1 Experimental protocol setup. A) electrode placed on BB muscle, B) wireless EMG sensor, C) a 3-kg dumbbell.

C. EMG Data Recording

In this experiment, a wireless three-channel EMG signal storage device, called SHIMMER™ (Model SHSHIM-KIT-004) was used to record the EMG signal from the muscles. The device is also touch-proof and Bluetooth enabled as well. Two channels were used for the EMG recording and another one was used as the reference channel. The built-in frequency range of the device is 5-482 Hz including an EMG amplifier gain of 682 dB. A sampling frequency of 1 kHz was used to record the raw EMG signal which was preamplified with a band-pass filter with a frequencyy range of 10–500 Hz. There was a distance of 5 feet between the EMG daughter board device and a laptop with Bluetooth facility.

Pre-gelled Ag/AgCl non-invasive electrodes with biopotential sensors were used in this study. The electrodes can identify the flow of ions through a nerve fiber in the human body. In addition, these electrodes have few more advantages such as *i*) non-polarized, *ii*) allow free current flow across the electrode junction, *iii*) quiet, generating noise levels lower than 10µV, *iv*) disposable, *v*) large (30 mm) and *iv*) have low adhesiveness. To obtain better EMG signals with reduced artifacts and bioimpedance, the skin of the muscle was prepared using a skin cleaning gel (sigma gel) and an alcohol swab. The skin preparation and the electrode placement procedures were similar to [12-14].

D. EMG Feature

The root mean square (RMS) is one of the most popular features used to interpret the amplitude of an EMG signal. Consequently, in this study, the RMS was used to calculate and analyse the surface EMG signals. RMS is used to statistically investigate the magnitude of a time-varying signal and can be defined according to [15, 16]:

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

E. Statistical Analysis

After recording, statistical analysis was performed using Minitab® software (version 13.32). Significant differences in the resting interval and EMG amplitudes were detected through repeated-measures analysis of variance (ANOVA) using a significance level of $\alpha=0.05$ and 95% ($P<0.05$) confidence intervals for all of the variables. The variation in the muscle activity which can be identified by the steadiness of the EMG signal was characterized by the coefficient of variation (CoV). CoV can be defined as the ratio of the standard deviations divided by the means, CoV = σ/μ.

III. RESULTS AND DISCUSSION

Table 1 and Fig. 2 present the effectiveness of EMG signal on the BB muscle after two (2- and 5-min) rest intervals. Most of the individual results show that EMG amplitude is increased after a 5-min interval in comparison with a 2-min interval. Accordingly, combined result also demonstrates the same scenario where a 5-min rest period generated higher signal activity (0.23±0.04mV) than a 2-min rest period (0.18±0.02 mV). This implies that muscles involved in higher activity after 5-min interval than the 2-min interval. Almost similar result was reported in [18] where it was demonstrated that adequate recovery of muscle force within trials is a prerequisite for the generation of tension in subsequent contractions. Thus, setting a relatively longer rest interval will allow sufficient time for the muscles to refill the intramuscular stores. However, different results found in terms of CoV calculation. Here, EMG signals were more variable (16.14%) during 5 min interval than 2 min interval period (7.61%). This indicates that the muscle activity is steadier with the short rest interval than with the longer resting period. Finally, significant differences ($p<0.05$) observed from both the interval periods between time and signal amplitude.

Table 1: Summarized RMS results from entire subjects from 2- and 5-minute experiments

Subject	2-minutes Interval				5-minutes Interval			
	Mean±SD		CoV (%)		Mean±SD		CoV (%)	
Sub 1	0.22±0.03		5.52		0.23±0.03		5.64	
Sub 2	0.33±0.04		11.13		0.41±0.03		6.26	
Sub 3	0.11±0.01		4.83		0.12±0.01		6.26	
Sub 4	0.12±0.02	0.18±0.02	18.86	7.61	0.13±0.03	0.23±0.04	11.64	16.14
Sub 5	0.11±0.01		4.76		0.29±0.06		19.94	
Sub 6	0.24±0.02		6.45		0.25±0.01		0.71	
Sub 7	0.16±0.01		1.69		0.15±0.02		9.07	
Sub 8	0.18±0.02		10.02		0.23±0.03		11.12	
Sub 9	0.01±0.01		3.58		0.15±0.12		80.49	
Sub10	0.25±0.03		9.12		0.29±0.04		10.27	

Assessment of the muscle activity and signal variations based on resting interval is a major unresolved challenge in human ergonomics, biomechanics, biomedicine, and rehabilitation. Keeping this in mind, the aim of the study was to identify the impact of the EMG signal on upper limb muscle during two different rest intervals. It has been found that the EMG activity was higher during 5-min rest interval than 2min rest period. But, according to the signal

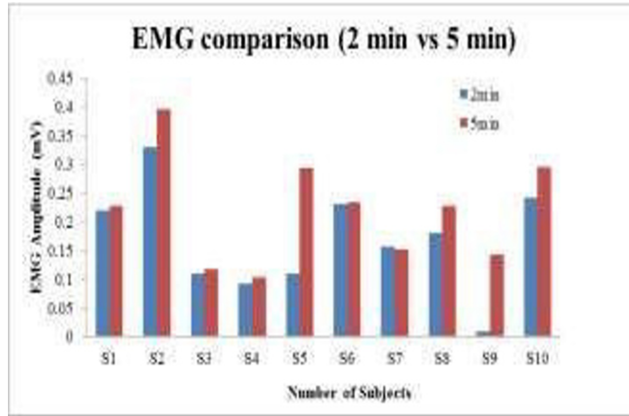

Figure 2: Comparison graph between two interval periods during each trial

consistency, the result was vice versa, *i.e.,* EMG signal was more consistent with a 2-min interval in comparison with that with a 5-min interval. So, the result suggests that the EMG data will be acquired more accurately if the interval between each trial is neither too short nor too long.

The findings can be helpful for developing an appropriate procedure of EMG data recording. Also, the results can be applied in diverse areas of biomedical applications such as the neuromuscular system analysis, ergonomics, biomechanics and rehabilitation engineering. Also, the result of the study may expand the current understanding of the mechanics of the upper limbs of subjects involved in the physical exercise with short and long rest interval. However, there were few limitations of the current study as well. For example, only two rest interval duration, one muscle (BB) and dynamic contraction have selected in this study. Thus, there is a need for further investigation examining different rest intervals in other muscles of the human body with different experimental protocols.

IV. CONCLUSIONS

In the EMG-based assessment, it is crucial to set an appropriate interval period between the trials. Otherwise, it may disrupt the signal recording from the subjects and thus, the recorded muscle activity may be erroneous. The results of the current study suggest that a very short interval may cause the muscle fatigue or cross talk among the adjacent muscle. On the other hand, a very long interval may cause the subject uninterested in data recording, which may affect the signal impedance or even signal-to-noise ratio. Thus, moderate rest interval (not very short or very long period) is the best way to record the EMG signal. However, our future research will be directed to study a large number of interval periods for further investigation on finding optimum value of the rest interval.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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