Stimulus phase duration, ~~not~~ and waveform, influence the variability of responses evoked by stimulation of axons in human peripheral nerve

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Introduction

Electrical stimulation can be used to evoke reflexes for a clinical exam, a research study or to produce contractions for rehabilitation.

Electrical stimulation recruits both motor and sensory axons, producing M-waves and H-reflexes, respectively (Figure 1).

To evoke H-reflexes, a 1 ms phase duration is recommended to preferentially recruit sensory axons and produce larger reflexes.

Whether phase duration or waveform also influences response variability is not presently clear.

High variability may make data collection and interpretation difficult and may increase the number of trials required to achieve sufficient statistical power.

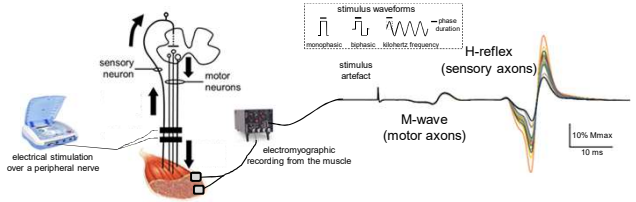
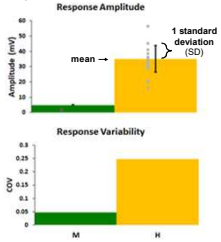


Figure 1A. Electrical stimulation over a mixed peripheral nerve recruits both motor and sensory axons.

1B. Stimulation of motor and sensory axons produces a motor (M) wave and Hoffman (H) reflex, respectively.



1C. Despite constant current stimulation, M-wave and H-reflex amplitudes are variable.

Objective

Characterize the effect of stimulus phase duration and waveform on the variability of responses evoked by stimulation of motor (M-waves) and sensory (H-reflexes) axons in a human peripheral nerve.

Method

PARTICIPANT SET UP

- n = 20 participants; 8 female, 12 male; 28 ± 9 years
- no neuromuscular injury or disease
- seated in a Biodex System 3 Dynamometer (Figure 3)
- ankle and knee secured at 90°
- right tibial nerve stimulated in popliteal fossa (Neurodyn, Ibramed or Digitimer DS7A)
- electromyography recorded from right soleus (Neurolog, Digitimer)

Fig 3. Participant position in the Biodex dynamometer and locations of the stimulating and recording electrodes.

EXPERIMENTAL DESIGN

- two phase durations (0.5ms. 0,1ms) were tested using three waveforms (monophasic, biphasic, KHz) in random order
- 1 and 2 ms phases were also tested using monophasic pulses only
- the maximal M-wave (Mmax) was found with each stimulation type
- twenty stimuli were delivered for each stimulation type at an intensity that produced an M-wave that was ~5% of Mmax
- outcome measures: mean response amplitude and coefficient of variation (COV = SD/mean)

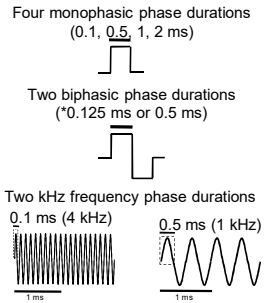


Fig 4. Representation of the 3 waveforms.
*125 µs used for biphasic pulses only

Results

Monophasic pulses: four phase durations
Single subject

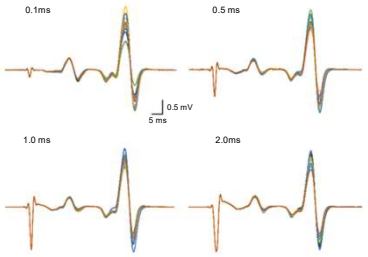
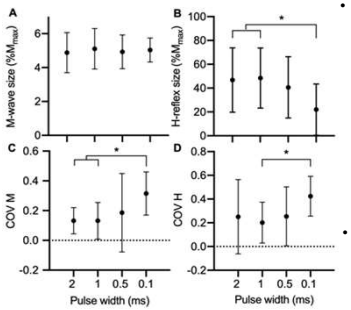


Fig 5. Twenty overlaid EMG traces recorded from a single subject using monophasic pulses delivered with 0.1, 0.5, 1 and 2 ms phase durations.

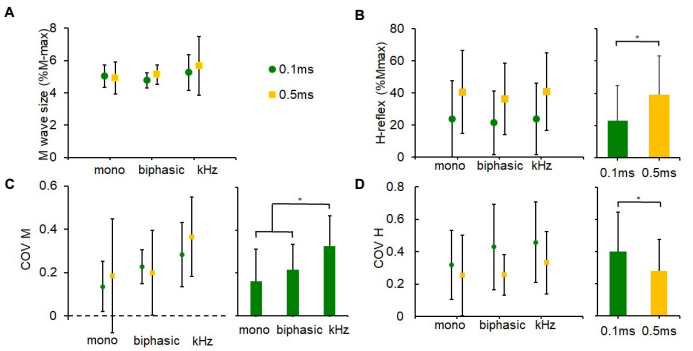
Group data



- when monophasic pulses produced M-waves ~5% M_{max} (A), H-reflexes were larger using 1 and 2 ms pulses than 0.1 ms pulses (B), consistent with recruiting more sensory axons relative to motor axons with wider pulses (see also ISEK 2020 poster by Kelly et al.)
- both M-waves (C) and H-reflexes (D) were most variable when using 0.1 ms pulses.

Fig 6. Mean data for the group for monophasic pulses. Panels A and B show the amplitudes of M-waves and H-reflexes, respectively. Panels C and D show the variability, measured as the coefficient of variation (COV), for M-waves and H-reflexes, respectively. (error bars = 1 SD)

Two phase durations and three waveforms: Group data



- when 2 pulse durations and 3 waveforms produced M-waves ~5% M_{max} (A), H-reflexes were larger using 0.5 than 0.1 ms pulses (B), consistent with recruiting more sensory axons relative to motor axons with larger phase durations.
- M-waves (C) and H-reflexes (D) were more variable when using 0.1 than 0.5 ms pulses.
- there was no effect of waveform on H-reflex amplitude or either M-wave or H-reflex variability when waveforms were matched for phase duration

Fig 7. Mean data for the group when using 2 phase durations and three waveforms. Panels A and B show the amplitudes of M-waves and H-reflexes, respectively. Panels C and D show the variability (COV) for M-waves and H-reflexes, respectively. Bars graphs show the significant main effect of phase duration on H-reflex amplitude (B) and the variability of M-waves (C) and H-reflexes (D). (error bars = 1 SD)

Conclusions

Altering stimulus phase duration (H-reflexes), and waveform (M-waves), influenced the recruitment of axons in the human tibial nerve.

M-waves were most variable when using kilohertz frequency waveforms.

H-reflexes were least variable, and largest, when longer phase durations were used.

Response variability can be decreased, and reflex amplitude increased, using long phase durations, and mono phasic or biphasic waveforms.

Reducing response variability may facilitate the collection and interpretation of clinical tests and experimental data.

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