33rd Annual International Conference of the IEEE EMBS
Boston, Massachusetts USA, August 30 - September 3, 2011

Effect of age and gender on the surface electromyogram during various levels of isometric contraction

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Abstract— **This study reports the effects of age and gender on the surface electromyogram while performing isometric contraction. Experiments were conducted with two age groups - Young (Age: 20-29) and Old (Age: 60-69) where they performed sustained isometric contractions at various force levels (50%, 75%, 100% of maximum voluntary contraction). Traditional features such as root mean square (RMS) and median frequency (MDF) were computed from the recorded sEMG. The result indicates that the MDF of sEMG was not significantly affected by age, but was impacted by gender in both age groups. Also there was a significant change in the RMS of sEMG with age and gender at all levels of contraction. The results also indicate a large inter-subject variation. This study will provide an understanding of the underlying physiological effects of muscle contraction and muscle fatigue in different cohorts.**

Keywords: *Aging, Muscle strength and levels of contraction.*

I. Introduction

Aging is considered to have a strong impact on the parameters of muscle strength, endurance, and fatigue. There is an associated decrease in muscle mass, caused by loss of muscle fibre numbers and a decrease in muscle fiber size [6]. Loss of muscle mass among the aged results in diminished muscle function. Older people have impaired motor performance, slowing of movements and a decrease in muscle strength or maximal force production. This process of aging is highly variable amongst muscle groups and individuals.

In general, the muscle weakness and slowing down is not only attributable to the changes in muscle mass, but is also associated with neurological changes. This has an impact on the force/torque production because force is modulated by the number and type of motor units recruited and firing rate of units [1]. However, some research findings indicate that the impact of age on muscle contraction is largely because of muscle atrophy and the alteration in percentage of contractile tissues within the muscle rather than a decrease in muscle activation (motor unit recruitment and firing rate) [7].

Manuscript received June 20, 2011.
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The muscles of old people contain less contractile tissue as compared to non-contractile tissue when compared with young people which results in decreased force production capability [6].

A review of related literature has indicated that the size of type I fibers does not change with age, but type II fast fibers undergo atrophy and greatly reduce in size with aging [10,11]. It was also suggested that endurance and strength training can limit the extent of sarcopenia (reduction in muscle mass) in elderly people [1], [8]. The physiological changes that occur in muscles as a result of aging can be of great importance to not only physical therapists but also to physiologists and other health care providers. Changes in the neuromuscular system based on the effects of age can be demonstrated by measuring the loss of muscle mass and muscular strength in older adults [3].

Surface electromyogram (sEMG) is the recording of the electrical activity induced by the muscle contraction and an indicator of neuromuscular activity. SEMG provides a non-invasive way of studying muscular function. It results from the interference of action potentials from motor units and represents a pattern characterizing the general activity state of the muscle examined [2], [5].

A number of studies with sEMG have assessed both neural and muscular function showing that the derived sEMG parameters contain significant information about both. Comparison of EMG parameters from different age groups has been reported in previous studies [4], [9]. Gender may also influence muscle properties. One study reports [13] that age exacerbates fatigue more in men than in women. Also greater fatigue resistance has been shown in females compared to males [12]. However, there is a need for detailed study on the impact on muscle activation of age and gender individually. It is important to understand these effects to improve the experimental protocol and our understanding of the underlying physiology of muscle fatigue in different cohorts.

This paper compares experimentally the neuromuscular activity at various force levels of younger and older subjects using sEMG. The objective was to investigate age and gender related changes in the *biceps* muscle using sEMG variables from the time and frequency domains.

II. Methods

Experiments were performed to analyse the changes in muscle activation during various levels of contraction in both genders and young and old healthy adults. The experiments were approved by the human ethics committee in accordance with Australian NHMRC guidelines.

A. Subjects

Twenty four healthy participants with no history of major neurological disorders participated in the study and were grouped into two different age groups:

1. Group 1: Younger: n = 12; age range: 20 – 29 years; six females and six males,
2. Group 2: Older: n = 12; age range: 60– 69 years; six females and six males.

The volunteers were given a clear explanation of the purpose and the protocol of the experiment.

B. SEMG recording

SEMG was recorded using the DELSYS (Boston, MA, USA) proprietary sEMG acquisition system. Two electrode channels were placed on the biceps brachii muscle. Each channel consisted of a pair of differential electrodes with a fixed inter-electrode distance of 10mm and a gain of 1000. The system had a fixed band pass filter range of 20-450Hz and sampling rate of 1000 samples/second.

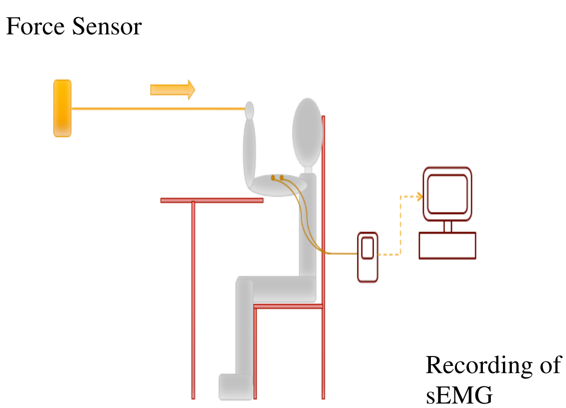

Fig. 1 Experimental procedure for recording sEMG

C. Experiment Protocol

The experimental protocol was designed to record the sEMG during different voluntary isometric contractions. During the experiments, the volunteers were seated in a sturdy and adjustable chair with their feet flat on the floor and their upper arm rested on the surface of an adjustable desk such that the forearm was vertical. Participants were asked to maintain the elbow at 90 degrees with the fingers in line with a wall mounted force sensor (S type force sensor - Interface SM25) attached to the hand by a padded string.

Two channels were used for recording. SEMG from the *biceps brachii* muscle was recorded while the subjects performed a maximum voluntary isometric contraction. Subjects then maintained various levels (50%, 75% and 100%) of maximum voluntary contraction as long as they could. In order to maintain the level of force, the force readings were displayed to subjects as feedback on the computer screen.

D. EMG data analysis

The data were analysed by computation of the following prominent time domain and frequency domain features which revealed information about the contraction level of the muscle:

1. Root Mean Square (RMS)

The RMS of an EMG signal represents the strength of the muscle activity. It is expressed as below where x represents data and N is the number of samples.

$$RMS = \sqrt{1/N \sum_{n=1}^{N} x_n^{\ 2}}$$

2. Median Frequency (MDF)

Median Frequency (MDF) is the frequency at which the spectrum is divided into two regions with equal amplitude and it can be expressed by

$$\sum_{j=1}^{MDF} P_j = \sum_{j=MDF}^{M} P_j = 1/2 \sum_{j=1}^{M} P_j$$

This study compared the changes in each of the features due to the onset of muscle fatigue. The features were computed using a non overlapping moving window of 1 sec. In order to identify the significant changes in the muscle activation, the activity during the initial phase of the contraction and the final phase of the contraction was considered.

E. Statistical analysis

ANOVA statistical model with four factors as main effects and their interactions was designed to test the significance of each feature and identify the significance of each factor based on neuromuscular activity. The four main factors used in this model are:

1. Effect of Age
2. Effect of fatigue
3. Effect of gender
4. Effect of force of contraction

III RESULTS

A. Mean and Standard Deviation

Figs 2 to 7 show mean and SD (error bars) plot of RMS and MDF of sEMG that compare the changes in muscle activation at various levels of contractions due to age and gender for each of the features. Figs 2 to 4 show higher values of RMS for the younger cohort as compared to the old cohort at 100%, 75% and 50% MVC. There is also a difference in muscle activity between young and old females. These figures also show a large difference in RMS of the sEMG between males and females at all levels of contraction.

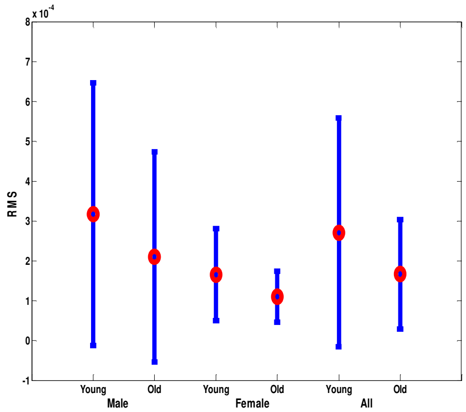

Fig.2 Mean and SD (error bars) plot of RMS (in volts) of the sEMG while subjects performed a maximum voluntary contraction.

Figs. 5 to 7 show the changes to MDF in response to muscle activation at 100%, 75% and 50% MVC for the young and old cohorts. The figures show only a small difference in the values of MDF for young and old males but a significant difference in males compared to females.

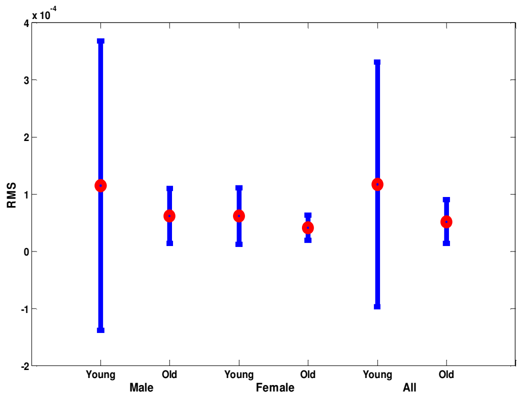

Fig.3 Mean and SD (error bar) plot of RMS (in volts) of sEMG while subjects performed 75% of MVC.

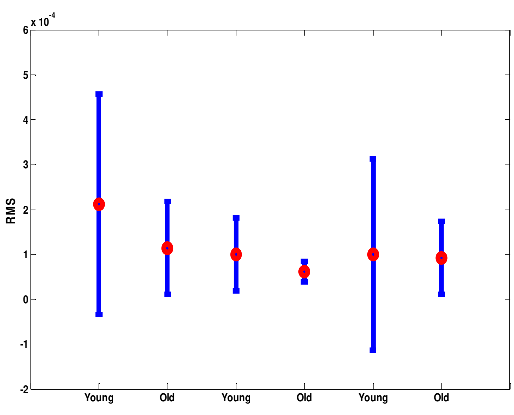

Fig.4 Mean and SD (error bar) plot of RMS (in volts) of sEMG while subjects performed 50% of MVC

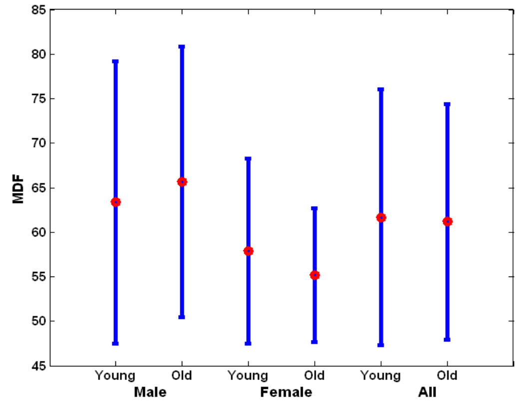

Fig.5 Mean and SD (error bar) plot of MDF (Hz) of sEMG while subjects performed maximum voluntary contraction.

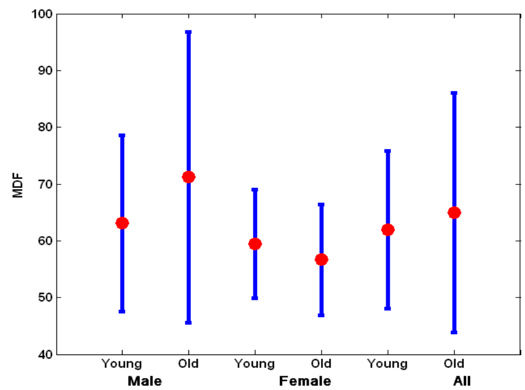

Fig.6 Mean and SD (error bar) plot of MDF (Hz) of sEMG while subjects performed 75% of MVC.

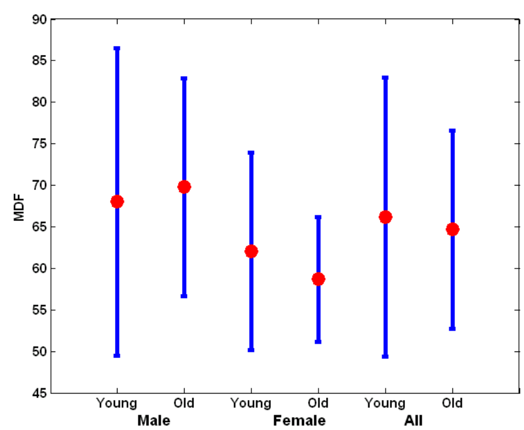

Fig.7 Mean and SD (error bars) plot of MDF (Hz) of sEMG while subjects performed 50% of MVC.

Figs.2 to 4 also show a significant increase in RMS value among younger males and females compared to older males and females, where the increase was smaller. The differences in MDF between the elder cohort and younger cohort were not significant but the difference in MDF between males and females of both age groups was significant at all levels of muscle contraction.

B. Statistical Analysis

Table I shows the ANOVA results of two sEMG features when considering the main effects of the factors. The results from ANOVA show that there is a significant difference in all factors for RMS. The results also indicate that the RMS is sensitive to the age of the participant while MDF is less sensitive to the age factor.

TABLE I
F VALUE FROM ANOVA MAIN EFFECTS STATISTICAL SIGNIFICANCE (*P <0.01)

Features	Effect of age	Effect of fatigue	Effect of gender	Effect of force
RMS	133.66*	13.69*	76.99*	93.02*
MDF	0.3 (p=0.58)	267.38*	51.13*	48.11*

There is also significant ($p<0.01$) difference in the RMS and MDF due to the force of contraction. The results suggest that there was no observed effect of age on MDF. From the results, the impact of aging and fatigue can be observed on the RMS values.

IV DISCUSSION AND CONCLUSION

The study was carried out to determine the changes in sEMG due to age and gender and two traditional parameters were considered. During MVC there was a significant difference in sEMG features (RMS and MDF) between the male and female participants, irrespective of their age. This was clearly measurable in the sEMG.

The results also indicate a significant difference in the RMS of the sEMG across the range of contraction between the younger and older participants. This indicates that young subjects produce an EMG signal of greater magnitude. The high standard deviations for all levels of contraction underline large inter-subject variations.

It was observed that the MDF of older and younger participants was not different. Thus the MDF of the sEMG is not sensitive to age and can be compared across a large range without age correction. However, the results also indicate a significant difference in MDF between males and females at all levels of contraction. Muscle strength is also different in young and old participants as observed by RMS. We conclude that the sEMG parameter, MDF has potential to inform on gender-based differences in motor unit activity that are independent of muscle activity level.

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