Motor Unit Control and Force Fluctuation during Fatigue

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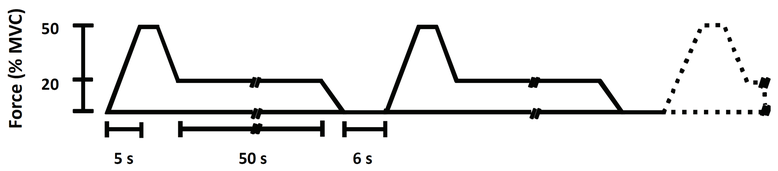
INTRODUCTION

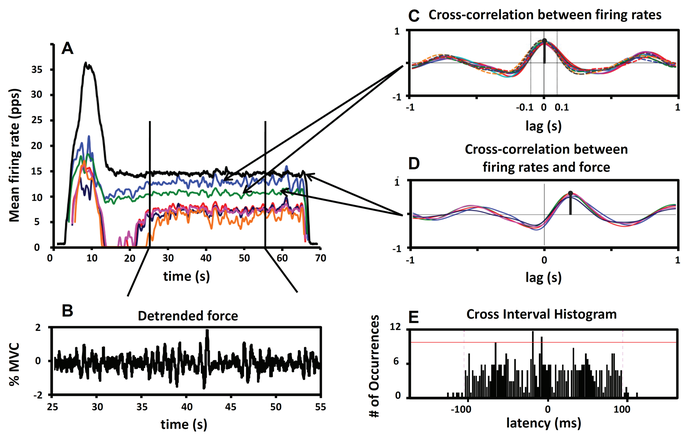
During isometric contractions, the fluctuation of the force output increases as the muscle fatigues and the contraction is sustained to exhaustion.
The firing behavior of motor units (MUs) can be assessed by parameters such as the firing rate variability, the synchronization of motor unit firings, and common modulation of motor unit firings. Contrasting reports can be found on the behavior, influence and causality of these parameters on the increasing force fluctuation during fatigue.
We analyzed motor unit firing data from the vastus lateralis muscle of four healthy subjects to investigate which motor unit control parameters were associated with the increased force fluctuation.

METHODS



Fatiguing protocol: successive isometric contractions were tracked to exhaustion, separated by 6s of rest. Each contraction started with a ramp up to 50% MVC (at a rate of 10% MVC/s) and a brief hold phase; the target value was then decreased to 20% MVC and maintained at this level for 50s. At the end of the cycle, the force level was decreased at 10% MVC/s.

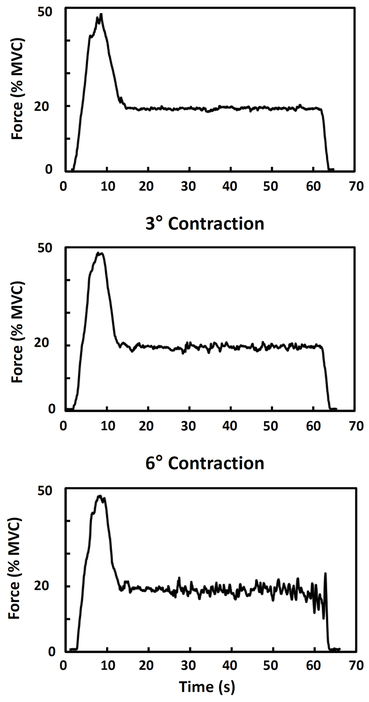
EMG signal: EMG signals were recorded by use of a quadrifilar fine wire sensor. Three combinations of pairs of wires were selected, differentially amplified, and decomposed into their constituent motor unit action potential trains. The firings of the same motor units could be followed throughout the sequence of contractions.



Data analysis: MU trains were low-pass filtered with a 0.4s Hanning window to obtain the mean firing rates (A). Firing rates and force over 30s of steady region were detrended by high-pass filtering the signals at 0.75 Hz (B), and the coefficient of variation (CV) was computed. The cross-correlation function between firing rates (C) and between firing rates and force (D) was calculated and the maximum value was measured. The synchronization between firings of concurrently active MUs (E) was also computed.

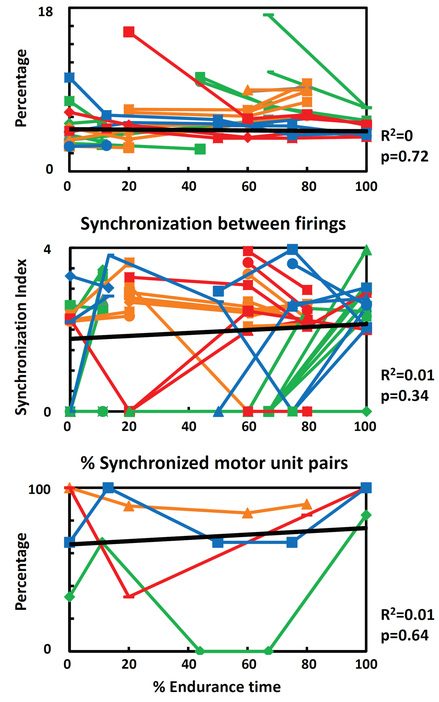
EXPERIMENTAL RESULTS

FORCE FLUCTUATIONS



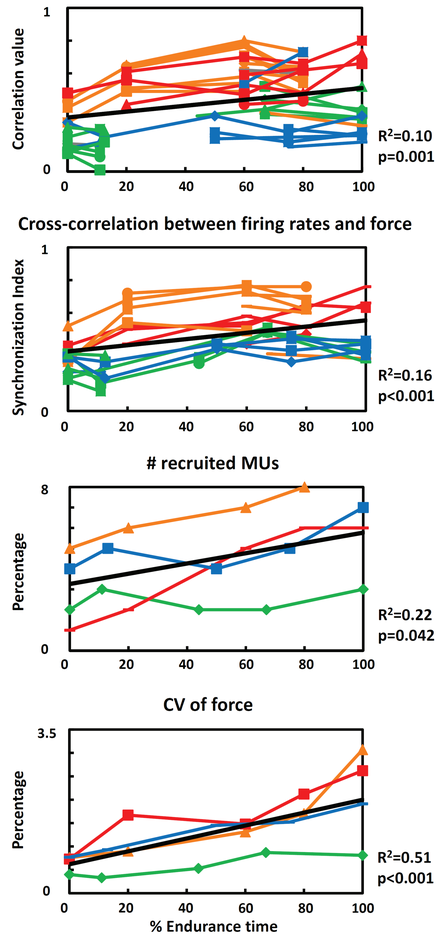
The first, middle and last force trajectories tracked by one of the subjects are presented in order to show the increase in force fluctuation with the progression of fatigue.

NON SIGNIFICANT PARAMETERS



The coefficient of variation of the firing rates, the synchronization between MU firings, and the number of synchronized MUs did not increase significantly with endurance time.

SIGNIFICANT PARAMETERS



The cross-correlation between firing rates, the cross-correlation between firing rates and force, the number of recruited MUs and the coefficient of variation of the force increased significantly with endurance time.

CONCLUSIONS

Potential causes of increasing force fluctuation during fatigue:

YES	Increasing common drive (correlation between firing rate and force increases) Motor unit recruitment
NO	Coefficient of variation of firings Synchronization of firings Number of synchronized motor units

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