EMG EVALUATION OF FATIGUE DURING ISOMETRIC CONTRACTIONS IN FEMALE ROWERS

Selda Uzun¹, Omer Sayli², Yasar Tatar¹, Nusret Ramazonoglu¹, Birol Cotuk¹

¹Marmara University, School of Physical Education and Sport, Istanbul
²Kocaeli University, Faculty of Technology, Biomedical Engineering, Kocaeli (TURKEY)

E-mails: suzun17@yahoo.com, omer.sayli@kocaeli.edu.tr, yasartatar@yahoo.com
nramazonoglu@marmara.edu.tr, hbcotuk@marmara.edu.tr

DOI: 10.7813/jmbs.2013/4/2/2

ABSTRACT

Relatively few studies were carried out to quantify muscle fatigue resulting from isometric contractions in elite female athletes. The purpose of this study was to evaluate fatigue profile of 30-seconds duration isometric contractions using surface electromyography (EMG) in female elite rowers. The subjects were eleven healthy female athletes between 16-24 years of age. The Vastus Lateralis (VL) muscle of the dominant leg was chosen for the EMG recordings. Experimental set up was designed in accordance to the rowing sport. While the hip joints for all the subjects were brought to a 100° flexion, the knee joints were brought to a 90° flexion. The range of the knee joint angle (15°) during the movement was set from 90 to 105° for each subject. The maximal value of MVC was used as the reference value to determine a load of 75% of MVC for each subject. The median frequency (MDF) and the mean frequency (MNF) of the power spectrum and Root Mean Square (RMS) were computed for the surface EMG signal. Least squares line fittings were computed for time series of each parameter to find initial and final values of MDF, MNF and RMS parameters. These values were compared by Wilcoxon test. Significant decreases were found between initial and final values for both MDF and MNF (p<0.01). Also, significant decrease (p<0.01) was found between initial and final RMS. The shift of the EMG power spectrum to lower frequency content has been reported in the literature accompanied by an increase of RMS values. As only few studies have been carried out with women subjects, our RMS results may indicate a special compensatory strategy of muscle load sharing or differences in muscle fiber content in these female rowers.

Key words: Electromyography, Female, Athletes, Rowers, Fatigue, Isometric

1. INTRODUCTION

Analysis of the surface electromyography (EMG) has been widely utilized for prediction of force, quantification of muscle fatigue and it has been also used as a diagnostic tool in rehabilitation medicine, ergonomy and sports physiology. Methods for assessing the electrical manifestations of muscle fatigue during isometric, constant-force contractions are reported in many studies such as EMG signal amplitude changes, spectrum and time-frequency analyses etc. (1, 2). Relatively few studies were carried out to quantify muscle fatigue resulting from isometric contractions in elite or trained female athletes (3).

Neuromuscular fatigue with respect to the motor unit function, has been defined as the physiological changes in the nerve-muscle activity and biomechanical processes used to sustain muscle force that eventually result in the inability to maintain a contraction task or decrease in force (4). Fatigue during voluntary muscular contractions is a complex multifaceted phenomenon and may be caused by the interplay of central nervous factors and electrochemical changes in the periphery. The development of fatigue depends on the type and intensity of muscular activity (5, 6). Muscle fatigue is a frequent problem encountered during sport rehabilitation and exercise physiology; it can limit the performance of athletes or the capacity of the individual (7).

Most of the studies (8-11) stated that exercise induced fatigue leads to decreased strength output accompanied by changes in electromyographic activity measured from the muscles during maximal and prolonged submaximal exercise. The spectrum of the EMG signal is observed to shift
towards the lower frequencies during isometric and dynamic contractions and this shift is usually quantified by the mean frequency (MNF) and median frequency (MDF). These spectral changes are explained generally by progressive decrease in muscle fiber conduction velocity (MFCV) and increase in motor unit synchronization, which also contributes to an increase in the amplitude of the surface EMG signal. However, the trend of the signal amplitude root mean square (RMS) is heterogeneous according to the literature; both increases and decreases have been reported (12).

In rowing, the required force and muscular power are very high for the knee extensors. It was found that vastus lateralis (VL) is the primary responsible muscle for the maintenance of the pace for maximal and submaximal 6-minute rowing test (13). Isometric contraction of vastus lateralis and vastus medialis is important to stabilize the knee, when the high level of muscular force is transmitted through the feet during the stroke (14). The examination of the effect of high-intensity isometric contractions may guide optimal conditioning and technical preparation in elite female rowers. Therefore, the aim of this study was to evaluate isometric conditioning and fatigue profile with 30-second duration isometric exercise for the Vastus Lateralis muscle using surface EMG in female elite rowers.

2. MATERIAL AND METHODS

2.1. Subjects

A total of eleven female athletes participated in the study. They were all national rowers in Turkey. All participants attended the study voluntarily. Demographic data of subjects are presented in Table 1. The athletes were examined during or at the end of the competitive season.

<table>
<thead>
<tr>
<th>N=11</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (year)</td>
<td>16</td>
<td>24</td>
<td>19.8±2.6</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>48</td>
<td>65</td>
<td>57±4.6</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>160</td>
<td>175</td>
<td>167.8±4.9</td>
</tr>
<tr>
<td>Training Year</td>
<td>3</td>
<td>7</td>
<td>4.2±1.5</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>18.1</td>
<td>22.8</td>
<td>20.2±1.2</td>
</tr>
</tbody>
</table>

N: Number, SD: Standard Deviation, BMI: Body mass index

The subjects were informed of the purpose, the protocol of experiment and they practiced for the voluntary contraction test before the experiments. The Marmara University Ethics Committee approved the study and informed consent was obtained from all the participants.

2.2. Experimental Procedure

The Vastus Lateralis (VL) muscle of the dominant leg was chosen for the recordings. Although the dominant extremity was the right leg in all subjects, the experiment was carried out with the left leg for only one subject because she had a meniscus injury in her right leg. The VL muscle particularly has been chosen because of its special morphology and its proximity to the surface, which makes it suitable for the EMG measurements (15, 16, 17).

Experimental set up was designed in accordance to the rowing sport. While the hip joints for all the subjects were brought to a 100° flexion, the knee joints were brought to a 90° flexion. The range of the knee joint angle (15°) during the movement was set from 90 to 105° for each subject. The Maximum Voluntary Contraction (MVC) force was determined using the instrumentation set up within three trials. The MVC was used as the reference value to determine a load of 75-80 % of MVC for each subject. During the isometric contractions, the subjects managed to close the spring for 30 seconds.
2.3. Recording EMG

Surface EMG data were recorded from the VL muscle with silver-silver chloride (Ag-AgCl) surface disk electrodes according to the recommendation by SENIAM (18). The diameters of the disk electrodes were 10 mm, and the inter-electrode distance (center to center) between the bipolar electrodes was set to 25 mm. The reference electrode was placed over the tuberositas tibia of the left leg. Electrodes were placed longitudinally in the direction of muscle fibers approximately halfway from the motor point area to the distal part of the muscle by observing muscle contraction during knee extension. Before the electrodes were placed, the skin was abraded, shaved and cleaned with alcohol in order to reduce impedance between the electrode and skin. Then a minimal amount of conductive paste was applied between the skin and the electrodes, which were attached to the leg with adhesive tape.

The SEMG signals were directly fed to a computer-driven data acquisition system. The SEMG signal was increased 1000 times using a differential amplifier and filtered through an analog band pass filter between 5-500 Hz at 2000 Hz sample rate. The median frequency (MDF) and the mean frequency (MNF) of the power spectrum and Root Mean Square (RMS) were computed for the SEMG signal. Data analysis was performed off-line using MATLAB 6.0 software. For the RMS, MNF and MDF parameters, regression lines were fitted using the least squares method. Initial and last values of these lines were calculated in addition to the slopes.

3. RESULTS

Initial and final values of MDF, MNF and RMS of elite female rowers were compared by Wilcoxon test (Table 2.). Significant decreases were found between initial and final values of the fitted lines for the MDF parameter (p<0.01), in the same way, significant decreases (p<0.01) were found between initial and final values of the fitted lines for the MNF of subjects. In this experiment, significant decreases (p<0.01) were found between initial and final values of the fitted lines for the RMS values. In Table 3, means and standard deviations of the percentage changes and fitted line slopes for the RMS, MNF and MDF parameters are given. For one subject, RMS, MNF and MDF traces were shown during 30 second sustained isometric contractions in figure 2.

### Table 2. Comparison of the initial and final values of the fitted lines for the MNF, MDF and RMS parameters

<table>
<thead>
<tr>
<th>SEMG Variables</th>
<th>Mean ± SD</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMS Initial Value</td>
<td>141.03 ± 57.6</td>
<td>P=0.00*</td>
</tr>
<tr>
<td>RMS Final Value (mV)</td>
<td>96.6 ± 54.7</td>
<td></td>
</tr>
<tr>
<td>MDF Initial Value</td>
<td>105.6 ± 17.2</td>
<td>P=0.00*</td>
</tr>
<tr>
<td>MDF Final Value (Hz)</td>
<td>95.6 ± 19.5</td>
<td></td>
</tr>
<tr>
<td>MNF Initial Value</td>
<td>124.2 ± 23.3</td>
<td>P=0.001*</td>
</tr>
<tr>
<td>MNF Final Value (Hz)</td>
<td>113 ± 25.8</td>
<td></td>
</tr>
</tbody>
</table>

*P<0.01* shows significant differences between the initial and final values.
Table 3. Means and standard deviations of the percentage changes and fitted line slopes for the RMS, MNF and MDF parameters

<table>
<thead>
<tr>
<th>SEMG Variables</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMS % Change</td>
<td>-33.67 ± 16.50</td>
</tr>
<tr>
<td>MNF % Change</td>
<td>-9.54 ± 7.21</td>
</tr>
<tr>
<td>MDF % Change</td>
<td>-9.92 ± 6.80</td>
</tr>
<tr>
<td>RMS Slope [mV/sn]</td>
<td>-1.49 ± 0.86</td>
</tr>
<tr>
<td>MNF Slope [Hz/sn]</td>
<td>-0.38 ± 0.25</td>
</tr>
<tr>
<td>MDF Slope [Hz/sn]</td>
<td>-0.34 ± 0.21</td>
</tr>
<tr>
<td>RMS Slope [%/sn]</td>
<td>-1.13 ± 0.56</td>
</tr>
<tr>
<td>MNF Slope [%/sn]</td>
<td>-0.32 ± 0.24</td>
</tr>
<tr>
<td>MDF Slope [%/sn]</td>
<td>-0.33 ± 0.23</td>
</tr>
</tbody>
</table>

Fig 2. Raw surface EMG signal, RMS, MNF and MDF traces during 30 seconds sustained isometric contractions for a female rower

4. DISCUSSION

It has been well documented that the EMG power spectrum shifts to lower frequency bands during development of muscle fatigue in sustained sub-maximal contractions (4, 17, 19). In agreement with the literature we found a significant decrease of MNF and MDF parameters. Although a spectral shift with fatigue is generally attributed to a decrease in muscle fiber conduction velocity over the duration of sustained contraction, there are many other possible causes of this shift. These causes may include changes in the duration of the motor unit action potential, recruitment and deactivation of motor units, synchronous discharge of motor units, alteration in activity between synergistic muscles, changes in tissue impedance, changes in diameter of muscle fibers, accumulation of metabolic by-products, water and electrolyte concentration shifts, changes of intra-muscular pressure, and decreased sarcolemmal excitability.

Interestingly, there was a decrease trend in RMS in general during 30 second sustained isometric contractions in these female rowers. Although most of the literature reported an increase of RMS during fatiguing contractions (8, 19, 20) in some studies RMS decreases have also been observed (12, 21). In the present study, RMS decrease may cause an increase of firing rates of motor units by special compensatory strategies in these trained rowers. In this study the contraction duration is only 30 seconds, which may also have resulted in a small fatiguing effect. Further points for considerations are the gender and sport specialization of the subjects. Rowing is a demanding sport, which involves fatigue-resistant oxidative muscle fibers with high force production. Fiber composition and size have been shown to influence both the frequency content and amplitude of the electromyographic (EMG) signals (22). It was found that the type IIA cross-sectional area appears to be greater than the type IIB for the VL muscle for both sex and fiber size order from largest to smallest.
was: I>IIA>IIB for the women and IIA>IIB>I for the men (23). Women have less muscle mass and strength than men and they have different intramuscular blood flow. Because of this, females can have advantage in fatigue-resistance for sustained muscle contraction (24). The gender has an effect on EMG spectral content. In a broad range of contraction intensity men display higher MDF than women (25). Gerdle et al. (12) stated that MNF correlated positively with the proportion of type I muscle fibers, and RMS correlated with the proportion of type II fibers. 

Variation of muscle fiber composition have also been reported between the different muscles forming the quadriceps complex (22). Pincivero et al. (25) investigated the effect of contraction intensity, muscle and gender on MDF of quadriceps femoris, and they demonstrated that MDF variability in the VL was significantly higher than other two superficial portions of quadriceps femoris, with no gender differences. In the general population, The Vastus medialis (VM) muscle contains a relatively greater proportion of slow twitch muscle fibers (~50%) than VL muscle (~30) (26). Females are not well studied in this context. It has been reported that the RMS increase was smaller in female subjects during isometric ramp contractions (22).

There are some limitations of this study. (1) We analyzed only VL muscle from the quadriceps muscle complex. (2) The force level %75 MVC may be not high enough to determine myoelectric manifestations of muscle fatigue during 30 seconds sustained isometric contractions for these female elite rowers. Rainoldi et al. (17) found limited signs of fatigue in VM and VL during 50 seconds of isometric contractions with %50 MVC. They suggested that VM and VL could provide small contributions and recruit more fatigue resistant fibers (slow twitch) than the fiber pool recruited by rectus femoris and intermedius. Mullany et al. (27) also showed a significantly greater compression in the RF muscle EMG frequency than the VM and VL muscles in five sedentary women performing sustained 75 % isometric contractions. In our study, female rowers may use other functional units of the quadriceps muscles during MVC measurements because of their training adaptations and this may prevent fatigue of VL muscle during 30 seconds isometric contractions.

In conclusion, RMS decreases observed in this study can be explained most easily with this load sharing strategy. Differences in muscle fiber content in these female rowers could also have contributed to these results. Considering the relatively very few researches for the investigation of elite female rowers for the evaluation of muscle fatigue, further research would be very beneficial. These could help to develop specific training programs for the female rowers and also to prevent injuries.

ACKNOWLEDGEMENTS

This study supported by Marmara University Scientific Research Committee (BAPKO), Project No:SAG-D-300409-0110.

REFERENCES

7. Uzun S. Fatigue Related EMG Power Spectrum Changes during Dynamic Contractions in Female Rowers. The Institute of Biomedical Engineering: Master of Science in biomedical Engineering, Bogazici Universitesi (2002), ISTANBUL.


