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Computation and Study of the Low-Frequency oscillation of Surface Electromyogram recorded in biceps during isometric upper limb contraction

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Abstract— **This study has experimentally studied the low frequency oscillation in surface electromyogram (sEMG) during isometric muscle contraction for Biceps brachii muscle. The time constant corresponding to this low frequency oscillation was computed for sEMG. Experiments were repeated for 25 subjects, and for isometric muscle contraction, ranging between 25% and 100 % maximum voluntary contraction (MVC), while the subjects were given real-time visual feedback of the force of contraction, recorded at 1000 samples/ second. The time constant (Tc) corresponding to the variability of sEMG was computed using the Hilbert transform and envelope detection. The results show that the time constant, Tc of sEMG recorded from the biceps during isometric contraction was the same for all the subjects, and for different levels of force of muscle contraction, and was 78ms (±1.1). This suggests that the low frequency oscillation of sEMG of the biceps brachii muscles is a fundamental property of that muscle, and corresponds to a fundamental phenomenon, which has never been observed earlier. By comparison from delays reported in literature, this delay is similar to M2 stretch reflex latency, and may be attributed to the neural pathway delay.**

I. INTRODUCTION

There is a low frequency variation in surface electromyography (sEMG) during isometric muscle contraction. This variability has been studied for different level of muscle contraction [12] and it has been observed that the magnitude of this variation increases with force of contraction. This low frequency (~10 Hz) variability has been found to increase with age [16]. The relationship of variability of muscle activity of different muscles during tracking tasks and the change in force variability when different muscles are simultaneously active have been reported [13] [14]. However, the cause of this variability is not yet understood.

Research studies [4] [11] have reported the identification of oscillatory input to muscle using the spectral analysis of sEMG. Neto and Christou [11] have reported the oscillatory input to the muscle can be identified using the power spectrum of the of the interference EMG signals. Farina et al [6] have investigated the approaches to estimate the neural drive to the muscle. According to Taylor et al [15], recruitment and rate-coding properties are likely contributors to the variability of force of muscle contraction, these mechanisms are not adequate to describe the fluctuations of force, and concluded that the pattern of force variability is a result of the interaction of multiple mechanisms of motor-unit activity. However, the cause and the factors that would describe this phenomenon have not been explained.

In this study, we have computed the time constant (Tc) of sEMG to understand the cause of these oscillations in sEMG during isometric contraction. Statistical analysis was performed to determine the significant effect of inter-subject and inter-experimental differences on the time constant (Tc) associated with the biceps brachii muscles.

II. MATERIALS AND METHODS

A. *Subjects*

Twenty five healthy volunteers, age range from 20 to 49 years, with no symptoms or history of major neurological, muscular or movement disorder, participated in this study. The participants were given a plain language statement outlining details of the experiments prior to the start of the experiment, and written informed consent was obtained. The experimental protocol was approved by RMIT University Human Research Ethics Committee and the experiments were conducted in accordance with the Declaration of Helsinki of 1975, as revised in 2004.

B. *SEMG Signal acquisition*

SEMG signal was recorded using Delsys (Boston, MA, USA), a proprietary sEMG acquisition system. The sampling rate was fixed at 1000 samples per second. Delsys (Boston, MA, USA) bipolar electrodes were used for this study which has a fixed inter-electrode distance of 10mm.

The bipolar electrode set was placed on the anterior of the arm above the biceps. Reference electrode was placed on the bony prominence at the elbow. Prior to electrode placement, the skin was cleaned with alcohol swabs and lightly abraded with paper towel to reduce skin impedance and ensure good adhesion of the electrodes.

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C. Protocol

During the experiments, the participants were seated on a sturdy and adjustable chair, with their feet flat on the floor and their upper arm resting on the surface of an adjustable desk such that the forearm was vertical (refer fig. 1). The elbow was maintained at 90 degrees, with the subjects' fingers in line with a wall mounted force sensor (S-type force sensor - INTERFACE SM25) which was attached to a comfortable hand sized wrist ring with a flexible steel wire. The output of the force sensor was recorded on one of the channel in the EMG acquisition system, and displayed in real time.

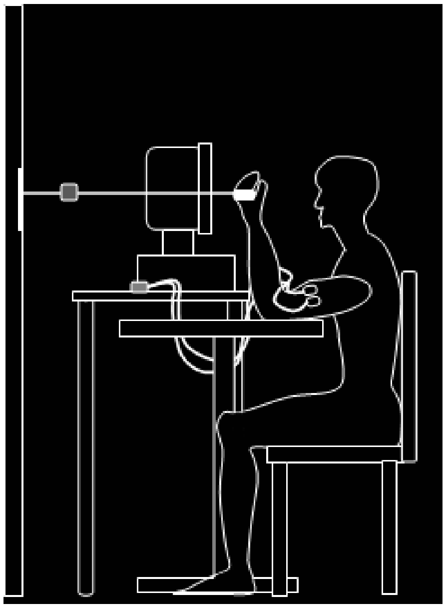

Figure 1. Illustration of the experiment

As a first step, the maximal voluntary contraction (MVC) was measured for each participant by taking the average of three maximal contractions, each contraction of 5 seconds duration and performed with 120 seconds rest-time between each effort. If there were any outliers, the experiment was repeated.

After identifying MVC, the participants performed isometric contractions at 25%, 50%, 75% and 100% MVC. The participants were provided with visual feedback of the force of contraction to assist them in maintaining steady contraction. Participants were asked to perform the contractions for 10 seconds.

Between each contraction experiment, the participants were given a rest period of a minimum of 60 minutes, but as long as they required ensuring that they were not fatigued. This experimental protocol has been reported in our previous study [2] [3].

III. DATA ANALYSIS

a. Computation of Time Constant (T_C) of sEMG

Step 1: Hilbert transform was applied to sEMG signal and the force of contraction [10].

Step 2: The transformed signal was smoothed by applying least-squared polynomial filter (refer Fig. 2)

Step 3: Envelope detection was performed on the filtered sEMG and peaks were identified.

Step 4: Both, the force and sEMG signals were divided into windows of 1000 samples and time constant, T_C of the interval between detected peaks were averaged for each window. The first 1 second of the data was ignored and the next 5 seconds of the recordings were considered for the analysis to ensure that all the participants were in the rested state.

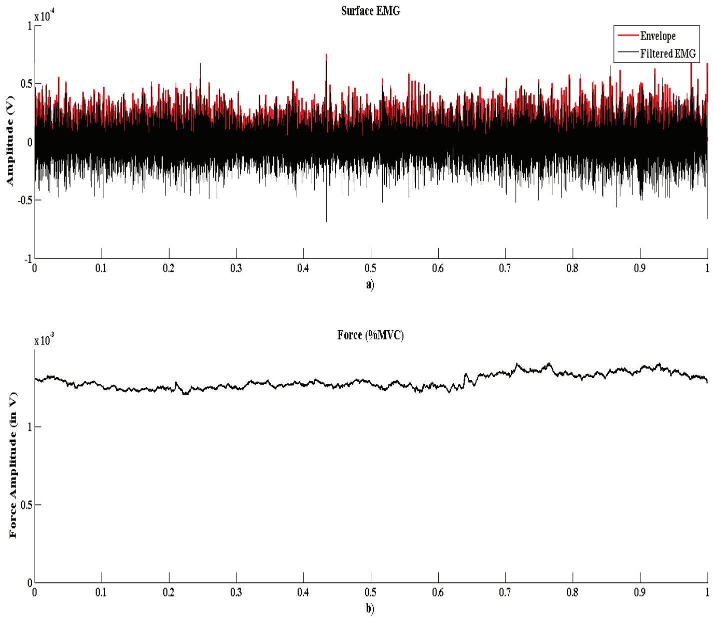

Figure 2. Computation of the time constant a) Envelope of EMG b) corresponding force of contraction.

IV. RESULTS

Figure 2a shows the example of a recording of sEMG while figure 2b is the corresponding force of contraction. From Figure 2b, it is observed that the force of contraction is not steady, but has an oscillation. Figure 3 is the plot of the average values of the time constant (Tc) of sEMG for different levels of muscle contraction (% MVC). It is observed that the time constant corresponding to the oscillation of the force and sEMG is not changed for different people, and for different levels of force of muscle contraction. The average Tc is 78ms (±1.1) for all the four different levels of muscle contraction (25%, 50%, 75% and 100% MVC). The standard deviation is very small for all the experiments (ref Fig.3).

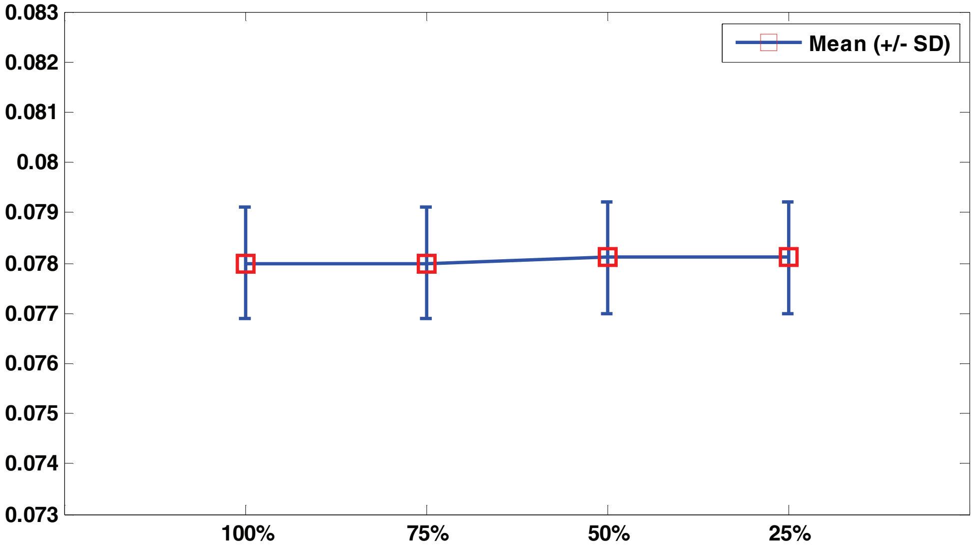

Figure 3. Mean and SD of the Time constant (low-frequency oscillation) of sEMG computed from all subjects and all MVCs.

V. CONCLUSION

Research studies [4] [10] [11] have reported the identification of oscillatory input to the muscle based on the power spectrum of the interference EMG signals. The power spectrum shows different information in the different bands and in particular 5 Hz - 60 Hz oscillations are physiologically relevant. This may not be consistent and information may be lost due to preprocessing, for example rectification of the EMG [6]. Lower frequency of sEMG is largely ignored and many of the commercial devices filter the lower frequency.

This study has determined that there is a steady low frequency oscillation of sEMG and force of muscle contraction obtained during isometric muscle contraction. The time constant (Tc) corresponding to the low frequency oscillation and variability in the EMG during isometric voluntary contraction is 78 ms, corresponding to 13 Hz. The results show that this time constant (Tc) remained unchanged for different subjects and for all four levels of muscle contraction ranging between 25 and 100% MVC. A comparison from research reported in literature shows that this time constant is close to the stretch reflex M2 latencies in the biceps brachii [1] [5] [8] [9]. While the underlying cause of long-latency during stretch reflex has not been established, but it is believed that this delay corresponds to the neural pathways delays [5].

The major outcome of this research is the demonstration that there is a fixed frequency of oscillation of force and sEMG during isometric muscle contraction for the biceps. This suggests that the frequency of oscillation during isometric muscle contraction is a basic property, and may be an indicator of the neural pathways. It is conceivable that this time constant may be used to identify changes in the neural pathway delays, and thus for identifying neuropathy. The authors are currently repeating the experiments for other muscles to study this phenomenon for different muscles, and in the future, would repeat the experiment for different nerve conduction velocities.

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