Stimulus phase duration, not waveform, influences the relative recruitment of sensory and motor axons in a human peripheral nerve

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INTRODUCTION

Electrical stimulation is used to evoke reflexes for clinical exams and research studies and to produce contractions and/or promote neuroplasticity for rehabilitation.

When delivered over a mixed peripheral nerve electrical stimulation recruits motor and sensory axons, producing M-waves and H-reflexes, respectively (Fig.1).

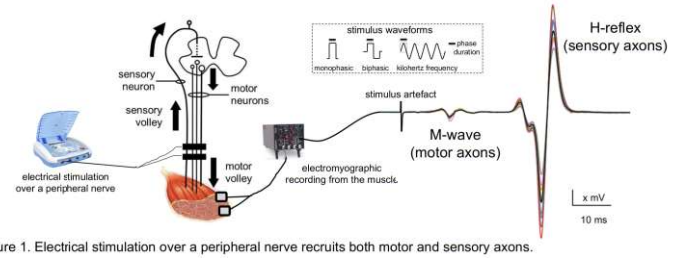

Figure 1. Electrical stimulation over a peripheral nerve recruits both motor and sensory axons.

Motor and sensory axon recruitment can be studied using M-wave/H-reflex recruitment curves (Fig. 2).

Relatively long monophasic pulses (up to 1 ms) preferentially recruit sensory axons, over motor axons. The effect of longer monophasic pulses, or different waveforms has not been studied.

Understanding how phase duration and waveform influence axonal recruitment has implications for reflex studies and rehabilitation.

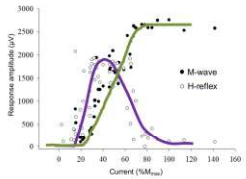

Figure 2. An example M-wave/H-reflex recruitment curve recorded from the soleus muscle.

OBJECTIVE

Assess the influence of stimulus phase duration and waveform on the relative recruitment of sensory and motor axons in the human tibial nerve.

METHODS

- participants (n=20); 8 female, 12 male; 28±9 years; no injury or disease

Figure 3. Representation of participant positioning and electrode and EMG placement.

- seated in a Biodex dynamometer, ankle and knee secured at 90°
- tibial nerve stimulated via electrodes over popliteal fossa
- electromyography recorded from soleus muscle
- stimulation was varied from below threshold required to elicit a response, up to 1.4X the intensity that produced a maximal M-wave (M_{max})

METHODS

M-wave – H-reflex recruitment curves

- recruitment curves were collected using three waveforms (monophasic, biphasic, kilohertz frequency) delivered using each of two phase durations (0.5 ms, 0.1 ms; biphasic pulses were 0.125 ms)
- 1 and 2 ms phases were also tested in the monophasic condition

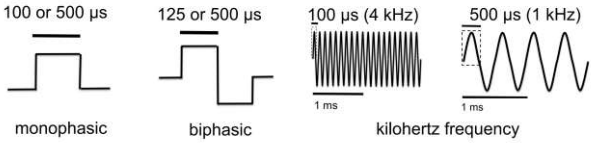

Fig 4. Illustration of the wave forms and phase durations that were studied.

- n=8 recruitment curves per participant, tested in random order
- for each recruitment curve, 40 stimuli were delivered with 8-10 s between pulses while participants remained relaxed

Outcome measures

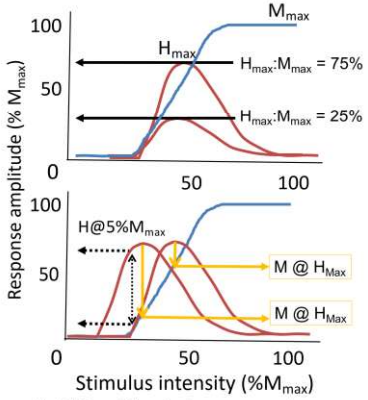

Fig 5. Interpretation of outcomes measured.

- **H_{max}:M_{max} ratio:** a larger H_{max}:M_{max} ratio indicates preferential recruitment of sensory axons.
- **H-reflex size at 5% M_{max}:** a larger H-reflex indicates a leftward shift of the H-reflex curve and preferential recruitment of sensory axons.
- **M-wave size at H_{max}:** a smaller M indicates a leftward shift of the H-reflex curve and preferential recruitment of sensory axons.

RESULTS

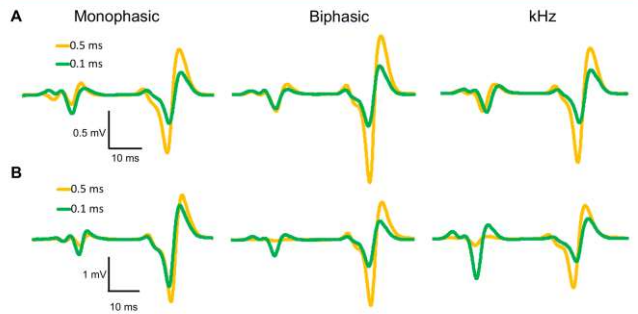

Fig 6. Data from a single subject showing the size of the H-reflex when the M-wave was 5% M_{max} (upper panels) and M-wave size when the H-reflex was maximal (lower panels) for 0.5 ms and 0.1 ms phase durations when using monophasic, biphasic and kHz frequency waveforms.

RESULTS

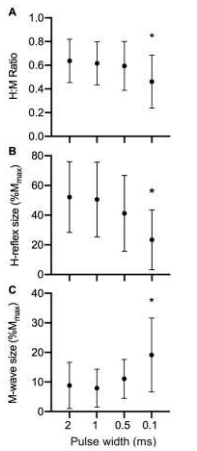

Fig 7. H:M ratio (A), H-reflex size at 5% M_{max} (B) and M-wave size at H_{max} (C) for the 4 monophasic phase durations tested.

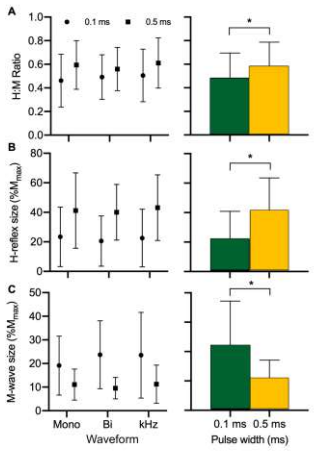

Fig 8. H:M ratio (A), H-reflex size at 5% M_{max} (B) and M-wave size at H_{max} using two phase durations and monophasic, biphasic and KHz waveforms.

CONCLUSIONS

Longer phase durations recruited more sensory axons, relative to motor axons, in the human tibial nerve.

There was no effect of stimulus waveform on motor or sensory axon recruitment when waveforms were matched for phase duration.

Longer phase durations are recommended to maximize the activation of sensory axons for clinical tests, research studies or to generate contractions or modulate neural circuits for rehabilitation.

FUTURE DIRECTIONS

Investigate how phase duration, waveform and stimulation intensity influence contraction fatiguability and corticospinal excitability during neuromuscular electrical stimulation.

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