Short-term synchronization of motor units in various functional subdivisions within the human flexor digitorum profundus muscle

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1. Introduction

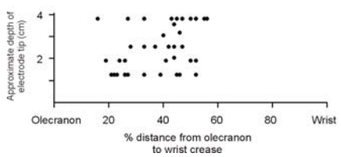
Flexor digitorum profundus (FDP) is the only muscle that attaches to the distal phalanx, and it therefore plays a unique and important role in grasping and object manipulation. The four-tendoned FDP is commonly assumed to achieve independent mechanical actions at the four fingertips by selective activation of a separate compartment within the muscle serving each finger. A central limitation to independent finger movements is the ability of the human nervous system to activate MUs acting on one finger without activating MUs acting on adjacent fingers.

The purpose of this study was to examine the strength and distribution of short-term synchronization between MUs in the same and different functional subdivisions of FDP.

2. Methods

•**Participants:** Studies were conducted on 8 right-handed volunteers.

•**Electrode Placement:** Fine-wire electrodes were inserted into the left FDP through the medial-ventral aspect of the forearm using a hypodermic needle. Once the electrode was in place the needle was removed. We sampled MUs from a range of different regions within the muscle by placing electrodes in parts of the muscle that were related to the isolated flexion of different digits.

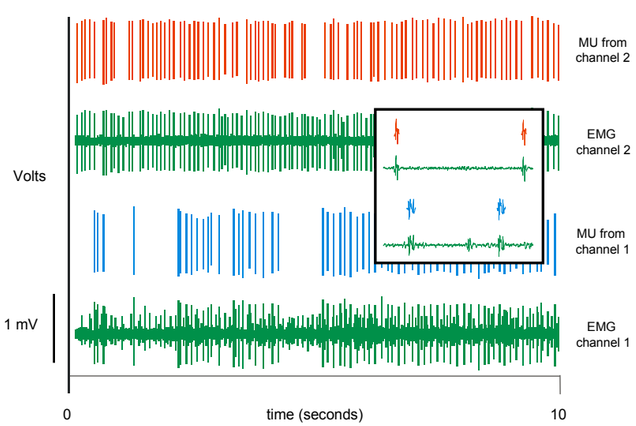


Electrode insertions

•**Data Acquisition:** EMG activity was sampled at between 5.5 and 20 kHz, band-pass filtered (300 Hz - 3kHz), and recorded for 5 to 20 minutes.

•**Experimental set-up and behavioral task:** Subjects placed their left hand in an apparatus that measured the fingertip force of each digit. Subjects slightly flexed all five digits or preferentially increased the flexion force in one of the four fingers.

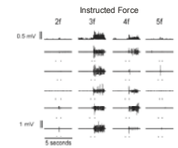
2. Raw Data



• Assignment of MU position within muscle

•Center of Activity (COA) of multi-unit EMG was used to assign the position of the MU within muscle

Multi-unit EMG recorded from same electrode used to record Single Motor Units



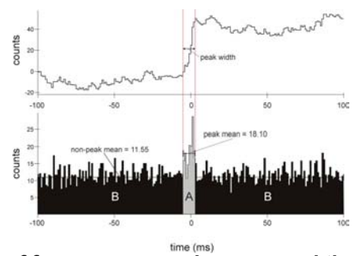
COA = -0.15

Digit 2 subdivision: -1 = COA < -0.5
Digit 3 subdivision: -0.5 = COA < 0
Digit 4 subdivision: 0 = COA < +0.5
Digit 5 subdivision: +0.5 = COA = 1

• Assessment of short-term synchrony

•After discriminating single MUs a cross-correlation histogram (bin-width 1 ms) was constructed around the discharge time of the reference motor unit. The position and duration of the synchronous peak was determined visually from CUSUM of the cross-correlogram.

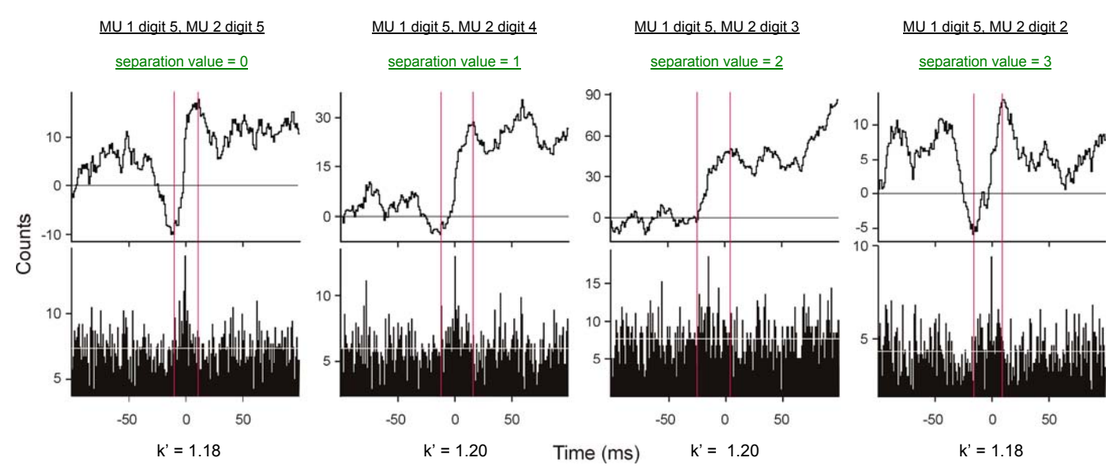
Strength of synchrony was determined as the ratio of the mean bin count in the peak region (A) to the mean bin count expected by chance (B). This index of synchronization is called k'.



Calculating strength of synchrony

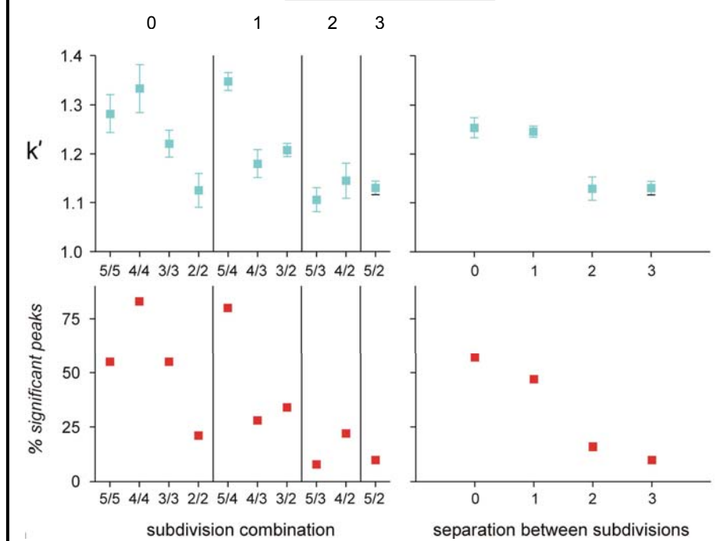
$$k' = \frac{\text{mean(A)}}{\text{mean (B)}}$$

6. Examples of four cross-correlograms and their corresponding cusums from pairs of motor units with separation values of 0, 1, 2, and 3 recorded from the same subject.



• **Within and adjacent compartment synchrony was greater than non-adjacent compartment synchrony**
Units in ulnar side of muscle showed more synchrony than units in the radial side of the muscle

N= 488 MU pairs



8. Conclusions

MU synchrony is not uniform for different functional subdivisions of FDP

Synchrony was greater between MUs in the ulnar than the radial side of the muscle

Strength of MU synchrony generally declined with increasing separation between the digits, indicating more independent CNS control of FDP subdivisions supplying more anatomically distant fingers

The CNS does not exert completely independent control over the different functional subdivisions of FDP

There is widespread divergence of last-order inputs within the FDP motoneuron pool

The observation that normal human subjects are better at independently flexing the index and middle fingers than the ring and little fingers might be partially explained by the tendency of motor units in the ulnar side of the muscle to be more synchronized than those in the radial side of the muscle.

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