Recruitment of human motor units during low current electrical stimulation

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Introduction

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

•Persistent inward currents (PICs) in motor neurons can develop over several seconds and produce sustained firing in response to excitatory synaptic input

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

Project hypotheses

•Motor units will fire asynchronously from the stimulation pulses, with firing sustained after stimulation ends

•The electrically-evoked synaptic activation will recruit the same low threshold motor units as weak voluntary contractions

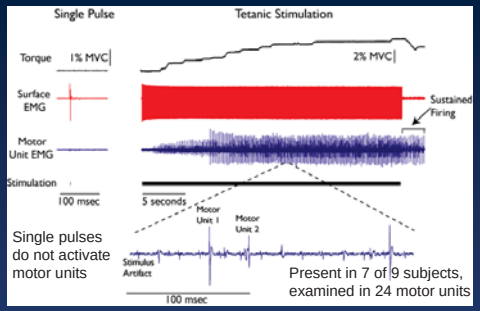
•The time course of motor unit recruitment will be consistent with PIC activation
- •PICs can "warm up" over 4-6 seconds (Bennett et al. 1998, Gorassini et al. 2002, Svirskis et al. 1997)
- •Recruitment latency will depend on stimulation frequency

Experimental Methods

•9 subjects
•Surface tibial nerve stimulation
- •1 ms pulses, 30 seconds at seven constant frequencies (10-100 Hz)

•Slow-rising voluntary contractions
•Measured variables:
- •Soleus EMG – surface electrodes
- •Soleus motor unit EMG – fine wire electrodes
- •Plantarflexion torque

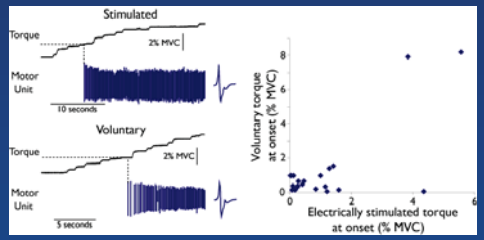
Low current stimulation evokes asynchronous, sustained motor unit firing



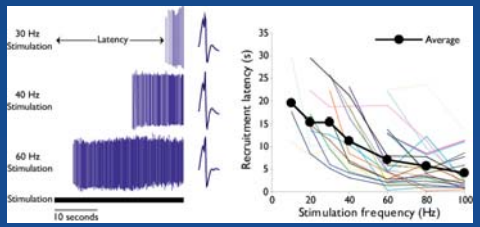
Single pulses do not activate motor units

Present in 7 of 9 subjects, examined in 24 motor units

The same motor units are recruited in stimulated and weak voluntary contractions

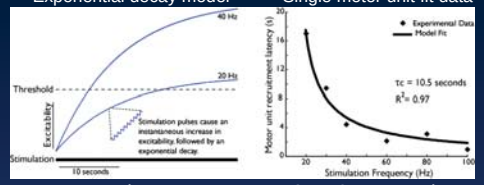


Higher stimulation frequencies recruit motor units with a shorter latency



A simple model fits the recruitment latency data

Exponential decay model | Single motor unit fit data



Average time constant = 15.3 10.4 seconds

Summary

•Low current stimulation can produce asynchronous, sustained motor unit activity

•Low current stimulation recruits the same motor units as weak voluntary contractions

•Motor unit activity develops with a slow time course (~15 second τ_c)

Consistent with PICs?

•Asynchronous, sustained motor unit firing would be expected if PICs are activated

•Recruitment order is consistent with synaptic excitation

•Recruitment time course is slower than expected
- •Human neurons may develop PICs with a different time course than animal neurons
- •We activated the lowest threshold motor units, which may have a slower time course than other motor units
- •Other factors including post-tetanic potentiation and changes in axonal properties could affect motor unit recruitment, contributing to the slow time course

References

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