ISB 2013 BRAZIL
XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS
XV BRAZILIAN CONGRESS OF BIOMECHANICS

TORQUE SHARING OF THE QUADRICEPS MUSCLES ESTIMATED BY EMG-DRIVEN MODEL AND SURFACE ELECTROMYOGRAPHIC OF VASTUS INTERMEDIUS

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SUMMARY

EMG-Driven models predict individual muscle forces, but it is necessary to obtain muscle electromyography (EMG), which is difficult for deep muscle, as *vastus intermedius* (VI). The purpose of this study is to determine the relative contribution of each quadriceps (QF) components to the knee extension torque by EMG-Driven model, with a protocol of surface VI EMG acquisition, at submaximal isometric contractions around 20% and 60% of maximum voluntary contraction (MVC). Surface EMGs were acquired from VI, *vastus lateralis* (VL), *rectus femoris* (RF) and *vastus medialis* (VM) muscles. The EMGs were filtered, rectified and normalized to enter the EMG-Driven model as excitation signals. The QF components contributions were for 20%MVC: 28% for VI, 31% for VL, 17 for RF and 24% for VM; for 60%MVC: 27% for VI, 32% for VL, 15% for RF and 26% for VM. Only RF contribution was significantly smaller than the other muscles, for both 20% and 60% MVC.

INTRODUCTION

To determine the contribution of individual muscles to the net joint torque of musculoskeletal systems is a challenging problem, EMG-Driven models can estimate muscle forces using electromyography (EMG) signals taking into account specific parameters of the muscle structure [1]. However, to access deep muscles activity, special strategies must be used.

The vastus *intermedius* (VI) is the deep *quadriceps femoris* (QF) component, and its EMG activity is usually estimated from its superficial counterparts [2]. Recently, a distal region at the lateral thigh was proposed to be a VI site for superficial EMG electrodes placement, with the guide of ultrasound (US) images, with negligible cross-talk effects and can to pick up global activation of the VI during isometric contraction [3, 4].

The purpose of the present study is to estimate the relative contribution of each QF components (*rectus femoris* (RF), *vastus lateralis* (VL), *vastus medialis* (VM), and VI) to the knee extension torque, at contraction steps of 20 and 60% of MVC, using the EMG-driven model and surface EMG of VI.

METHODS

Seven healthy men (age 22.7 ± 3.1 years; weight 76.4 ± 12.2 kg; height 1.78± 0.1m) participated in the study. The superficial region for electrode positioning on VI was identified with the aid of a US B-mode axial-plane (MyLab25 Gold, ESAOTE S.p.A., Italia), with a 10 MHz, linear probe. The subject sat with the knee joint angle at 90°. In lateral right thigh, the muscle bellies of the VL and VI were identified. The examiner moved the transducer distally to find out a thickness of VI greater than the VL. After locating the center of the probe in the skin, the area was marked, prepared and a pair of electrodes was applied in the direction of the fibers of VI, as suggested by Watanabe and Akima [3]. The RF, VL and VM received electrodes according to the SENIAM protocol.

In the sequence, subjects were evaluated for the maximum knee extension voluntary contraction (MVC) by a dynamometer (Biodex System 4, New York, EUA), with the knee flexed at 80°. Two repetitions of 10 sec, with an interval 60 sec were performed. The subjects performed two isometric steps of 20 and 60% MVC torque, during 40 seconds each, with feedback torque target on a screen. Torque signals and surface EMG from the four QF muscles (EMG-USB2, OTBioeletronica, Italia) were synchronized. Raw EMG signal was sampled at 2048, band-pass filtered (10-500 Hz), rectified and low-pass filtered (6th order digital Butterworth, 2 Hz). For the model input u(t), the muscles excitation signals at 20 and 60% MVC were normalized by the processed EMG MVC test.

In the model representation, *activation dynamics* is the transformation of neural excitation to activation of contractile components. *Contraction dynamics* represents the transformation from activation to muscle force. Finally, each muscle torque (τ) is estimated. Figure 1 shows the representation of the EMG-Driven model. Muscle architecture parameters from literature (OpenSim Lower-limb Model) were used in the dynamic model. Force estimations of the four muscles were multiplied by 0.048m moment arm [5] to calculate joint extension torque.

The statistical differences among the relative contribution of each muscle were verified by one-way repeated measures ANOVA test, with *post hoc* HSD Tukey. Statistic analysis was performed with Statistica 7.0 application (StatSoft Inc., Tulsa, Ok, USA), and the significance level (α value) was set at 0.05.

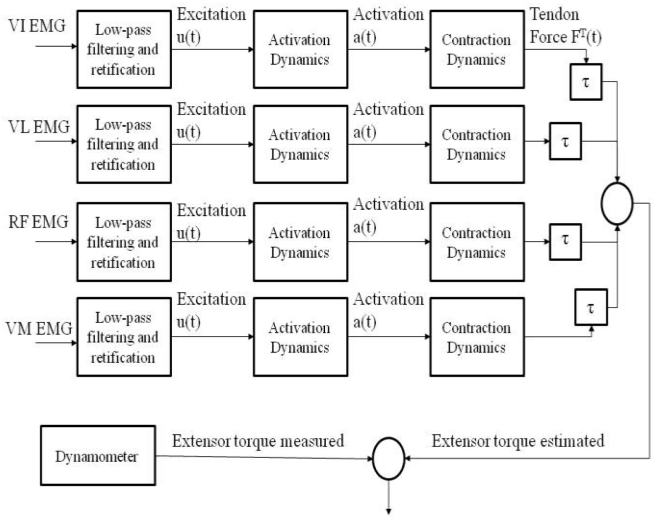

Figure 1: Diagram of the EMG-Driven model

RESULTS AND DISCUSSION

The Figure 2 shows the mean and standard deviation torque sharing of the four QF components (20 and 60% MVC).

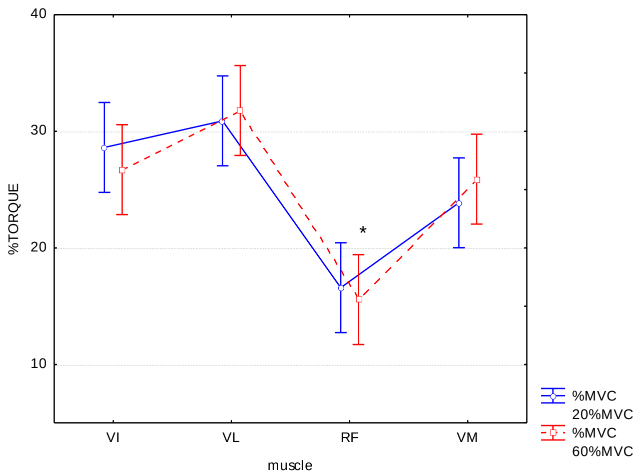

Figure 2: Relative torque generated each muscle in total knee extension torque.

The pattern of individual contributions followed the sequence: RF < VM < VI < VL. Menegaldo and Oliveira [2] estimated of VI EMG as the average between VL and VM, as well as using a regression equation based from least square curve fitting of EMG/torque relationships, as reported Watanabe and Akima. [6].

Zhang *et al.* [7], with intramuscular VI electrodes and functional electrical stimulation found a contribution order in which VI contribution (39.6 to 51.8%) greater than VM (9.5 to 12.2%), during submaximal isometric contraction. However, this study evaluated muscles contribution with functional electrical stimulation.

When comparing the relative torque contribution of each muscle between the 20% and 60% MVC steps, no significant difference was observed. A significant smaller RF torque contribution, compared to the other components, was found for 60%MVC ($p < 0.01$) and less than VL and VI for the 20%MVC step ($p < 0.01$). In an EMG-force study (n=13), with no muscle dynamic modeling, at 20%MVC the VL presented significant higher RMS activation than the other three components. At 60%MVC, activation was significantly higher than RF, exclusively [6]. The differences in sample characteristics should be considered in both studies. QF torque sharing is still an open problem. An additional question relies on hip position, either extended or flexed. In hip extension, the RF has a biomechanical advantage provide a greater contribution to knee extension torque. Future studies with different population and other submaximal activation levels could clarify the issue of QF torque sharing.

CONCLUSIONS

The contribution pattern of knee extension torques among QF components was similar for both 20%MVC and 60%MVC submaximal isometric contractions. The RF relative torque contribution was smaller than the three vastii.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the financial support of the Brazilian Research agencies CAPES, FINEP, FAPERJ and CNPq.

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