Amplifying Electrically-Evoked Contractions: Two techniques, one goal

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INTRODUCTION

Neuromuscular Electrical Stimulation (NMES)

Pulses of electrical stimulation delivered through the skin over a muscle or nerve can generate muscle contractions for individuals experiencing paralysis.

Figure 1: NMES-assisted exercise. NMES can help participants participate in exercise programs (cycling image from Restorative Therapies) (https://restorative-therapies.com/flex-systems/rt300-leg-core/)

Transcutaneous Spinal Cord Stimulation (tSCS)

Pulses of electrical stimulation delivered through the skin over the spinal cord can help restore movement for people experiencing paralysis after a spinal cord injury.

For people with a spinal cord injury, this can improve voluntary movement in a single session, and, with repeated sessions, voluntary movement remains improved even when the tSCS is off.

We know that tSCS can increase the size of voluntary contractions, but the present experiments address if it can do the same for electrically-evoked contractions.

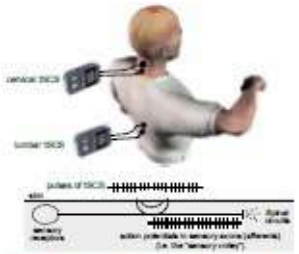


Figure 2: Transcutaneous spinal cord stimulation (tSCS) can be delivered over the parts of the spinal cord that control the arms (cervical) or legs (lumbar).

HYPOTHESIS AND RATIONALE

Aim: Determine whether delivering *NMES and tSCS together* produces contractions that are *"better"* for rehabilitation than those produced by *NMES* alone.

Hypotheses: **(a)** *NMES + tSCS* will produce larger H-reflexes than *NMES* alone.
(b) H-reflexes during NMES + tSCS will get bigger as tSCS intensity gets higher.

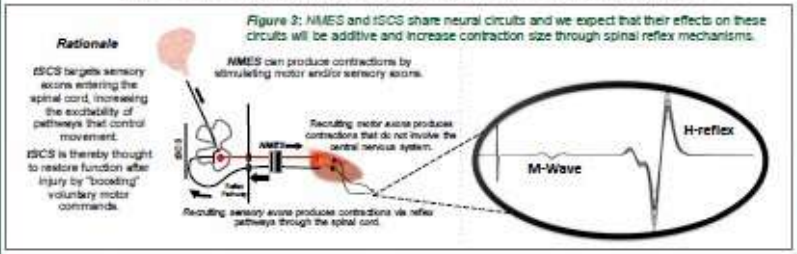


Figure 3: *NMES* and *tSCS* share neural circuits and we expect that their effects on these circuits will be additive and increase contraction size through spinal reflex mechanisms.

Rationale: We propose that tSCS "boosts" NMES-evoked contractions by increasing the excitability of spinal reflex pathways and thereby increasing the "reflexive" contribution to contractions produced by NMES.

Predictions

1. H-reflexes will be larger immediately after tSCS is turned "on" compared to when tSCS is "off".
2. H-reflexes during NMES contractions will be larger when tSCS is "on" compared to when tSCS is "off".
3. H-reflexes will increase as tSCS intensity increases.

METHODS

Participants: Nine participants (ages 20-60, 2 women) with no history of neuromuscular injury or disease took part in a single 2–3-hour session. The size of H-reflexes was measured using electromyography and compared between control and test trials.

Protocol: Experiments were conducted in sets of control-test pairs.
Control = NMES only Test = NMES + tSCS

A. Control trials (*NMES only*): 5 single NMES pulses, then 5 NMES contractions (20Hz; 7s "on"/10s "off")

B. Test trials (*NMES + tSCS*): 5 single NMES pulses, turn tSCS "on" (30Hz), 5 single NMES pulses, then 5 NMES contractions (20Hz; 7s "on"/10s "off")

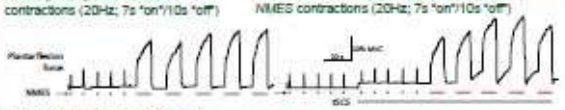


Figure 4: Experimental Protocol.
(A) Shows the protocol for control trials. (B) Shows the protocol for the test trials.

NMES electrodes are placed on the skin behind the knee to stimulate the tibial nerve and cause plantarflexion (i.e., gas pedal motion) contractions.

Electromyography (EMG) electrodes are placed over the soleus (calf muscle) of the right leg.

Figure 5: An exemplary participant sitting in the Biodex dynamometer.

tSCS
Test trials - tSCS is turned "on" continuously for ~3 minutes (30Hz) while NMES produces 5 single twitches followed by 5 contractions.

tSCS intensities:
- *Low* (0.7x Reflex Threshold)
- *Medium* (1.0x Reflex Threshold)
- *High* (1.3x Reflex Threshold).
- Maximum Tolerable

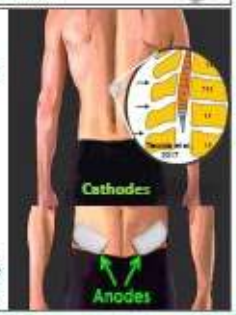


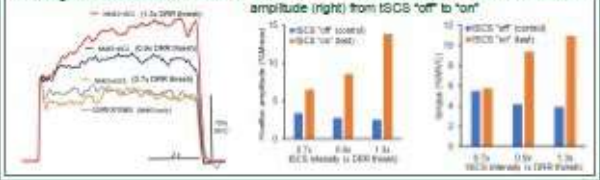
Figure 6: tSCS Electrode Configuration. Single active electrode (cathode) placed at T11/12 or T12/L1 levels of the spinal cord and return electrodes (anodes) are placed over the iliac crests (hips). (from Barss et al., *J. Clin Med* 2022)

PRELIMINARY RESULTS
no carrier (n = 4)

Figure 7: Preliminary data (n=4). Data collected applying tSCS without modifying the waveform, and applying it relative to its own threshold, before discovering that this resulted in a much higher relative intensity of stimulation than what others in the field were doing.

A. Average force traces for an individual

B. Group average H-reflex amplitude (left) and contraction amplitude (right) from tSCS "off" to "on"



SINGLE PARTICIPANT RESULTS
(with 10kHz carrier)

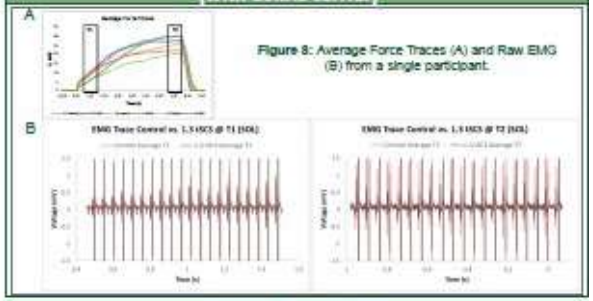
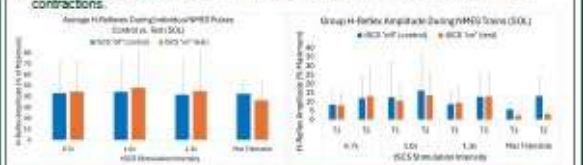


Figure 8: Average Force Traces (A) and Raw EMG (B) from a single participant.

GROUP RESULTS
(with 10kHz carrier)

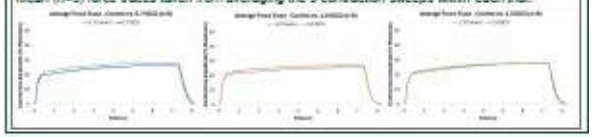
Figure 9: Average M-wave and H-reflex amplitudes during pulses and contractions.
(A) Average H-reflex amplitude across 9 participants (n=4 for maximum tolerable) for each condition's individual control and test pulses.
(B) Compares the average H-reflex amplitude for each condition's control and test NMES contractions.



A. Average H-reflex amplitude during single NMES pulses with tSCS "off" vs. "on".

B. Average H-reflex amplitude during NMES contractions with tSCS "off" vs "on".

Figure 10: Group Average Force Traces.
Mean (n=9) force traces taken from averaging the 5 contraction sweeps within each trial.



CONCLUSIONS & IMPLICATIONS

SUMMARY

1. Early data demonstrated increases in H-reflex amplitude and contraction size when tSCS was turned "on" compared to "off".
2. When the hypothesis is tested using more "standard" protocols for setting tSCS intensity, the effect seems to disappear.

CONCLUSION

tSCS may increase the size of H-reflexes and contractions, but perhaps only at higher relative intensities.

POTENTIAL IMPLICATIONS

The ability to "boost" H-reflex amplitude with tSCS would:

- Increase the "central contribution" to NMES contractions, making them larger and less fatigable.
- Contribute to the ability to engage in longer and more efficient exercise for individuals with spinal cord injury.

CURRENT STATUS

Data collection is ongoing.

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