Spinal direct current stimulation enhances vertical jump power in healthy adults.

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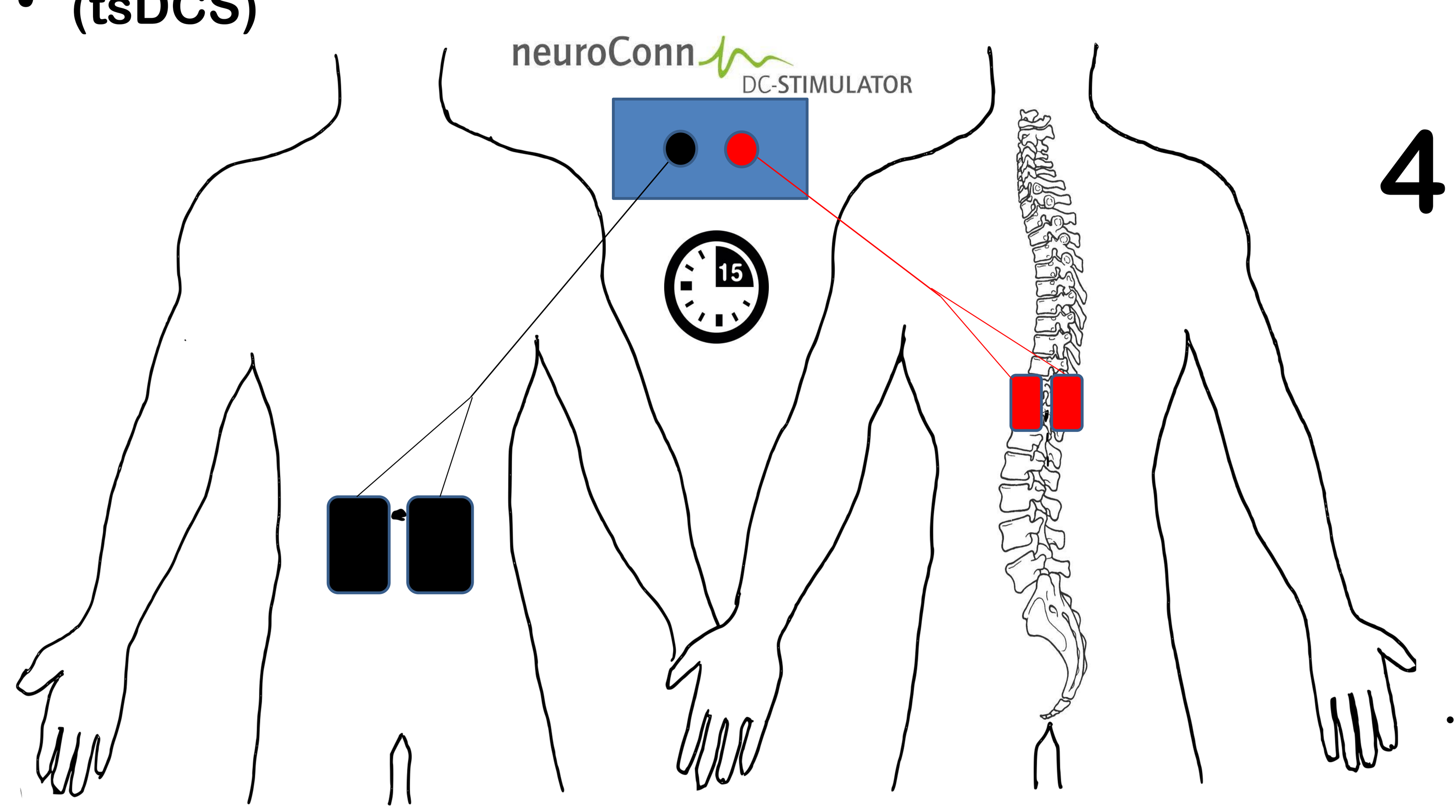
Introduction

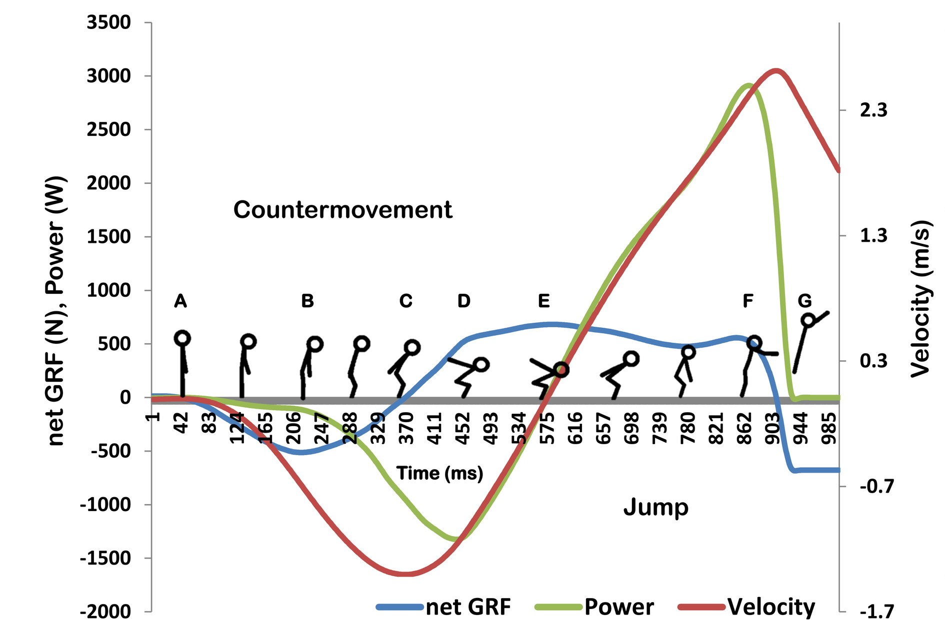
- Transcutaneous spinal direct current stimulation (tsDCS) is a simple, non-invasive tool that affects sensory, motor and pain conducting spinal circuits by modulating neural pathways and segmental reflex activity.
- Effects persist after stimulation in a dosage dependent manner and these effects depend on polarity: anodal DCS increases the excitability of the underlying neural structures, whereas cathodal DCS decreases it.
- tsDCS is considered safe, with no adverse events or tissue damage reported in the literature (1).
- To date, tsDCS research has focused on neurophysiological outcomes including; spinal reflex behaviours (2,3), somatosensory pathway conduction (4) and motor unit recruitment (5).
- The spinal cord is the final common pathway for all motor behaviours: locomotor spinal reflex circuits adjust via ascending and descending CNS inputs to modulate and produce appropriate motor behaviour i.e. standing, running, walking or jumping (6).
- This bi-directional activity also determines the long term neuromotor adaptations associated with motor skill acquisition, sport and athletic training and the impact of CNS trauma and rehabilitation.
- It is not known whether tsDCS delivered over the lumbosacral cord has any effect on gross motor power
- In this unique study, we investigated the immediate and short term influence (up to 3 hours) of 15 min of sham and active anodal tsDCS on explosive vertical countermovement jump (VCJ) power and posterior root-muscle (PRM) lower limb reflexes (7) in healthy individuals.
- We aimed to induce short term neuroplasticity in the lumbosacral cord that would influence VCJ power production and PRM reflex excitability.
- tsDCS modulation of spinal locomotor reflex circuits in the absence of any physical activity may have potential for rehabilitation where mobility is limited or absent, for example, after sporting or combat injury, or for neuro-modulation in patients with brain or spinal cord injury.

1 Transcutaneous spinal direct current stimulation (tsDCS)



subject supine on couch
Anodal tsDCS current: 2.5 mA
Current density: 0.083 mA/cm²
Total charge applied 0.075 C/cm²

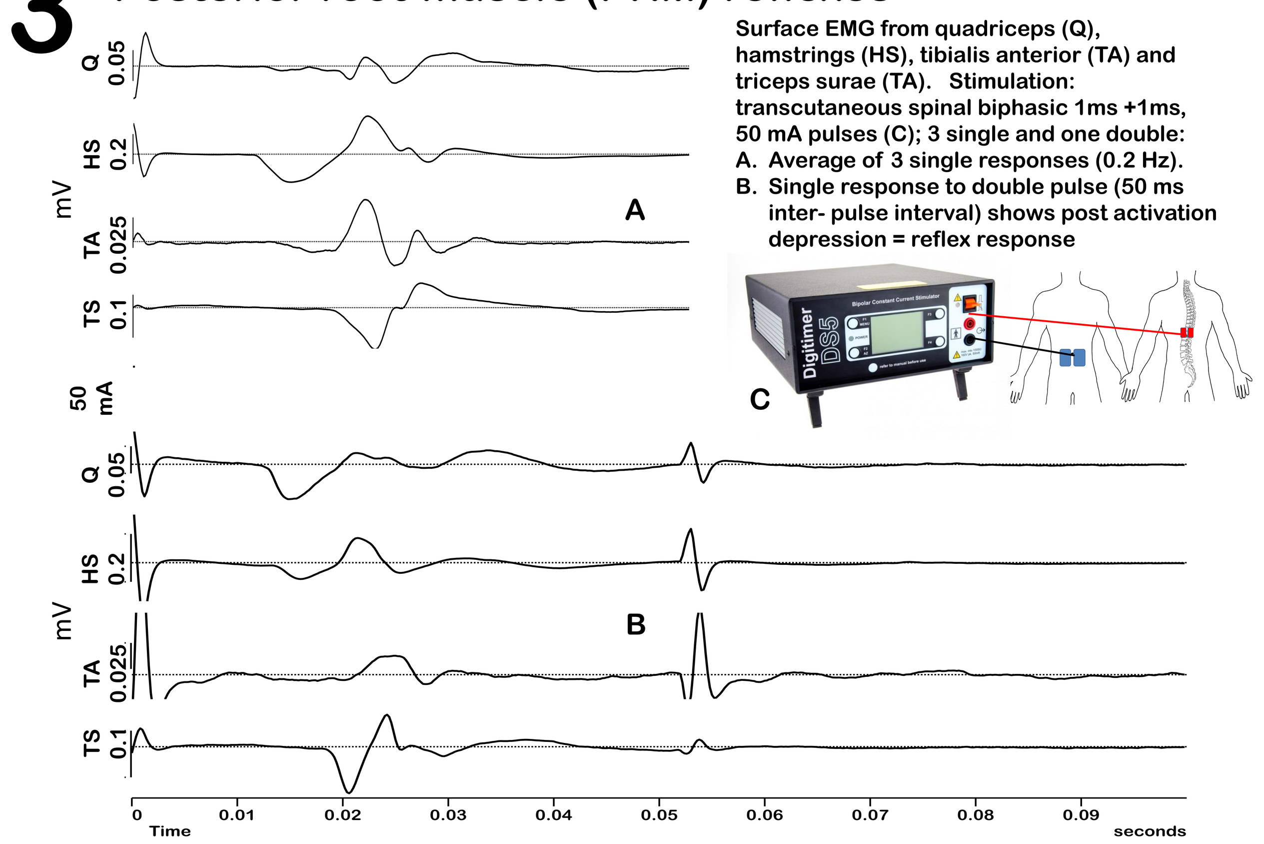
2 Vertical countermovement jump (VCJ)



A. Initial drop: accelerating downwards
B. Max unweighting: braking starts (eccentric muscle activation)
C. Return to bodyweight: maximum downward velocity reached
D. Peak eccentric power: decelerating
E. Amortisation: velocity zero, lowest centre of mass.
F. Peak concentric power
G. Take off

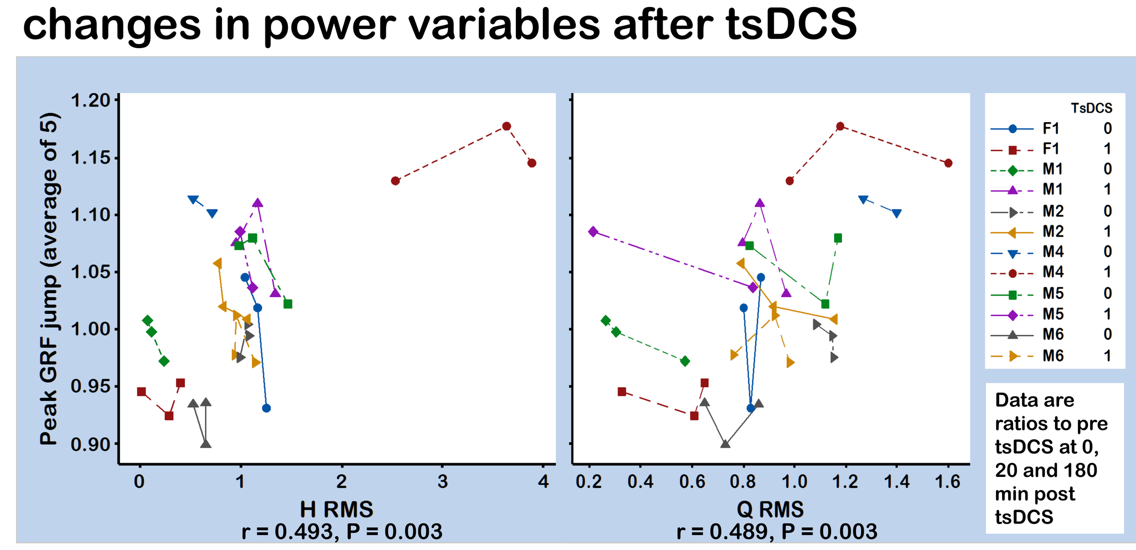
After a warm up stepping on/off a low stepper, 12 healthy adults (2 female) aged mean (SD) 29 (11), BMI 23 (2) completed 5 maximal effort VCJs with 20 s rest between efforts. This was repeated 0, 20, 60 and 180 min after each double-blinded sham and active tsDCS treatment (minimum of one week apart). Impulse, velocity and power were calculated from net ground reaction force (GRF) and work calculated as the area under the power curve. All power data were analysed as a ratios to pre tsDCS values using a GLM (Minitab 17) .

3 Posterior root-muscle (PRM) reflexes



Surface EMG from quadriceps (Q), hamstrings (HS), tibialis anterior (TA) and triceps surae (TA). Stimulation: transcutaneous spinal biphasic 1ms +1ms, 50 mA pulses (C); 3 single and one double:
A. Average of 3 single responses (0.2 Hz).
B. Single response to double pulse (50 ms inter- pulse interval) shows post activation depression = reflex response

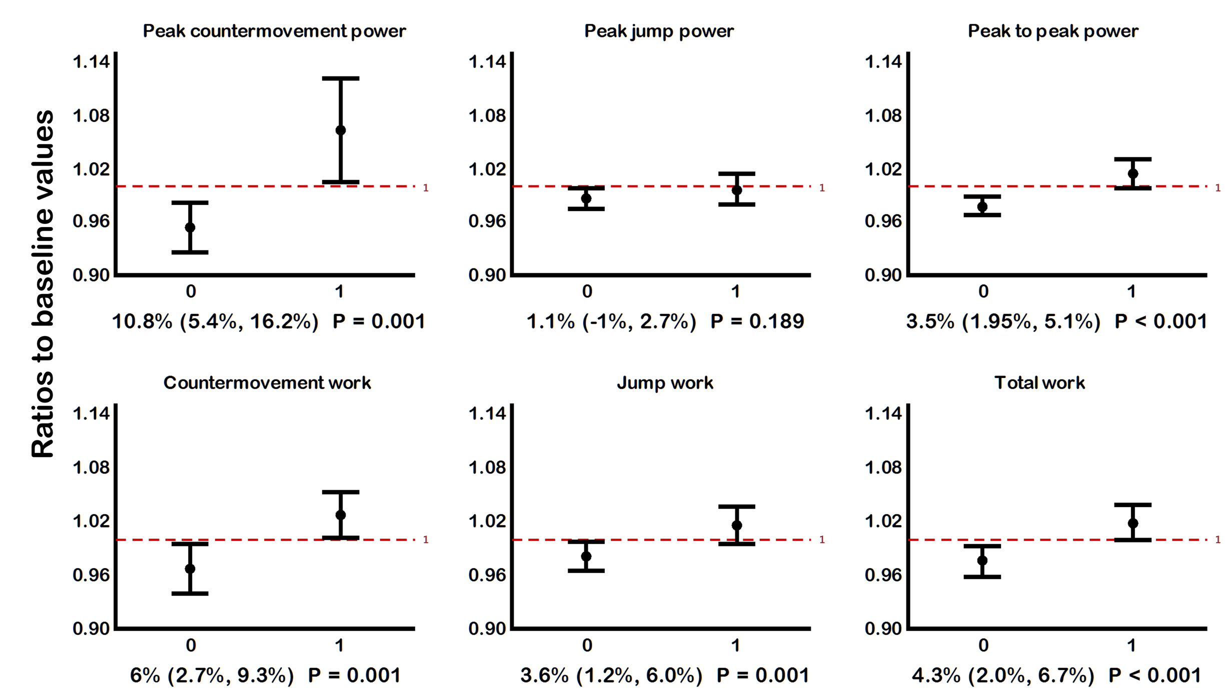
4 Changes in PRM reflex RMS moderately correlated to changes in power variables after tsDCS



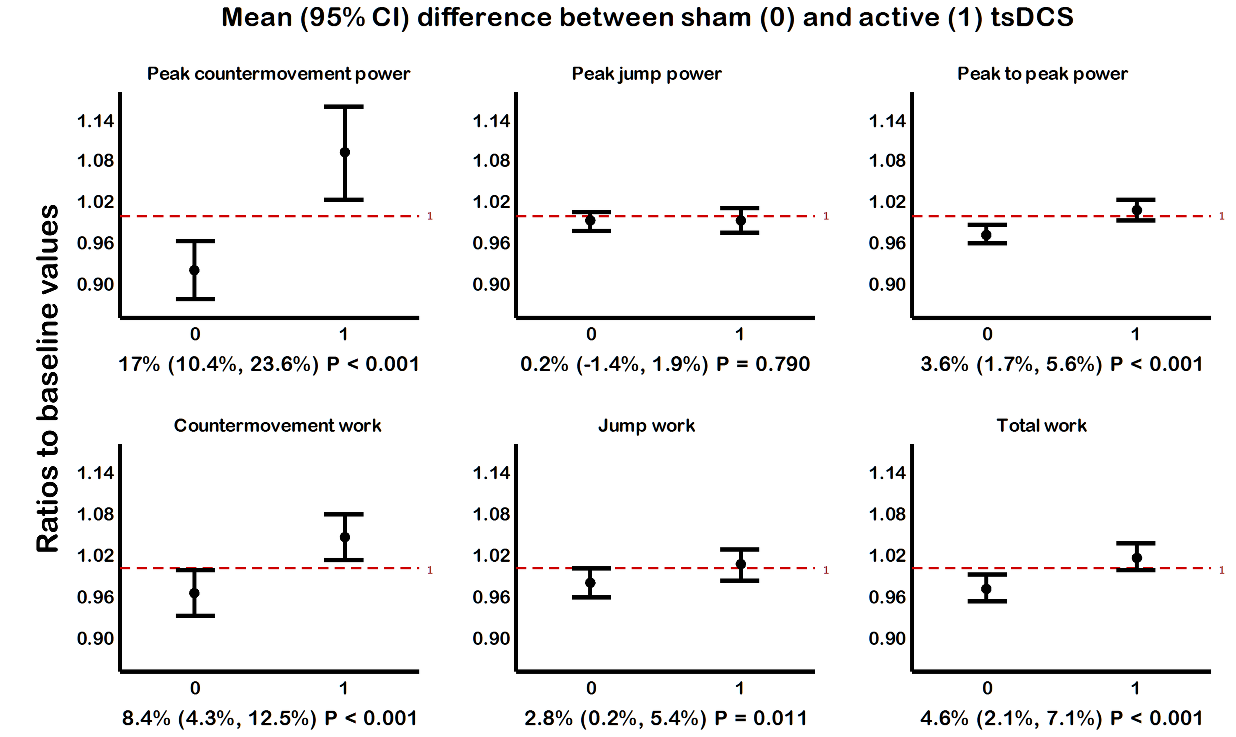
- Changes in hamstring (H) and quadriceps (Q) PRM reflexes were moderately correlated with changes in peak GRF (shown above) and: amortisation GRF (r = 0.421, P = 0.013 and r = 0.349, P = 0.044 respectively).
- Changes in H PRM RMS were also correlated with changes in CM velocity and power (r = 0.353, P = 0.041 and r = 0.390, P = 0.023 respectively).
- Changes appear to be due to alterations in force potentiation mechanisms, demonstrated by excitability changes in reflex circuitry after sham and active tsDCS.

5 tsDCS-induced fatigue resistance and enhancement of VCJ power

Average of 5 jumps
Mean (95% CI) difference between sham (0) and active (1) tsDCS



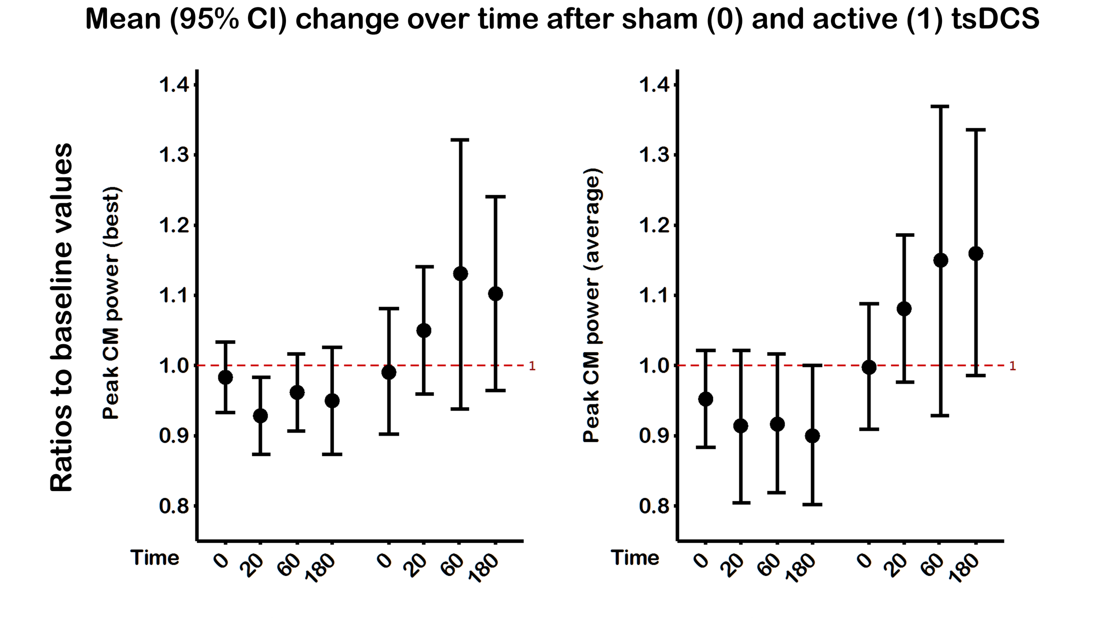
Best of 5 jumps
Mean (95% CI) difference between sham (0) and active (1) tsDCS



- Anodal tsDCS maintained and/or enhanced VCJ work and power output.
- Sham tsDCS maintained best peak jump power, but resulted in fatigue in all other variables..

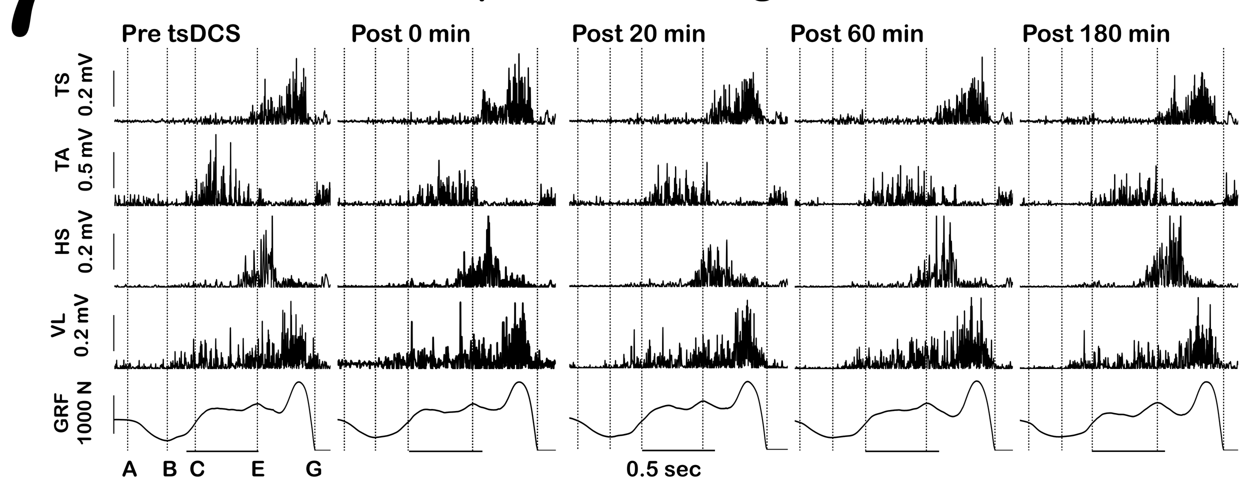
6 No return to baseline values at any time post tsDCS

Mean (95% CI) change over time after sham (0) and active (1) tsDCS



- The significant difference between sham tsDCS fatigue and the tsDCS power/work enhancement persisted without decrement over the 3 hours
- The difference in countermovement (CM) power changes from 0 to 180 min post tsDCS were not significant: best, P = 0.685, and average, P = 0.491.
- The duration of tsDCS effect beyond the three hour test point is not known.

7 Post hoc: EMG responses during VCJ



Rectified EMG (right leg) and total ground reaction force (GRF) responses during one VCJ at pre and 0, 20, 60 and 180 min post active tsDCS. Data gathered post hoc from subject M1. Triceps surae (TS), tibialis anterior (TA), hamstrings (HS), vastus lateralis (VL). Jump phases are as described in VCJ panel.

- Pre tsDCS, the most active muscles during the eccentric phases were TA and VL. The most active during the concentric phase were TS and VL (figures in red).
- Changes in muscle activity and activation pattern post tsDCS led to increased eccentric power and VCJ work.

pre tsDCS to post 180

iEMG % change	Eccentric B - C	C – E	Concentric E – G
TS	121	92	96
TA	87	74	126
HS	108	101	151
VL	71	76	99

Conclusions

- We have shown for the first time that anodal tsDCS counters the fatigue normally associated with repeated maximal VCJ performance.
- We have shown for the first time that tsDCS increases peak eccentric (braking) power and VCJ work.
- The effects of tsDCS last for at least 3 hours without decrement.
- The magnitude of response to tsDCS varies from person to person.
- tsDCS is simple, non-invasive, comfortable, low cost and easy to administer.
- tsDCS-induced fatigue resistance and enhancement of motor power and work in the absence of any physical training has very important implications for rehabilitation after central nervous system injury

Further work

Our laboratory is now investigating the effect of anodal tsDCS on EMG, torque and power production in isolated joint movements. We are also investigating the EMG responses during VCJ in more subjects. We are also investigating genetic factors that may explain the variation in response to tsDCS between subjects.

References

1. Hubli M, Dietz V, Schrafl-Altermatt M, and Bolliger M. Modulation of spinal neuronal excitability by spinal direct currents and locomotion after spinal cord injury. Clinical Neurophysiology 124: 1187-1195, 2013.
2. Winkler T, Hering P, and Straube A. Spinal DC stimulation in humans modulates post-activation depression of the H-reflex depending on current polarity. Clinical neurophysiology : official journal of the International Federation of Clinical Neurophysiology 121: 957-961, 2010.
3. Cogiamanian F, Vergari M, Pulecchi F, Marceglia S, and Priori A. Effect of spinal transcutaneous direct current stimulation on somatosensory evoked potentials in humans. Clinical neurophysiology: official journal of the International Federation of Clinical Neurophysiology 119: 2636-2640, 2008.
4. Bocci T, Vannini B, Torzini A, Mazzatenta A, Vergari M, Cogiamanian F, Priori A, and Sartucci F. Cathodal transcutaneous spinal direct current stimulation (tsDCS) improves motor unit recruitment in healthy subjects. Neuroscience letters 578: 75-79, 2014.
5. Cogiamanian F, Ardolino G, Vergari M, Ferrucci R, Ciocca M, Scelzo E, Barbieri S, and Priori A. Transcutaneous spinal direct current stimulation. Frontiers in psychiatry 3: 63, 2012.
6. Wolpaw JR. What Can the Spinal Cord Teach Us about Learning and Memory? The Neuroscientist : a review journal bringing neurobiology, neurology and psychiatry 16: 532-549, 2010.
7. Minassian K, Persy I, Rattay F, Dimitrijevic MR, Hofer C, and Kern H. Posterior root-muscle reflexes elicited by transcutaneous stimulation of the human lumbosacral cord. Muscle & Nerve 35: 327-336, 2007.

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