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Electromyographic Activities of the Vastus Medialis Oblique and Vastus Lateralis Oblique During Sustained Contraction After Eccentric Exercise

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Abstract

We tested the electromyography (EMG) activities of the oblique and longus parts of the vastus medialis and vastus lateralis muscles before, 24 and 48 h after eccentric exercise. Surface electromyographic signals were recorded from the oblique and longus parts of the VMO and VLO muscles of the right quadriceps muscle of 10 healthy men during sustained contraction of 50% MVC, before, 24 and 48h after eccentric exercise. The eccentric exercise was performed with a KinCom Isokinetic Dynamometer (Chattanooga, TN) and comprised four bouts of 25 maximum voluntary concentric/ eccentric knee extension contractions at a speed of 60 deg/s. Average rectified value (ARV) was estimated from the EMG signals for epochs of 1s, and were averaged over intervals of 10% of the time to task failure. Results**:** Maximal voluntary force and time to task failure were reduced ($p < 0.001$) following eccentric exercise. ARV reduced over sustained contraction for both VMO and VLO muscles ($p < 0.05$). ARV rat of reduction over time for VMO was greater than VLO muscle ($p < 0.05$). The results indicate a greater effect of eccentric exercise on VMO than on VLO muscle.

Keywords: Eccentric exercise, quadriceps, sustained contraction, electromyography

Introduction

It has been reported that the oblique portion of the vastus medialis (VMO) and vastus lateralis muscle (VLO) are anatomically positioned to act primarily as dynamic stabilizers of the patella. From the biomechanical point of view, a normal alignment and function of the patellofemoral joint depends on an appropriate balance of medial and lateral forces exerted on the patella by passive structures (e.g. the patellar retinacula) and by active muscular forces [1]. Studies of muscle fiber orientations suggest that force components are obliquely directed by vastus medialis oblique and vastus lateralis oblique with respect to the femoral shaft and they play a key role in patella stabilization [2]. The fiber of vastus medialis longus (VML) and vastus laterlais longus (VLL) muscles appear to be more closely aligned with the intermedius muscle and contributes to the knee extension. Eccentric contraction is commonly adopted in strength training because it is characterized by high force generation and low energy expenditure [3]. However, eccentric contraction induces fiber injury, which is associated with a decreased ability of the muscle to generate force [4]. A reduced ability to generate force may be directly caused by damage to the fibers and/or by factors associated with fiber damage [4]. The extent of muscle fiber damage after eccentric exercise depends on the morphological and architectural characteristics of the fibers [5, 6]. Vastus lateralis and vastus medialis are characterized by varying fiber pennation angles and fiber-type composition in distal with respect to proximal portion [7, 8]. Thus it is expected that eccentric exercise results in nonuniform fiber damage and, as a consequence, nonuniform motor control changes in distal part as compared with proximal portion of the vasti muscles. However, there are no studies that have investigated EMG activity of the oblique and longus parts of the vasti muscles during sustained contraction of the quadriceps injured by eccentric exercise. This knowledge may be relevant for exercise-related musculoskeletal disorders after unaccustomed exercise. Therefore, the aim of this study was to investigate the electromyographic activities of the oblique and longus parts of the vastus medialis and vastus lateralis muscles before, 24 and 48 h after eccentric exercise.

Method

Participants

Ten healthy volunteers (age, mean ± SD, 23 ±

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5.4 years, body mass 70.4 ± 3.6 kg, and height 1.76 ± 0.05 m) participated in the study. All participants were right leg-dominant and were not involved in regular exercise of their knee extensor muscles for at least one year before the experiment. The study was conducted in accordance with standards of the ethics committee of the university(N-20070019). Participants provided informed written consent before participating in the study.

Procedures

A KinCom Isokinetic Dynamometer (Chattanooga Corp., Chattanooga, TN) was used to measure knee extension torque. The participant was seated comfortably on the adjustable chair of the KinCom with the hip in 90-deg flexion. The chair position was modified until the knee axis of rotation (tibiofemoral joint) was aligned with the axis of rotation of the dynamometer's attachment arm. The participant was fixed with straps secured across the chest and hips. The right leg was secured to the attachment arm in 90- deg knee flexion with a Velcro strap. Visual feedback of torque was provided on a screen positioned in front of the participant. The participant was asked to perform three maximal isometric knee extensions of three to five s in duration in 90- deg knee flexion, with 2-min rest intervals between contractions. The participant was encouraged verbally during each trial to exceed the previously obtained torque level. The highest MVC value was used as a reference for the definition of the submaximal torque level for the subsequent sustained contractions. The submaximal forces were relative to the MVC measured on the same day of the test.

EMG recording and analysis

Surface EMG signals were recorded from the oblique portion of the vastus medialis and lateralis muscle by circular Ag–AgCl surface electrodes (Ambu Neuroline, conductive area 28 mm2) during an isometric contraction at 50% MVC, which was sustained until task failure. Average rectified value (ARV) was estimated from the EMG signals for epochs of 1s; the values were averaged over intervals of 10% of the time to task failure.

Statistical Analysis

One-way repeated-measures ANOVA was conducted to analyze MVC and time to task failure before, 24h and 48h after eccentric exercise. A two-way ANOVA was also conducted to the percent change of ARV across the sustained contraction at 50% MVC (percent change from the first to the last epoch), with day and location in the two as dependent factors.

Results

Maximum voluntary force and time to task failure decreased after eccentric exercise ($p < 0.001$). ARV significantly increased over time during sustained contraction ($p < 0.05$), and the distal location of the VM and VL resulted in higher increase than did the proximal location ($p < 0.05$) (Figure 1).

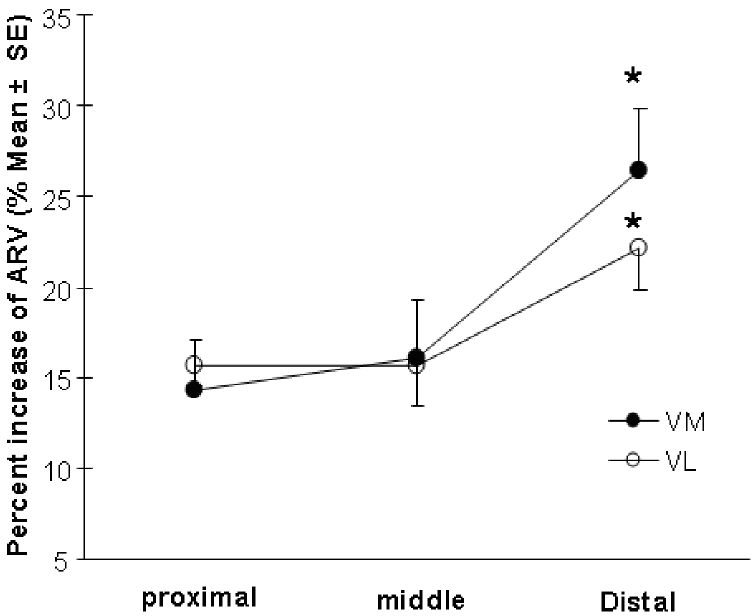

Figure 1: Percent increase in average rectified value (ARV) (mean ± SE, %, n = 10) for different locations of the vastus medialis and vastus lateralis muscles during sustained isometric contractions performed at 50% MVC. * $p < 0.05$.

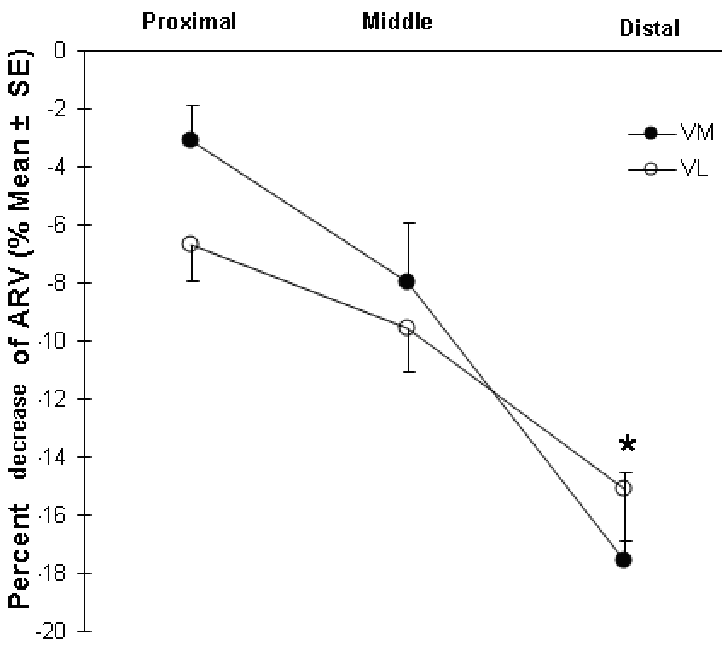

Figure 2: Percent decrease in average rectified value (ARV) (mean ± SE, %, n = 10) for different locations of the vastus medialis and vastus lateralis muscles during post exercise sustained isometric contractions (averaged 24 and 48 h) performed at 50% MVC. * $p < 0.05$.

ARV decreased after eccentric exercise ($p < 0.05$). The percent decrease of ARV (in the final epoch with respect to the initial epoch) was greater in the distal part as compared with proximal portion ($p < 0.05$). Moreover, there was a significant interaction between muscle location and day, in which the most distal location of the VM resulted in higher reduction than did the VL muscle ($p < 0.05$). (Figure 2).

Discussion

In this study, eccentric exercise contributed to a reduced maximal force and time to task failure in quadriceps muscle. In both longue and oblique parts of the VM and VL muscles average rectified value of EMG significantly increased over sustained contraction. The increased EMG activity observed in the load-bearing vastus medialis and lateralis muscles support previous findings on muscle activity over sustained isometric contractions [9, 10].

The increased EMG activity during sustained contractions can be explained by a greater muscle effort exerted by the participant to increase motor unit recruitment required to compensate for contractile failure caused by fatigue [11, 9]. However ARV significantly decreased after eccentric exercise, and the distal part of the VM and VL muscles showed a higher reduction as compared with the proximal part. Moreover, the decreased ARV was larger in distal part of the VM muscle in comparison with the distal portion of the VL muscle. Such EMG changes could be explained by morphological and architectural characteristics of muscle fiber within the quadriceps muscle. The quadriceps muscles are characterized by a large variation in fiber-type composition [8], fiber orientation [12, 7], and fiber length [13,] within each muscle compartment that enable the quadriceps to contribute to an extensive range of activities such as stabilization of the patella, external/internal rotation of the tibia, and knee extension [14]. Vatsus medialis and vastus lateralis, as components of the quadriceps muscle, are characterized by higher percentage of FT fiber and a greater fascicle angle at the distal with respect to proximal part. Takekura et al. [7] report differences in the structural disruption of fast and slow-twitch fibers after eccentric tasks, with fast-twitch fibers more susceptible to damage. In agreement with this observation, Homonko and Theriault [15] have shown preferential damage after downhill running within an area of the rat medial gastrocnemius, which was compartmentalized with fast-twitch fibers. This nonuniformity in susceptibility to damage may be related to the mechanical and metabolic capacity of muscle fibers in producing tension, temperature [16], activation of phospholipase A2 [17], and lipid peroxidation from oxygen radicals [18].

Accordingly, the present results show greater eccentric exercise-induced changes in the distal region of the quadriceps, where a greater proportion of IIb fibers and a lower proportion of Type I fibers have been reported in comparison with proximal regions [19]. Moreover, fascicle angle are significantly different along the longitudinal and transverse directions in quadriceps components [12]. Variations in fascicle angles relative to the bone may result in regions with different physiological cross-sectional areas and thus variations in the production of tension, resulting in regional damage during eccentric exercise. The frequency of exposure to stretch as a result of the change in fiber pennation angle [20] may also expose specific muscle fibers to further injury. Moreover, VMO resulted in greater ARV rat of reduction as compared with VLO muscle most likely due to greater fiber injuries within this muscle. The greatest damage and thus EMG changes observed in VMO muscle may be related to the greater activity of this muscle [13] to stabilize the patella during high tension eccentric exercise. The results indicate a much greater effect of eccentric exercise on VMO in than on VLO muscle.

Conclusion

During the post exercise sustained contractions ARV rate of reduction over time for both VMO and VLO muscle were significantly greater than pre exercise phase. However, VMO resulted in greater ARV rate of reduction, as compared with VLO muscle most likely due to greater fiber injuries within this muscle. The greatest damage and thus EMG changes observed in VMO muscle may be related to the greater activity of this muscle (to stabilize the patella during high tension eccentric exercise). These results indicate a much greater effect of eccentric exercise on VMO in comparison with VLO muscle.

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