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Original Article

Mean power frequency of the vastus medilais oblique muscle after eccentric exercise

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ABSTRACT

Change in propagation velocity of of electomyographic signals has been reported after fatiguing exercise and as well as after eccentric exercise induce muscle fiber damage, most likely due to change in membrane permeability of muscle fibers. Both mean power frequency (MPF) and conduction velocity (CV) has been used to estimate change in propagation velocity of of electomyographic signals. Thus, it is expected that eccentric exercise of quadriceps muscle result in significant changes in both MPF and CV after eccnteric exercise. The aim of the study was to investigate MPF and CV of the VMO muscle before and after eccentric exercise. Multichannel surface EMG signals were concurrently recorded from the right VMO muscles of 15 healthy men during sustained isometric contractions at 50% of the maximal force. Maximal voluntary force significantly reduced after eccentric exercise with respect to the baseline ($P<0.004$). MPF and CV of EMG signals significantly decreased over time during the sustained contraction after eccentric exercise($P<0.05$). Moreover, change in MPF and CV of EMG signals was significantly correlated ($r= \%73.8$) . The result indicate that MPF of EMG signals can be used as an index to estimate change in propagation velocity of EMG in the injured muscle.

Keywords: eccentric exercise, sustained contraction, mean power frequency, conduction velocity.

Introduction

Mean frequency of EMG is often used to assess muscular fatigue from surface electromyography (sEMG) signals [1]. Muscle fiber conduction velocity is the speed at which an action potential propagates along the membrane of a skeletal muscle fiber [2]. Reduction in MFCV and MNF of EMG has
been frequently reported during a sustained contraction [3, 4], most likely due to metabolite accumulations. Muscle fiber meembern is subjected to substantial tears during eccentric contractions [5]. For example, increased membrane permeability of muscle fibers has been indicated as one of the features of the damaged muscle fiber, as assessed by loss of soluble intracellular proteins (e.g., creatine kinase, myoglobin) and uptake of membrane impairment dyes by damaged cells [5]. In the injured fiber, the altered membrane permeability would also depolarize the fiber membrane because of increased intracellular sodium [Na+] and calcium [Ca2+] and extracellular potassium [K+] [6], and as a consequnnce reduce MFCV [4].

Previous studies has frequently reported a significant positive correlation between MNF and MFCV changes during sustained fatiguing contraction [7]. Thus it is expected that any change in MFCV in the injured muscle to be associated with change in MNF after eccentric exercise. This knowledge may help to use MNF as non-invasive method to estimate change in propagation velocity of action potential in the injured muscle . Therefore, in the current study, we analysed MFCV and MNF of the VMO muscle during sustained contraction performed before and after eccentric exercise induced muscle damage. Surface EMG signals were recorded from VMO muscle during sustained contraction before and after eccentric exercise.

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Methods

Participants:

12 healthy men (age, mean ± standard deviation; SD, 20.5 ± 1.2 years, body mass 67.7 ± 3.6 kg, height 1.74 ± 0.06 m) volunteered to participate in the study. All subjects were right-leg dominant (self-reported) and were not involved in regular exercise of their knee extensor muscles for at least 6 months before the experiment

Eccentric exercise:

The subject performed 4 sets of 25 repetitions of their right quadriceps with 150% of the 1-RM using a weight-training machine (Universal Gym, USA) whilst positioned in supine. The leg press was brought to the starting position (170 ° - 180 ° knee extension, 180 ° = full knee extension) using two assistants, and the subject lowered the load to the end position (60 ° knee extension) in a controlled manoeuvre. The workload was determined for each subject based on their initial one repetition maximum (1-RM) and load was defined as 150% of the initial value of 1-RM.

Muscle function:

Three 5-second maximum voluntary contractions (MVC) with the right knee in 90° of flexion performed before and after eccentric exercise. 2-min rest was given betwwen MVCs. During each MVC, verbal encouragement was provided to exceed the previous force level. The highest MVC value was considered as a reference value to define submaximal load. submaximal isometric knee extension contraction was performed at 50% MVC sustained until task failure, with the participant in the same position as in the MVCs. Submaximal force was defined relative to the highest MVC measured on the same day of the test.

Pain assessment:

Participants were asked to rate their average pain intensity based on 10 cm visual analogue scale (VAS), labelled with end points on the left (no pain) and right (worst pain imaginable) during dialy activities (eg, climbing stairs) since their last visit to the laboratory.

Electromyography recording: Adhesive arrays (ELSCH008, SPES Medica, Salerno, Italy) of eight equi-spaced electrodes (interelectrode distance 5 mm, electrodes 5 mm · 1 mm) was placed between the most distal innervation zone and the distal tendon region of the vastus medialis muscle. Before electrode placement, the skin was lightly abraded. To assure proper electrode–skin contact, 20–30 lL of conductive gel were inserted into the cavities of the adhesive electrode array. Surface EMG signals were amplified bipolar (EMG amplifier, EMG-64, LISiN – OT Bioelettronica, Torino, Italy; bandwidth 10–500 Hz), sampled at 2048 Hz, and stored after 12 bit A/D conversion.

Signal analysis MNF was estimated from the central single differential channel of the same array. Muscle fiber conduction velocity was computed from the maximum number of channels showing propagation of the action potentials with minimal shape changes without the presence of the innervations zone (visual selection of the channels).Accordingly, mean power spectral frequency (MPF) was estimated from all channels of the EMG array for epochs of 250ms. The values obtained from 250ms-long epochs in intervals of 10% of the time to task failure were averaged to obtain one representative value for each 10% interval.

Statistical analysis

A one-way repeated-measures analysis of variance (ANOVA) was used to assess change in MVC and time to task failure from pre eccentric to post eccentric exercise (immediately after and 24 h after). Moreover, two-way repeated measures ANOVA was used to measure percent change in MFCV and MNF of EMG with time (before, immediately after and 24 h after) as the repeated measure. Finally, a Pearson correlation coefficient was obtained to assess the relationship between the percent change in MFCV and the percent change in EMG MNF during sustained contraction across testing sessions. Pairwise comparisons were performed with the Student-Newman-Keuls post hoc test when ANOVA was significant. The significance level was set at $p<0.05$ for all statistical procedures. Results are reported as the mean and SD in the text and SE in the figures.

Results

Muscle performance:

Pain intensity increased over the VMO muscle after eccentric exercise (4.5 ± 0.55). A significant reduction in MVC of quadriceps ($F=8.3$, $P<0.009$) and time to task failure ($F= 5.5$, $P < 0.02$) observed after eccentric exercise. MVC and time to task failure were not significantly different between the two postexercise sessions (immediately after and at 24 h, $P > 0.05$). two-way repeated-measures ANOVA revealed a high percentage of decrease in MFCV ($F=9.9$, $P<0.001$) and MPF of the EMG ($F= 14$, $P<0.0001$) during the post exercise sustained isometric contractions (immediately after and at 24 h) compared with the pre-exercise condition (Figures 1)

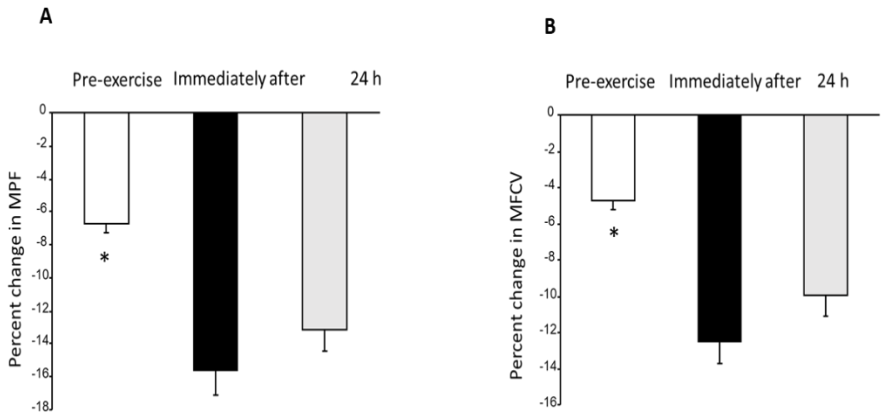

Figure 1: Percent change (change from the first to last interval) in MPF (A) and MFCV (B) for the vastus medialis oblique muscle during sustained contractions performed at 50% MVC, recorded before (white), immediately after (black) and 24 h (gary) after the eccentric exercise. *P <0.05.

Moreover, two-way repeated-measures ANOVA showd a high percentage of reduction in intial value of MFCV (F=5.9, P<0.001) and intial value of MPF (F= 6.1 , P<0.001) during the post exercise sustained isometric contractions (immediately after and 24 h) compared with the pre-exercise condition (Figures 2).

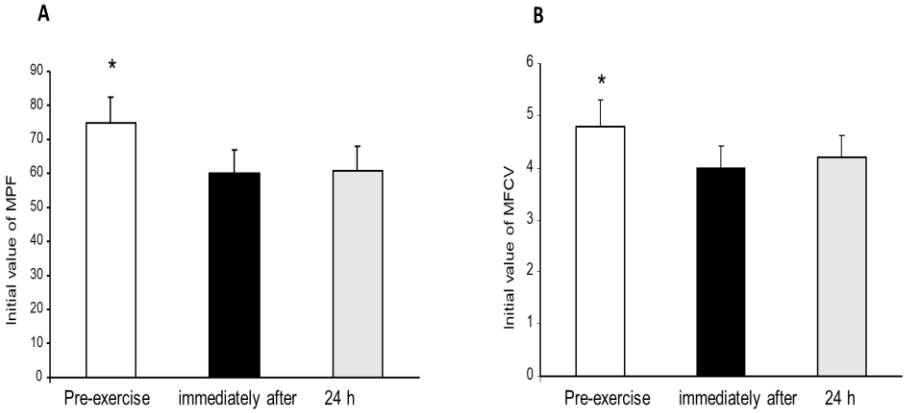

Figure 2: Percent decrease in intial value of MPF (A) and MFCV (B) for the vastus medialis oblique muscle during sustained contractions performed at 50% MVC, recorded before (white), immediately after (black) and 24 h (gary) after the eccentric exercise. *P <0.05.

Percent change in MFCV and percent change in EMG MPF were positively correlated (R=−73.8, P<0.0001) .

Discussion

MFCV and MPF of EMG were significantly reduced over sustained contractions after eccentric exercise as compared with the pre-exercise condition. Moreover, MFCV and MPF of EMG were significantly correlated ((R=−73.8, P<0.0001). The results indicates that MPF of EMG can be used as valid parameter to estimate change in propogation velocity of action potential after eccentric exercise induced muscle damage.

Muscle perfomance:

In the current study, participants reported that their quadriceps muscle was painful at 24 h after eccentric exercise, which might be related to damage of the contractile elements and connective tissue [8]. a significant reduction in MVC and time to task failure of the painful quadriceps was also observed after eccentric exercise, indirectly suggests that the ability of the injured muscle was reduced to generate force [9, 10].

MFCV and MPF:

After eccentric exercise, muscle fiber conduction velocity of the VMO muscle significantly decreased with respect to the baseline. Accordingly, A greater reduction in mean power frequency of EMG was also observed over post eccentric sustained contraction with respect to the bassline. This is in agreement with previous studies that reported any characteristic frequency of the surface EMG power spectrum, including the mean and median frequencies, will decrease proportionally with MFCV [11]. Both MFCV and MPF of EMG decreased at faster rates for VMO

muscle when assessed 24 h after eccentric exercise. This indicate that any change in MPF of EMG after eccentric exercise may be partly due to change in propagation velocity of action potential along the muscle fiber. Reduction in MFCV and MPF of EMG which were observed after eccentric exercise can be attributed to membrane depolarization most likely because of alteration in the resting membrane permeability of the muscle fibers [6, 12]. It has been proposed that change in resting membrane permeability of the muscle fiber increase potassium [K+] conductance, which in turn result in membrane depolarization and reducing conduction velocity [4, 13]. There are several potential mechanisms by which eccentric exercise might decease the propagation velocity of action potential along the muscle fiber

In the inured muscle, the elevated K+ in the interfiber space as result of membrane disruption may expose further muscle fibers to a reduced membrane excitability and conduction velocity during a sustained task [14]. A greater reduction in conduction velocity after eccentric exercise may also be explained by insufficient activity of the Na+ –K+ pump within the injured muscle. Typically, the capacity of the Na+ – K+ pump is not sufficient to fully compensate for the ionic fluxes during sustained fatiguing contractions [15]. An increase in fiber ionic membrane permeability as result of membrane damage would further decrease the capacity of the Na+ –K+ pump to maintain the normal concentration gradients for Na+ and K+ during sustained fatiguing contractions [16] and thus lead to a further reduction in propagation velocity over time.

Conculsion:

The result of this study showed change in MFCV and change in EMG MPF were significantly correlated. This indicate that any change in MPF of EMG after eccentric exercise may be partly due to change in propagation velocity of action potential along the muscle fiber. Thus, MPF of EMG can be used as an index to estimate change in propagation velocity of EMG in the injured muscle.

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