EFFECTS OF CHANGING THE RECTUS FEMORIS MUSCLE LENGTH ON NEURAL AND MECHANICAL BEHAVIOR OF THE VASTI MUSCLES

Milena A. dos Santos, Helio V. Cabral, Caterina Cosentino, Elmira Pourreza, Nijia Hu, J Greig Inglis, Francesco Negro
Department of Clinical and Experimental Sciences, Università degli Studi di Brescia, Brescia, Italy
Email: milena.aguiardossantos@unibs.it

Summary

Changes in the length of the bi-articular rectus femoris (RF) muscle, by changing the hip joint angle, may directly influence the neural output of the monoarticular vasti. Here, we investigate the effects of lengthening RF on the motor unit and muscle twitch properties of the vastus lateralis (VL) and vastus medialis (VM) during isometric knee extension. When increasing the length of the RF, the motor units mean discharge rate (MDR) increased for VL at low force levels. These results were followed by a decrease in VM-VL twitch size at low-frequency stimulation. These findings indicate that force-dependent alterations in the mechanical properties of the quadriceps significantly affect the neural inputs of the vasti.

Introduction

The control of knee extension torque relies on the interaction between mechanical and neural input to the spinal motor neurons. For instance, mechanical changes, such as lengthening the muscle, can influence the torque output[1], and increase the changes in discharge rate with increasing torque[2]. However, most studies focus on the lengthened muscle without considering the synergistic muscles that also produce movement. Here we evaluated the effect of modifying the RF length, by altering the hip angle, on the motor unit properties of VL and VM. To further understand the results derived from motor unit spike trains, we assessed how changes in RF length affected the vasti muscle twitch properties through peripheral electrical stimulation with different frequencies.

Methods

Eighteen healthy individuals (8 women; age 29 ± 6 years, weight 67.5 ± 19.1 kg, height 1.74 ± 0.1 m) were positioned on an isokinetic dynamometer with their right knee at 90° to perform knee extension isometric contractions. Initially, they were asked to perform three maximal voluntary contractions (MVC) followed by two submaximal contractions at 10% and 30% MVC. This protocol was repeated for two conditions: hip joint at 90° (seated position) and at 180° (supine position). High-density surface electromyograms (HDsEMG) were recorded from the VM and VL muscles and decomposed into motor unit spike trains. The MDR and coefficient variation of the interspike interval (CoV-ISI) of tracked MUs between conditions were calculated. To investigate the effect of RF length changes on vasti twitches, we evaluated a subgroup of 6 participants (3 women). Two pairs of electrodes were positioned on the VM and VL to electrically evoke twitches for the same two hip conditions of voluntary contraction. For each condition, two frequencies (10 and 20 Hz) were used with an ISI variability of 80% to allow the deconvolution of individual VM-VL twitches. The amplitude was set at 20 mA. The evoked twitch results are presented descriptively, considering the summation between VM and VL responses.

Results and Discussion

There were no changes in the MVC peak between hip angles ($p = 0.88$). At 10% of MVC, the MDR increased between hip 90° and hip 180° for the VL (Figure 1A; $p=0.029$), but not the VM ($p=0.06$). No differences in MDR were observed at 30% MVC (Figure 1C VL; $p > 0.05$ for both muscles). No differences in CoV-ISI were observed at 10% MVC ($p > 0.45$ for both muscles). At 30% MVC, the CoV-ISI was greater for the VM at hip 180° compared to hip 90° ($p = 0.018$), with no differences for the VL ($p = 0.72$).

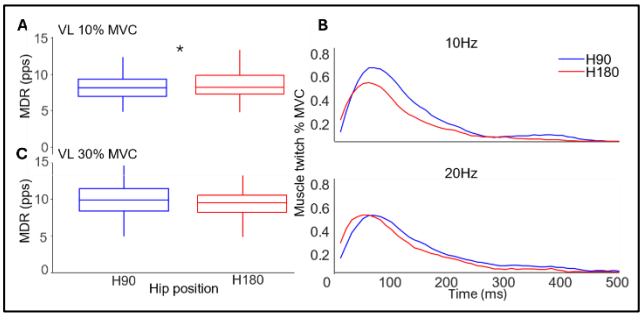

Figure 1. Mean discharge rate of VL at 10% MVC (A) and at 30% MVC (C). Summation of the force twitch from VL and VM at different frequencies (B). * Corresponds to $p<0.005$.

Increasing the length of RF by changing the hip angle decreased the VM-VL twitch size, but only at lower stimulation frequency (i.e., 10 Hz; Figure 1B). Collectively, our results indicate that mechanical changes are more prominent at low force levels and might influence the neural properties of the vasti muscles during knee extension, specifically the VL.

Conclusions

Our findings suggest that the neuromuscular system demonstrates compensatory strategies to cope with alterations in RF muscle force generation capacity induced by changing the hip position.

Acknowledgments

European Research Council Consolidator Grant INcEPTION (contract no. 101045605 to FN).

References

[1] P. Mela, P. H. Veltink, and P. A. Huijing, (2001). *Journal Electromyography and Kinesiology.* 11(1): 53-63.

[2] A. Cudicio et al. (2022) *Eur J Appl Physiol*, 122(2): 317-330