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MOTOR UNIT FIRING PROPERTIES OF VASTUS MEDIALIS MUSCLE AFTER A SECOND ANTERIOR CRUCIATE LIGAMENT TEAR

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Introduction

Judging athletes' readiness to return to their pre-injury activity levels is still challenging. Repeated rupture of the Anterior Cruciate Ligament (ACL) is a fundamental complication after primary ACL reconstruction surgery. Amongst others, muscle function is affected by variations in the recruitment of motor units and in their discharge rate. This study aimed to identify possible neuromuscular features that may account for failed rehabilitation success.

Methods

Submaximal isometric knee extension was examined on the Ruptured (R) sides and uninjured (C) sides of 18 male soccer players (age: 28±6 SD years, body mass index: 25±3 kg/m², Tegner activity level: 7±1, 16/18 non-contact injuries) after determining Maximum Voluntary Torque (MVT) and before revision surgery.
Activity of patients' Vastus Medialis muscle was recorded with a surface array (Delsys Inc, Natick, Massachusetts, USA; sampling rate: 20 kHz). A ramp contraction with a constant-force region at 80% MVT was utilized for a maximum duration of 33 seconds. Firing characteristics of individual Motor Unit (MU) action potentials were extracted using surface electromyography decomposition. Three commonly reported MU Firing Rate (FR) statistics (initial, iFR; average, aFR; maximum, mFR; e.g. 2) and the difference between mFR and iFR (dFR) were compared between sides using two-sided paired t-tests and they are reported in pulses per second (pps). The magnitude of side differences was expressed in terms of Cohen's d. Also, linear regression analyses were applied to iFR, aFR, mFR, dFR, and the corresponding recruitment thresholds (RT) of the MUs (goodness of fit, r), separately for each patient and side, respectively. The relationship between FR and RT of the motor units reflects muscles contraction smoothness (1).

Results

The MVT values on the injured side were lower on average (R: 238±83 Nm; C: 303±61 Nm; P<0.001; d=-1.2). The average number of correctly identified MUs was 23±11 and 29±7 on the ruptured and uninjured sides (P=0.06; d=-0.5), respectively.
In contrast, iFR (R: 7.6±1.4 pps; C: 7.3±1.0 pps), aFR (R: 17.3±3.3 pps; C: 16.5±2.6 pps), mFR (R: 20.1±3.7 pps; C: 19.0±2.9 pps) as well as dFR (R: 12.5±2.4 pps; C: 11.7±2.0 pps) did not differ between sides (P<0.4; d>0.2).
However, the goodness of linear fit with RT revealed substantial differences between sides for mFR (R: -0.86±0.10; C: -0.92±0.06; P<0.05; d=0.5), dFR (R: -0.72±0.17; C: -0.83±0.10; P<0.02; d>0.6) and aFR (P<0.05; d=0.5; see Figure 1), but not for iFR (R: -0.65±0.28; C: -0.66±0.32; P>0.9; d<0.1).

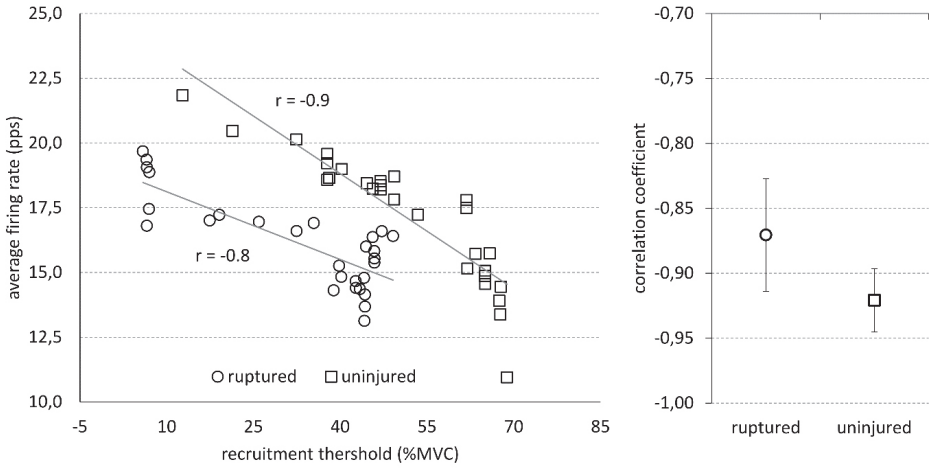

Figure 1. Association between recruitment thresholds and corresponding average firing rates of the identified motor units in a representative patient (left panel) and linear correlation coefficients of the ruptured and uninjured sides (right panel). Values are means with 95% confidence intervals.

Discussion

The task examined can be considered highly intensive. Since the control of force during low-force contractions relies mainly on the recruitment of motor units, higher contraction forces are presumably modulated by their firing characteristics. Consequently, for contractions with higher intensities the firing properties of the motor units provide more useful information. Although, the MU firing rate statistics showed, on average, merely equal behavior in muscles after sustaining a second ACL tear compared with those of the uninjured side, their contraction smoothness was revealed to be clearly altered. The missing differences, especially in maximum firing rates, can probably be explained by different time periods until reinjury and until the second surgery. However, the alterations in motor unit properties detected over the vastus medialis muscle do not explain the large force deficits on the injured side. Future work should focus on distinct analyses of MU action potentials, their amplitude and waveforms.

Conclusion

A comprehensive neuromuscular assessment might provide valuable information on rehabilitation success and support the decision-making process substantially.

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