Evidence for persistent inward currents in human motor neurons during low intensity electrical stimulation: Asynchronous motor unit firing

Dean J.C., Clair J.M., Lagerquist O., Collins D.F.
Centre for Neuroscience, Human Neurophysiology Laboratory,
Faculty of Physical Education and Recreation
University of Alberta, Edmonton, AB, Canada

Introduction

•Persistent inward currents (PICs) in motor neurons can produce sustained firing in response to brief excitatory synaptic input (Heckman et al. 2005)

•Under natural conditions motor neurons are subject to continuous synaptic input, potentially influencing the firing pattern produced by PICs

•Continuous electrical stimulation of peripheral nerves can produce muscle contractions that develop with a time course that is too slow for a simple reflexive pathway (Lang and Vallbo, 1967; Collins et al. 2001)

•We propose that peripheral nerve stimulation activates sensory axons, providing excitation to spinal neurons and activating PICs

Project hypotheses

•Motor units activated by the electrical stimulation will exhibit self-sustained firing, continuing to fire after the stimulation ends

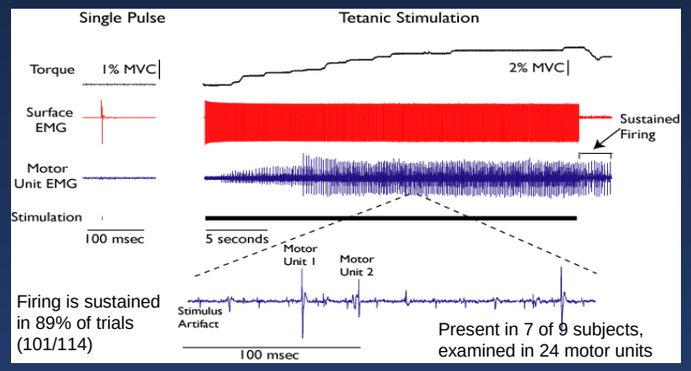
•The firing rate will be determined by intrinsic properties of the motor unit (PICs), and will not be affected by the stimulation frequency

•Motor units will fire asynchronously from the stimulation pulses

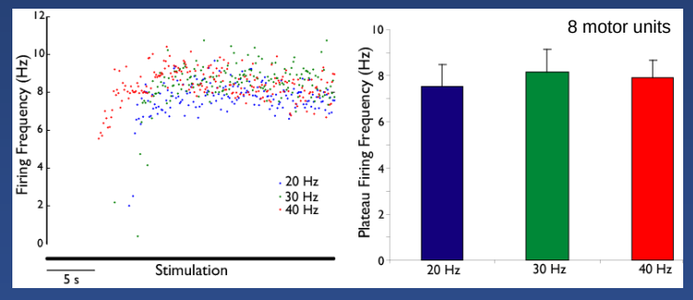
Experimental Methods

•9 subjects
•Surface tibial nerve stimulation
  •1 ms pulses, 30 seconds at seven constant frequencies (10-100 Hz)
  •Stimulation current below M-wave and H-reflex threshold
•Measured variables:
  •Soleus EMG – surface electrodes
  •Soleus motor unit EMG – fine wire electrodes
  •Plantarflexion torque

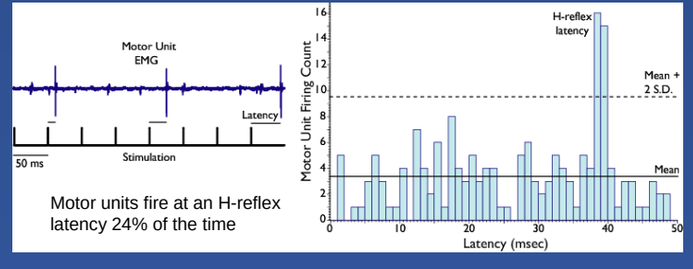
Low current stimulation gradually evokes sustained motor unit firing



Motor unit firing frequency is not proportional to stimulation frequency

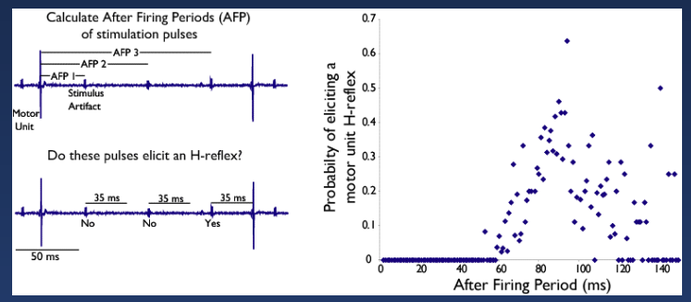


Motor unit firing is only partially asynchronous from the stimulation pulses



Motor units fire at an H-reflex latency 24% of the time

Appropriately timed stimulation pulses can activate motor units at an H-reflex latency



Consistent with PICs?

•Once activated, the majority of motor units (89%) continue to fire after stimulation has ceased

•Motor unit firing rate is not proportional to the stimulation frequency, but fires at approximately the motor unit's "preferred rate"

•Motor units usually (76% of the time) fire asynchronously from the stimulation pulses, but fire at an H-reflex latency more often than would be expected in a random distribution

  •Stimulation pulses deliver an excitatory volley to the motor neurons through a monosynaptic pathway

  •We propose that this excitatory volley is only effective in activating motor neurons when delivered after the afterhyperpolarization period is finished

References

Collins DF, Burke D, Gandevia SC. *J Neurosci* 2001.
Heckman CJ, Gorassini MA, Bennett DJ. *Musc Nerve* 2005.
Lang AH, Vallbo AB. *Exp Neurol* 1967.

Acknowledgements

NSERC CRSNG
CIHR IRSC Canadian Institutes of Health Research / Instituts de recherche en santé du Canada
AHFMR Alberta Heritage Foundation for Medical Research