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The effect of isometric contraction on the regulation of force tremor in the contralateral limb

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HIGHLIGHTS

- Force tremor was examined in the contralateral limb during isometric contractions.
- Tremor selectively increased in the contralateral limb with brief contractions.
- Tremor decreased in the contralateral limb with prolonged contractions to failure.

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ABSTRACT

This study examined how regulating force tremor in a single limb is altered when the opposite limb is actively engaged in a force generating task. Index finger abduction force and first dorsal interosseous (FDI) activity were assessed in thirteen healthy subjects, at target forces from 5% to 60% MVC for the non-dominant limb (unilateral task), and again when the dominant limb simultaneously generated a submaximal abduction force (bilateral task). When the non-dominant limb generated force at 20% MVC, tremor was greater during the bilateral task compared with the unilateral task; a finding reflected in the amplitude of peak power of force. Bilateral responses were also examined during a prolonged 60% MVC unilateral contraction. Force tremor and muscle activity amplitude increased while the frequency of activity decreased for the contracting limb. Additionally, force tremor significantly decreased towards the end of the prolonged contraction in the contralateral limb. Overall, it appears that the process of performing isometric contractions invokes tremor-related changes in the opposite limb at selective force targets, and performing prolonged unilateral contractions invokes tremor-related changes in the opposite limb when it is at rest.

1. Introduction

When performing isometric voluntary contractions, the force exerted by the muscle is not entirely steady. Instead, small fluctuations exist that are dependent on the intensity and duration of contraction [1–5]. It is clear that variability in force production in a single limb is enhanced during and after prolonged submaximal isometric contractions [6–9]; however little is known about how force tremor in one limb is regulated when the opposite limb is engaged in a force producing task. Although several studies have examined tremor-related responses in the contralateral limb during brief muscle contractions and following fatiguing contractions [10–12], these observations are for postural tremor, and not force tremor. In general, postural tremor in the contralateral limb is enhanced at high intensities or during extended periods of contractions (e.g. repeated isometric MVC's or contractions to task failure); however it is unknown if force tremor in a single limb is altered when the opposite limb becomes actively engaged in a force producing task.

In the current study, variability of index finger abduction force and first dorsal interosseous (FDI) activity was assessed at different levels of force output for the non-dominant limb (unilateral task). Force tremor and muscle activity data were then collected for the non-dominant limb when the dominant limb index finger simultaneously generated a submaximal abduction force maximising FDI motor unit recruitment (bilateral task) [13,14]. It was hypothesised that force tremor and muscle activity would be greater in the non-dominant limb during the bilateral task compared with the unilateral task. A second experiment was undertaken where a prolonged submaximal unilateral isometric contraction was performed to fatigue. Force tremor and

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muscle responses were examined during the prolonged contraction.

2. Materials and methods

2.1. Subjects

Thirteen subjects (age: 23 ± 4 yrs, 7 female, 12 right hand dominant) with no history of formal history of resistance training or recent musculoskeletal injury participated in the study. Subjects abstained from caffeine, alcohol, and any form of central nervous system (CNS) stimulant or depressant for at least 6 h prior to testing. Written informed consent was obtained before testing. All experimental procedures were approved by the Institutional Ethics Committee and experiments were performed in accordance with the Declaration of Helsinki.

2.2. Bilateral force tremor and muscle activity

Force tremor was quantified as fluctuations in index finger abduction force during isometric contractions. The palmar surface of each hand was placed flat on a custom-designed device for measuring index finger abduction force (Fig. 1). The device was adjustable so that hand and finger position could be standardised for each subject. Thumbs were abducted and supported by a solid bracket and the forearm and digits 3–5 were secured with Velcro straps. The index finger metacarpophalangeal joint was positioned at 0° abduction and 0° flexion, and the interphalangeal joints were maintained in extension. Abduction force was measured at the proximal interphalangeal joint for each of the index fingers with Ultra Precision Mini Load Cells (Transducer Techniques, MDB-2.5, range 2.5 lbs).

EMG activity was measured for the FDI muscle. Following skin preparation, bipolar Ag/AgCl electrodes (Kendall Arbo) were placed over the muscle belly of the superficial head of FDI, and over the distal tendon at the second metacarpophalangeal joint [4] with an inter-electrode spacing of 10 mm. Ultrasound imaging confirmed that the larger superficial head of the FDI was the primary head contracting during this task. The reference electrode was placed over the ulnar styloid process. EMG power spectra were monitored during subject preparation, and electrode placement was adjusted if clear data could not be obtained. Surface EMG were amplified 10,000 times using an NL844 amplifier (Digitimer Ltd.) and band-pass filtered at 3–400 Hz (NL135, NL144, Digitimer Ltd.) during data acquisition. Impedance was kept below 5 kΩ at each electrode site. All force and EMG data were acquired at 1000 Hz using a 16-bit Power 1401 interface and custom Spike2 software (Cambridge Electronic Design).

2.3. Experiment protocol

Prior to experimental testing, maximum voluntary contraction (MVC) was determined using the same apparatus outlined above. To accommodate for the larger abduction forces, Applied Measurements Xtran load cells with a range of 250 N were used. MVCs were calculated separately for each hand and also bilaterally with index fingers abducting simultaneously. Five maximal contractions were recorded for each condition and the greatest force measured was designated the MVC for each condition.

Baseline force tremor and muscle activity were assessed unilaterally and then bilaterally when both index fingers abducted simultaneously against the load cells. For the *unilateral task*, subjects were required to generate target forces at 5%, 10%, 15%, 20%, and 60% MVC using only their non-dominant limb (target force based on non-dominant MVC). The *bilateral task* required subjects to always maintain a 60% MVC target force with their dominant limb while generating target forces at 5%, 10%, 15%, 20%, and 60% MVC using their non-dominant limb (target forces based on bilateral MVC) (e.g. Fig. 1). Real-time feedback was provided using custom Spike2 software, where the target force and the force exerted by the subject was displayed on a monitor placed at eye level. Subjects were verbally encouraged to keep their non-active limb relaxed. Four 15 s trials were performed for each task and contraction intensity, with 3 min rest between tasks. The order of testing was randomised for all subjects.

After baseline force tremor data was collected, a second experiment was performed to determine the effect of a prolonged unilateral isometric submaximal contraction on contralateral force tremor generation. The task involved sustained isometric index finger abduction of the dominant limb at 60% MVC until the contraction could not be maintained, while the non-dominant index finger rested against the load cell (mean 1.9% MVC, range 1.1–2.7% MVC). The contraction protocol ceased when force output of the dominant limb dropped below 55% MVC for longer than 5 consecutive seconds.

2.4. Data analysis

For finger abduction force and EMG data during the unilateral task and the bilateral task, the initial 3 s and final 3 s of data were discarded to ensure only steady state data was used for analysis. Force data were low-pass filtered with a 4th order Butterworth filter set with a cut off frequency of 45 Hz, and force tremor was quantified using the standard deviation (SD) and coefficient of variation (CV) of raw force data. Force and EMG data were examined in the frequency domain using Welch's averaged periodogram method (frequency resolution: 0.325 Hz). The peak power and the frequency of peak power were extracted from force power spectra. Prior to spectral analysis, EMG data were rectified and low-pass filtered with a 6th order dual-pass Butterworth filter set with cut-off frequency of 45 Hz. Power spectral analysis was applied to the rectified and low-pass filtered EMG signal and two bandwidths were examined: 1–15 Hz and 15–45 Hz [15]. Within each bandwidth, the peak power and frequency of peak power for FDI EMG were extracted.

To examine force tremor and muscle activity during the prolonged submaximal isometric task, data were analysed using the abovementioned techniques across specified epochs: 5–15%, 25–35%, 45–55%, 65–75%, and 85–95% of the duration of contraction for each subject. For clarity, these data are reported as 10%, 30%, 50%, 70%, and 90% of contraction duration in the results. All data analyses were performed using custom Matlab software (MathWorks Inc., v7.11, R2010b).

2.5. Statistical analysis

Repeated-measures ANOVA was used to examine differences in task (unilateral, bilateral) when the non-dominant limb generated different finger abduction target forces, and multiple comparison tests were performed at each target force using Tukey's HSD procedures. In the prolonged contraction experiment, repeated-measures ANOVA with Dunnett's method of multiple comparisons was used to compare time points during the contraction with baseline measures (the first 5 s of steady state contraction). The partial eta squared test was used to determine effect sizes, and the level of significance was set at $p < 0.05$. All statistical analyses were performed with IBM SPSS Statistics (v20).