Control of Motor Units and Strategies of Force Generation during Fatigue

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Motivation

It is well known that the amplitude of the motor unit (MU) force twitches decreases during sustained or repeated fatiguing contractions, and that the excitation to the motoneuron pool increases to compensate for decreasing force generating capacity and sustain muscle force with fatigue [1]. Despite increasing excitation, some studies have reported that motor unit firing rates may decrease during fatiguing contractions due to selective inhibition by sensitive afferents [2]. These observations contradict the known control mechanisms of motor unit firing behavior, by which motor unit firing rates increase in response to increasing excitation [3].

Objective

Investigate the firing rates of motor units in the First Dorsal Interosseous (FDI) muscle and the concurrent activation of forearm muscles during repeated isometric contractions to identify whether changes in muscle co-activation may provide an alternative explanation for decreases in motor unit firing rates with fatigue.

Data Collection

Subject Population

5 healthy subjects, 4 males and 1 female (22-34 years old)

Set Up

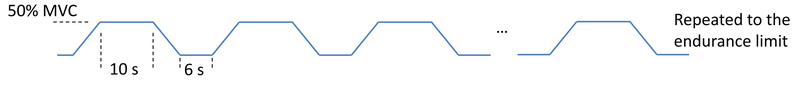
The hand was placed in a restraining apparatus for isometric contractions

Recorded Signals

- dEMG: first dorsal interosseous (FDI)
- sEMG: extensor carpi radialis (ECR), flexor carpi radialis (FCR), pronator teres (PT)
- Force: index finger abduction

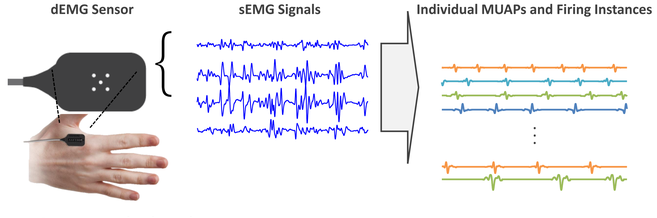
Fatigue Task

Isometric index finger abductions held at 50% maximum voluntary contraction (MVC) for 10s and repeated until task failure with 6s rest between contractions.



Data Analysis

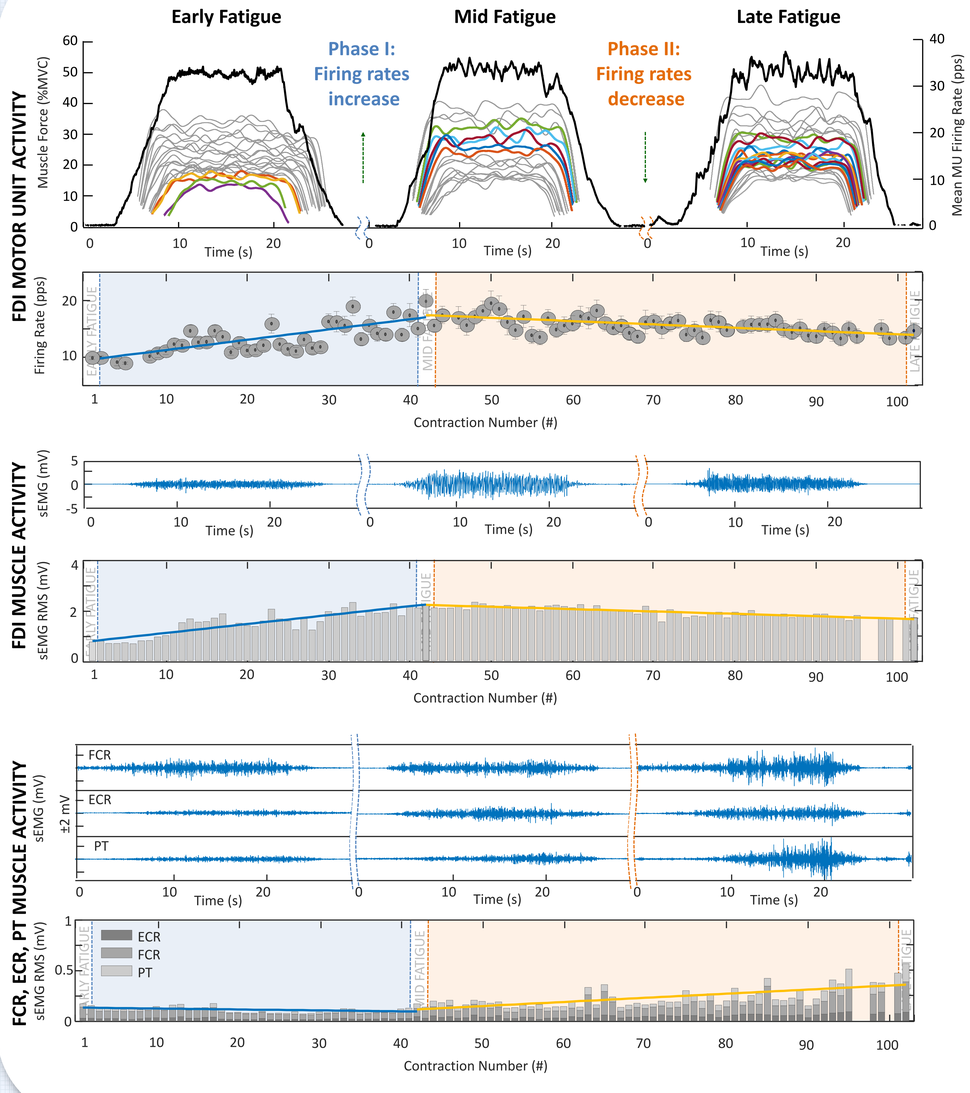
We used the dEMG System (Delsys Inc., Natick, MA) to non-invasively record four channels of surface EMG signals during isometric index finger abductions. sEMG signals were decomposed into the constituent MU action potentials (MUAPs) and their firing instances [4].



For each contraction, we calculated:

- the FDI MU mean firing rates;
- the FDI MUAP amplitude;
- the sEMG root mean square (RMS) amplitude of all monitored muscles.

Results



1) Two general patterns of MU firing rate adaptations were observed throughout the contraction series:

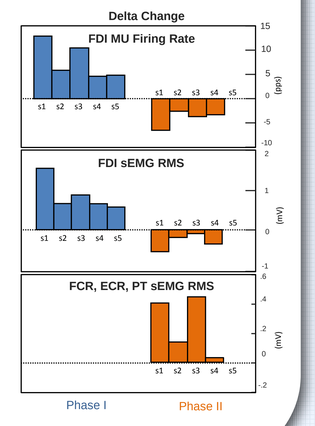
- Phase I: FDI motor unit firing rates increased significantly from the first contraction to a mid-fatigue contraction ($p<0.05$ for all subjects).
- Phase II: FDI motor unit firing rates decreased from the mid-fatigue contraction to the last contraction in four of five subjects ($p<0.02$ for subjects 1, 2, 4; $p=0.49$ for subject 3).

2) Changes in MU firing rates were associated with similar changes in FDI muscle activation:

- Phase I: Increases in FDI MU firing rates were always associated with significant increases ($p<0.001$ for all subjects) in the sEMG RMS amplitude of the FDI muscle.
- Phase II: Decreases in FDI MU firing rates were always associated with decreases in the sEMG RMS amplitude of the FDI muscle ($p<0.07$ for subjects 1,2,4; $p=0.72$ for subject 3).

3) Decreases in FDI MU firing rates were always associated with significant increases in the sEMG RMS amplitude of the FCR, ECR, and PT muscles ($p<0.005$ for all subjects) .

4) Similar patterns of FDI MU firing rates, FDI activation, and FCR, ECR & PT activation were observed in all subjects.



Conclusion

Adaptations in FDI MU firing rates were always associated with similar adaptations in FDI activation, indicating that changes in MU firing rates are directly related to changes in the excitation to the motoneuron pool of the fatiguing muscle, following the well-known control mechanisms of muscle force generation [3].

MU firing rates & activation of the FDI muscle increased to sustain force output as fatigue developed. Decreases in MU firing rates & activation of the FDI muscle may be explained by changes in the strategy for sustaining force output and increased co-activation of concurrently active muscles.

Acknowledgments

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References

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