Altered neural drive following submaximal lengthening and shortening contractions of the human tibialis anterior

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Summary

The aim of this study was to determine whether neural drive differs following active lengthening (LEN) or shortening (SHO) contractions compared with torque- and joint-angle-matched fixed-end reference (REF) contractions. Single-differential surface EMG signals from a 64-electrode grid were evaluated over a 6-s steady-state in three contraction conditions. We found that EMG root-mean-square (RMS) amplitudes were ~2% lower following LEN and 1-3% higher following SHO relative to REF at 20 and 40% of maximal voluntary contraction (MVC). The activity increase following SHO was also greater at 40 than 20% MVC. Initial results indicate that motor unit (MU) discharge rates (DRs) were higher following SHO than following LEN or REF, which suggests that neural drive depends on muscle force capacity.

Introduction

MU behavior is seldom studied during submaximal voluntary contractions with active LEN or SHO despite the potential insights that could be gained about force control strategies during everyday movement. In the only published study that investigated neural drive following submaximal LEN and SHO, vastus lateralis MU discharge rates (DRs) estimated with intramuscular EMG were respectively unaltered (LEN) or increased (SHO) compared with torque- and joint-angle-matched fixed-end REF contractions [1]. As the corresponding surface EMG amplitudes were respectively decreased or increased following LEN and SHO [1], these findings indicate different neural drive following LEN or SHO. Thus, we were interested in the replicability of these findings in a different lower limb muscle at two intensities.

Methods

Seventeen healthy participants (22-31 yr, six women) sat on a reclined seat (90° knee flexion, 110° hip flexion) with the sole of their right foot secured to the footplate attachment of a motorized dynamometer (IsoMed2000, Ferstl GmbH, DE) that measured net ankle joint torque and crank arm angle (2 kHz). Simultaneously, 64 monopolar high-density surface electromyography (HDsEMG) channels (GR08MM1305, OT Bioelettronica, IT) from the tibialis anterior (TA) muscle were recorded using Sessantaquattro hardware (2 kHz). Data were later synchronized with a digital pulse from an analog-digital converter (Power3 1401, Cambridge Electronic Design, UK).

After at least two dorsiflexion MVCs at -5°, 20°, and 45° plantar flexion (90° = footplate perpendicular to shank), participants performed three contraction conditions (REF, LEN, SHO) at 20 or 40% MVC in a randomized order. LEN and SHO occurred after a 2-s preload over a 25° amplitude at 25°·s^{-1} and ended at 20° plantar flexion. Each contraction had respective ramp and hold phases of 1 and 13 s and torque was matched within a 10% range of the desired torque in REF with the help of smoothed (0.01 s moving average) visual feedback.

A 6-s steady state that ended 1-s before the end of the hold phase was defined and 59 means from the single-differential EMG RMS signals were calculated for each trial and normalized to the maximum values from the strongest MVC at 20° plantar flexion. Trials within each condition with a mean RMS amplitude within one median absolute deviation were averaged, which resulted in 2-5 trials per condition. TA MU decomposition is ongoing (n=1) with MUedit [2].

Results and Discussion

RMS amplitudes at 20 and 40% MVC were respectively 1.5% and 1.7% lower following LEN and 1.2% and 3.2% higher following SHO compared with REF (4 comparisons: $p \leq .018$), whereas torque was similar (≤0.1 Nm; Fig. 1). The activity increase was larger at 40 than 20% MVC (p=.029; Fig. 1). 20 and 22 matched MUs at 20 and 40% MVC had respective DRs (median±IQR) in REF, LEN, and SHO of 10.6±2.2, 11.3±2.0, and 12.5±2.1 Hz and 13.7±2.5, 14.0±2.0, and 14.1±2.0 Hz.

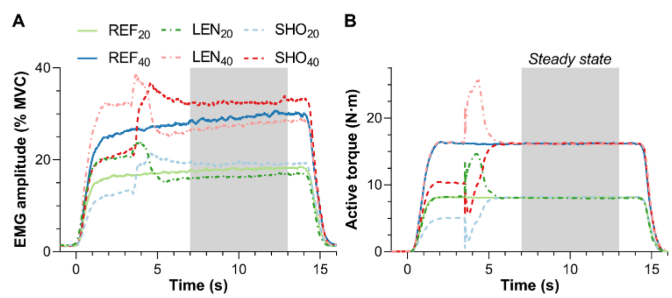

Figure 1: Mean (N=17) EMG-RMS-amplitude- (A) and torque-time (B) traces from the three conditions at 20 and 40% MVC.

Conclusions

Neural drive at similar net joint torques was modulated differently following LEN and SHO. This indicates that long-lasting history-dependent changes to a muscle's force capacity determine the neural drive for a given torque.

Acknowledgments

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References

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