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Background

Neuromuscular electrical stimulation (NMES) can be applied over a muscle belly or nerve trunk to generate contractions for rehabilitation.

Muscle belly stimulation activates fast-twitch muscle fibers first (reverse to the normal order of activation) inducing higher levels of fatigue.

Nerve stimulation can activate muscles via reflex pathways through the spinal cord back to the muscle, activating the muscle in a more normal order (slow-to-fast) and reducing fatigue.

We can measure which pathway contributes to the contractions using electromyography (EMG, a measure of the electrical activity in muscle).

During NMES two responses can be identified in the EMG signal: the first is the M-wave (Fig 1, in blue), which represents the direct activation of the motor axons beneath the stimulation electrodes; the second is the H-reflex (Fig 1, in green), this represents the activation of sensory axons and contributes to the contraction via reflex pathways (hence the longer latency).

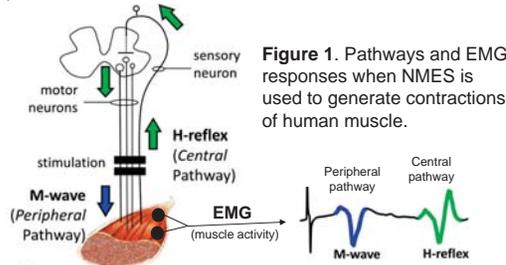


Figure 1. Pathways and EMG responses when NMES is used to generate contractions of human muscle.

Sometimes, when a "burst" of NMES at a higher frequency is delivered during NMES at low frequency, torque remains unexpectedly high after the "burst" (see Fig 2); this is called extra torque. Previous studies³ showed that extra torque is related with a larger activation of reflex pathways. One of the goals of our lab is improve the protocols of NMES increasing the activation of reflex pathways reducing fatigue.

Purpose

To compare extra torque generated in the calf muscles at two ankle positions (flexed and extended) and four stimulation sites (3 over the muscle belly and one over the tibial nerve). Moreover, identify the pathways that contribute to contractions generated by each stimulation protocol.

Hypotheses

1. Larger extra torque when the ankle is extended.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 1 session
- ✓ 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 (Fig 2):
 - 1) over the gastrocnemius muscles² (GG);
 - 2) over the proximal gastrocnemius muscles and over soleus¹(GS);
 - 3) over the soleus muscle (SS);
 - 4) over the tibial nerve trunk¹(Nerve).
 - ✓ All protocols tested with the ankle at 90° and 120°
 - ✓ EMG recorded from soleus as shown on Figure 2.

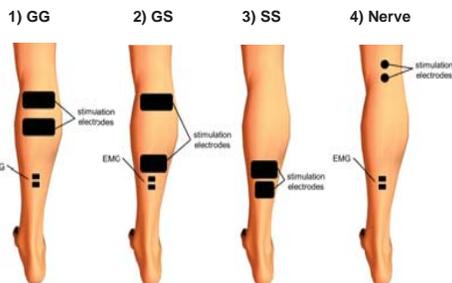


Figure 2. Stimulation and recording sites.

Results

3A

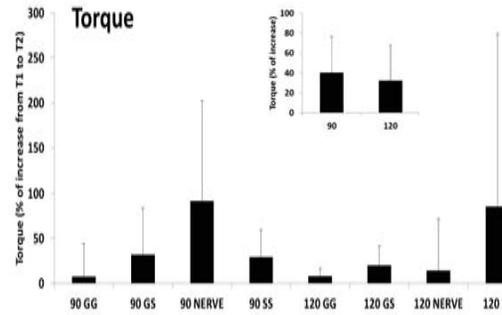
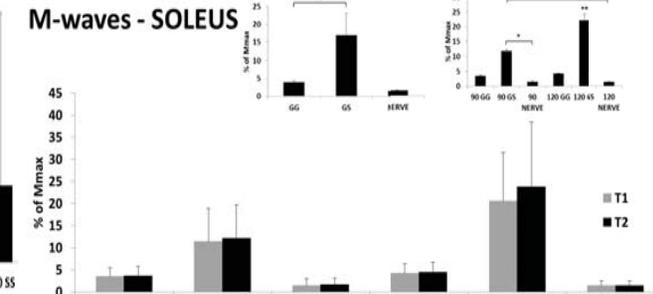


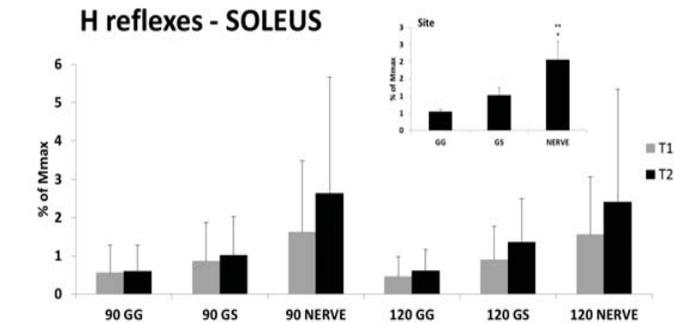
Figure 3. Torque (3A), M-waves (3B) and H-reflexes (3C) mean and standard deviation for the groups. (* difference between 2 groups; ** different from all other groups; $p < 0.05$)

- There was no effect of ankle position on extra torque generation (3A). However, we found a trend for less extra torque when the muscle was shortened.
- Muscle stimulation (mainly GS) generated larger M-waves than Nerve stimulation. Moreover, larger M-waves were found during muscle stimulation and in shortened muscles.
- Nerve stimulation elicited larger H-reflexes than muscle stimulation.

3B



3C



Conclusions

1. We showed more extra torque when the ankle was flexed. This is a result of a longer muscle length in this joint position decreasing the inhibition of antagonist muscles (tibialis anterior).
2. H-reflexes were larger and M-waves smaller during nerve trunk compared to muscle belly stimulation. This 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. Muscle belly stimulation seems 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

When the ankle was flexed the calf muscles generated more extra torque than with the ankle flexed. In general, when torque increased H-reflexes did also, suggesting at least some of the extra torque was due to increased transmission along reflex pathways.

References

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2. Frigon et al. (2011) J Neurosci. 13:31(15):5579-88./
3. Klakowicz et al. (2006) J Neurophysiol. 96:1293-1302.

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