

Title of Entry: EMG-EMG coherence during muscle fatigue.

Innovation: Here we propose the analysis of coherence between simultaneously recorded EMG signals as a means of examining characteristics of common neural inputs to co-contracting muscles during fatiguing contractions. Coherence between surface EMG signals from the first dorsal interosseous and flexor digitorum superficialis was examined before and immediately following sustained fatiguing finger flexion. To enable changes during fatigue to be examined as a function of time, wavelet coherence was used to examine coherence between EMG signals recorded from the biceps brachii and brachioradialis during fatiguing elbow flexion. Application of coherence in this manner provides insight into the effects of fatigue on coherence and neuromuscular coupling across muscles, about which little is currently known.

Description: Analysis of coherence between EMG signals provides a means of examining the characteristics of common neural inputs to co-contracting muscles during voluntary contraction. The central nervous system oscillatory drives responsible for this coherent activity are typically characterized within different frequency bands, including low frequency 1-3 Hz oscillations, that may also be observed as the common modulation of motor unit firing times known as 'common drive'^{1,2}, oscillations at the frequency of physiological tremor (8-12 Hz)³ and within the beta (15-30 Hz) and gamma (30-60 Hz)⁴ frequency ranges, of which beta-band coherence is associated with short-term motor unit synchronization. Although synchronization of motor unit activity is commonly suggested as a means of maintaining force output as muscle fatigues, direct evidence of changes in synchronization or coherence with fatigue is limited and experimental findings to-date have been contradictory, with results varying depending on the muscles and conditions examined⁵.

The aim of this study was to examine changes in coupling across synergistic muscles during sustained fatiguing contractions using coherence analysis. By examining the coherence between EMG signals, representing the summated activity of many motor units, a measure of correlated activity across both motoneuron pools can be achieved. This provides an alternative to measures based on the firing times of individual motor units, such as synchronization, which can be difficult to obtain during fatiguing contractions and reflect the activity of a limited sample of motor units only.

EMG signals recorded during fatiguing contraction are non-stationary in nature. Conventional coherence estimation, based on Fourier analysis, is limited to stationary data, providing an average estimate of the coherence over the entire time course. In contrast, time-frequency methods, such as wavelet coherence⁶ allow the temporal structure of coherence to be analyzed and the variation in coherence to be estimated as a function of time. Two different approaches are, therefore, presented. Fourier-based coherence is first used to examine changes in coherence before and immediately after sustained fatiguing contraction. In a separate experiment, wavelet coherence is then used to examine changes in EMG-EMG coherence during a sustained, fatiguing contraction.

15 healthy, right-hand dominant subjects with no known neuromuscular disorders or musculoskeletal injuries of the hand participated in each experiment. Coherence between surface EMG signals from two index finger flexor muscles, the first dorsal interosseous (FDI) and flexor digitorum superficialis (FDS), during and immediately following sustained, fatiguing isometric contraction was first examined. Bipolar surface EMG signals were recorded from the FDI and FDS muscles using 8 mm diameter Ag/AgCl electrodes with a 10 mm inter-electrode distance. The surface EMG signals were amplified with a gain of 1000 and band-pass filtered (3Hz-1 kHz) with a sampling rate of 2.5 kHz. The force signal was low pass filtered at 100 Hz and displayed to the subject. A significant increase in EMG-EMG coherence in the beta (8-12 Hz) and gamma frequency (35-60 Hz) bands was observed immediately following the fatiguing contraction, Fig. 1. No change in coherence in the tremor band was observed.

To examine whether similar effects occur across other synergistic muscle pairs and to examine changes in coherence during the fatiguing contraction, bipolar surface EMG signals were recorded from the biceps brachii (BB) and brachioradialis (BR) muscles during isometric voluntary elbow flexion at 30 % and 70 % MVC. The EMG signals were filtered, amplified and recorded as described above. Wavelet coherence was used to examine changes in the coherence between the BB and BR EMG signals during the fatiguing contraction, Fig. 2. A progressive increase in the wavelet coherence was observed during the contraction in both the tremor and beta bands at 30 % MVC, Fig. 3, and in the beta and gamma bands at 70 % MVC.

The mechanisms underlying the observed increase in coupling across the muscles with fatigue, or the functional significance if any, are not clear. While tremor is known to be multifactorial in origin, with both cortical and peripheral components³, it is likely that the increase in beta and gamma band coherence may reflect greater levels of corticomotoneuronal drive to both muscles⁴. The increase in coherent activity may help to overcome reduced motoneuron excitability with fatigue⁷, bind together sensorimotor elements or to co-ordinate force generation in a more synergistic manner as the force generating capacity of the muscle is decreased.

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Figures

Comparison of EMG-EMG coherence pre and post fatigue

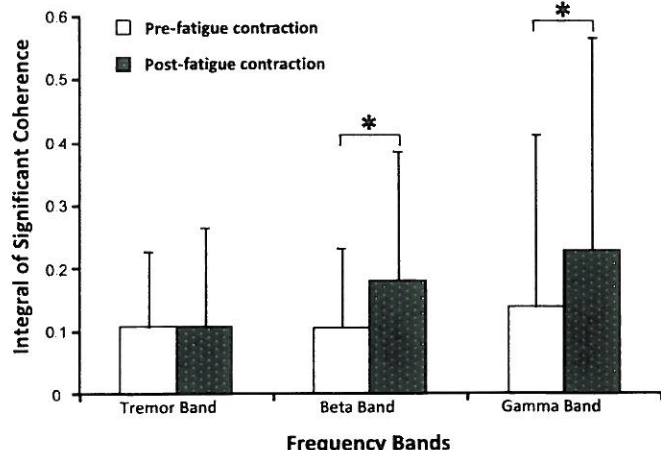


Fig. 1. Mean and standard deviation of the integral of the significant coherence between the FDI and FDS EMG signals during the pre- and post-fatigue contractions. The data has been averaged over all subjects. A statistically significant increase in coherence during the post-fatigue contraction was observed in the beta (15–35 Hz) and gamma (35–60 Hz) bands. Statistically significant difference between the two groups is indicated with an asterisk ($P < 0.05$).

EMG-EMG wavelet coherence at 30 % MVC

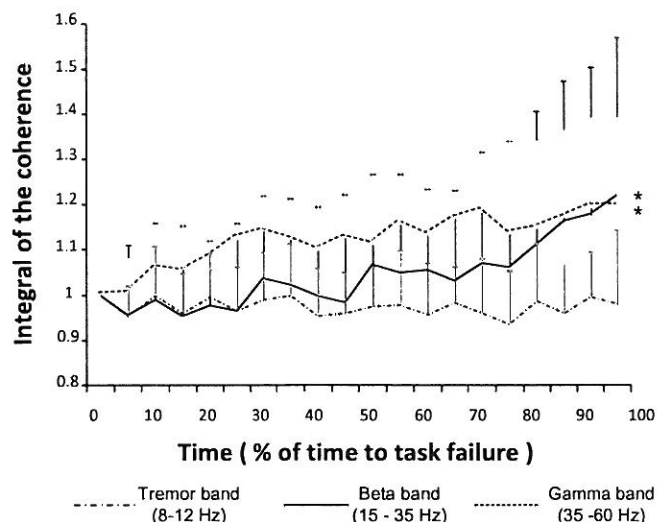


Fig. 3. Mean and standard deviation of the integral of the wavelet coherence, in each frequency band, between the BB and BR EMG signals at 30% MVC during sustained isometric fatiguing contraction. Data have been averaged over all subjects. A statistically significant effect of time is indicated with an asterisk *(ANOVA, $P < 0.05$).

BB-BR Wavelet coherence at 30 % MVC – Subject 1

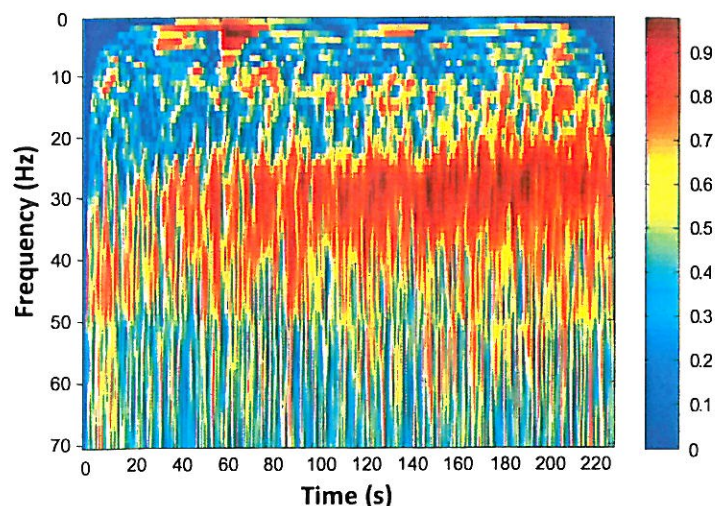


Fig. 2. EMG-EMG wavelet coherence between the BB and BR EMG signals for a representative subjects during the sustained fatiguing contraction at 30% MVC presented as a function of time and frequency. Red color corresponds to stronger coherence values and blue corresponds to lower coherence values.

References

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History of Dissemination

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