A COMPARISON OF TORQUE GENERATED BY THE HUMAN PLANTARFLEXOR MUCLES USING FOUR DIFERENT STIMULATION PROTOCOLS

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Background

Neuromuscular electrical stimulation (NMES) can generate contractions through peripheral and central pathways. The central contribution can be augmented when NMES at 20 Hz is interspersed with bursts of stimulation at 100 Hz which leads to the development of increased or "extra" torque. We have shown that extra torque was abolished during a nerve block and was associated with enhanced H-reflexes and electromyographic activity that was "asynchronous" from the stimulus pulses, providing strong evidence that extra torque has a central origin.[1] In contrast, recently when NMES was applied used a slightly different protocol than our previous work, the extra torque that remained after bursts of high-frequency NMES was not abolished during a nerve block, raising doubt about its central origin.[2] Frigon et al. also showed that more extra torque was generated when the stimulated muscles were held in short vs long lengths, an effect they attributed to muscle properties (staircase and/or post tetanic potentiation). However, these authors did not recorded electromyography (EMG) activity, which can be used to access central contribution to the extra torque generation.

Purpose

To compare extra torque generated at two muscle lengths using the protocol used by Frigon et al. (Protocol #1, below)[2] and protocols used previously in our lab (Protocols 2, 3 & 4). Moreover, identify the pathways that contribute to contractions generated by each stimulation protocol.

Hypotheses

1. Larger extra torque when the muscle is shortened.[2]
2. Larger H-reflexes and smaller M-waves during nerve trunk stimulation compared to muscle belly stimulation.[1]
3. The most extra torque will be generated by nerve trunk stimulation and the least by stimulation over the gastrocnemius muscles.

Methods

9 subjects participated in 2 sessions on separate days

✓ Torque: Biodex dynamometer, seated, knee extended (170°-180°)

✓ NMES: 1 ms pulse duration, 3 trains of 20-100-20 Hz for 3-2-3 s, respectively, 60 s apart

✓ Stimulation protocols:

1) anode and cathode over the gastrocnemius muscles[2] (*GG*);
2) cathode over the proximal gastrocnemius muscles, anode over soleus[1](*GS*);
3) anode and cathode over the soleus muscle (*SS*);
4) anode and cathode over the tibial nerve trunk[1](*Nerve*).

✓ All protocols tested with the ankle at 90° and 120°

✓ EMG recorded from soleus as shown on Figure 1.

✓ Maximal evoked twitch torque (MET- ankle at 90°) was used to match torque in the first 3s of stimulation

MET: 5 pulses, 100 Hz, 50 – 100% of stimulator output[1]

10-15% of MET during the first 3s of stimulation

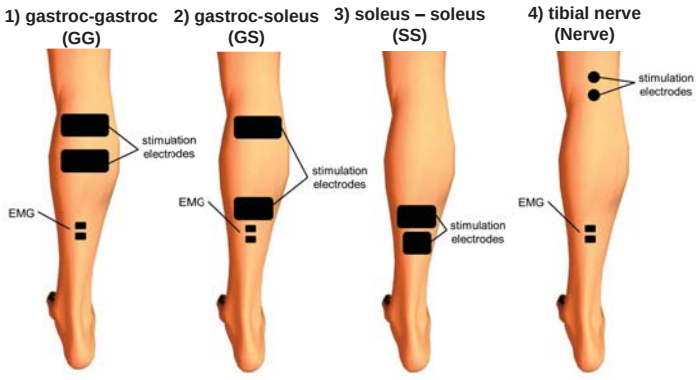


Figure 1. Stimulation and recording sites.

Data Analysis

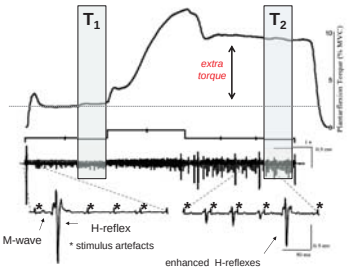


Figure 2. Data analysis. Torque and soleus EMG were quantified before (T_1; 2-3s into the stimulation) and after (T_2; 6–7s into the stimulation) 100 Hz stimulation . M-waves and H-reflexes were measured peak to peak and reported as % M_{max}. Torque is expressed as % of increase from T_1 to T_2. (*Adapted from Klakowicz et al.*[3])

Results

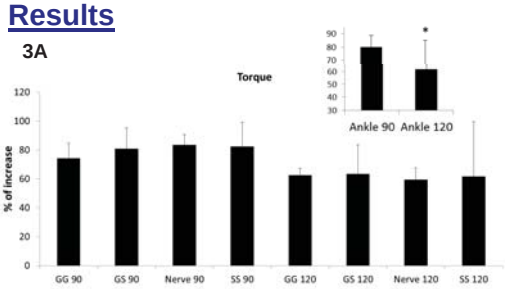
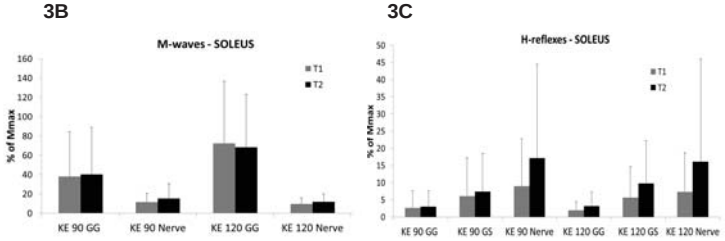


Figure 3. Torque (3A), M-waves (3B) and H-reflexes (3C) mean and standard deviation for the groups. There was a main effect of ankle position on extra torque generation (3A). No significant interactions or main-effects were found for soleus M-waves or H-reflexes. (*$p<0.05$)



Conclusions

1. Frigon et al. (2011) showed more extra torque at short muscle lengths while we showed significantly less extra torque was produced by shortened muscles. The reasons for this discrepancy are unclear.
2. H-reflexes were larger and M-waves smaller during nerve trunk compared to muscle belly stimulation. This result is likely due to a more effective activation of sensory axons during Nerve stimulation.
3. There was no significant effect of stimulation protocol on the amount of extra torque that was generated.
4. There was a trend for the GG stimulation to be driven primarily by peripheral pathways (M-waves) compared to the Nerve stimulation which generated contractions primarily through central pathways (H-reflexes). This increased central contribution induced by Nerve stimulation was not translated into increased extra torque (not supporting the third hypothesis).

Summary

Contrary to Frigon et al., lengthened muscle generated more extra torque than shortened muscle. In general, when torque increased H-reflexes did also, suggesting at least some of the extra torque was due to increased transmission along central pathways.

References

1. Bergquist et al. (2011) Eur J Appl Physiol. 111(10):2409-26.
2. Frigon et al. (2011) Neurosci. 13;31(15):5579-88.
3. Klakowicz et al. (2006) Neurophysiol. 96:1293-1302.

Acknowledgements

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