A Novel Form of Neuromuscular Electrical Stimulation to Reduce Discomfort of Electrically-Evoked Contractions

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Background

Neuromuscular electrical stimulation (NMES) evokes contractions through delivery of electrical pulses to electrodes over a muscle belly or nerve trunk.

NMES can reduce muscle atrophy and restore movement for individuals who have had a stroke or a spinal cord injury.

However, contractions **fatigue** rapidly and high stimulation intensities create **discomfort**, both of which **limit the use of NMES in rehabilitation**.

To address these issues, we investigated a novel form of NMES, interleaved NMES (iNMES), in which stimulus pulses are alternated between mNMES and nNMES.

Fatigue: nNMES and mNMES recruit different motor units, thus alternating pulses reduces motor unit discharge rates by half.

Discomfort: Pilot data suggest that to generate contractions of equal amplitude, iNMES requires lower stimulation intensities than either mNMES or nNMES. This may reduce discomfort associated with NMES.

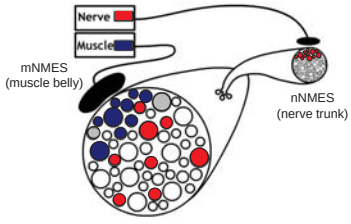

Figure 1. mNMES and nNMES recruit different sets of motor units. mNMES recruits superficial motor units preferentially (●). nNMES recruits motor units evenly throughout the muscle (●). Some motor units are recruited by both nNMES and mNMES (◎).

Purpose

Compare contraction fatigue and discomfort between three types of NMES (mNMES, nNMES and iNMES) applied to generate contractions of the tibialis anterior muscle.

Hypothesis

iNMES will generate contractions with the least fatigue and discomfort, followed by nNMES and mMES, respectively.

Methods

• N = 8 able-bodied participants

• Volunteers participated in three experimental sessions (one per method of stimulation)

• Fatigue protocol: NMES was delivered to generate 250 contractions (2 s on, 2 s off) with an initial amplitude of 10-15% of a maximum voluntary contraction (MVC).

• NMES was applied at 40 Hz. Each pulse had a duration of 50 μs.

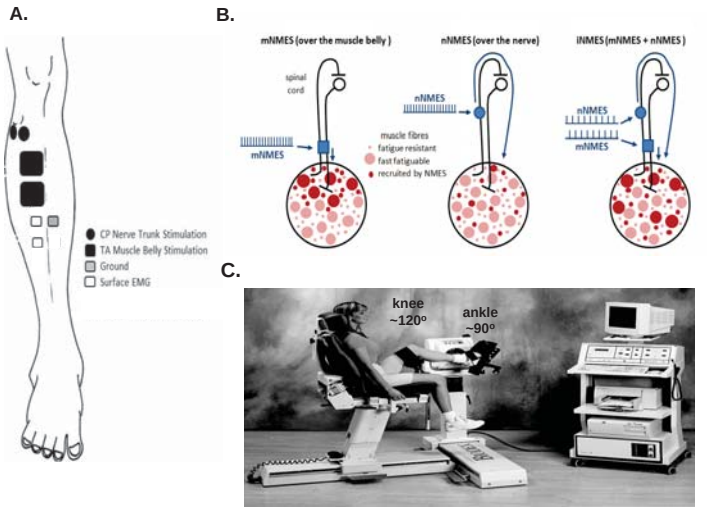

Figure 1. Schematic of experimental set-up. Panel A depicts electrode configuration. During mNMES, stimulating electrodes were placed over TA. During nNMES, stimulating electrodes were placed over the common peroneal (CP) nerve. During iNMES, stimulating electrodes were placed over TA and the CP nerve. During iNMES, the stimulation frequency at each site is half of that during nNMES or mNMES (Panel B). Panel C depicts the configuration of the participant's knee and ankle, when seated in the Biodex dynamometer.

Methods

• Torque was quantified as the mean torque over the middle 1 s of each contraction.

• Torque from every 5 contractions was averaged into 1 bin.

Fatigue was quantified through a fatigue index.

$$\text{Fatigue Index Score} = \frac{\text{Torque of First Bin}}{\text{Torque of Last Bin}} \times 100$$

Discomfort was assessed through a visual analog scale (VAS).
The VAS was a 10 cm scale printed on paper. At the midpoint of the NMES protocol, participants drew a line along the scale to indicate their discomfort levels.

Results

Individual Data

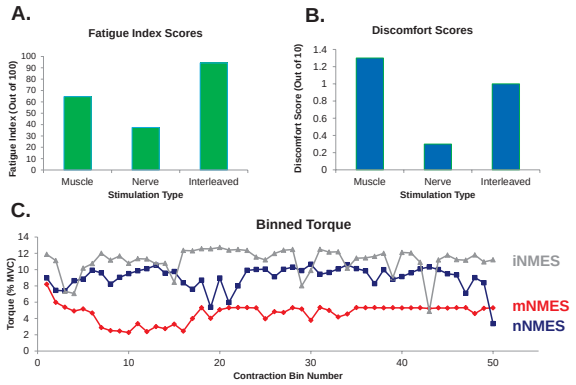

Figure 3. Panel A shows the fatigue index scores associated with mNMES, nNMES, and iNMES for one participant. Panel B depicts discomfort scores associated with stimulation. Panel C shows the binned torque throughout the fatigue protocol.

Group Data

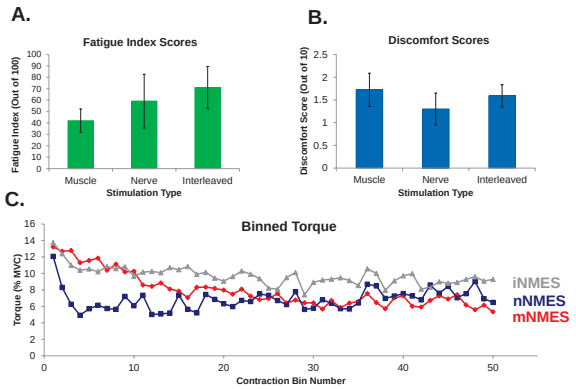

Figure 4. Panels A, B and C depict the fatigue index scores, discomfort scores and binned torque respectively for mNMES, nNMES, and iNMES. Standard error bars are shown in Panels A and B.

Conclusion

There were no significant differences in fatigue index or discomfort scores between protocols (p>0.05).

Although iNMES appears to generate contractions that fatigue less, more data need to be collected to determine if this trend is significant.

Identifying NMES protocols that produce the most fatigue-resistant contractions with the least discomfort will help to increase participation in NMES- based rehabilitation programs and maximise its benefits. .

Reference

Okuma, Y., Bergquist, A. J., Hong, M., Chan, K. M., & Collins, D. F. (2013). Electrical stimulation site influences the spatial distribution of motor units recruited in tibialis anterior. *Clinical Neurophysiology : Official Journal of the International Federation of Clinical Neurophysiology, 124*(11), 2257-2263.

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