Common drive of motor units during activities of the upper limb

Joshua C. Kline[1], Paola Contessa[1] , Serge H. Roy[1], Gianluca De Luca[1]
Delsys Inc. and Altec Inc., Natick, MA, USA

DELSYS®
WEARABLE SENSORS
FOR MOVEMENT SCIENCES

Motivation

Studies of motor unit (MU) firing behavior have reported varying degrees of "common drive", or correlated firings, when muscles are activated in a synergistic or antagonistic manner [1]. However, these studies are limited to voluntary isometric contractions. Little is known on how the central nervous system coordinates the activation of muscle synergists during unconstrained and dynamic functional tasks of normal daily activities.

Objective

Investigate the firing behavior of MUs in muscle synergists of the upper limb during cyclic dynamic movements.

Methods - Acquisition

Subjects
3 males 3 females (40 ± 16 yo)

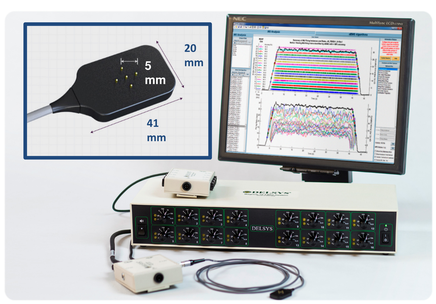
Muscles
Extensor digitorum, flexor digitorum profundus, pronator teres, biceps brachii

Activities
Finger flexion/extension, forearm pronation/supination, object grasping

Recordings
sEMG signals (dEMG, Delsys Inc.), finger force, joint angle, wrist inertial measurement (Trigno™, Delsys Inc.)

Methods - Analysis

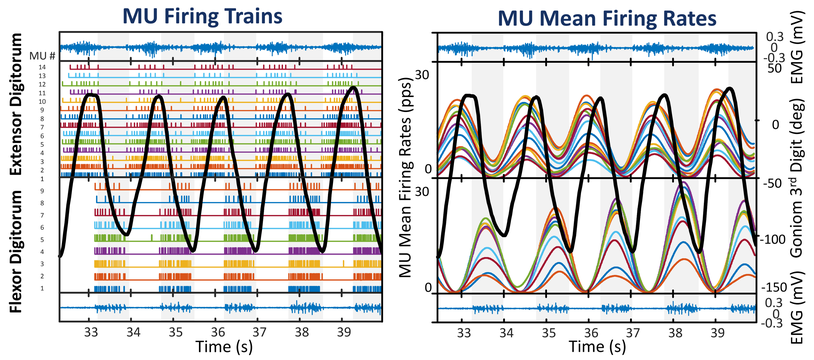
We used the dEMG System (Delsys Inc., Natick, MA) to non-invasively record sEMG signals during upper limb movement activities. sEMG signals were decomposed into the constituent MU action potentials (MUAPs) and their firing instances [2].



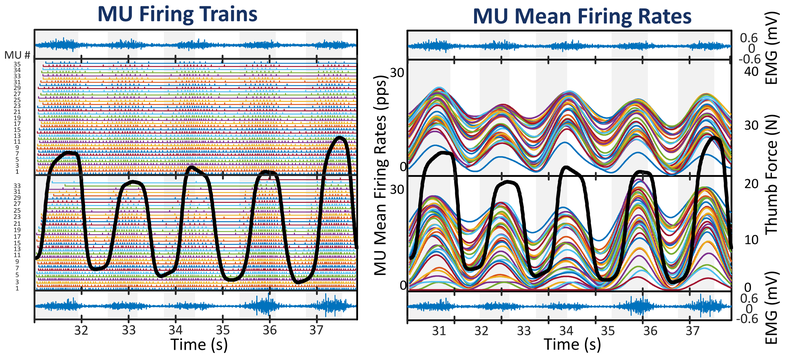
For each contraction cycle, we calculated:

1. the MU mean firing rates;
2. the MU peak firing rates;
3. the MUAP amplitude;
4. the cross-correlation between MU firing rates and output movement/ force.

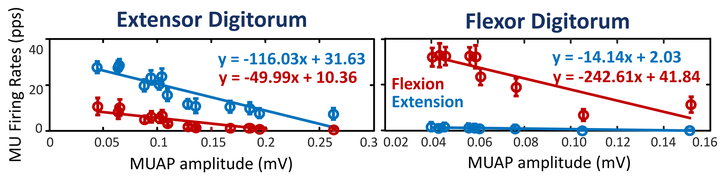
Results - Finger Flexion/Extension



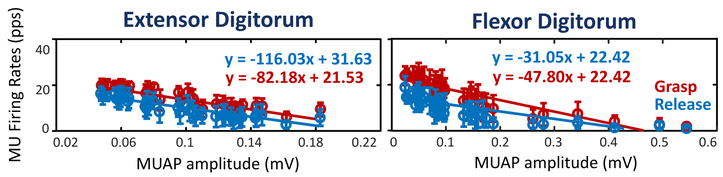
Results - Object Grasp



In accordance to the Onion Skin property, MU firing rates are inversely related to MUAP amplitude

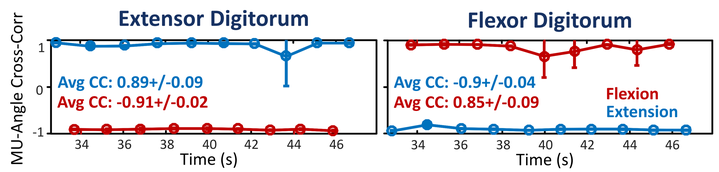


During the movement task, the inverse relation between MU firing rate and MUAP amplitude [3] shows that MU contribution is higher when muscles act in synergy with the output movement.

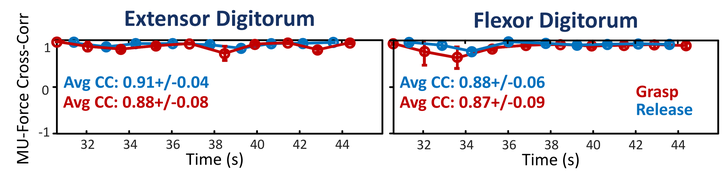


During the force task, the inverse relation between MU firing rate and MUAP amplitude [3] shows high MU contribution throughout the output task, particularly from the lower-amplitude MUs.

In accordance to the Common Drive property, MU firing rates are highly correlated with the output task and one another.



High positive/negative correlation indicates muscles act as agonist/antagonists to the output task [1].



High positive correlation at approx. zero time lag indicates muscles act in synergy to the output force [1].

Conclusions

- ❑ MUs from different muscles maintain a relatively high degree of correlation across all activities with varying latency.
- ❑ When muscles act in synergy, such as during object grasping - they are positively correlated with the output movement at approx. zero time lag.
- ❑ When muscles act as antagonists, such as during finger flexion/extension - they are negatively correlated with varying degrees of co-activation.

References

[1] De Luca et al. *J Neurophysiol*, 2001.
[2] De Luca et al. *J Neurophysiol*, 2015.
[3] De Luca & Erim. *Trends Neurosci*, 1994.

Acknowledgements/Support

This work was supported in part by De Luca Foundation and two grants from NIH-NINDS under awards R44NS077526 and R43NS09365.