6 MUST-READ, PEER-REVIEWED TDCS STUDIES

tDCS research has exploded in the past 15 years. These studies reveal why.
tDCS studies summarized in this booklet

1. How does tDCS work?  
   *Nitsche et al. 2015*

2. tDCS increases max muscle contraction  
   *Hazime et al. 2017*

3. tDCS improves performance on a balance task  
   *Kaminski et al. 2016*

4. tDCS accelerates fine motor skill acquisition  
   *Waters-Metenier et al. 2014*

5. tDCS increases cycling endurance  
   *Vitor-Costa et al. 2015*

6. tDCS decreases muscle fatigue  
   *Cogiamanian et al. 2007*
How does tDCS work?

Nitsche et al. 2015

What is Transcranial Direct Current Stimulation (tDCS)?
A non-invasive way of modulating brain excitability and activity by applying continuous electric current to areas of the scalp overlaying specific parts of the brain.

Short-Term Effects of tDCS

tDCS works by depolarizing neurons, bringing their membrane potential closer to the threshold for an action potential. In lay terms, this means that tDCS helps neurons in the stimulated brain regions fire more easily.

Long-Term Effects of tDCS

By depolarizing neurons, or allowing them to fire more easily, tDCS improves neuroplasticity. When paired with training, tDCS allows the brain to more efficiently create, strengthen, and organize neuronal connections — this is the process of learning, just faster.

The Specifics

tDCS induces plasticity by increasing calcium influx, upregulating the excitatory glutamate system. tDCS also decreases inhibitory GABA levels, which usually oppose this glutamatergic plasticity. The resulting finding for Nitsche and colleagues is that tDCS allows the brain to optimize itself more quickly, which neuroscientists describe as “hyperplasticity.”
tDCS increases max muscle contraction by 10-20%
Hazime et al. 2017

Background
In the past two decades, medical researchers have seen promising results with tDCS. But can the technique be used on the motor cortex to increase muscle strength in younger athletes? Hazime and colleagues find out.

Details
8 female handball players ages 17-21 with ~7 years of experience were randomly split into 2 testing groups. One group received tDCS and the other received placebo tDCS, which feels like the real thing but does not have an effect on brain plasticity. The researchers tested max shoulder rotator muscle contraction before, during, and both 30 and 60 minutes after stimulation. The following week, the real and placebo stimulation groups switched, and max contraction was assessed once again.

Results
Athletes improved their strength by 10-20% during real tDCS, and they retained these gains 30 and 60 minutes after stimulation. In comparison, there was no performance difference with placebo stimulation. This means pairing neurostimulation with training leads to more rapid development of strength.
tDCS improves performance on a balance task

Kaminski et al. 2016

Background
Several studies show that tDCS over the motor cortex increases motor skill acquisition, but previous research focused primarily on skills involving the hands. To round out the scientific literature, Kaminski explored the effect of tDCS on balance when applied to leg-specific regions of the motor cortex.

Details
26 young adults were tested on a dynamic balancing task (think balance board!) while they received real or placebo tDCS. They were also tested the following day without any stimulation to determine if tDCS has a longer-lasting impact on motor skill consolidation.

Results
Those who received tDCS were significantly better at the balance task when compared to the control group, and their improvement was still evident the following day when both groups trained equally without stimulation. Essentially, the same amount of training was more effective when completed with tDCS. In the figure, notice that those who received tDCS (green line) while performing the task were able to balance for much longer than those who did not (grey line). That skill differential only widened the following day — even without additional applications of tDCS.

Figure 2. Adapted from Kaminski et al. 2016. Improvement of balance ability with training and tDCS. The real stimulation group improved significantly faster than the sham group on training Day 1 and maintained that difference on Day 2. The initial shaded period of Day 1 represents the stimulation period, while the error bars represent standard deviation.
tDCS accelerates fine motor skill acquisition

Waters-Metenier et al. 2014

Background

tDCS over the motor cortex has been shown to increase strength and muscular endurance, but can it also improve fine motor skill development?

Details

52 right-handed adults were randomly split into two groups: tDCS and placebo tDCS. All participants spent four days learning to produce difficult piano chords. Waters-Metenier and her team assessed their performance across various measures (force, time) before and after training. Training consisted of learning different piano chords with one hand, but the tests measured performance in both hands.

Results

Compared to the placebo group, the tDCS group demonstrated more speed and accuracy both during and after the four-day training period. Importantly, they maintained their skills for at least four weeks without additional tDCS applications. The participants even saw improvements in the untrained hand and with untrained chords, showing that they improved in overall skill, not just what they practiced. In the image above, we can see that those in the tDCS group (green) had significantly shorter execution times.
Background
Previous research has shown that tDCS impacts motor skill acquisition and strength development. Vitor-Costa and his team next explored its effect on cycling endurance.

Details
11 physically active men were told to pedal for as long as they could at 80% max power, or between 60 and 90 RPM. Their max power was determined a week beforehand, and they completed the cycling test three times in three weeks. During the three tests, participants received either anodal (excitatory), cathodal (inhibitory), or placebo tDCS targeting the leg area of the motor cortex.

Results
Anodal tDCS significantly improved time to exhaustion compared to the cathodal and placebo groups. The anodal stimulation group outperformed the placebo group by about 90 seconds, which translates to a 20% improvement. Researchers concluded the improvement came from tDCS helping cyclists learn to pedal more efficiently, meaning the cyclists maintained good form and thus conserved energy for longer.
Background
As we exercise, we slowly lose our ability to generate max force. Can tDCS applied to the motor cortex decrease this neuromuscular fatigue?

Details
First, the researchers tested 24 healthy adults on their maximum elbow flexion force (like a biceps curl). The participants then completed a muscular endurance task at 35% of their maximum before (baseline) and after (posttest) tDCS. The control group followed the same protocol but did not receive stimulation.

Results
Following tDCS, subjects maintained ~80% of their baseline endurance time. Conversely, those who did not receive stimulation were able to manage only ~60-65% of baseline endurance time.

Figure 5. Adapted from Cogiamanian et al. 2007. Endurance time before and after stimulation. The cathodal and no-stimulation groups displayed significantly shorter endurance time during the posttest. However, the anodal stimulation group did not perform differently during the posttest compared to baseline and performed significantly better (i.e. fatigued less) in the posttest compared to the cathodal or no-stimulation groups.
References


Recap

With over 15 years, 4,000 peer-reviewed papers, and 100,000 subjects, tDCS is a well-researched technology with the potential to improve neuroplasticity and accelerate improvements in skill, strength, and endurance.

Learn more at www.haloneuro.com