Increased Shared Drive Between Synergistic Muscles to Compensate for Muscle Failure

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Summary

The human neuromuscular system utilises coordinated muscle synergies to generate movement, with sensory feedback modulating motor output. This study investigated the short-term adaptation of the neural drive between synergistic muscles when one muscle, the vastus lateralis, is fatigued through electrical stimulation. High-density surface EMG was recorded from the vastus lateralis, rectus femoris, and vastus medialis muscles pre- and post-fatigue. The coherence of cumulative motor unit spike trains was calculated within and between muscles to assess common drive. Results showed an increase in delta-band coherence (<5 Hz) between muscles post-fatigue, supporting the hypothesis that the central nervous system compensates for the reduced force-generating capacity of the fatigued muscle by enhancing shared drive. Within the fatigued muscle, intramuscular coherence increased, while non-fatigued muscles maintained force by recruiting larger motor units. Further investigation is needed to confirm these findings and elucidate underlying neural mechanisms.

Introduction

The human neuromuscular system is highly complex, involving the coordinated activation of multiple muscles to generate movement. This complexity is reduced through the common activation of muscle synergies — functional groupings of muscles that work together to produce efficient movement [1]. Sensory feedback plays a crucial role in this process, continuously modulating motor output in response to external and internal stimuli. While previous studies have examined the shared neural drive between muscle groups, the short-term adaptation of this drive when the force-generating capacity of one synergistic muscle is compromised remains poorly understood. We hypothesise that increased neural drive is required to maintain the desired force output. To investigate this, the vastus lateralis, fatigued through electrical stimulation, along with the rectus femoris and vastus medialis muscles, were analysed using high-density surface EMG (HDsEMG) pre- and post-fatigue. Coherence of the cumulative motor unit spike trains (cMUST) was calculated within and between muscles to assess the extent of common drive in synergistic muscles.

Methods

9 healthy, physically active young adults volunteered to participate in this study. HDsEMG was recorded from the vastus lateralis, rectus femoris, and vastus medialis muscles. To fatigue the vastus lateralis, two stimulation electrodes were placed on the distal and proximal motor points. After a warm-up, subjects performed superimposed maximal voluntary contractions (MVC+), followed by three pre-fatigue submaximal isometric ramp conditions at 30 % MVC. The fatigue protocol consisted of n on:off-cycles (7 s : 5 s), beginning with three single stimulations to assess the M-wave and twitch force (1 Hz, 200 µs, 90 % of the 'pain-threshold'), followed by five tetanic stimulations (80 Hz, 400 µs, 90 % of the 'pain-threshold') to induce muscle fatigue. Upon reaching the fatigue criteria, the main protocol continued with MVC+ recordings and six post-fatigue ramp conditions at 30 % MVC, followed by a final round of MVC+. Fatigue was defined as a 30 % decrease in twitch force and a 30 % increase in half-relaxation time. HDsEMG data were visually inspected and decomposed into MUST. The coherence of the cMUST was calculated within and between muscles. Root means square and median frequency were calculated at the global EMG level.

Results and Discussion

The analysis of the first pilot dataset revealed an increase in delta-band coherence (<5 Hz) between synergistic muscles post-fatigue, which returned to baseline after 15 minutes. This supports our hypothesis that the CNS compensates for the decreased force-generating capacity of one synergistic muscle by increasing shared drive across muscles, likely driven by sensory feedback from visual input [2]. Within the fatigued muscle, intramuscular coherence increased, reflecting enhanced motor unit synchronisation as all available motor units were recruited due to reduced contractile capacity. In contrast, non-fatigued muscles maintained force by recruiting larger motor units, as indicated by an increased mean frequency, without changes in intramuscular coherence. These results align with previous studies on shared neural drive among synergistic muscles [1]. Further investigation involving additional participants is necessary to confirm these findings and explore the underlying neural mechanisms in more detail.

Conclusions

This first dataset indicates that when one synergistic muscle becomes fatigued, the central nervous system compensates by increasing shared neural drive to maintain force output, primarily through adjustments in motor unit synchronisation. Further investigation involving additional participants is necessary to confirm these findings.

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