The effects of transcutaneous spinal cord stimulation on torque produced during functional electrical stimulation

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INTRODUCTION

Functional Electrical Stimulation (FES)

Functional electrical stimulation (FES) involves the delivery of electrical pulses through the skin over a muscle or nerve via electrodes to generate muscle contractions.

FES is commonly used in a rehabilitation context for individuals experiencing paralysis or living with a spinal cord injury (SCI). This can be helpful with exercise or activities of daily living (ADL) and is often referred to as FES.

Figure 1: FES-assisted exercise can help participants with exercise programs. (Tajali et al., 2022)

Transcutaneous Spinal Cord Stimulation (tSCS)

Transcutaneous spinal cord stimulation (tSCS) entails the delivery of electrical pulses on the skin of the back over the spinal cord and aids in restoring movement to individuals that experience paralysis after an SCI.

The efficacy of tSCS is based on the excitation of spinal pathways, activating incoming sensory nerves as they reach the spinal cord and "boosting" weakened signals from the brain along descending pathways to generate movement.

tSCS can improve voluntary movement for individuals with paralysis or SCIs after just one session, with improvements remaining after multiple sessions. tSCS produces a quantifiable response in the lower extremity muscles, namely the soleus, however standardized terminology for this response remains unresolved.

HYPOTHESIS & RATIONALE

Aim: Assess whether delivering tSCS and FES together produces larger contractions than delivering FES on its own.

Hypothesis: tSCS + FES will produce larger contractions than FES alone, with torque increasing with stimulation intensity.

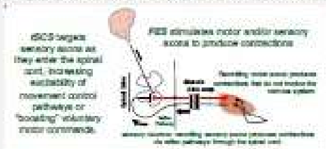


Figure 2: FES and tSCS share neural circuits and we expect them to be better together, adding to contraction amplitude (McConnell, 2023).

Rationale: If tSCS boosts voluntary contractions by increasing spinal circuit excitability, then tSCS will also boost voluntary contractions on the reflex pathway during FES.

METHODS

Participants

Nine participants (ages 23-59, 2 females), with no history of neuromuscular injury or disease participated in a single 2-3 hour session. Plantarflexion torque (ie. contraction amplitude) was measured during FES alone and FES + tSCS.

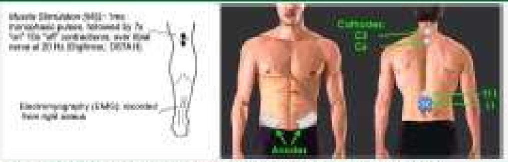


Figure 3: Electrode Placement for Muscle Stimulation (or FES) and Spinal Stimulation (or tSCS).
For FES, electrodes are placed behind the knee to target the tibial nerve. For tSCS, active electrodes (cathodes) were placed at T11/L1 levels and return electrodes (anodes) were placed over the iliac crests. Electromyography (EMG) was recorded from soleus, tibialis anterior, and medial & lateral gastrocnemius of the right leg.

Figure 4: Example participant sitting in the Biodex dynamometer.

Protocol

Experiments conducted in pairs of control (FES) & test (FES + tSCS) trials, with each trial containing 5 contractions.

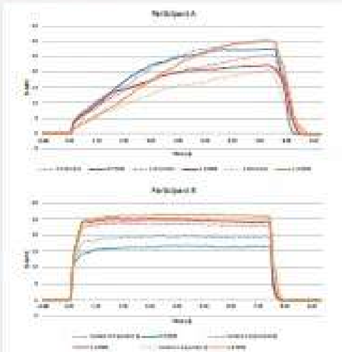
FES delivered via electrodes positioned to stimulate the tibial nerve, located behind the knee to elicit **plantarflexion contractions**, which were measured with a Biodex System III dynamometer. Groups of 5 contractions that ran 7s "ON" & 10s "OFF" were delivered by stim at 20Hz. Intensity of stimulation determined by M-H recruitment curve.

tSCS delivered through electrodes placed approximately in an intervertebral space between T11 & L1 and was on for ~2 min at 3 different intensities relative to reflex threshold (low=0.7x, medium=1.0x, high=1.3x) while FES delivered stimulation to produce 5 contractions. tSCS was delivered at 30Hz using a 10kHz modulated 1ms biphasic waveform.

RESULTS

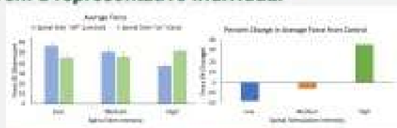
Figure 5: Individual force data

1.0x & 1.3x thresholds of tSCS have higher amplitude contractions with tSCS on vs control compared to the 0.7x threshold, however trends were not consistent among participants.



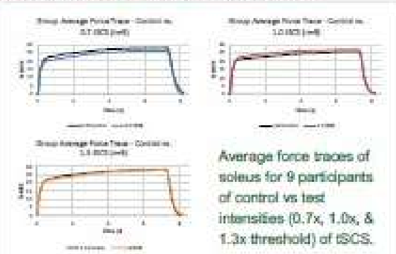
RESULTS

Figure 6: Mean force data & percent change from a representative individual



Left: Average force (% maximum) during control and test trials at each intensity.
Right: High intensity (1.3x threshold) tSCS saw a larger increase in average force, medium (1.0x threshold) & low (0.7x threshold) saw slight decreases when compared to controls.

Figure 7: Group average force traces



Average force traces of soleus for 9 participants of control vs test intensities (0.7x, 1.0x, & 1.3x threshold) of tSCS.

CONCLUSIONS & IMPLICATIONS

Summary

1. tSCS had no consistent increased effect on the amplitude of muscle contractions
2. Low intensity tSCS may decrease contraction amplitude, while higher tSCS had minimal effect on "boosting" contraction amplitude when compared to control contractions

Conclusion

tSCS appeared to have little effect on contraction amplitude and was inconsistent with the intensity of the stimulation. Data collection is still ongoing.

Potential Implications

Bidirectional modulation of spinal excitability may be possible if this trend holds true in a larger, properly powered sample.

- Higher intensity tSCS could generate larger contractions, and may be beneficial for muscle strengthening
- Subthreshold intensity decreased contraction amplitude compared to control, which could help reduce spasticity after an SCI

Limitations include comfortability and tolerability with stimulation.

Future Directions

Future studies could explore the following:

- Do the effects of tSCS on contraction amplitude and torque require a longer duration of "ON" time?
- Could timing of FES & tSCS delivery as signals arrive at the spinal cord impact contraction amplitude?

REFERENCES

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