# Detecting the Transient Recruitment of Motor Units in the Surface Electromyogram During A Sustained Contraction

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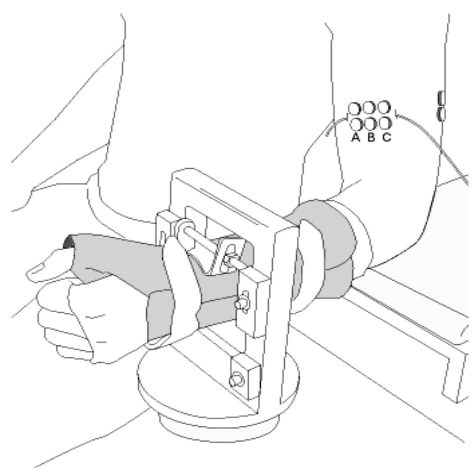
## INTRODUCTION

To sustain a submaximal force for a prolonged duration, motor units must be recruited progressively to compensate for the decline in discharge rate of the active motor units, the cessation of discharge by some motor units, and the decrease in contractile force of many muscle fibers. The recruitment of motor units is responsible for the gradual increase in the amplitude of surface electromyogram (EMG) during a fatiguing contraction. Due to the effects of amplitude cancellation, however, the surface EMG is relatively insensitive to modest changes in motor unit activity (Keenan et al. 2005). The purpose of the study was to characterize the discharge of transiently recruited single motor units during a sustained contraction, and to compare it with signals detected in the surface EMG.

## METHODS

Eleven healthy adults (10 men; 27.5 ± 4.9 yrs; range, 21-35 yr) participated in the study. Twenty motor units in biceps brachii were isolated with fine wire subcutaneous electrodes and the discharge was compared with concurrently recorded surface EMG signals (Fig.1) during a sustained isometric contraction. The target force (25.4 ± 10.6% of the maximal voluntary contraction [MVC] force) was ~10% below the recruitment threshold of the motor unit (35.3 ± 11.3% MVC).

Fig. 1



Surface EMG signals were high-pass filtered at 400 Hz (Potvin and Brown 2004; Staudenmann et al. 2007). Similarities between the surface EMG signal (rectified, smoothed 0.5 s window) and the motor unit signal (downsampled 20k to 2k, rectified, smoothed 0.5 s window) were tested with Pearson's R correlations. Processing the surface EMG also included the following steps previously used by Hunter et al. (2002): (1) rectification of the signals; (2) low-pass filtering at 2 Hz; (3) differentiation; and

(4) normalization to the average EMG of the entire signal. The threshold for the beginning and end of each burst of activity was defined as the instant when the smoothed and differentiated surface EMG signal exceeded 2.5 standard deviations above the mean that had been calculated from 25 samples at the beginning of the contraction. The minimum time between bursts was limited to 2 s and minimum burst duration was 0.5 s.

**RESULTS AND DISCUSSION**

Twenty motor units discharged 2-9 trains of action potentials when they were recruited. High-pass filtering the surface EMG signal with a 400-Hz cutoff significantly improved the correlation ($r$ = 0.74, see Fig. 2) with the single motor unit signal compared with the correlation obtained with the non-filtered signal ($r$ = 0.66, $P$ = 0.04). The algorithm based on the high-pass filtered signal was able to detect 75% of the trains of action potentials discharged by the transiently recruited single motor units within 1.1 s of the beginning and 0.62 s of the end of each train of action potentials. The same algorithm applied to the standard band-pass filtered surface EMG only resulted in 58% of the single motor unit trains being detected.

**SUMMARY/ CONCLUSIONS**

These results indicate that most of the trains of action potentials discharged by motor units that were recruited transiently during a sustained contraction can be detected in the surface EMG signal with a relatively simple algorithm. In addition, high-pass filtering the surface EMG may a useful tool for isolating single motor units in a surface EMG signal.

**REFERENCES**

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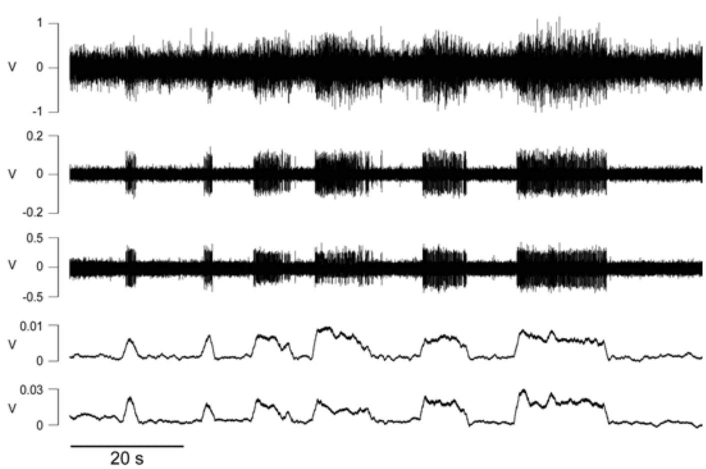


Fig 2. Representative data displaying the effect of high-pass filtering the surface EMG and the resulting method used to correlate the surface EMG signal with the single motor unit signal. The top trace represents the interference EMG detected with electrodes placed on the skin above the recording site for the single motor unit. The second trace indicates the surface EMG after high-pass filtering at 400 Hz. The third trace corresponds to the subcutaneous recording of the single motor unit activity. The fourth trace denotes the rectified and smoothed (0.5-s window) surface EMG channel after high-pass filtering. The bottom trace displays the single motor unit signal after down-sampling (20 kHz to 2 kHz), rectification, and smoothing (0.5-s window). The correlation between the bottom two traces was $r$ = 0.89.