Onion Skin and Common Drive of Motor Units During Voluntary Dynamic Contractions

DELSYS
SENSORS FOR MOVEMENT SCIENCES

BOSTON UNIVERSITY

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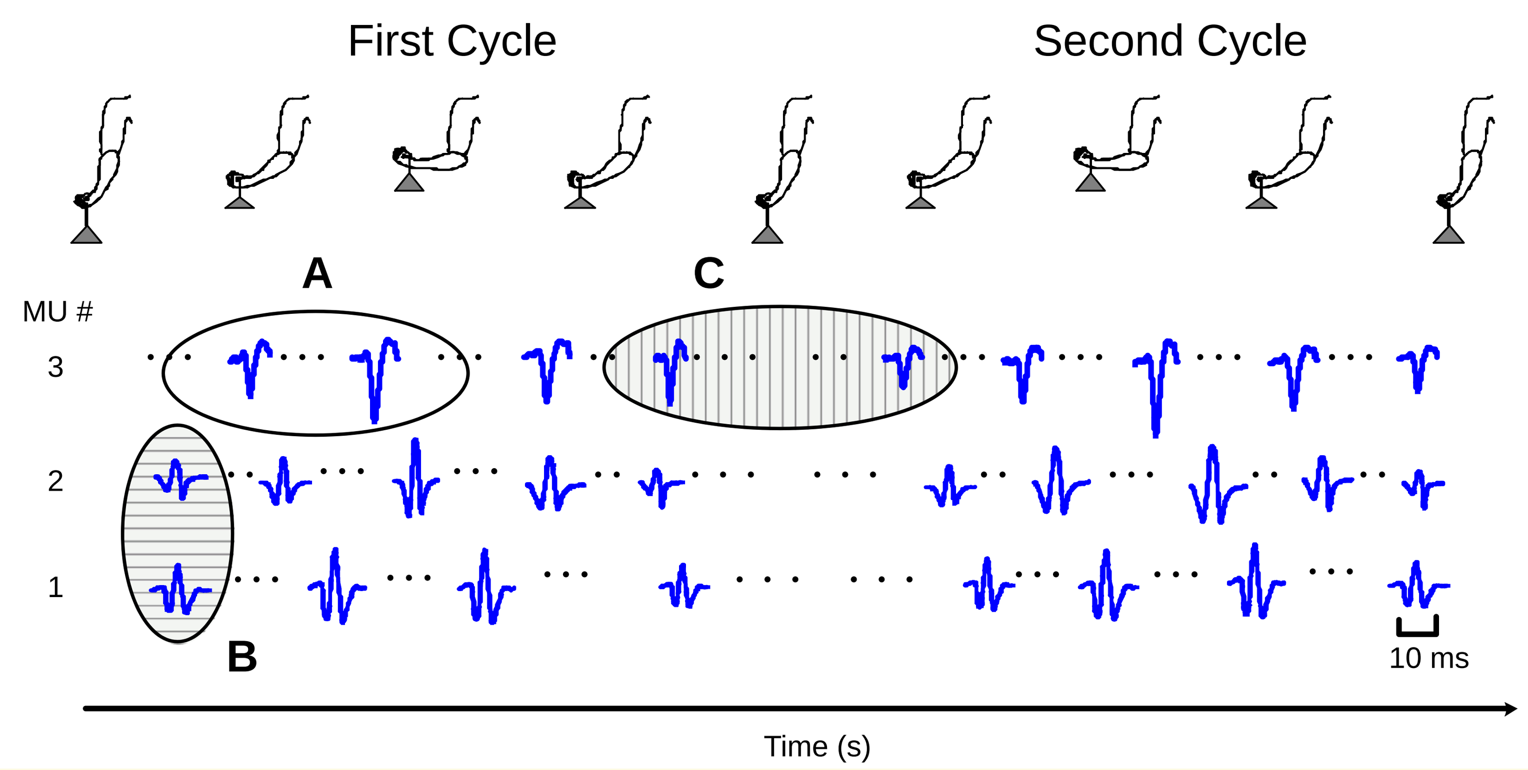
Motivation

All algorithms used to decompose the electromyographic (EMG) signal into its constituent motor unit action potentials (MUAPs) are limited to decomposing EMG signals from isometric contraction. With the exception of postural muscles and some small muscles stabilizing joints, most muscles contract anisometrically during mobile activities. Thus, we set out to develop an algorithm that is capable of decomposing the surface EMG (sEMG) signal during dynamic contractions to study the control strategies of the nervous system during movement involving concentric and eccentric activity.

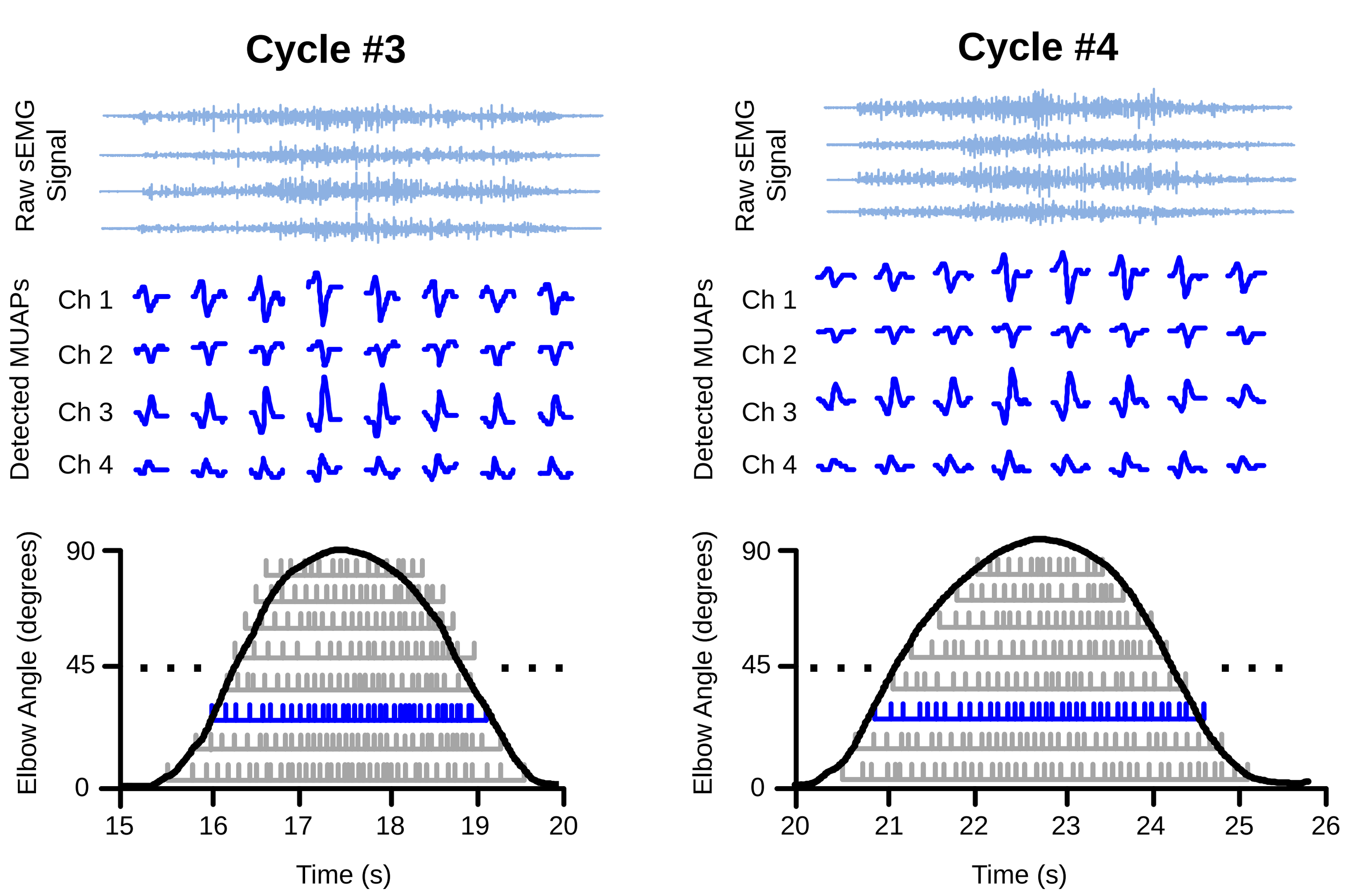
Dynamic Decomposition Challenges

Decomposing sEMG signals acquired during cyclic dynamic contractions requires an algorithm capable of solving three major challenges illustrated in the figure below:
- A) intra-cycle shape change (no shading);
- B) intra-cycle shape similarity (horizontal bar shading); and
- C) inter-cycle shape change (vertical bar shading).



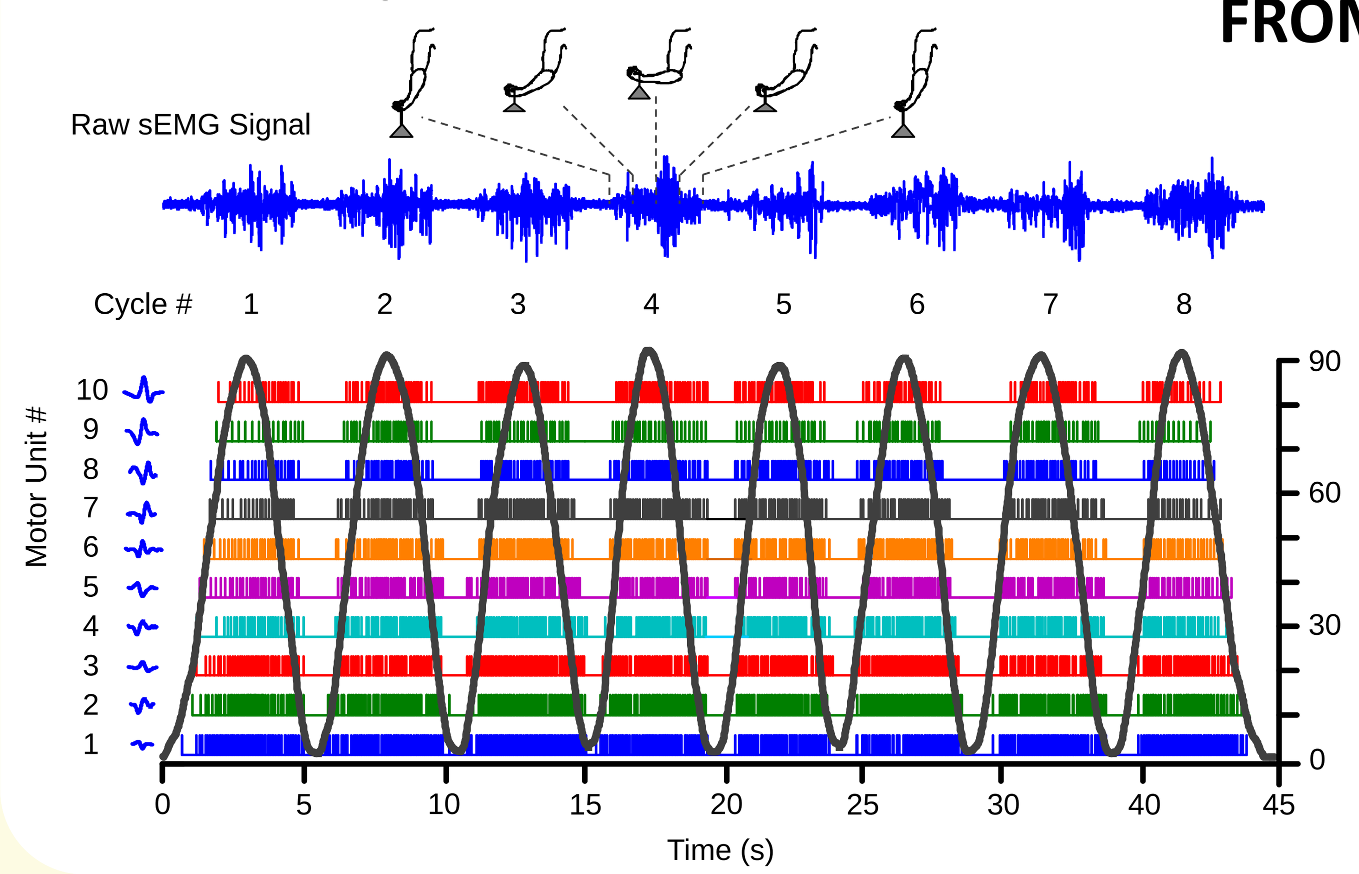
Dynamic Decomposition Solution

We developed a dynamic decomposition algorithm (De Luca et al, 2015) that was able to track MUAPs within and across cycles of changing joint angle and discriminate the changing MUAPs from different motor units successfully.



MOTOR UNIT FIRINGS FROM DYNAMIC CONTRACTIONS

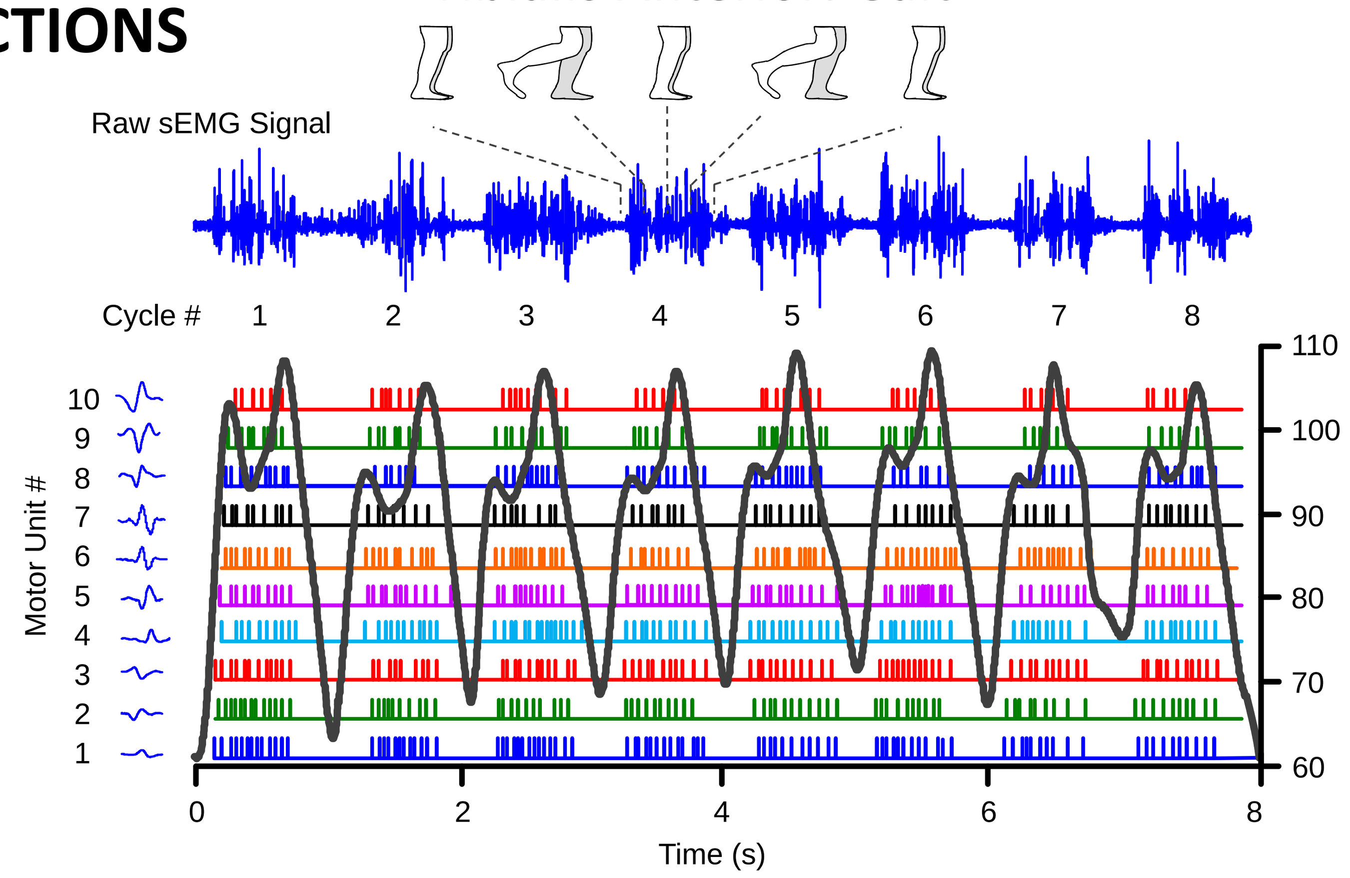
Biceps Brachii: Elbow Flex./Ext.



The decomposition of sEMG signals recorded during cyclic concentric/ eccentric contractions of the elbow and during gait revealed that motor unit firing behavior is governed by the same properties previously reported for isometric contractions:

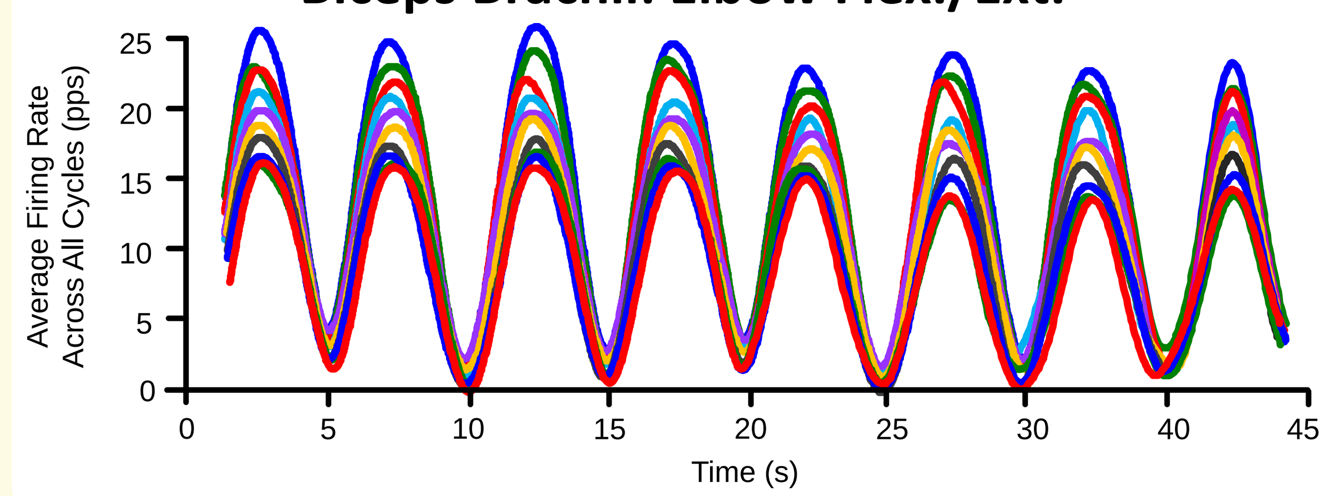
1) Common Drive and
2) The Onion Skin.

Tibialis Anterior: Gait



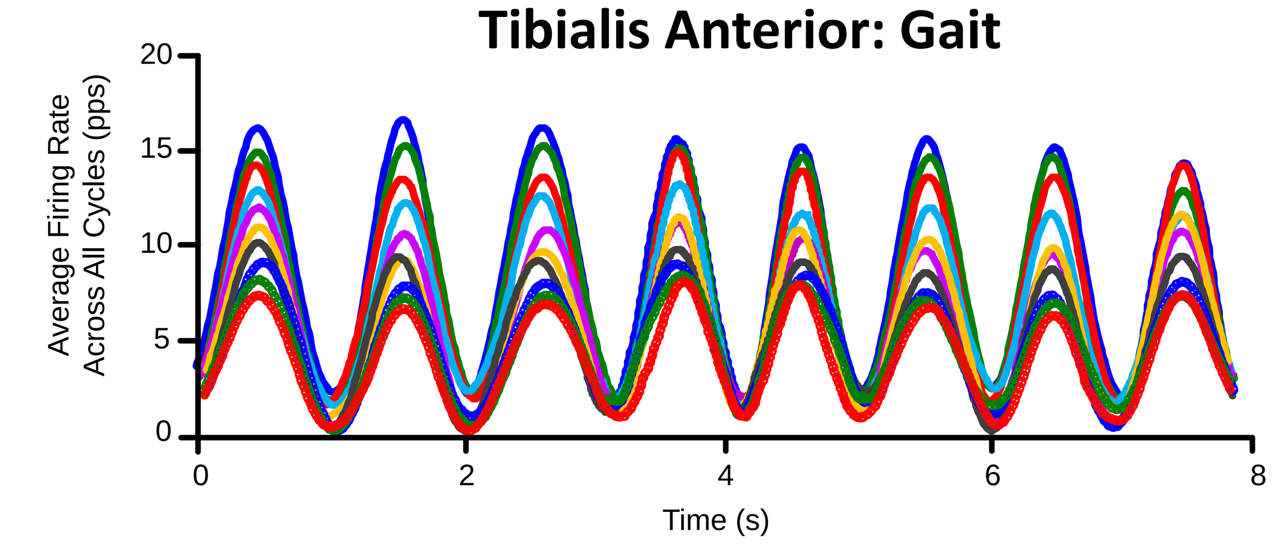
COMMON DRIVE

Biceps Brachii: Elbow Flex./Ext.



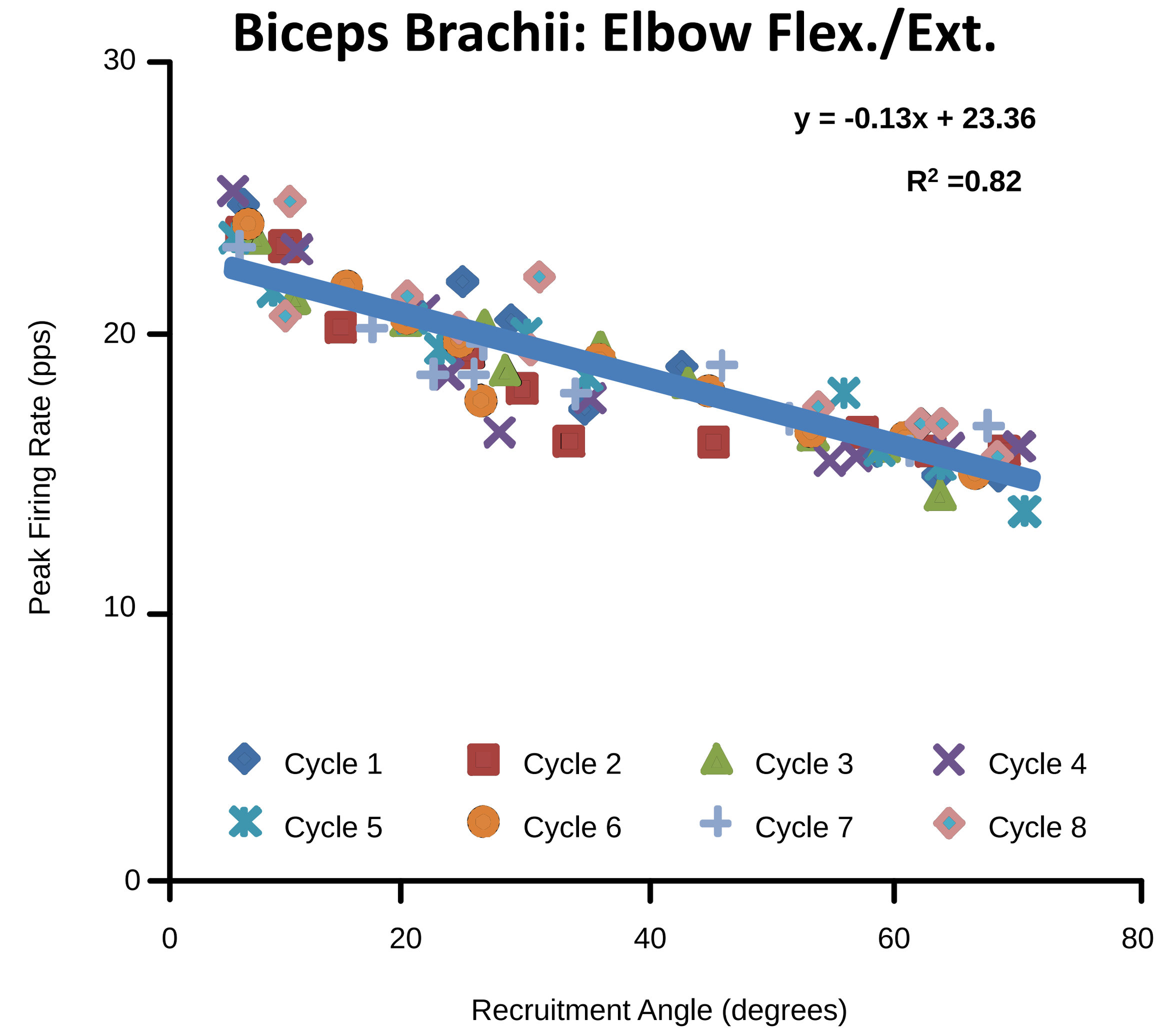
Average firing rates of concurrently active motor units fluctuate in unison and with each other and with the cyclic profile of the contraction. The highly correlated firing rates indicate that ***common drive*** (De Luca et al. 1982b) is a control scheme that governs motor unit behavior across the spectrum of voluntary contractions.

Tibialis Anterior: Gait



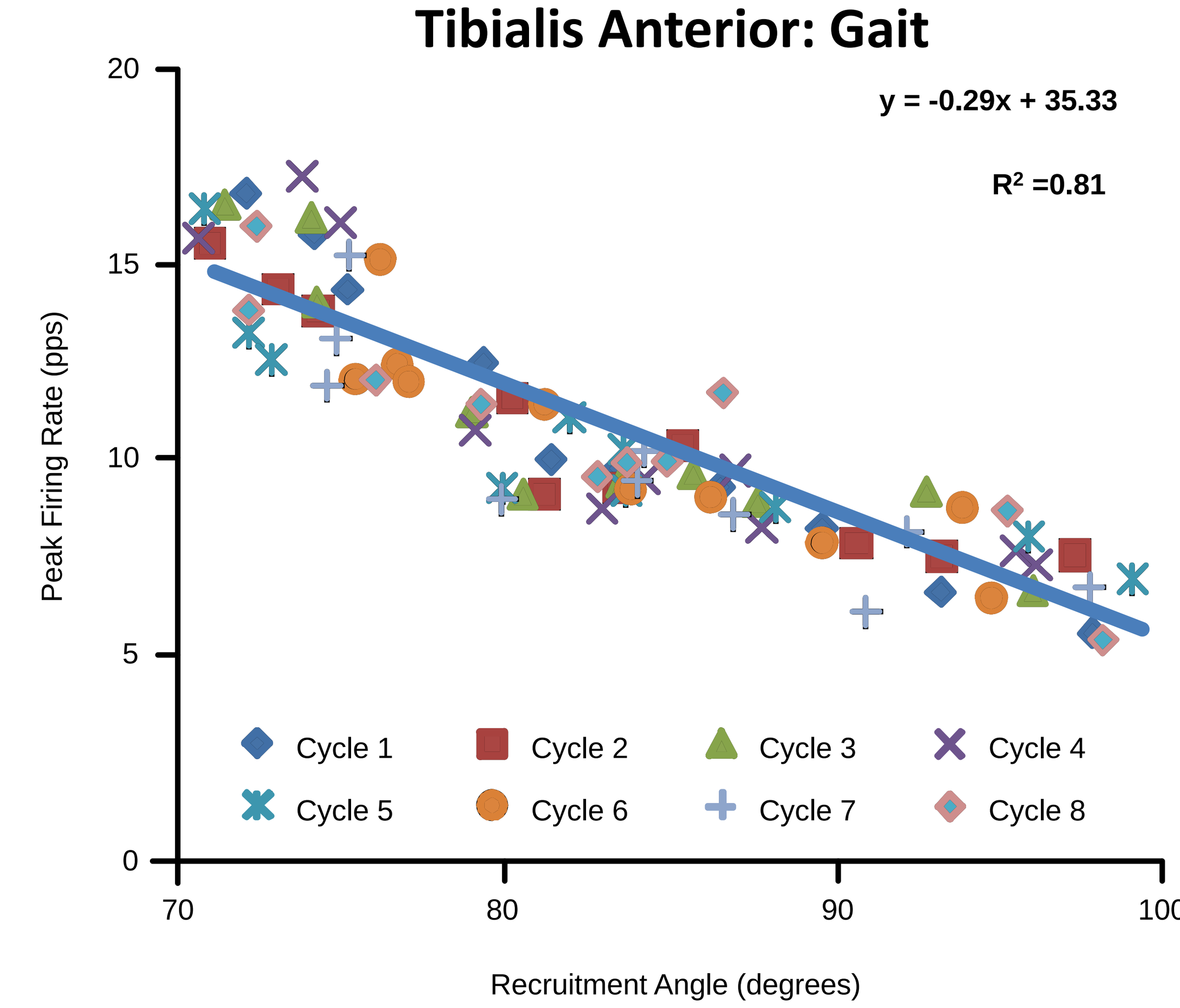
ONION SKIN

Biceps Brachii: Elbow Flex./Ext.



When the peak firing-rates observed in each cycle were regressed against the angle at which the motor units were recruited, there was an inverse linear relationship between the two parameters, a phenomenon known as the onion skin (De Luca et al. 1982a; and De Luca and Contessa, 2012). This inverse relationship has been interpreted as an "operating point" that remains invariant for the motoneurons in a pool, which are modulated by the excitation to the pool when changes in muscle contraction force are required. Although we did not measure the contractile force in these experiments, the force required by the muscle to maintain a fixed load during a flexion/extension contraction is related to the joint angle.

Tibialis Anterior: Gait



References

De Luca et al, *J Physiol* (1982a)
De Luca et al, *J Physiol* (1982b)
De Luca and Contessa, *J Neurophysiol* (2012)
De Luca et al, *J Neurophysiol* (2015)

Acknowledgments

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