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Faculteit Revalidatiewetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

The effectiveness of transcranial direct current stimulation tDCS in arm-hand function after stroke: A Systematic Review and Meta-Analysis

Eva Bloemers
Laurens Vanderzande

Scriptie ingediend tot het behalen van de graad van master in de revalidatiewetenschappen en de kinesitherapie, afstudeerrichting revalidatiewetenschappen en kinesitherapie bij kinderen

PROMOTOR :
Prof. dr. Raf MEESEN

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Foreword

Before we present our master thesis to you, we would like to thank some people who supported us in making this study.

First of all, Dr. Raf Meesen, our promoter where we could always go with our questions and who guided us through the difficulties in making a meta-analysis.

Secondly, we want to thank Dr. Caroline Strouwen who supported us in the static analysis of our master thesis and who was always available to answer our questions. This study was conducted during the Covid-19 pandemic, but did not effect our study results in any way.

Voetbalstraat 19 3580 Beringen, 24/05/2020 E.B.

Overdemerstraat 30 3511 Kuringen, 24/05/2020 L.V.

Context

This paper belongs to the field of neurological rehabilitation and contains a systematic review and meta-analysis for investigating the clinically relevant parameters of transcranial direct current stimulation tDCS in stroke patients. tDCS is a non-invasive way of brain stimulation, which allows the activity of over- or under-active parts of the brain to return to normal. Electrodes are placed over the scalp and an electric current penetrates the brain. The 10-20-EEG electrode system is a standard system that, in combination with cortical representations via the homunculus, determines the location for the electrodes. This way, one can selectively stimulate the affected brain regions. This review focusses on the use of tDCS in upper limb stroke rehabilitation.

This paper came to be in function of master's thesis for obtaining a master's degree in Rehabilitation Sciences and Physiotherapy at Hasselt University. The research question arose in consultation with a promoter and co-promoter. A central format was chosen. Both students worked together on one literature study to analyze the statistical data of the included studies to create a meta-analysis. The work was evenly distributed. The research protocol was drawn up independently based on the Cochrane Handbook for Systematic Reviews of Interventions.

THE EFFECTIVENESS OF TRANSCRANIAL DIRECT CURRENT STIMULATION TDCS IN ARM-HAND FUNCTION AFTER STROKE: A SYSTEMATIC REVIEW AND META-ANALYSIS

Which parameters play an important role in the effectiveness of transcranial direct current stimulation in rehabilitation of arm-hand function in stroke patients?

1. Abstract

Background: Motor impairment is the most common cause of disability after stroke. After 6 months, 33–66% of the patients still have upper extremity (UE) impairments. Transcranial direct current stimulation is a method that allows over- or underactive parts of the brain return to normal. This systematic review and meta-analysis aims to summarize the clinically relevant parameters of transcranial direct current stimulation in stroke patients.

Method: Two independent researchers systematically searched Embase, Pubmed and Web of Science until the end of December 2019. Only randomized controlled trials were included where the intervention group received tDCS and the control group received sham stimulation. Quality was assessed with the PEDro checklist and Cochrane risk of bias tool.

Results: Fifteen studies with 371 patients were included. Evidence shows a significant difference in favor of tDCS in overall measurements (MD = 2.61; CI-95% [0.75 – 3.58]; P = 0.003). Significant effects in favor of tDCS were found when higher density and coulomb were used. Bilateral stimulation is more effective for upper limb recovery than anodal or cathodal stimulation. Chronic stroke patients appear to benefit more. Stimulation is most effective when used during the additional therapy.

Discussion and conclusion: Higher intensities cause higher neural activation, although there seem to be a ceiling effect on the amount of sessions. Limited effects in (sub)acute stroke patients because of spontaneous adaptive rewiring (plasticity) of the damaged neural circuitry. Bilateral tDCS uses a more latero-medial current flow. Gating theory of motor learning whereas an acute increase of cortical excitability is necessary to enhance motor learning.

Goal: To conduct a systematic review and meta-analysis summarizing the clinically relevant parameters of transcranial direct current stimulation in stroke patients.

Operationalizing of the research question: Statistical analysis of the data collected from the included studies to make evidence-based recommendations for the clinical practice.

Key words: Transcranial direct current stimulation, tDCS, stroke, upper limb, FMA-UE.

2. Introduction

According to the World Health Organization, stroke or cerebrovascular accidents are the second leading cause of death and the third leading cause of disability (WHO, 2018). A stroke occurs when brain cells suddenly die due to lack of oxygenated blood flow to a part of the brain. The two most common types are ischemic stroke, a lack of blood flow due to an obstruction and hemorrhagic stroke, the rupture of an artery causing a bleeding (NHLBI, 2014). Motor impairment is the most common disability after stroke. After 6 months, 33–66% of the patients still have upper extremity (UE) impairments (Kwakkel & Kollen, 2013). This underlines the importance of developing new treatment techniques to improve rehabilitation. One of these new promising techniques is transcranial direct current stimulation (tDCS). tDCS is a non-invasive brain stimulation technique. A low intensity constant current is applied on the head to stimulate the underlying parts of the brain. This stimulation provides a change in cortical excitability by hypopolarizing or hyperpolarizing the neuron's resting membrane potential (Bindman, Lippold, & Redfearn, 1964; Kwakkel & Kollen, 2013; Moreno-Duarte et al., 2014; Nitsche & Paulus, 2000; Nitsche et al., 2003; Purpura & McMurtry, 1965; Sist et al., 2012). In general, anodal stimulation, the positive electrode, is used to excite the stimulated area in inactive parts of the brain by hypopolarization of the resting membrane potential. Cathodal stimulation, the negative electrode, is used to inhibit overactive areas of the brain by hyperpolarizing the resting membrane potential (Nitsche et al., 2003). The low intensity of the current makes it possible to apply the current in a placebo-controlled way, this is called sham stimulation. Sham stimulation is usually ramped up for 30 seconds and then ramped down, so no cortical changes can occur (Gandiga, Hummel, & Cohen, 2006). The goal with tDCS is to create long lasting cortical changes, even after the stimulation is ended. The long-lasting effects are protein synthesis-dependent (Nitsche et al., 2008). Brain derived neurotrophic factor (BDNF), a brain made molecule that helps neuroplasticity, is the key molecule that is needed for neural development and cell survival (Binder & Scharfman, 2004).

tDCS has been proven to be safe when stimulating with an intensity < 4 mA, up to 60 min duration per day, electrode sizes between 1 cm^2 and 100 cm^2 with stimulation frequencies between 0 and 10,000 Hz (Antal et al., 2017).

Extensive safety studies have been conducted. No adverse effects were reported in over 33,200 sessions and 1000 subjects with repeated sessions of transcranial direct current stimulation (Bikson et al., 2016). tDCS can produce changes up to 40%. The changes can last between 30 and 120 minutes after the end of stimulation. Stimulation is most commonly delivered through two 20–35 cm^2 saline-soaked sponges. A constant flow of weak current is delivered through a battery-operated tDCS current stimulating device. In neurorehabilitation, the active electrode is most commonly placed over the motor cortex (M1) or the dorsolateral prefrontal cortex and the reference electrode is placed over the contralateral hemisphere (Moreno-Duarte et al., 2014)

Previous research has suggested that anodal-tDCS may benefit motor recovery of the paretic upper limb in chronic stroke patients (Butler et al., 2013). Some studies found tDCS to be effective to improve ADL performance and function after stroke (Elsner, Kugler, Pohl, & Mehrholz, 2013). Other studies suggested that multiple sessions of tDCS combined with upper limb rehabilitation had a small, non-significant effect on impairments and activities of daily living post-intervention (L Tedesco Triccas et al., 2016). Overall no high-quality evidence can be found for any of the interventions, due to limited comparability between trails caused by the wide range of different protocols (Pollock et al., 2014).

Although there are many guidelines on how to stimulate, no consensus has been reached for the most effective parameters. Most common used intensities are 1 or 2 mA with a minimum duration of 20 minutes. Several studies found an increase in primary motor cortex activity after tDCS stimulation, yet there is no conclusion if tDCS should be a standalone therapy or used in a combination with other rehabilitation therapy forms, e.g. CIMT (Hummel et al., 2005; R. Lindenberg, V. Renga, L. Zhu, D. Nair, & G. Schlaug, 2010; Simonetti et al., 2017). This study will conduct a meta-analysis to investigate which parameters have the most effect on the efficiency of tDCS on stroke patients. By bundling data from various high quality randomized controlled trials, this study aims to make a consensus on which parameters should be used when tDCS is used in rehabilitation or research with stroke patients.

3. Method

3.1. Research question

In this study the effectiveness of transcranial direct current stimulation (tDCS) to improve arm-hand function in a stroke population is investigated. Therefor following research question came to be: Which parameters play an important role in the effectiveness of transcranial direct current stimulation in rehabilitation of arm-hand function in stroke patients?

3.2. Selection criteria

Stroke type

Ischaemic or haemorrhagic.

Stroke phase

Acute

Within the first 24 hours after the clinical diagnosis of stroke.

Subacute

Until 6 months after the onset of stroke.

Chronic

More than 6 months after the onset of stroke.

Types of studies

Randomized controlled trails.

Type of interventions

tDCS of any form (anodal, cathodal, bilateral, uni- and bihemispheric) vs sham therapy.

tDCS of any form combined with an additional intervention vs sham therapy combined with the same additional intervention.

Inclusion criteria

Studies will be included if a) a randomized controlled trial, in which the control group received sham therapy; b) the given intervention consists of the following technique: tDCS only or combined with an additional intervention (e.g. CIMT, physical therapy,…);
c) study was conducted in a clinical setting; d) study was conducted in a stroke population with upper limb impairment; e) outcome measurements included Fugl Meyer Assessment.

Exclusion criteria

Studies will be excluded if a) other forms of stimulation or combinations with tDCS were used; b) Cross-over designs; c) full text or essential information cannot be obtained through various approaches.

Outcome measurements

This study focusses on the arm-hand improvement measurable with the Fugl-Meyer Assessment. Therefor only studies using the Fugl-Meyer Assessment as outcome measurement were included. The Fugl-Meyer assessment is a reliable tool to quantitatively evaluate motor impairment in stroke patients. It has a high relative, inter- and intra-rater reliability (Gladstone, Danells, & Black, 2002; H. Kim et al., 2012). The concurrent validity is moderate to good and responsiveness moderate to large (H. Kim et al., 2012). Due to these current evidence, the Fugl-Meyer Assessment is a highly recommended clinical and research tool to investigate motor impairment changes in patients following stroke (Gladstone et al., 2002).

3.3. Search strategy

The search included data from Embase, Pubmed and Web of Science. The conducted search was done until the end of December 2019. Terms were modified for each database. The search strategy in PubMed and Web of Science consisted of the use of MeSH terms with builder OR in between comparable terms. The builder AND was used for the combination of terms. If no MeSH term was available, then screening was continued with "All fields". The terms used were “tDCS”, “Transcranial direct current stimulation” and "Stroke". For Embase the term "cerebrovascular accident" was added. Only English written randomized controlled trials were considered. All obtained studies were first screened on title and abstract. Then full text articles were retrieved and checked for compliance with inclusion and exclusion criteria. The selection process was conducted by two independent researchers, conflicts were resolved in consultation.

3.4. Quality assessment

Methodological quality of all included studies was assessed by two independent researchers with two known checklists: a) the *PEDro scale*, a binary scale with 11 items to asses validity of a study's conclusions. Points are given when a criterion is met.

If the information was unclear, no points were given. Studies were excluded if 6/10 or less points were scored; b) *RoB 2: A revised Cochrane risk-of-bias tool for randomized trials*. 7 items to assess the risk of bias, each item has 3 scoring options: high, low or unclear. Studies were excluded if two or more items scored high risk of bias.

3.5. Data extraction and statistical analysis

The following data was extracted from the studies: patient characteristics, sample size, type of intervention, outcome measures, characteristics of stimulation (type, electrode placement, electrode size, current intensity and session duration) and conclusions. For the statistical analysis of the Fugl-Meyer Assessment, mean difference between groups and standard deviation were extracted. If mean difference data were not available, the available data was used to calculate the mean difference and standard deviation between groups.

Formulas:

- Mean difference MD = mean (after) – mean (before)
  Standard deviation SD = MD*sqrt(n)/t
    - n = number of subjects
    - t-value
    - Reported in the article
    - F-value reported in the article: F = t^2
    - Exact p-values reported in the article: t-distribution calculator (https://stattrek.com/online-calculator/t-distribution.aspx)
- If the author provided raw data, mean difference (MD) and standard deviation (SD) were calculated using SAS JMP statistical software®.
    - Extra column was made: Post score FMA – Pre score FMA per patient
    - Distribution was used:
        - Y, column: Post score – pre score
        - Sort by stimulation type (real and sham)
    - MD and SD were then automatically calculated per group

Where no data was available, contact with the corresponding author was attempted though email. Without response, the study was excluded.

3.6. Heterogeneity

Due to the great variety of parameters, subgroup analyses were performed to ensure homogeneity between the different studies. Following subgroups and interaction effect analysis were composed:

- Coulomb: the unit of electric charge, is the amount of electric charge that is transported by a constant electric current of one ampere in one second (Fitzpatrick, 2008). Using this value, the intensity of current per stimulation session can be compared between studies using different times of stimulation and intensities.
    - Type of stimulation: anodal, cathodal, bilateral, uni- and bihemispheric.
    - Patient type: acute, subacute or chronic stroke patients.
    - Timing of stimulation: prior to, partially during or during the complete session of additional therapy.
    - Electrode size: size of the used electrodes.
    - Number of sessions: the number of times stimulation was used.
- Density: the magnitude of the electric current per cross-sectional area. The current density is measured in amperes per square meter (Fitzpatrick, 2008). Using this value, the amount of current applied on the stimulated area can be compared between studies using different size electrodes and intensities.
    - Type of stimulation: anodal, cathodal, bilateral, uni- and bihemispheric.
    - Patient type: acute, subacute or chronic stroke patients
    - Timing of stimulation: prior to, partially during or during the complete session of additional therapy.
    - Total minutes of stimulation: the duration of stimulation multiplied by total amount of sessions
- Patient type: acute, subacute or chronic stroke patients. Previous research has shown a difference in recovery of the brain tissue between the different phases of stroke (Sist et al., 2012).
    - Type of stimulation: anodal, cathodal, bilateral, uni- and bihemispheric.
    - Timing of stimulation: prior to, partially during or during the complete session of additional therapy.
    - Number of sessions: the number of times stimulation was used.

- Timing of stimulation: prior to, partially during or during the complete session of additional therapy. This parameter is used to examine the appropriate time to use stimulation in the clinical setting.
    - Type of stimulation: anodal, cathodal, bilateral, uni- and bihemispheric.

3.7. Measurements of the treatment effect

All outcome measures were analyzed with RevMan (Version 5.3) as continuous variables, using mean difference between groups and standard deviation. To estimate the treatment effect, inverse variance with mean difference (MD) and associated 95% confidence intervals were used in the random-effects model.

4. Results

4.1. Study selection

The search terms and results are presented in table 1-3. Of the 322 hits identified in the database search, 25 studies met the inclusion criteria. Ten of the 25 included studies did not report the required data, nor were they provided after contacting the corresponding author through e-mail. Fifteen articles were included to conduct this meta-analysis. The study selection is presented in figure 1.

Table 1
Key words in Embase

Key words		**Hits November 2019**
#1	tDCS [Title or Abstract] OR Transcranial direct current stimulation [Title or Abstract] AND Randomized Controlled Trial	1184
#2	Stroke [Title or Abstract] OR cerebrovascular accident [Title or Abstract] AND Randomized Controlled Trial	16.626
#3	#1 AND #2	236

Table 2
MeSH-terms and key words in PubMed

Key words		**Hits November 2019**
#1	tDCS [MeSH] OR Transcranial direct current stimulation [MeSH]	5174
#2	Stroke [MeSH]	126.614
#3	#1 AND #2	299
#4	#3 AND randomized control trial [Filter]	105

Table 3
Key words in Web of Science

Key words		**Hits November 2019**
#1	tDCS [Topic] OR Transcranial direct current stimulation [Topic]	4129
#2	Stroke [Topic]	221.177
#3	#1 AND #2	643
#4	#3 AND randomized control trial [Topic]	123

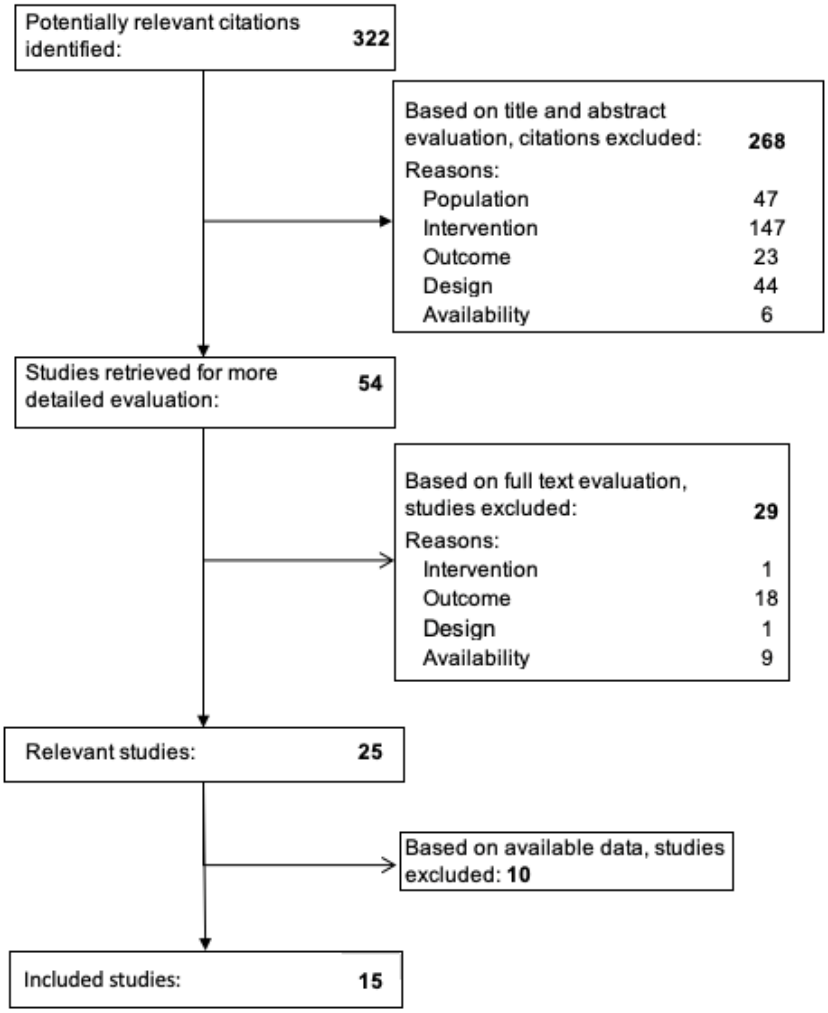

Figure 1 Study selection flowchart

4.2. Quality assessment

The quality assessment is shown in table 4 and table 5. All of the included studies scored seven or higher out of ten on the *PEDro scale*, which can be considers as high quality. One study scored 10/10, seven studies scored 9/10, five studies scored 8/10 and two studies scored 7/10. None of the 25 included studies scored high on a criterion of the *Cochrane Risk of Bias Checklist*. Five studies scored unclear on one or more criteria, one of the studies scored unclear more than twice. Because the study scored 7/10 on the PEDro scale and this is considered high quality, the study was included.

Table 4

PEDro quality checklist of included studies

Citation	Eligibility criteria	Randomisation	Concealment of allocation	Baseline charateristics	Blinding subjects	Blinding therapists	Blinding researchers	>85% follow-up	Intention to treat	Point between-group statistical comparisons	Point measures and measures of variability	Total score (/10)
Ang et al. (2015)	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	7
Beaulieu, Blanchette, Mercier, Bernard-Larocque, and Milot (2019)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	9
Cunningham et al. (2015)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	9
Edwards et al. (2019)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	8
Fusco et al. (2014)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	8
Jin, Zhang, Bai, and Fong (2019)	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	8
D. Y. Kim et al. (2010)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	10

Koh, Lin, Jeng, Huang, and Hsieh (2017)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	9
R. Lindenberg, V. Renga, L. L. Zhu, D. Nair, and G. Schlaug (2010)	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	8
Mazzoleni, Tran, Dario, and Posteraro (2019)	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	7
Oveisgharan, Organji, and Ghorbani (2018)	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	8
Rocha et al. (2016)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	9
Straudi et al. (2016)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	9
L. T. Triccas et al. (2015)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	9
Viana et al. (2014)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	9

Table 5

Cochrane Risk of Bias Checklist of the included studies

Citation	Selection bias: Random sequence generation	Selection bias: Allocation concealment	Reporting bias: Selective reporting	Other bias	Performance bias: Blinding (participants and personnel)	Detection bias: Blinding (outcome assessment)	Attrition bias: Incomplete outcome data
Ang et al. (2015)	Unclear	Unclear	Low	Unclear	Unclear	Unclear	Low
Beaulieu et al. (2019)	Low	Low	Low	Low	Low	Low	Low
Cunningham et al. (2015)	Low	Low	Low	Low	Low	Low	Low
Edwards et al. (2019)	Low	Low	Low	Low	Low	Low	Low
Fusco et al. (2014)	Low	Low	Low	Low	Low	Low	Low
Jin et al. (2019)	Low	Low	Low	Low	Unclear	Unclear	Low
D. Y. Kim et al. (2010)	Low	Low	Low	Low	Low	Low	Low
Koh et al. (2017)	Low	Low	Low	Low	Low	Low	Low
R. Lindenberg et al. (2010)	Low	Low	Low	Low	Low	Unclear	Low
Mazzoleni et al. (2019)	Low	Low	Low	Low	Unclear	Unclear	Low
Oveisgharan et al. (2018)	Low	Low	Low	Low	Unclear	Unclear	Low
Rocha et al. (2016)	Low	Low	Low	Low	Low	Low	Low
Straudi et al. (2016)	Low	Low	Low	Low	Low	Low	Low

L. T. Triccas et al. (2015)	Low	Low	Low	Low	Low	Low	Low
Viana et al. (2014)	Low	Low	Low	Low	Low	Low	Low

4.3. Description of included articles

Fifteen studies were included in this systematic review and meta-analysis. A total of 371 participants were analyzed. A summary of the included studies is presented in table 6.

Eight included studies used anodal tDCS (Ang et al., 2015; Cunningham et al., 2015; Edwards et al., 2019; Fusco et al., 2014; D. Y. Kim et al., 2010; R. Lindenberg et al., 2010; Mazzoleni et al., 2019; Straudi et al., 2016; L. T. Triccas et al., 2015; Viana et al., 2014). One of the included studies used cathodal tDCS (Fusco et al., 2014). Two included studies used both anodal and cathodal tDCS (D. Y. Kim et al., 2010; Rocha et al., 2016). Three studies used bilateral tDCS (Beaulieu et al., 2019; Jin et al., 2019; Koh et al., 2017). One study used bihemispheric tDCS (Oveisgharan et al., 2018).

All studies combined tDCS with an additional intervention, except for Oveisgharan et al. (2018). Three studies combined conventional physical therapy with tDCS (Fusco et al. (2014); D. Y. Kim et al. (2010) R. Lindenberg et al. (2010).Two studies used constraint induced movement therapy (CIMT) as additional intervention (Cunningham et al. (2015) Rocha et al. (2016).

Four studies combined robot assisted arm training (RAAT) with tDCS (Edwards et al. (2019); Mazzoleni et al. (2019); Straudi et al. (2016) L. T. Triccas et al. (2015). One study used motor imagery brain-computer interface (MI BCI) as additional intervention (Ang et al. (2015). One study used mirror therapy (MT) as additional intervention (Jin et al. (2019). One study combined virtual reality training (VRT) with tDCS (Viana et al. (2014). One study used sensory modulation as additional intervention (Koh et al. (2017). One study used resistance training as additional intervention (Beaulieu et al. (2019).

One study used acute patients (Oveisgharan et al., 2018). Three studies used subacute stroke patients (Fusco et al., 2014; D. Y. Kim et al., 2010; Mazzoleni et al., 2019). Nine studies used chronic stroke patients (Ang et al., 2015; Beaulieu et al., 2019; Cunningham et al., 2015; Edwards et al., 2019; Jin et al., 2019; Koh et al., 2017; R. Lindenberg et al., 2010; Rocha et al., 2016; Viana et al., 2014) and two studies used both subacute and chronic stroke patients (Straudi et al., 2016; L. T. Triccas et al., 2015).

Five studies applied stimulation prior to the additional therapy (Ang et al., 2015; Edwards et al., 2019; Fusco et al., 2014; Rocha et al., 2016; Viana et al., 2014). Five studies used stimulation during a part of the additional therapy (Beaulieu et al., 2019; D. Y. Kim et al., 2010; R. Lindenberg et al., 2010; Mazzoleni et al., 2019; L. T. Triccas et al., 2015). Three studies applied stimulation during the complete additional therapy sessions (Cunningham et al., 2015; Koh et al., 2017; Straudi et al., 2016). One study applied stimulation before and during the complete additional therapy session (Jin et al., 2019). One study used stimulation only (Oveisgharan et al., 2018).

Thirteen studies found a significant improvement in the FMA-UE post-intervention relative to baseline, except Koh et al. (2017) who found a nonsignificant improvement favoring tDCS-group. However, none found a significant between-group difference. Two studies found significant improvements of tDCS compared with sham (R. Lindenberg et al., 2010; Oveisgharan et al., 2018). If an analysis was conducted, a significant difference was found in favor of tDCS (MD = 2.61; CI-95% [0.75 – 3.58]; heterogeneity: $Tau^2 = 4.55$; $Chi^2 = 48.04$, df = 18 (P = 0.0001); $I^2 = 63\%$; test for overall effect: Z = 3.00, P = 0.003)(Figure 2).

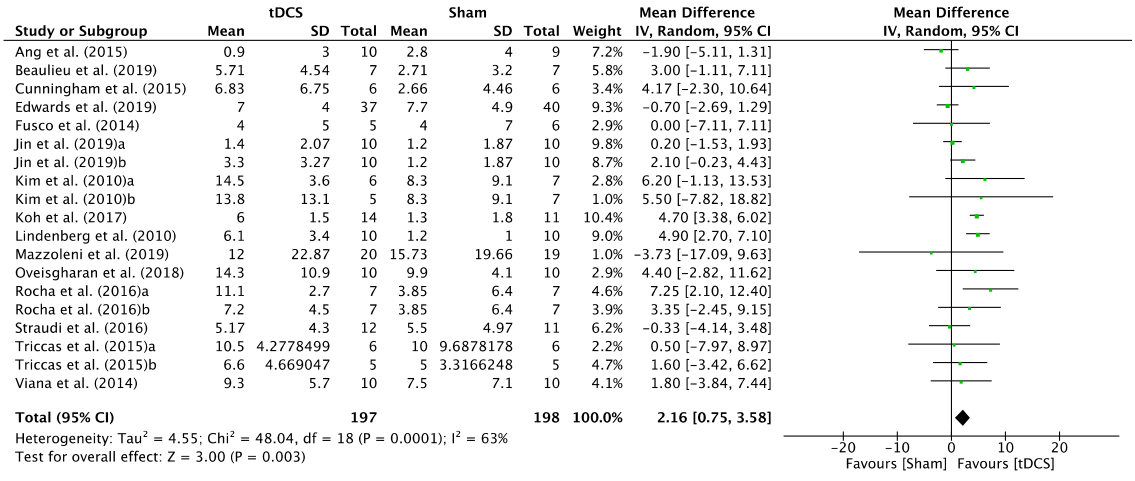

Figure 2 Meta-analysis of overall measurements

Table 6

Included studies

Citation	Design	Participants	Intervention	Method	Outcome measures	Conclusion	PEDro scale (/10)
Ang et al. (2012)	A sham-controlled, randomized controlled trial	19 Chronic stroke patients	Anodal tDCS + motor imagery brain-computer interface with robotic feedback	**Protocol:** 10 sessions, 20 min tDCS + 1h MI-BCI, 1mA. Two sponge electrodes. **Anodal**: M1 motor cortex of the ipsilesional hemisphere **cathodal:** contralesional M1	FMA-UE, online BCI accuracies, EEG	tDCS can play a role in facilitating MI in stroke patients, but the difference was not significant	7
Beaulieu et al. (2019)	Two-arm parallel pilot randomized controlled trial	14 Chronic stroke patients	Bilateral tDCS + Resistance training	**Protocol:** 12 sessions (3x/week), 20 min stimulation, 2mA, Saline-soaked 5X7cm electrodes **Anodal:** ipsilesional M1 **Cathodal:** contralesional M1	FMA-UE, BBT, WMFT, grip strength, MAS, MAL	tDCS did not significantly do better than sham when combined with resistance training	9
(Bolognini et al., 2011)	An exploratory study, pilot RCT	14 Chronic stroke patients	Bilateral tDCS + CIMT	**Protocol:** 10 sessions, 4h CIMT of which 40 min with tDCS, 2mA. Two sponge electrodes. **Anodal:** over the affected M1 **Cathodal:** over the contralateral (unaffected) M1	JTHFT, grip strength, MAL, FMA-UE, BI, BDI, MMSE	tDCS combined CIMT can improve the transcallosal inhibition, CIMT alone can improve excitability in the damaged zones.	6
Cunningham et al. (2015)	A proof-of-concept, randomized, double-blinded	12 Chronic stroke patients	Anodal tDCS + CIMT	**Protocol:** 3 times/week for 5 weeks, 30 min, twice a day, 1mA. Two sponge electrodes (5×7 sq. cm). **Anodal:** on the higher motor cortices in the ipsilesional hemisphere,	FMA-UE, NHPT, MAL, functional	Stimulation of the high motor areas can help activate contralateral hemisphere when	9

	placebo-controlled study			2.5cm anterior to a site in ipsilesional M1. **Cathodal:** on the subraorbial area contralateral to the ipsilesional hemisphere.	MRI activation with TMS	the ipsilateral hemisphere is damaged.	
Edwards et al. (2019)	Double-blind, sham-controlled, 95 repeated-measures study design	77 Chronic stroke patients	Anodal tDCS + robot assisted arm training	**Protocol:** 36 sessions, 20 min, 2mA, rubber-carbon electrodes (35cm2) with surrounding saline soaked sponges (0.9% NaCl) **Anodal:** 5 cm lateral to the vertex **Cathodal:** contralateral supraorbital area	FMA-UE, MRC, WMFT, BI, Stroke Impact Scale	tDCS combined with RAAT did not resulted in better iprovements compared to sham.	8
Fusco et al. (2014)	A double-blind, randomized, and sham-controlled trial	11 Subacute stroke patients	Cathodal tDCS + conventional physical therapy	**Protocol:** 10 sessions, twice a day, 45 min, 1.5mA, 10 min before each training session. Two gel sponge electrodes (5x7 cm) **Cathodal:** primary motor cortex area in the contralateral affected hemisphere (C3'/C4' according to the International classification system of EEG electrodes placement) **Anodal:** positioned in a noncephalic side, above the right shoulder, contralateral to the electric circuit of the heart	10MWT, 6MWT, TUG, NHPT, pinch strength, grip strength, FMA-UE, Rivermead Mobility Index, FAC, BI, CNS	The study shows no functional improvement in early phase of stroke when cathodal tDCS is used.	8
Jin et al. (2019)	Randomized, controlled pilot trial	30 Chronic stroke patients	Bilateral tDCS + mirror therapy	**Protocol:** 10 sessions, 30 min, 1mA, 35 cm×35 cm saline-soaked surface sponge electrodes **Anodal:** primary motor cortex (M1) of the ipsilateral hemispere **Cathodal:** the primary motor cortex (M1) of the contralesional hemisphere	FMA-UE, ARAT, BBT	Concurrent tDCS combined with mirror therapy gave significant better results then prior tDCS and sham. These results were only displayed in one motor function test	8

D. Y. Kim et al. (2010)	A prospective, randomized controlled trial with blinded assessment	18 Subacute stroke patients	Anodal or cathodal tDCS + Occupational therapy	**Protocol:** 10 sessions, 30 min OT of which 20 min with tDCS, 2mA. Two sponge electrodes. Anodal stimulation: over the "hot spot" of the paretic FDI; other electrode: contralateral supraorbital region Cathodal stimulation: over the "hot spot" of the intact FDI; other electrode: contralateral supraorbital region	FMA, mBI	10 sessions of tDCS combined with conventional occupational therapy elicited more improvement in paretic upper limb function than did sham treatment with occupational therapy, when assessed 6 months after treatment.	10
Koh et al. (2017)	Double-blind, randomized controlled trial with placebo control	24 Chronic stroke patients	Bilateral tDCS + sensory modulation	**Protocol:** 24 sessions, 30 min, 1,5mA, 2 25cm2 electrodes with sponge surfaces in saline solution **Anodal**: primary motor cortex (M1) of the ipsilateral hemispere **Cathodal**: the primary motor cortex (M1) of the contralesional hemisphere	FMA-EU, MAS, BI, ARAT	tDCS gave better results in upper extrimity recovery, but these were not significant.	9
R. Lindenberg et al. (2010)	A randomized, sham-controlled trial	20 Chronic stroke patients	Anodal tDCS + PT/OT	**Protocol:** 5 sessions, 60 min PT/OT of which 30 min with tDCS/sham, 1,5 mA, 2 saline-soaked surface gelsponge electrodes (16.3 cm2 active area**) Anodal:** ipsilesional C3 and C4 of the international 10 –20 EEG electrode system **Cathodal:** contralesional C3 and C4 of the international 10 –20 EEG electrode system	FMA-UE, WMFT, functional MRI	The combination of bihemispheric tDCS and peripheral sensorimotor activities improved motor functions in chronic stroke patients that outlasted the intervention period. This novel approach may potentiate cerebral adaptive processes that facilitate motor recovery after stroke.	8

Mazzoleni et al. (2019)	A single-blind, randomized, sham-controlled trial	40 Subacute stroke patients	Anodal tDCS + InMotion WRIST robot	**Protocol:** 5 sessies per week, 6 weeks, 30 min per session of which 20 min with stimulation, 2mA, 2 ellipsoidal electrodes (35 cm2) **Anodal:**on primary motor area (M1, corresponds to C3/C4 location according to the International 10-20 System for EEG) of the affected hemisphere **Cathodal:** on the controlateral orbit	FMA-UE, MAS, MI, BBT	This study shows that the use of tDCS combined with robot assissted arm training is a safe and effective method for rehabilitation. However no additional effect of tDCS was found.	7
Oveisgharan et al. (2018)	A randomized clinical trial	20 Acute stroke patients	Anodal tDCS	**Protocol:** 10 sessions, 2 weeks, 30 minutes (with 30 seconds of fade in and fade out), 2mA, four saline-soaked sponges 4 cm2 **Anodal:** left DLPFC and M1 of the affected hemisphere **Cathodal:** right supraorbital ridges and M1 of the nonaffected hemisphere (C3 or C4 electrodes of the international 10-20 EEG system)	FMA-UE, ARAT	This study shows that stimulation the left DLPFC combination with M1 results in better motor recovery than M1 alone.	8
Rocha et al. (2016)	A pilot double-blind sham-controlled randomized trial	21 Chronic stroke patients	Anodal tDCS or cathodal tDCS + mCIMT	**Protocol:** 3 sessions, 4 weeks, 1mA for 13 min (anodal) or 9 min (cathodal), two saline-soaked surface sponge electrodes (surface 35 cm2) **Anodal:** over the primary motor cortex (M1; C3 or C4 according to EEG 10/20 system) of the affected hemisphere **Cathodal:** placed above supra-orbital region	FMA-UE, MAL	This study shows greater improvement of anodal tDCS combined with mCIMT than cathodal tDCS.	9
Straudi et al. (2016)	A double-blinded	23 Subacute and chronic	Anodal tDCS + RAAT	**Protocol:** 5 sessions/week, 2 weeks, 30 min, 1mA, two sponge electrodes (35 cm2) **Anodal:** on the M1 of the affected	FMA-UE, BBT, MAL, Quality of Movement,	This study shows an additional effect of tDCS combined with RAAT compared to RAAT alone,	9

	exploratory RCT pilot study	stroke patients		hemisphere **Cathodal:** on the contralateral M1 area	Amount of Movement	depending on the duration and type of stroke.	
L. T. Triccas et al. (2015)	A double-blinded pilot RCT	22 Subacute and chronic stroke patients	Anodal tDCS + Robot training	**Protocol:** 18 sessions, 8 weeks, 60 min of which 20 min stimulation, 1mA, two rubber electrodes (35 cm2) **Anodal:** over the affected M1 **Cathodal:** on the contralateral supraorbital region	FMA, ARAT, UL functional measure	This study shows no additional effect of tDCS on UL impairment.	9
Viana et al. (2014)	A pilot double-blind randomized control trial	20 Chronic stroke patients	Anodal tDCS + VRT	**Protocol:** 15 sessions, 13 min, 2mA, two saline-soaked surface sponge electrodes (surface of 35 cm2)**Anodal:** over the primary motor cortex (M1) (C3 or C4, international 10–20 system) of the affected hemisphere **Cathodal:** above the contra lateral orbit	FMA-UE, WMFT, MAS, HHD, Stroke specific quality of life scale	This studys shows soms effect of VRT combined with tDCS, futher research is needed.	9

4.4. Effect of the interventions

To ensure homogeneity the results were divided into subgroups. The interaction effect of different parameters was investigated within each group. Jin et al. (2019) used tDCS before and during the additional motor therapy, the results of the before group are shown in Jin et al. (2019) a and the results of the group who received tDCS during therapy are shown in Jin et al. (2019) b. D. Y. Kim et al. (2010) used anodal and cathodal stimulation, results of anodal stimulation are shown in D. Y. Kim et al. (2010) a and results of cathodal stimulation are shown in D. Y. Kim et al. (2010) b. Rocha et al. (2016) used anodal and cathodal stimulation, the results of anodal stimulation are shown in Rocha et al. (2016) a and the results of cathodal stimulation are shown in Rocha et al. (2016) b. L. T. Triccas et al. (2015) used subacute and chronic stroke patients, the results of the subacute patients are shown in L. T. Triccas et al. (2015) a and the results of the chronic patients are shown in L. T. Triccas et al. (2015) b. These studies will be analyzed and discussed as separate data.

Coulomb

≤ 1 As

Three studies used a coulomb below 1 As (Fusco et al., 2014; Rocha et al., 2016). All studies found a significant improvement in the FMA-UE post-intervention relative to baseline. When compared to sham, none found a significant difference. When tDCS was compared to sham, results suggested a beneficial effect in favor of tDCS (MD = 4.08; CI-95% [0.05, 8.11]; heterogeneity: $Tau^2 = 3.56$; $Chi^2 = 2.77$, df = 2 (P = 0.25); $I^2 = 28\%$, test for overall effect: Z = 1.99, P = 0.05)(Figure 3).

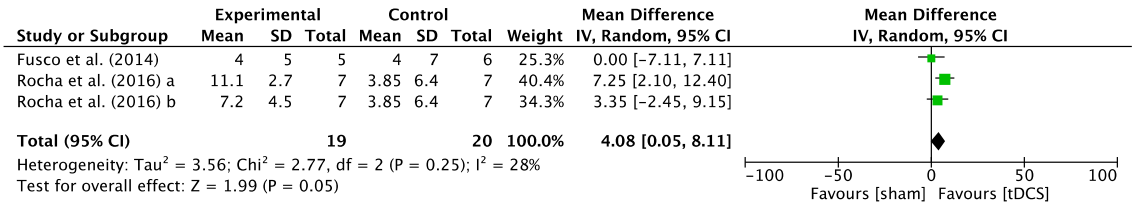

Figure 3 Meta-analysis of overall measurements by coulomb below 1 As

When analysis was corrected for **type of stimulation**, one study used anodal stimulation (Rocha et al., 2016). This study showed a significant effect of tDCS over sham stimulation (MD = 7.25; CI-95% [2.10, 12.40]; test for overall effect: Z = 2.76, P = 0.006). Two studies used cathodal stimulation (Fusco et al., 2014; Rocha et al., 2016). The results were inconsistent, the studies showed a nonsignificant benefit of tDCS over sham stimulation (MD = 2.01; CI-95% [-2.48, 6.51]; heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.51$, df = 1 (P = 0.47); $I^2 = 0\%$; test for overall effect: Z = 0.88, P = 0.38).

When analysis was corrected for **patient type,** one study failed to show a significant effect of tDCS compared to sham in subacute stroke patients (MD = 0.00; CI-95% [-7.11, 7.11]; test for overall effect: Z = 0.00, P = 1.00) (Fusco et al., 2014). Two studies showed a significant effect in favour of tDCS compared to sham in chronic stroke patients (MD = 5.53; CI-95% [1.68, 9.38]; heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.97$, df = 1 (P = 0.32); $I^2 = 0\%$; test for overall effect: Z = 2.82, P = 0.005) (Rocha et al., 2016). All studies stimulated prior to the additional therapy, used 35 cm^2 electrodes and had 15 or fewer sessions.

1 As <…< 2 As

Eight studies used a coulomb between 1 As and 2 As (Ang et al., 2015; Cunningham et al., 2015; Jin et al., 2019; Straudi et al., 2016; L. T. Triccas et al., 2015; Viana et al., 2014). All studies found a significant improvement in the FMA-UE post-intervention relative to baseline. When compared to sham, none found a significant difference. If an analysis was conducted, a nonsignificant difference was found in favor of tDCS (MD 0.59; CI-95 [-0.53, 1.72]; heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 5.85$, df = 7 (P = 0.56); $I^2 = 0\%$; test for overall effect: Z = 1.04, P = 0.30)(Figure 4).

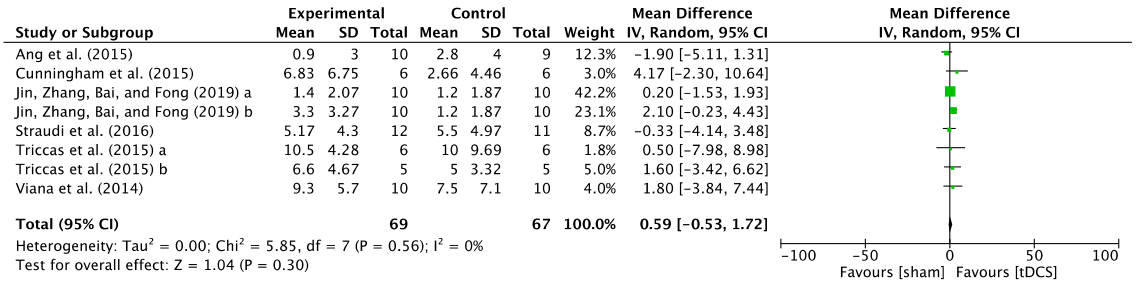

Figure 4 Meta-analysis of overall measurements by coulomb between 1 As and 2 As

When analysis was corrected for **type of stimulation,** the results were consistent. Six studies used anodal stimulation (Ang et al., 2015; Cunningham et al., 2015; Straudi et al., 2016; L. T. Triccas et al., 2015; Viana et al., 2014). Results showed a small nonsignificant effect of tDCS compared with sham (MD = 0.07; CI-95% [-1.84, 1.98]; heterogeneity: Tau^2 = 0.00; Chi^2 = 3.76, df = 5 (P = 0.58); I^2 = 0%; test for overall effect: Z = 0.07, P = 0.94). Two studies used bilateral stimulation (Jin et al., 2019). A nonsignificant effect of tDCS compared to sham stimulation is seen (MD = 0.98; CI-95% [-0.85, 2.81]; heterogeneity: Tau^2 = 0.71; Chi^2 = 1.64, df = 1 (P = 0.20); I^2 = 39%; test for overall effect: Z = 1.05, P = 0.29).

When analysis was corrected for **patient type**, the results remained consistent. Two studies used subacute patients (Straudi et al., 2016; L. T. Triccas et al., 2015). The results showed a small nonsignificant effect of tDCS compared to sham (MD = -0.19; CI-95% [-3.67, 3.29]; heterogeneity: Tau^2 = 0.00; Chi^2 = 0.03, df = 1 (P = 0.86); I^2 = 0%; test for overall effect: Z = 0.11, P = 0.91). Seven studies used chronic stroke patients (Ang et al., 2015; Cunningham et al., 2015; Jin et al., 2019; Straudi et al., 2016; L. T. Triccas et al., 2015; Viana et al., 2014). The results showed a nonsignificant effect in favor of the tDCS-group compared to the sham group (MD = 0.60; [-0.54, 1.73]; heterogeneity: Tau^2 = 0.00; Chi^2 = 5.85, df = 6 (P = 0.44); I^2 = 0%; test for overall effect: Z = 1.03, P = 0.30). Straudi et al. (2016) used subacute and chronic patients, the data is included in both analyses. When we remove this study from the analysis, a consistent result can be found for subacute stroke patients (MD = 0.50; CI-95% [-7.98, 8.98]; test for overall effect: Z = 0.12, P = 0.91). A consistent result can also be found for chronic stroke patients (MD = 0.72; CI-95% [-0.61, 2.05]; heterogeneity: Tau^2 = 0.32; Chi^2 = 5.60, df = 5 (P = 0.35); I^2 = 11%; test for overall effect: Z = 1.06, P = 0.29).

When analysis was corrected for **timing of the stimulation**, the results remained consistent. Three studies stimulated prior to the additional therapy (Ang et al., 2015; Jin et al., 2019; Viana et al., 2014). A small nonsignificant difference can be found in favor of tDCS-group (MD = -0.13; [-1.60, 1.34]; heterogeneity: Tau^2 = 0.00; Chi^2 = 1.76, df = 2 (P = 0.41); I^2 = 0%; test for overall effect: Z = 0.18, P = 0.86). Two studies used tDCS partially during the additional intervention (L. T. Triccas et al., 2015).

A small nonsignificant difference was found in favor of tDCS (MD = 1.31; CI-95% [-3.01, 5.63]; heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.05$, df = 1 (P = 0.83); $I^2 = 0\%$; test for overall effect: Z = 0.60, P = 0.55). Three studies used tDCS during the complete session of additional therapy (Cunningham et al., 2015; Jin et al., 2019; Straudi et al., 2016). The results suggested a beneficial effect of tDCS compared with sham (MD = 1.67; CI-95% [-0.23, 3.58]; heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 1.76$, df = 2 (P = 0.41); $I^2 = 0\%$; test for overall effect: Z = 1.72, P = 0.08). All studies used 35 cm^2 electrodes, except for Ang et al. (2015) who did not report electrode size.

When analysis was corrected for **number of sessions**, the results remained consistent. Four studies used 10 sessions of tDCS (Ang et al., 2015; Jin et al., 2019; Straudi et al., 2016). The results showed a small nonsignificant effect of tDCS compared with sham (MD = 0.29; CI-95% [-1.22, 1.81]; heterogeneity: $Tau^2 = 0.69$; $Chi^2 = 4.20$, df = 3 (P = 0.24); $I^2 = 29\%$; test for overall effect: Z = 0.38, P = 0.70). Four studies used 10 or more sessions (Cunningham et al., 2015; L. T. Triccas et al., 2015; Viana et al., 2014). The results showed a nonsignificant effect in favor of tDCS-group compared to sham (MD = 2.08; CI-95% [-0.95, 5.11]; heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.58$, df = 3 (P = 0.90); $I^2 = 0\%$; test for overall effect: Z = 1.35, P = 0.18).

≥ 2 As

Eight studies used a coulomb above 2 As. Two studies found a significant effect of tDCS compared with sham stimulation (R. Lindenberg et al., 2010; Oveisgharan et al., 2018). Six studies found a significant improvement in the FMA-UE post-intervention relative to baseline, except Koh et al. (2017) who found a nonsignificant improvement favoring tDCS-group. However, none found a significant between-group difference (Beaulieu et al., 2019; Edwards et al., 2019; D. Y. Kim et al., 2010; Koh et al., 2017; Mazzoleni et al., 2019). If an analysis was conducted, a significant difference can be found in favor of tDCS (MD = 3.22; CI-95% [0.87, 5.58]; heterogeneity: $Tau^2 = 5.73$; $Chi^2 = 23.62$, df = 7 (P = 0.001); $I^2 = 70\%$; test for overall effect: Z = 2.68, P = 0.007)(Figure 5).

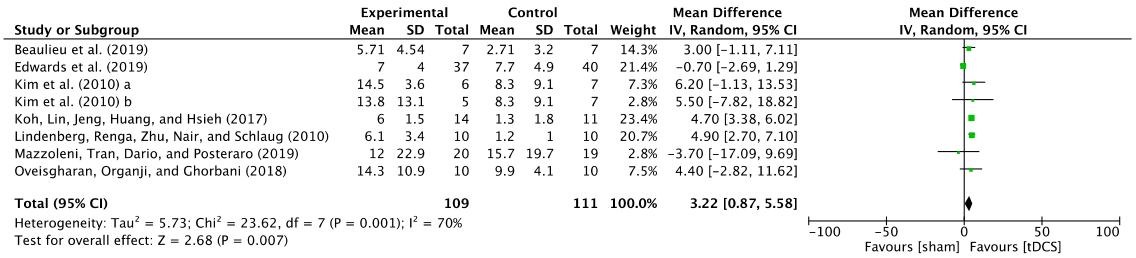

Figure 5 Meta-analysis of overall measurements by coulomb above 2 As

When analysis was corrected for **type of stimulation**. Four studies used anodal stimulation. The results showed a nonsignificant benefit of tDCS compared to sham (MD = 2.36; CI-95% [-2.02, 6.75]; heterogeneity: $Tau^2 = 12.60$; $Chi^2 = 15.70$, df = 3 (P = 0.001); $I^2 = 81\%$; test for overall effect: Z = 1.06, P = 0.29) (Edwards et al., 2019; D. Y. Kim et al., 2010; R. Lindenberg et al., 2010; Mazzoleni et al., 2019). One study used cathodal stimulation. A nonsignificant benefit of tDCS compared to sham was seen (MD = 5.50; CI-95% [-7.82, 18.82]; test for overall effect: Z = 0.81, P = 0.42) (D. Y. Kim et al., 2010). One study used bihemispheric stimulation. The results showed a nonsignificant benefit of tDCS compared with sham (MD = 4.40; CI-95% [-2.82, 11.62]; test for overall effect: Z = 1.19, P = 0.23) (Oveisgharan et al., 2018). Two studies used bilateral stimulation (Beaulieu et al., 2019; Koh et al., 2017). A consistent result is seen were a significant benefit in favor of tDCS-group is found. (MD = 4.54; CI-95% [3.28, 5.80]; heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.59$, df = 1 (P = 0.44); $I^2 = 0\%$; test for overall effect: Z = 7.07, P < 0.00001).

When analysis was corrected for **patient type**, the results were inconsistent. One study showed a nonsignificant effect of tDCS compared to sham in acute stroke patients (MD = 4.40; CI-95% [-2.82, 11.62]; test for overall effect: Z = 1.19, P = 0.23) (Oveisgharan et al., 2018). Three studies showed a nonsignificant effect of tDCS compared with sham in subacute stroke patients (MD = 4.22; CI-95% [-1.57, 10.01]; heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 1.66$, df = 2 (P = 0.44); $I^2 = 0\%$; test for overall effect: Z = 1.43, P = 0.15) (D. Y. Kim et al., 2010; Mazzoleni et al., 2019).

Four studies showed a significant an effect of tDCS compared with sham in chronic stroke patients (MD = 2.99; CI-95% [0.11, 5.88]; heterogeneity: $Tau^2 = 7.11$; $Chi^2 = 21.82$, df = 3 ($P < 0.0001$); $I^2 = 86\%$; test for overall effect: Z = 2.03, P = 0.04) (Beaulieu et al., 2019; Edwards et al., 2019; Koh et al., 2017; R. Lindenberg et al., 2010).

When analysis was corrected for **timing of the stimulation**, the results were inconsistent. One study showed a nonsignificant benefit of tDCS without additional therapy compared to sham (MD = 4.40; CI-95% [-2.82, 11.62]; test for overall effect: Z = 1.19, P = 0.23) (Oveisgharan et al., 2018). One study used stimulation prior to additional therapy (Edwards et al., 2019). The results showed a nonsignificant benefit of tDCS prior to additional therapy compared with sham (MD = -0.70; CI-95% [-2.69, 1.29]; test for overall effect: Z = 0.69, P = 0.49). Five studies used tDCS during a part of the additional therapy (Beaulieu et al., 2019; D. Y. Kim et al., 2010; R. Lindenberg et al., 2010; Mazzoleni et al., 2019). The results showed a significant effect of tDCS compared to sham (MD = 4.45; CI-95% [2.61, 6.29]; heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 2.31$, df = 4 (P = 0.68); $I^2 = 0\%$; test for overall effect: Z = 4.75, $P < 0.00001$). One study used stimulation during the complete session of additional therapy (Koh et al., 2017). The results showed a significant effect of tDCS compared to sham (MD = 4.70; CI-95% [3.38, 6.02]; test for overall effect: Z = 6.97, $P < 0.00001$).

When analysis was corrected for the **number of sessions**, the results remained consistent. One study used 5 sessions of stimulation (R. Lindenberg et al., 2010). The results showed a significant effect compared to sham (MD = 4.90; CI-95% [2.70, 7.10]; test for overall effect: Z = 4.37, $P < 0.0001$). Four studies used between 10 and 12 sessions of stimulation (Beaulieu et al., 2019; D. Y. Kim et al., 2010; Oveisgharan et al., 2018). The results showed a significant effect of tDCS compared to sham (MD = 3.98 CI-95% [0.86, 7.10]; heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.63$, df = 3 (P = 0.89); $I^2 = 0\%$; test for overall effect: Z = 2.50, P = 0.01). One study used 24 sessions of tDCS (Koh et al., 2017). The results showed a significant effect compared with sham (MD = 4.70 CI-95% [3.38, 6.02]; test for overall effect: Z = 6.97, $P < 0.00001$).

Two studies used 30 or more sessions of tDCS. A nonsignificant effect in favor of sham was seen (MD = -0.76; CI-95% [-2.74, 1.21]; heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.19$, df = 1 (P = 0.66); $I^2 = 0\%$; test for overall effect: Z = 0.76, P = 0.45) (Edwards et al., 2019; Mazzoleni et al., 2019).

When analysis was corrected for **electrode size**, the results were inconsistent. One study used 4 x 4 cm^2 electrodes (Oveisgharan et al., 2018). The results showed a nonsignificant effect of tDCS compared with sham (MD = 4.40; CI-95% [-2.82, 11.62]; test for overall effect: Z = 1.19, P = 0.23). One study used 16,3 cm^2 electrodes (R. Lindenberg et al., 2010). The results showed a significant effect of tDCS compared with sham (MD = 4.90; CI-95% [2.70, 7.10]; test for overall effect: Z = 4.37, P < 0.0001). Three studies used 25 cm^2 electrodes (D. Y. Kim et al., 2010; Koh et al., 2017). The results showed a significant effect of tDCS compared to sham (MD = 4.75; CI-95% [3.46, 6.05]; heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.17$, df = 2 (P = 0.92); $I^2 = 0\%$; test for overall effect: Z = 7.19, P < 0.00001). Three studies used 35 cm^2 electrodes (Beaulieu et al., 2019; Edwards et al., 2019; Mazzoleni et al., 2019). The results showed a small nonsignificant effect of tDCS compared with sham (MD = 0.32; CI-95% [-2.43, 3.07]; heterogeneity: $Tau^2 = 2.00$; $Chi^2 = 2.81$, df = 2 (P = 0.25); $I^2 = 29\%$; test for overall effect: Z = 0.23, P = 0.82).

Density

≤ 0.4 mA/cm^2

Eight studies used a density of 0.04 mA/cm^2 or less (Cunningham et al., 2015; Jin et al., 2019; Rocha et al., 2016; Straudi et al., 2016; L. T. Triccas et al., 2015). All studies found a significant improvement in the FMA-UE post-intervention relative to baseline. When compared to sham, none found a significant difference. If an analysis was conducted, a significant difference was found in favor of tDCS (MD = 1.66; CI-95% [0.13 – 3.18]; heterogeneity: $Tau^2 = 1.06$; $Chi^2 = 9.12$, df = 7 (P = 0.24); $I^2 = 23\%$, test for overall effect: Z = 2.12, P = 0.03)(Figure 6).

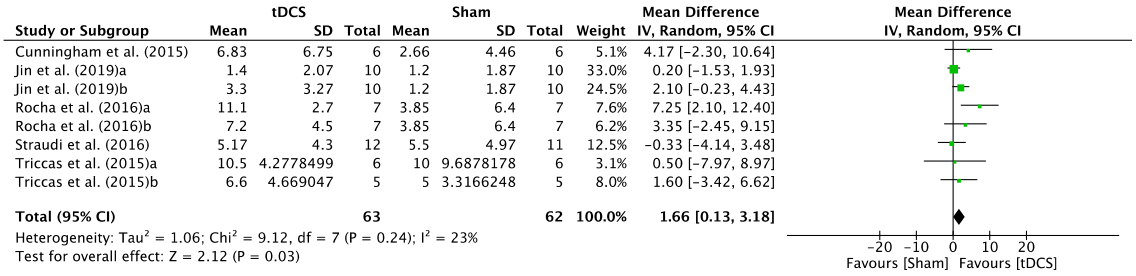

Figure 6 Meta-analysis of overall measurements by density of 0.04 mA/cm^2 or under

When analysis was corrected for **type of stimulation**, five studies used anodal stimulation (Cunningham et al., 2015; Rocha et al., 2016; Straudi et al., 2016; L. T. Triccas et al., 2015). The results showed a nonsignificant difference favoring tDCS-group (MD = 2.52; CI-95% [-0.44 – 5.47]; Heterogeneity: Tau² = 3.68; Chi² = 5.95, df = 4 (P = 0.20); I² = 33%, test for overall effect: Z = 1.67, P = 0.10). One study used cathodal stimulation (Rocha et al., 2016). A nonsignificant difference can be seen in favor of tDCS-group (MD = 3.35; CI-95% [-2.45 – 9.15]; test for overall effect: Z = 1.13, P = 0.26). Two studies used bilateral tDCS (Jin et al., 2019). A nonsignificant difference can be found in favor of tDCS-group (MD = 0.98; CI-95% [-0.85 – 2.81]; Heterogeneity: Tau² = 0.71; Chi² = 1.64, df = 1 (P = 0.20); I² = 39%, test for overall effect: Z = 1.05, P = 0.29).

When analysis was corrected for **patient type**, no study used acute patients. Two studies used subacute stroke patients (Straudi et al., 2016; L. T. Triccas et al., 2015). An inconsistent result is seen were a small nonsignificant difference can be found in favor of sham-group (MD = -0.19; CI-95% [-3.67 – 3.29]; Heterogeneity: Tau² = 0.00; Chi² = 0.03, df = 1 (P = 0.86); I² = 0%, test for overall effect: Z = 0.11, P = 0.91). Seven studies used chronic stroke patients (Cunningham et al., 2015; Jin et al., 2019; Rocha et al., 2016; Straudi et al., 2016; L. T. Triccas et al., 2015). The results remained consistent, were a significant difference can be found in favor of tDCS-group (MD = 1.79; CI-95% [0.11 – 3.48]; Heterogeneity: Tau² = 1.60; Chi² = 9.09, df = 6 (P = 0.17); I² = 34%, test for overall effect: Z = 2.08, P = 0.04). However, Straudi et al. (2016) used both subacute as well as chronic stroke patients, but no separate data is available. Therefore, this study is included in both corrected analyses.

When this study is removed from the analysis, the results showed a small nonsignificant difference in favor of tDCS-group for subacute stroke patients (MD = 0.50; CI-95% [-7.79 – 8.97]; test for overall effect: Z = 0.12, P = 0.91). In chronic stroke patients, the results remained the same were a significant difference favoring tDCS-group is found (MD = 2.21; CI-95% [0.30 – 4.13]; Heterogeneity: $Tau^2 = 2.04$; $Chi^2 = 8.27$, df = 5 (P = 0.14); $I^2 = 40\%$, test for overall effect: Z = 2.26, P = 0.02).

When analysis was corrected for **timing of the stimulation**. Three studies stimulated prior to the additional therapy (Jin et al., 2019; Rocha et al., 2016).
A nonsignificant difference was found favoring tDCS-group (MD = 3.10; CI-95% [-1.42 – 7.62]; Heterogeneity: $Tau^2 = 11.27$; $Chi^2 = 7.11$, df = 2 (P = 0.03); $I^2 = 72\%$, test for overall effect: Z = 1.34, P = 0.18). Two studies used stimulation for a part of the additional therapy (L. T. Triccas et al., 2015). A nonsignificant difference is found favoring tDCS-group (MD = 1.31; CI-95% [-3.00 – 5.63]; Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.05$, df = 1 (P = 0.83); $I^2 = 0\%$, test for overall effect: Z = 0.60, P = 0.55). Three studies stimulated the complete session of the additional therapy (Cunningham et al., 2015; Jin et al., 2019; Straudi et al., 2016). A nonsignificant difference is found in favor of tDCS-group (MD = 1.67; CI-95% [-0.23 – 3.58]; Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 1.76$, df = 2 (P = 0.41); $I^2 = 0\%$, test for overall effect: Z = 1.72, P = 0.08).

When analysis was corrected for **total minutes of stimulation**, two studies had a total of more than 100 minutes of stimulation (Rocha et al., 2016). A significant difference is found favoring tDCS-group (MD = 5.53; CI-95% [1.68 – 9.38]; Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.97$, df = 1 (P = 0.32); $I^2 = 0\%$, test for overall effect: Z = 2.82, P = 0.005). Five studies had a total of more than 300 minutes of stimulation (Jin et al., 2019; Straudi et al., 2016; L. T. Triccas et al., 2015). A nonsignificant difference is found in favor of tDCS-group (MD = 0.78; CI-95% [-0.47 – 2.03]; Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 2.09$, df = 4 (P = 0.72); $I^2 = 0\%$, test for overall effect: Z = 1.22, P = 0.22). Only one study had over 400 minutes of total stimulation time (Cunningham et al., 2015). A nonsignificant difference can be found favoring tDCS-group (MD = 4.17; CI-95% [-2.30 – 10.64]; test for overall effect: Z = 1.26, P = 0.21).

0.04 mA/cm²<…<0.08 mA/cm²

Six studies used a density between 0.04 mA/cm² and 0.08 mA/cm² (Beaulieu et al., 2019; Edwards et al., 2019; Fusco et al., 2014; Koh et al., 2017; Mazzoleni et al., 2019; Viana et al., 2014). All studies found a significant improvement in the FMA-UE post-intervention relative to baseline, except Koh et al. (2017) who found a nonsignificant improvement favoring tDCS-group. However, none found a significant between-group difference. If an analysis was conducted, a nonsignificant difference can be found in favor of tDCS (MD = 1.74; CI-95% [-1.26 – 4.74]; Heterogeneity: Tau² = 8.23; Chi² = 21.40, df = 5 (P = 0.0007); I² = 77%, test for overall effect: Z = 1.14, P = 0.26)(Figure 7).

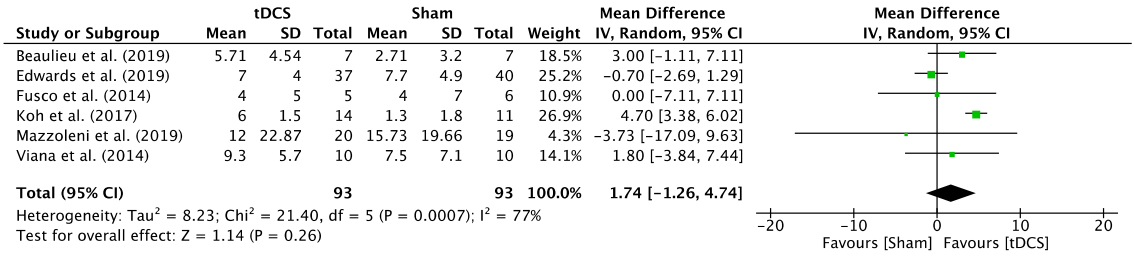

Figure 7 Meta-analysis of overall measurements by density between 0.04 mA/cm² and 0.08 mA/cm²

When analysis was corrected for **type of stimulation**, three studies used anodal stimulation (Edwards et al., 2019; Mazzoleni et al., 2019; Viana et al., 2014). A nonsignificant difference can be found in favor of the sham group (MD = -0.49; CI-95% [-2.35 – 1.37]; Heterogeneity: Tau² = 0.00; Chi² = 0.90, df = 2 (P = 0.64); I² = 0%, test for overall effect: Z = 0.51, P = 0.61). One study used cathodal tDCS (Fusco et al., 2014). No difference was found between sham- and tDCS-group (MD = 0.00; CI-95% [-7.11 – 7.11]; test for overall effect: Z = 0.00, P = 1.00). Two studies used bilateral tDCS (Beaulieu et al., 2019; Koh et al., 2017). A significant difference is seen favoring the tDCS-group (MD = 4.54; CI-95% [3.28 – 5.80]; Heterogeneity: Tau² = 0.00; Chi² = 0.59, df = 1 (P = 0.44); I² = 0%, test for overall effect: Z = 7.07, P < 0.00001).

When analysis was corrected for **patient type**, no study used acute patients. Two studies used subacute stroke patients (Fusco et al., 2014; Mazzoleni et al., 2019).

The results were inconsistent, a small nonsignificant difference was found favoring sham-group (MD = -0.82; CI-95% [-7.10 – 5.46]; Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.23$, df = 1 (P = 0.63); $I^2 = 0\%$, test for overall effect: Z = 0.26, P = 0.80). Four studies used chronic stroke patients (Beaulieu et al., 2019; Edwards et al., 2019; Koh et al., 2017; Viana et al., 2014). The results were consistent, a nonsignificant difference is found in favor of tDCS-group (MD = 2.23; CI-95% [-1.15 – 5.62]; Heterogeneity: $Tau^2 = 9.05$; $Chi^2 = 19.78$, df = 3 (P = 0.0002); $I^2 = 85\%$, test for overall effect: Z = 1.30, P = 0.19).

When analysis was corrected for **timing of the stimulation**, three studies stimulated prior to the additional intervention (Edwards et al., 2019; Fusco et al., 2014; Viana et al., 2014). Result were inconsistent, where a nonsignificant difference was found in favor of sham-group (MD = -0.40; CI-95% [-2.21 – 1.42]; Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.68$, df = 2 (P = 0.71); $I^2 = 0\%$, test for overall effect: Z = 0.43, P = 0.67). Two studies used stimulation for a part of the additional therapy (Beaulieu et al., 2019; Mazzoleni et al., 2019). A nonsignificant difference can be found in favor of the tDCS-group (MD = 2.42; CI-95% [-1.52 – 6.35]; Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.89$, df = 1 (P = 0.35); $I^2 = 0\%$, test for overall effect: Z = 1.20, P = 0.23). One study used stimulation for the complete sessions of the additional therapy (Koh et al., 2017). A significant difference is seen favoring the tDCS-group (MD = 4.70; CI-95% [3.38 – 6.02]; test for overall effect: Z = 6.97, P < 0.00001).

When analysis was corrected for **total minutes of stimulation**, two studies had a total of more than 100 minutes of total stimulation time (Fusco et al., 2014; Viana et al., 2014). A small nonsignificant difference is seen favoring tDCS-group (MD = 1.10; CI-95% [-3.32 – 5.53]; Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.15$, df = 1 (P = 0.70); $I^2 = 0\%$, test for overall effect: Z = 0.49, P = 0.62). One study had more than 200 minutes of total stimulation time (Beaulieu et al., 2019). A nonsignificant difference is seen favoring tDCS-group (MD = 3.00; CI-95% [-1.11 – 7.11]; test for overall effect: Z = 1.43, P = 0.15). Three studies had over 600 minutes of total stimulation time (Edwards et al., 2019; Koh et al., 2017; Mazzoleni et al., 2019). A small nonsignificant difference is seen favoring tDCS-group (MD = 1.44; CI-95% [-3.50 – 6.38]; Heterogeneity: $Tau^2 = 13.48$; $Chi^2 = 20.58$, df = 2 (P < 0.0001); $I^2 = 90\%$, test for overall effect: Z = 0.57, P = 0.57).

≥ 0.08 mA/cm²

Four studies used a density of 0.08 mA/cm² or above (D. Y. Kim et al., 2010; R. Lindenberg et al., 2010; Oveisgharan et al., 2018). Two studies found a significant improvement post-intervention between- and within-group in favor of tDCS (R. Lindenberg et al., 2010; Oveisgharan et al., 2018). D. Y. Kim et al. (2010) found nonsignificant improvements favoring tDCS. If an analysis was conducted, a significant difference was found favoring tDCS (MD = 4.97; CI-95% [2.97 – 6.97]; Heterogeneity: Tau² = 0.00; Chi² = 0.14, df = 3 (P = 0.99); I² = 0%, test for overall effect: Z = 4.88, P < 0.00001)(Figure 8).

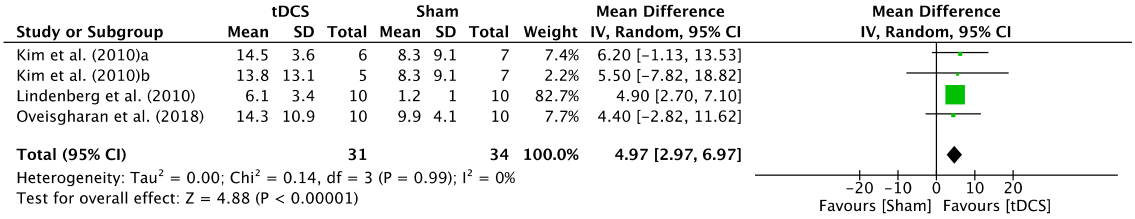

Figure 8 Meta-analysis of overall measurements by density of 0.08 mA/cm² or above

When analysis was corrected for **type of stimulation**, two studies used anodal stimulation (D. Y. Kim et al., 2010; R. Lindenberg et al., 2010). A significant difference can be found in favor of the tDCS-group (MD = 5.01; CI-95% [2.90 – 7.11]; Heterogeneity: Tau² = 0.00; Chi² = 0.11, df = 1 (P = 0.74); I² = 0%, test for overall effect: Z = 4.66, P < 0.00001). One study used cathodal tDCS (D. Y. Kim et al., 2010). A nonsignificant difference can be found in favor of tDCS-group (MD = 5.50; CI-95% [-7.82 – 18.82]; test for overall effect: Z = 0.81, P = 0.42). One study used bihemispheric tDCS (Oveisgharan et al., 2018). A nonsignificant difference is found in favor of the tDCS-group (MD = 4.40; CI-95% [-2.82 – 11.62]; test for overall effect: Z = 1.19, P = 0.23).

When analysis was corrected for **patient type**, only one study used acute patients (Oveisgharan et al., 2018). A nonsignificant difference can be found in favor of tDCS group (MD = 4.40; CI-95% [-2.82 – 11.62]; test for overall effect: Z = 1.19, P = 0.23). D. Y. Kim et al. (2010) used subacute patients for the two conditions (prior and concurrent).

The results found a nonsignificant difference in favor of the tDCS-group (MD = 6.04; CI-95% [-0.38 – 12.46]; Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.01$, df = 1 (P = 0.93); $I^2 = 0\%$, test for overall effect: Z = 1.84, P = 0.07). One study used chronic stroke patients (R. Lindenberg et al., 2010). Results found a significant difference in favor of tDCS-group (MD = 4.90; CI-95% [2.70 – 7.10]; test for overall effect: Z = 4.37, P < 0.0001).

When analysis was corrected for **timing of the stimulation**. Three studies used stimulation for a part of the additional therapy (D. Y. Kim et al., 2010; R. Lindenberg et al., 2010). A significant difference is seen favoring tDCS-group (MD = 5.02; CI-95% [2.94 – 7.10]; Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.12$, df = 2 (P = 0.94); $I^2 = 0\%$, test for overall effect: Z = 4.73, P < 0.00001).

When analysis was corrected for **total minutes of stimulation**. One study had a total of more than 100 minutes of total stimulation time (R. Lindenberg et al., 2010). A significant difference is seen favoring tDCS-group (MD = 4.90; CI-95% [2.70 – 7.10]; test for overall effect: Z = 4.37, P < 0.0001). Two studies had a more than 200 minutes of total stimulation time (D. Y. Kim et al., 2010). A nonsignificant difference was found in favor of tDCS-group (MD = 6.04; CI-95% [-0.38 – 12.46]; Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.01$, df = 1 (P = 0.93); $I^2 = 0\%$, test for overall effect: Z = 1.84, P = 0.07). One study used more than 300 minutes of total stimulation time (Oveisgharan et al., 2018). A nonsignificant difference is found in favor of the tDCS-group (MD = 4.40; CI-95% [-2.82 – 11.62]; test for overall effect: Z = 1.19, P = 0.23).

Patient type

Acute stroke patients

One study used acute stroke patients. This study used 10 sessions of anodal tDCS without an additional therapy. If an analysis was conducted, a nonsignificant effect of tDCS compared to sham was found (MD = 4.40; CI-95% [-2.82, 11.62]; test for overall effect: Z = 1.19, P = 0.23) (Oveisgharan et al., 2018) (Figure 9).

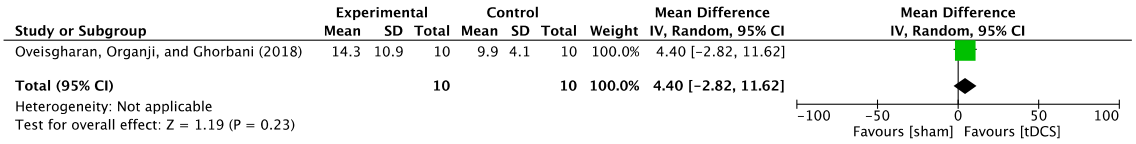

Figure 9 Meta-analysis of overall measurements by acute stroke patients

Subacute stroke patients

Six studies used subacute stroke patients (Fusco et al., 2014; D. Y. Kim et al., 2010; Mazzoleni et al., 2019; Straudi et al., 2016; L. T. Triccas et al., 2015). Straudi et al. (2016) used subacute and chronic patients, the data is included in both analyses. All studies found a significant improvement in the FMA-UE post-intervention relative to baseline. When compared to sham, none found a significant difference. If an analysis was conducted, the results showed a small nonsignificant effect of tDCS compared to sham (MD = 0.83; CI-95% [-1.92, 3.58]; heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 3.39$, df = 5 (P = 0.64); $I^2 = 0\%$; test for overall effect: Z = 0.59, P = 0.55)(Figure 10).

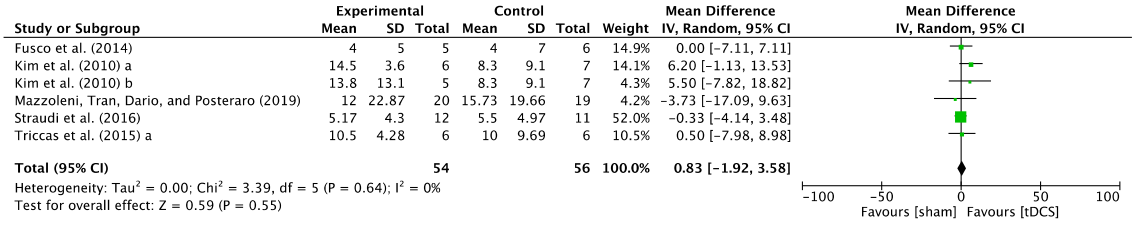

Figure 10 Meta-analysis of overall measurements by subacute stroke patients

When analysis was corrected by **type of stimulation**, the results remained consistent. Five studies used anodal stimulation (D. Y. Kim et al., 2010; Mazzoleni et al., 2019; Straudi et al., 2016; L. T. Triccas et al., 2015). The results showed a small nonsignificant effect of tDCS compared to sham (MD = 0.74; CI-95% [-2.32, 3.80]; heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 2.87$, df = 3 (P = 0.41); $I^2 = 0\%$; test for overall effect: Z = 0.47, P = 0.64). Two studies used cathodal stimulation (Fusco et al., 2014; D. Y. Kim et al., 2010). The results showed a small nonsignificant effect of tDCS compared to sham (MD = 1.22; CI-95% [-5.05, 7.49]; heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.51$, df = 1 (P = 0.48); $I^2 = 0\%$; test for overall effect: Z = 0.38, P = 0.70).

When analysis was corrected by the **timing of stimulation**, the results remained consistent. One study did not show a significant effect of tDCS prior to the additional therapy compared to sham (MD = 0.00; CI-95% [-7.11, 7.11]; test for overall effect: Z = 0.00, P = 1.00) (Fusco et al., 2014). Four studies showed a non-significant effect of tDCS for a part of the additional therapy compared to sham (MD = 3.03; CI-95% [-1.75, 7.81]; heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 2.18$, df = 3 (P = 0.54); $I^2 = 0\%$; test for overall effect: Z = 1.24, P = 0.21) (D. Y. Kim et al., 2010; Mazzoleni et al., 2019; L. T. Triccas et al., 2015). One study used tDCS for the full additional therapy session. The results showed a small nonsignificant effect of tDCS compared to sham (MD = -0.33; CI-95% [-4.14, 3.48]; test for overall effect: Z = 0.17, P = 0.87) (Straudi et al.).

When analysis was corrected by the **number of sessions**, the results remained consistent. Four studies used 10 sessions of stimulation (Fusco et al., 2014; D. Y. Kim et al., 2010; Straudi et al., 2016). The results showed a nonsignificant effect of tDCS compared with sham (MD = 1.10; CI-95% [-1.88, 4.07]; heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 2.91$, df = 3 (P = 0.41); $I^2 = 0\%$; test for overall effect: Z = 0.72, P = 0.47).
One study used 18 sessions of stimulation (L. T. Triccas et al., 2015). The results showed a small nonsignificant effect compared to sham (MD = 0.50; CI-95% [-7.98, 8.98]; test for overall effect: Z = 0.12, P = 0.91). One study used 30 sessions of stimulation (Mazzoleni et al., 2019). The results showed a small nonsignificant effect in favor of sham (MD = -3.73; CI-95% [-17.09, 9.63]; test for overall effect: Z = 0.55, P = 0.58).

Chronic stroke patients

Thirteen studies used chronic stroke patients. One study found a significant effect in favor of tDCS (R. Lindenberg et al., 2010). Twelve studies found a significant improvement in the FMA-UE post-intervention relative to baseline, except Koh et al. (2017) who found a nonsignificant improvement favoring tDCS-group (Ang et al., 2015; Beaulieu et al., 2019; Cunningham et al., 2015; Edwards et al., 2019; Jin et al., 2019; Koh et al., 2017; Rocha et al., 2016; Straudi et al., 2016; L. T. Triccas et al., 2015; Viana et al., 2014). However, none found a significant between-group difference. Straudi et al. (2016) used subacute and chronic patients, the data is included in both analyses.

The results showed a significant effect in favor of tDCS (MD = 2.12; [0.52, 3.71], heterogeneity: Tau² = 5.29; Chi² = 45.06, df = 12 (P < 0.0001); I² = 73%, test for overall effect: Z = 2.60, P = 0.009)(Figure 11).

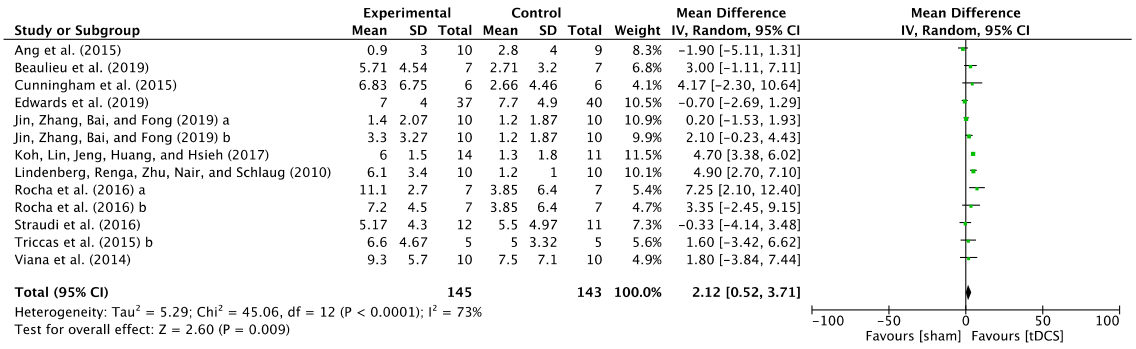

Figure 11 Meta-analysis of overall measurements by chronic stroke patients

When analysis was corrected for **type of stimulation**, the results were inconsistent. Eight studies used anodal stimulation (Ang et al., 2015; Cunningham et al., 2015; Edwards et al., 2019; R. Lindenberg et al., 2010; Rocha et al., 2016; Straudi et al., 2016; L. T. Triccas et al., 2015; Viana et al., 2014). The results showed a nonsignificant effect in favor of tDCS (MD = 1.81; CI-95% [-0.60, 4.21]; heterogeneity: Tau² = 7.71; Chi² = 24.55, df = 7 (P = 0.0009); I² = 71%; test for overall effect: Z = 1.47, P = 0.14).

One study used cathodal stimulation (Rocha et al., 2016). The results showed a nonsignificant effect of tDCS compared to sham (MD = 3.35; CI-95% [-2.45, 9.15]; test for overall effect: Z = 1.13, P = 0.26). Four studies used bilateral stimulation (Beaulieu et al., 2019; Jin et al., 2019; Koh et al., 2017). The results suggested a significant effect of tDCS compared to sham (MD = 2.49; CI-95% [0.01, 4.97]; heterogeneity: Tau² = 4.94; Chi² = 16.94, df = 3 (P = 0.0007); I² = 82%; test for overall effect: Z = 1.97, P = 0.05).

When analysis was corrected for the **timing of stimulation**, the results were inconsistent. Six studies showed a nonsignificant effect of tDCS prior to the additional therapy compared to sham (MD = 0.74; CI-95% [-1.24, 2.72]; heterogeneity: Tau² = 2.92; Chi² = 11.08, df = 5 (P = 0.05); I² = 55%; test for overall effect: Z = 0.73, P = 0.46) (Ang et al., 2015; Edwards et al., 2019; Jin et al., 2019; Rocha et al., 2016; Viana et al., 2014).

Three studies showed a significant effect of tDCS during a part of the additional therapy compared to sham (4.11; CI-95% [2.30, 5.91]; heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 1.74$, df = 2 (P = 0.42); $I^2 = 0\%$; test for overall effect: Z = 4.45, P < 0.00001) (Beaulieu et al., 2019; R. Lindenberg et al., 2010; L. T. Triccas et al., 2015). Four studies showed a significant effect of tDCS during the complete session of additional therapy compared to sham (MD = 2.82; CI-95% [0.45, 5.18]; heterogeneity: $Tau^2 = 3.32$; $Chi^2 = 8.31$, df = 3 (P = 0.04); $I^2 = 64\%$; test for overall effect: Z = 2.33, P = 0.02) (Cunningham et al., 2015; Jin et al., 2019; Koh et al., 2017; Straudi et al., 2016).

When analysis was corrected for the **number of sessions**, the results were inconsistent. One study used 5 sessions of stimulation (R. Lindenberg et al., 2010). The results showed a significant effect in favor of tDCS (MD = 4.90; CI-95% [2.70, 7.10]; test for overall effect: Z = 4.37, P < 0.0001). Seven studies used 10 or more sessions of stimulation (Ang et al., 2015; Beaulieu et al., 2019; Jin et al., 2019; Rocha et al., 2016; Straudi et al., 2016). The results showed a nonsignificant effect of tDCS compared to sham (MD = 1.36; CI-95% [-0.44, 3.17]; heterogeneity: $Tau^2 = 2.79$; $Chi^2 = 12.49$, df = 6 (P = 0.05); $I^2 = 52\%$; test for overall effect: Z = 1.48, P = 0.14). Three studies used 15 or more sessions of stimulation (Cunningham et al., 2015; L. T. Triccas et al., 2015; Viana et al., 2014). The results showed a nonsignificant effect of tDCS compared to sham (MD = 2.31 CI-95% [-0.93, 5.56]; heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.43$, df = 2 (P = 0.81); $I^2 = 0\%$; test for overall effect: Z = 1.40, P = 0.16).One study showed a significant effect of 24 sessions tDCS compared to sham (MD = 4.70 CI-95% [3.38, 6.02]; test for overall effect: Z = 6.97, P < 0.00001) (Koh et al., 2017). One study used 36 sessions of stimulation and showed a nonsignificant effect in favor of sham (MD = -0.70 [-2.69, 1.29]; test for overall effect: Z = 0.69, P = 0.49) (Edwards et al., 2019).

Timing of the stimulation

Prior

Seven studies stimulated prior to additional intervention. All studies found a significant improvement in the FMA-UE post-intervention relative to baseline, but not when compared to sham (Ang et al., 2015; Edwards et al., 2019; Fusco et al., 2014; Jin et al., 2019; Rocha et al., 2016; Viana et al., 2014).

If analysis was conducted, a small nonsignificant difference was found in favor of tDCS-group (MD = 2.15; CI-95% [0.05 – 4.26]; Heterogeneity: $Tau^2 = 6.38$; $Chi^2 = 26.41$, df = 11 (P = 0.006); $I^2 = 58\%$, test for overall effect: Z = 2.00, P = 0.05)(Figure 12).

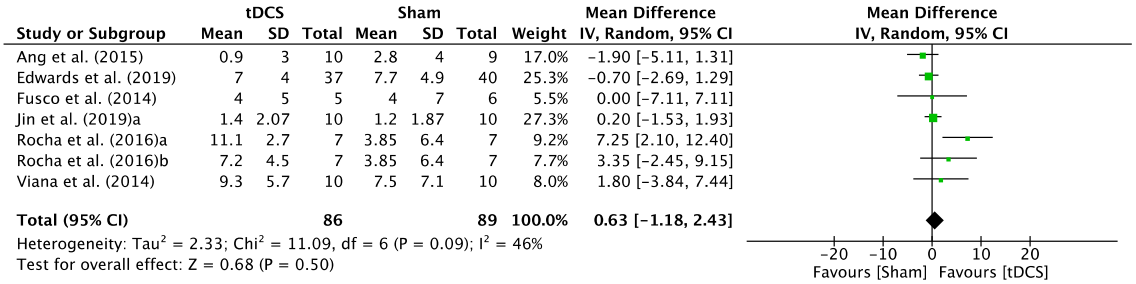

Figure 12 Meta-analysis of overall measurements by prior stimulation

When analysis was corrected for **type of stimulation**, four studies who stimulated for a prior to the additional therapy used anodal tDCS (Ang et al., 2015; Edwards et al., 2019; Rocha et al., 2016; Viana et al., 2014). A nonsignificant difference is found in favor of tDCS-group (MD = 1.00; CI-95% [-2.32 – 4.32]; Heterogeneity: $Tau^2 = 7.46$; $Chi^2 = 9.83$, df = 3 (P = 0.02); $I^2 = 69\%$, test for overall effect: Z = 0.59, P = 0.55). Two studies used cathodal tDCS (Fusco et al., 2014; Rocha et al., 2016). A nonsignificant difference was found favoring tDCS-group (MD = 2.01; CI-95% [-2.48 – 6.51]; Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.51$, df = 1 (P = 0.47); $I^2 = 0\%$, test for overall effect: Z = 0.88, P = 0.38). One study used bilateral tDCS (Jin et al., 2019). A small nonsignificant difference was found favoring tDCS-group (MD = 0.20; CI-95% [-1.53 – 1.93]; test for overall effect: Z = 0.23, P = 0.82).

Partially

Seven studies stimulated during a part of the additional therapy. All studies found a significant improvement in the FMA-UE post-intervention relative to baseline (Beaulieu et al., 2019; D. Y. Kim et al., 2010; R. Lindenberg et al., 2010; Mazzoleni et al., 2019; L. T. Triccas et al., 2015). When compared to sham, none found a significant difference. One study found a significant effect of tDCS compared to sham (Lindenberg et al., 2010). If analysis was conducted, the results suggested a significant difference in favor of tDCS-group (MD = 3.97; CI-95% [2.28 – 5.66]; Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 4.08$, df = 6 (P = 0.67); $I^2 = 0\%$, test for overall effect: Z = 4.60, P < 0.00001)(Figure 13).

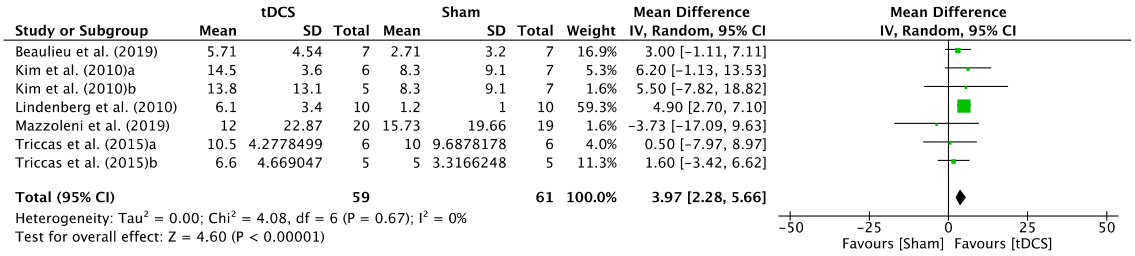

Figure 13 Meta-analysis of overall measurements by partial stimulation

When analysis was corrected for **type of stimulation**, five studies who stimulated partially during the additional therapy used anodal tDCS (D. Y. Kim et al., 2010; R. Lindenberg et al., 2010; Mazzoleni et al., 2019; L. T. Triccas et al., 2015). A significant difference is seen in favor of tDCS-group (MD = 4.14; CI-95% [2.27 – 6.01]; Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 3.79$, df = 4 (P = 0.44); $I^2 = 0\%$, test for overall effect: Z = 4.33, P < 0.0001). One study used cathodal tDCS (D. Y. Kim et al., 2010). The results showed a nonsignificant difference favoring tDCS-group (MD = 5.50; CI-95% [-7.82 – 18.82]; test for overall effect: Z = 0.81, P = 0.42). One study used bilateral tDCS (Beaulieu et al., 2019). A nonsignificant difference is seen favoring tDCS (MD = 3.00; CI-95% [-1.11 – 7.11]; test for overall effect: Z = 1.43, P = 0.15).

Full

Four studies stimulated the full time of the additional intervention. All studies found a significant improvement in the FMA-UE post-intervention relative to baseline, except Koh et al. (2017) who found a nonsignificant improvement favoring tDCS-group. However, none found a significant between-group difference (Cunningham et al., 2015; Jin et al., 2019; Koh et al., 2017; Straudi et al., 2016). If an analysis was conducted, a significant difference is found favoring tDCS-group (MD = 2.82; CI-95% [0.45 – 5.18]; Heterogeneity: $Tau^2 = 3.32$; $Chi^2 = 8.31$, df = 3 (P = 0.04); $I^2 = 64\%$, test for overall effect: Z = 2.33, P = 0.02)(Figure 14).

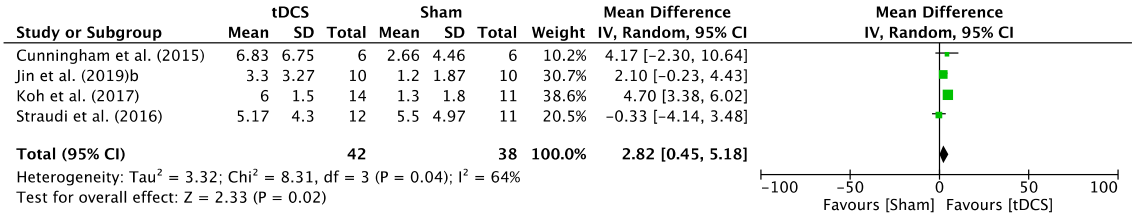

Figure 14 Meta-analysis of overall measurements by full stimulation

When analysis was corrected for **type of stimulation**, two studies who stimulated the complete session of the additional therapy used anodal tDCS (Cunningham et al., 2015; Straudi et al., 2016). A small nonsignificant difference is seen favoring tDCS-group (MD = 1.13; CI-95% [-3.00 – 5.26]; Heterogeneity: $Tau^2 = 2.78$; $Chi^2 = 1.38$, df = 1 (P = 0.24); $I^2 = 27\%$, test for overall effect: Z = 0.54, P = 0.59). Two studies used bilateral tDCS (Jin et al., 2019; Koh et al., 2017). The results showed a significant difference favoring tDCS-group (MD = 3.59; CI-95% [1.06 – 6.11]; Heterogeneity: $Tau^2 = 2.44$; $Chi^2 = 3.61$, df = 1 (P = 0.06); $I^2 = 72\%$, test for overall effect: Z = 2.79, P = 0.005).

5. Discussion

5.1. Summary of main results

Based on pooled data from 15 randomized controlled trials with 371 participants, significant evidence in favor of tDCS is found in overall measurements with transcranial direct current stimulation compared with sham stimulation. The results of overall measurements are presented in forest plots, which showed statistical significance in favor of tDCS compared to sham in the following subgroups: coulomb below 1 As and above 2 As, density below 0.4 mA/cm^2 and above 0.08 mA/cm^2, chronic stroke patients, partial stimulation and stimulation during the complete session of the additional therapy. The results showed a nonsignificant difference in favor of tDCS compared to sham in the following subgroups: coulomb between 1 As and 2 As, density between 0.04 mA/cm^2 and 0.08 mA/cm^2, acute and subacute stroke patients and stimulation prior to the additional therapy.

The results showed a better therapeutic effect when a higher density is used. It should be noted that when a density is applied between 0.04 mA/cm^2 and 0.08 mA/cm^2 results showed a nonsignificant difference, where of 0.04 mA/cm^2 or less gave a significant difference favoring tDCS-group. A possible explanation could be that different mechanisms play at roll in cortical excitability at various densities. It is known that GABA activation, which also plays an important role in regulating neuronal excitability, is voltage dependent (Mellor & Randall, 1998; Wolff, Joo, & Kasa, 1993). This means that when higher densities are used, GABA activation is higher (Mellor & Randall, 1998). In other words, when lower voltages are used, excitatory changes are accomplished through voltage-gated Ca^{2+} channels, which thresholds are normally lower than those of NMDA and AMPA receptors (Bastani & Jaberzadeh, 2013). Another explanation could be that Edwards et al. (2019) used the most total of sessions (36 sessions). All other studies used less than 25 sessions, except for Mazzoleni et al. (2019) who used 30 sessions. Results of these studies showed a nonsignificant difference in favor of the sham-group. A ceiling effect on the amount of sessions stimulate can be used for could be the reason (Naros et al., 2016).

Significant effects of tDCS compared with sham were found when stimulation of 2 As or more was used. This result is consistent with the effects Nitsche and Paulus (2000) found, higher intensities cause a higher increase cortical activity. Agboada, Samani, Jamil, Kuo, and Nitsche (2019) also showed a trend of increased effects when higher current intensities were used. This review found a linear dose-response relationship between intensity and the duration of the stimulation. A higher intensity with a low stimulation time can induce the same effect as a low intensity combined with a prolonged stimulation time. But Agboada et al. (2019) found tDCS to have a saturation effect after prolonged duration of the stimulation. This confirms our findings considering the amount of sessions and total minutes of stimulation that were effective. The results showed that more than 30 sessions had a nonsignificant effect in favor of the sham-group. Less time also seems more beneficial, only 100 minutes of total stimulation time found a significant difference in favor of tDCS-group.

The results showed significant effects of tDCS compared with sham in chronic stroke patients, no significant effect in acute and subacute stroke patients. A possible explanation is the adaptive rewiring or plasticity of the damaged neural pathways. Adaptive rewiring causes axonal sprouting, the growth of the intact axons to reinnervate denervated parts of the cortex (Brown, Boyd, & Murphy, 2010; Carmichael, Wei, Rovainen, & Woolsey, 2001; Dancause et al., 2005; Sist et al., 2012). These neuroanatomical changes are important in regaining function in the damaged parts of the brain. This is less present in the subacute phase of stroke and not present in chronic stoke. This could be the reason why patients in the acute and subacute phase of stroke probably do not have more benefit of stimulation of the motor cortex because in either way there is neuroplasticity present (Sist et al., 2012).

Bilateral stimulation seems more beneficial for stroke patients than anodal or cathodal stimulation. This could be due the fact that bilateral tDCS uses a more latero-medial current flow, instead of a more posterior-anterior current flow (cfr. Anodal/cathodal tDCS). Because upper extremity is presented more medial on the motor homunculus, bilateral tDCS can reach these area's better due to the latero-medial current flow (Naros et al., 2016).

Another explanation could be that bilateral stimulation uses anodal tDCS to increase excitability, while cathodal tDCS decreases excitability. This form of stimulation is consistent with the mechanistic model of the Interhemispheric Competition. This model suggests an imbalance between the lesioned and non-lesioned hemisphere. Due to the damage after the stroke, the lesioned hemisphere does not inhibit the non-lesioned hemisphere. The non-lesioned hemisphere is overly active, which results in a stronger inhibition of the lesioned hemisphere. Bilateral stimulation focusses on reducing or removing the interhemispheric competition (Harris-Love & Harrington, 2017). Anodal stimulation seemed more beneficial than cathodal stimulation. Anodal stimulation is used to excite inactive parts of the brain by depolarization of the resting membrane potential. Due to the ischemia followed by an interruption or blockage of a blood vessel, sudden dysfunction occurs in the affected parts of the brain. This part of the brain becomes inactive, stimulating that part of the brain has to be the main focus for making the brain more active or stimulate neuroplasticity (Nitsche et al., 2003). Recent studies suggested anodal stimulation to have an inhibiting effect after multiple stimulation sessions. A possible explanation could be the calcium overflow leading to saturation (Agboada et al., 2019). These results are consistent with our findings in the subgroup of coulomb, whereas anodal stimulation was found to be significant in coulomb below 1 As, but not for more than 1 As. No significant effects were found when stimulation with cathodal stimulation. A possible explanation is the inhibiting effect on the cortex. This hypothesis supports the Interhemispheric Competition model, where cathodal tDCS is used to reduce overactive areas (Harris-Love & Harrington, 2017). Considering the lack of activity in the damaged part of the brain after a stroke, the effect of cathodal tDCS is limited when using quantitative outcome measures. Martens et al. (2019) used cathodal stimulation in rats and showed a significant decrease in motor impulsivity. Future reviews will need to use qualitative outcome measures the evaluate the effect of the cathodal inhibition.

Results can suggest that stimulation during additional intervention (partially and full) is more effective than stimulating prior to the additional intervention. A possible explanation could be the Gating theory of motor learning.

This theory suggests that an acute increase of cortical excitability is necessary to enhance motor learning (Ziemann & Siebner, 2008). This process is called motor priming and it increases neural activity which facilitates the induction of LTP or LTD-like plasticity (Rioult-Pedotti, Friedman, & Donoghue, 2000; Rioult-Pedotti, Friedman, Hess, & Donoghue, 1998; Ziemann, Iliać, Pauli, Meintzschel, & Ruge, 2004; Ziemann & Siebner, 2008). Motor priming thus induces changes in the process of motor learning and is likely to be time-dependent (Jin et al., 2019; Sriraman, Oishi, & Madhavan, 2014). Task attributes is another factor to take in consideration. The type of task performed during the additional intervention should be matched with the stimulated part of the brain (Abraham, Mason-Parker, Bear, Webb, & Tate, 2001; Harris-Love & Harrington, 2017). Whether stimulation should be used partially, or the complete session of additional therapy remains unclear. None of the included studies used tDCS for more than 30 minutes. Future research will need to investigate the effect of a part of the additional therapy session with stimulation compared to a complete session of additional therapy with stimulation that lasts longer than the stimulation time of partial stimulation.

5.2. Overall completeness and applicability of evidence

The results of this review are complete, no data of ongoing trails were included. The evidence includes all forms of tDCS (anodal, cathodal, uni-, bilateral and bihemispheric), patients from different phases of stroke and different intensities of stimulation. Important findings for daily practice, stimulation should be used during the additional therapy. The additional therapy should be linked to the stimulated brain area. Bilateral stimulation is the most effective stimulation form for upper limb rehabilitation. Higher intensity increases neural activity. Using stimulation for too long may not be beneficial, there is likely a ceiling effect.

5.3. Quality of the evidence

The quality of the evidence in all included studies was high, as presented in table 4 PEDro quality checklist of included studies and table 5 Cochrane Risk of Bias Checklist of the included studies. The most common reasons for reduced quality were blinding of the therapists and researchers. Only one study did not report transparently (Ang et al., 2015), four criteria of the Risk of Bias Checklist were scored unclear.

The criteria include random sequence generation, concealment of allocation and blinding of personnel and outcome assessors. After comparison with the score on the PEDro scale, this study was seen as a moderate risk of bias but remained included. Subgroups and interaction analysis were performed to minimize the bias and decrease heterogeneity.

5.4. Potential biases in the review process

Strengths of this review included a comprehensive search across multiple databases, assessment of eligibility by two independent researchers, quality assessments for validity and risk of bias and a comprehensive approach to receive the necessary data from eligible trails. The primary limitation of this review is the heterogeneity between study protocols. To ensure uniformity subgroups were created. The subgroups focused on one parameter, therefor others were not taken in consideration. To minimize this effect, interaction analyses were performed within the subgroups. Further, included trails used different forms and times of therapy for the additional intervention. The effect of this interaction will remain unclear. Future reviews will need to focus on assessing effects of tDCS combined with a specific intervention. Other limitations include language restrictions in the selection process and possible bias due to limited experience of the researchers.

5.5. Agreements and disagreements with other studies or reviews

This study is the second study who analyzed the effectiveness of tDCS on improvement of upper limb where Fugl-Meyer Assessment was used as primary outcome. Chhatbar et al. (2016) was the first meta-analysis. The results of this study agree with the results found in Chhatbar et al. (2016). However, the result of this study are more elaborate and more conclusive than the results of Chhatbar et al. (2016). Yet, no definitive conclusions can be made due to great variety of study protocols between the randomized controlled trails investigating transcranial direct current stimulation.

6. Conclusion

6.1. Implications for practice

Moderate to high quality evidence shows tDCS to be an effective additional therapy to promote motor recovery in the upper limb after stroke. However, limited evidence is available on the parameters for stimulation. Although some recommendations can be made. tDCS is more beneficial for chronic stroke patients than acute or subacute patients. Bilateral tDCS appears to be the most effective form of stimulation for upper limb recovery. Higher intensities cause higher neural activity, but a ceiling effect appears to be present. Stimulation is most effective when used during physiotherapy targeting the stimulated parts of the brain.

6.2. Implications for research

Future research should focus on finding the appropriate stimulation parameters and the limits of stimulation, the so-called ceiling effect. Researchers should investigate the difference between bilateral stimulation and anodal stimulation for motor improvements. Further, the difference in efficiency of stimulating partially or during the full time of the additional therapy should be investigated. There should be taken into account that the stimulation time of both groups are the same, but the length of the additional therapy should be either as long as the stimulation time or longer.

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8. Appendix

8.1 Overview of excluded studies

Table 7

Excluded studies based on Availability

Reason of exclusion	Number of studies	Citations
Full text not available	15	Bakulin et al. (2019); Beaulieu, Blanchette, Mercier, Bernard-Larocque, and Milot (2019); Bernard-Larocque, Beaulieu, Blanchette, Mercier, and Milot (2018); Garcia-Vega, Gregory, Lind, Blacker, Ghosh, et al. (2016); Garcia-Vega, Gregory, Lind, Blacker, Souyma, et al. (2016); Handiru, Guan, Ang, and Chew (2019); Miller, Márquez, Van Vliet, Lagopoulos, and Parsons (2013); Nicolo, Pedrazzini, Schnider, and Guggisberg (2017); Paolucci et al. (2017); Powell, Carrico, Chelette, Nichols, and Sawaki (2017); Qu and Song (2017); Tedesco Triccas et al. (2014); Tedesco Triccas et al. (2013); Tedesco Triccas et al. (2015); Wong (2017)
Incomplete data	6	Allman et al. (2016); Andrade et al. (2017); Bolognini et al. (2011); Hesse et al. (2011); Hong et al. (2017); Ilić et al. (2016); Mazzoleni, Tran, Iardella, Dario, and Posteraro (2017); Nair, Renga, Lindenberg, Zhu, and Schlaug (2011); Pavlova et al. (2017); Wu et al. (2013)

Table 8

Excluded studies based on Design

Reason of exclusion	Number of studies	Citations
Not a RCT	33	"18th Biennial Meeting of the World Society for Stereotactic and Functional Neurosurgery" 2019); "46th ESAO Congress 3-7 September 2019 Hannover, Germany Abstracts" 2019); Burns, Bavishi, Bockbrader, Basobas, and Nielsen (2015); Butler et al. (2013); Chhatbar et al. (2016); Conforto et al. (2019); Darkow and Floel (2016); Elsner, Kugler, Pohl, and Mehrholz (2012a, 2012b, 2013a, 2013b, 2015); Elsner, Kwakkel, Kugler, and Mehrholz (2017); Feng and Belagaje (2013); Fuentes et al. (2018); Fuentes, Borrego, Noe, and Llorens (2019); Gandiga, Hummel, and Cohen (2006); Geeganage, Beavan, and Bath (2012); B. T. Gillick and Zirpel (2012); Hathaiareerug and Vearasilp (2019); Kasashima-Shindo et al. (2015); Klomjai et al. (2015); Lee and Chun (2014); Luft (2013); "NYC Neuromodulation 2017 Abstracts" 2017); Ochi, Saeki, Oda, Matsushima, and Hachisuka (2013); Otal et al. (2016); Peters, Pisegna, Faieta, and Page (2017); Peters, Richards, Basobas, Faieta, and Page (2017); Platz and Schmuck (2016); Pollock et al. (2014); Tedesco Triccas, Burridge, Hughes, Verheyden, and Rothwell (2011); Triccas et al. (2018)
Protocol	12	Andrade et al. (2015); Andrade et al. (2016); de Amorim et al. (2017); De Souza et al. (2019); Geiger et al. (2017); B. Gillick et al. (2015); Levin et al. (2018); Luvizutto et al. (2016); Milot, Palimeris, Corriveau, Tremblay, and Boudrias (2019); Plow et al. (2013); Welsby, Ridding, Hillier, and Hordacre (2018); Zandvliet et al. (2019)
Cross-over design	1	Achacheluee et al. (2018)

Table 9

Excluded studies based on Intervention

Reason of exclusion	Number of studies	Citations
Intervention was not focused on Upper limb	129	Ahmed, El Gohary, Al-Azab, Marzouk, and Youssef (2018); Ahn et al. (2017); Al Harbi, Armijo-Olivo, and Kim (2017); Alber, Moser, Gall, and Sabel (2017); Alohali et al. (2017); Andrade et al. (2017); Antonenko and Floel (2016); Aparecida Pietrobon et al. (2019); Baker, Rorden, and Fridriksson (2010); Bang and Bong (2015); Binkofski et al. (2011); Blom-Smink et al. (2017); Bornheim, Maquet, Croisier, Crielaard, and Kaux (2018); Branscheidt, Hoppe, Zwitserlood, and Liuzzi (2018); Cattagni et al. (2019); Chang, Kim, and Park (2015); Chilvers, Cluff, Kirton, Hill, and Dukelow (2019); Cohen Kadosh, Soskic, Iuculano, Kanai, and Walsh (2010); Cotelli et al. (2011); Danzl, Chelette, Lee, Lykins, and Sawaki (2013); Darkow, Martin, Würtz, Flöel, and Meinzer (2017); dos Santos et al. (2017); Dumont et al. (2017); Ewa Polanowska, Leśniak, Barbara Seniów, and Członkowska (2013); Feil et al. (2019); Flöel, Rösser, Michka, Knecht, and Breitenstein (2008); Fridriksson et al. (2019); Fridriksson, Elm, et al. (2018); Fridriksson, Rorden, et al. (2018); Gall et al. (2015); Geroin et al. (2011a, 2011b); Grecco et al. (2016); Harvey, Muir, Benwell, Walters, and Learmonth (2019); Hesse et al. (2007); Hillis (2019); Jayaram and Stinear (2009); Jo et al. (2009); Kang, Baek, Kim, and Paik (2009); Kang, Kim, Sohn, Cohen, and Paik (2011); Kazuta et al. (2017); Keser et al. (2017); Khedr et al. (2014); Kim, Lee, and Chun (2011); Kitisomprayoonkul (2012); Klomjai et al. (2018); M. H. Ko, Han, Park, Seo, and Kim (2008); S. H. Ko, Kim, Park, Yang, and Shin (2016); Koo, Jang, and Kim (2018); Kumar et al. (2011); Lefebvre et al. (2017); Li, Fan, Yang, He, and Li (2018); Luvizutto et al. (2016); Madhavan, Weber, and Stinear (2011); Manji et al. (2018); Marangolo, Fiori, Caltagirone, Pisano, and Priori (2018); Marchina, Schlaug, and Kumar (2015); Martens et al. (2019); Meinzer et al. (2014); Montenegro et al. (2016); D. H. Park (2013); E. Park et al. (2017); S. H. Park, Koh, Choi, and Ko (2013); Pestalozzi et al. (2017); Pestalozzi et al. (2018); Picelli et al. (2019); Picelli et al. (2018); Picelli et al. (2015); Pingue, Priori, Malovini, and Pistarini (2018); Plow, Obretenova, Jackson, and Merabet (2012); Polanowska, Lesniak, Seniow, and Czlonkowska (2013); Polanowska,

		Leśniak, Seniów, Czepiel, and Członkowska (2013); Richardson, Datta, Dmochowski, Parra, and Fridriksson (2015); Roy, Bhatia, Kumar, Wadhawa, and Srivastava (2019); Roy, Shrivastava, Bhatia, Kumar, and Wadhwa (2018); Saeys et al. (2015); Saleh, Yarossi, Manuweera, Adamovich, and Tunik (2017); M. D. Santos et al. (2013); M. D. D. Santos et al. (2017); T. E. G. Santos et al. (2018); Santos-Pontelli et al. (2016); Sebastian, Saxena, et al. (2017); Sebastian, Tippett, Celnik, and Hillis (2017); Sebastian et al. (2016); Seo et al. (2017); Shah-Basak et al. (2015); Shaker, Sawan, Fahmy, Ismail, and Elrahman (2018); Shamapant et al. (2018); Shigematsu, Fujishima, and Ohno (2013); F. R. D. Silva, Mac-Kay, Chao, Santos, and Gagliadi (2018); T. Silva et al. (2018); T. Silva et al. (2019); Smit et al. (2015); Spielmann, Van De Sandt-Koenderman, and Ribbers (2016); K. Spielmann, M. W. E. Van De Sandt-Koenderman, M. H. Heijenbrok-Kal, and G. M. Ribbers (2018); Spielmann, Van De Sandt-Koenderman, and Ribbers (2014); K. Spielmann, W. M. van de Sandt-Koenderman, M. H. Heijenbrok-Kal, and G. M. Ribbers (2016, 2018); K. Spielmann, W. M. E. van de Sandt-Koenderman, M. H. Heijenbrok-Kal, and G. M. Ribbers (2016, 2018); Suntrup and Dziewas (2013); Suntrup-Krueger et al. (2018); Suntrup-Krüger, Ringmaier, Muhle, Warnecke, and Dziewas (2017); Sunwoo et al. (2013); Szépfalusi et al. (2019); Szepfalusi et al. (2017); Szépfalusi et al. (2017); Tahanzadeh et al. (2018); Tahtis, Kaski, and Seemungal (2014); Thiel et al. (2015); Torrente et al. (2018); Torrente et al. (2017); Tsai et al. (2014); Tsapkini et al. (2017); Ulm, McMahon, Copland, de Zubicaray, and Meinzer (2015); Utarapichat and Kitisomprayoonkul (2018); Valiengo, Goulart, de Oliveira, Bensenor, et al. (2017); Valiengo et al. (2016); Valiengo, Goulart, De Oliveira, Benseñor, et al. (2017); Van Asseldonk and Boonstra (2016); Vasant et al. (2014); Wang et al. (2019); Woodhead et al. (2018); Yang et al. (2012); Yarossi, Manuweera, Adamovich, and Tunik (2017); You, Kim, Chun, Jung, and Park (2011); Yun, Chun, and Kim (2015); Zandvliet, Meskers, Kwakkel, and van Wegen (2018); Zumbansen et al. (2019)
Transcranial magnetic stimulation	4	Chervyakov et al. (2018); Cho et al. (2017); Guan et al. (2017); Takeuchi, Tada, Matsuo, and Ikoma (2012)
Transcranial direct current stimulation was not used	7	Hayward, Brauer, Ruddy, Lloyd, and Carson (2017); Hosomi et al. (2016); H. Kuo, Zewdie, Giuffre, and Kirton (2019); H. C. Kuo, Zewdie, Grab, Giuffre, and Kirton (2018); Kwon, Park, Kang, Chang, and Kim (2016); Lee et al. (2018); Wu et al. (2013)

tDCS combined with TENS	7	Domen, Takebayashi, Takahashi, and Moriwaki (2018); Lindenberg, Zhu, and Schlaug (2012); McCambridge, Stinear, and Byblow (2018); Menezes et al. (2017); Shaheiwola, Zhang, Jia, and Zhang (2018); Takebayashi, Takahashi, Moriwaki, Sakamoto, and Domen (2017); Yagüe et al. (2018); Yagüe et al. (2017)

Table 10

Excluded studies based on Outcome

Reason of exclusion	Number of studies	Citations
FMA was not used	38	Ang et al. (2012); Au-Yeung, Wang, Chen, and Chua (2014); Bao, Wong, Leung, and Tong (2019); Boasquevisque et al. (2019); Celnik, Paik, Vandermeeren, Dimyan, and Cohen (2009); Dehem et al. (2018); Del Felice, Daloli, Masiero, and Manganotti (2016); Doost et al. (2019); Figlewski et al. (2017); Fusco et al. (2014); Geiger, Roche, Vlachos, Cattagni, and Zory (2019); Goh, Chan, and Abdul-Latif (2015); Goodwill, Teo, Morgan, Daly, and Kidgell (2016); Hamoudi et al. (2018); Hodics et al. (2012); B. Hordacre, B. Moezzi, and M. Ridding (2018); B. Hordacre, B. Moezzi, and M. C. Ridding (2018); Hosseinzadeh et al. (2018); Kasashima et al. (2012); E. Khedr, Shawky, Tohamy, Darwish, and El Hamady (2012); E. M. Khedr et al. (2013); D. Y. Kim, Ohn, Yang, Park, and Jung (2009); Y. H. Kim (2013); Learmonth, Muir, Benwell, Walters, and Harvey (2018); Lefebvre et al. (2015); Lefebvre et al. (2013); Lefebvre et al. (2014); Mahmoudi et al. (2011); Marquez et al. (2017); Marquez et al. (2014); Menezes et al. (2018); Pruvost-Robieux et al. (2018); Rabadi and Aston (2017); Salazar et al. (2019); Saleh Velez, Bonin Pinto, Ortiz, Mansour, and Lazaridis (2019); Şik, Dursun, Dursun, Sade, and Şahİn (2015); Wang et al. (2014); Zimerman et al. (2012)
Full FMA variables were not available	3	Nicolo et al. (2018); Rossi, Sallustio, Di Legge, Stanzione, and Koch (2013); van der Vliet, Ribbers, Vandermeeren, Frens, and Selles (2017)

Table 11

Excluded studies based on Population

Reason of exclusion	Number of studies	Citations
Stroke patients were not included	33	Alhussien et al. (2017); Benussi et al. (2017); Braun et al. (2016); Broeder et al. (2019); Bystad et al. (2016); Cabibel, Froger, Muthalib, and Perrey (2017); Cortes et al. (2017); David, de Moraes, da Costa, and Franco (2018); Dufka, Munch, Dworkin, and Rowbotham (2015); Dutt-Mazumder et al. (2018); Faber, Zipser, Tünnerhoff, Müller-Dahlhaus, and Ziemann (2016); Fan, Voisin, Milot, Higgins, and Boudrias (2017); Fregni et al. (2006); Friel et al. (2018); Guernon et al. (2018); Iodice, Dubbioso, Ruggiero, Santoro, and Manganelli (2015); Ishikuro et al. (2018); Jones, Stephens, Alam, Bikson, and Berryhill (2015); Lesniak, Polanowska, Seniow, and Czlonkowska (2014); Lindenberg, Sieg, Meinzer, Nachtigall, and Flöel (2016); McCambridge, Bradnam, Stinear, and Byblow (2011); Meinzer et al. (2014); Mori et al. (2013); Mortensen, Figlewski, and Andersen (2016); O'Neil-Pirozzi, Doruk, Thomson, and Fregni (2017); Oveisgharan, Karimi, Abdi, and Sikaroodi (2019); Potter-Baker et al. (2018); E. Powell and Sawaki (2019); E. S. Powell et al. (2016); Rosset-Llobet, Fabregas-Molas, and Pascual-Leone (2015); Thibaut et al. (2017); Williams, Pascual-Leone, and Fregni (2010); Yozbatiran et al. (2016)
Patients under 18 year were included	14	H. Carlson and Kirton (2019); H. L. Carlson, Ciechanski, Harris, MacMaster, and Kirton (2018); Ciechanski and Kirton (2017); Cole et al. (2018); B. Gillick et al. (2017); B. Gillick et al. (2018); B. T. Gillick et al. (2015); Giuffre et al. (2018); Grecco et al. (2014); Kirton et al. (2016); Kirton et al. (2015); Kirton et al. (2017); Lazzari et al. (2015); Nemanich et al. (2019)

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UHASSELT
KNOWLEDGE IN ACTION

INVENTARISATIEFORMULIER WETENSCHAPPELIJKE STAGE DEEL 2

DATUM	INHOUD OVERLEG	HANDTEKENINGEN
11/10/19	Bespreking aanpak MP2	Promotor: Copromotor/Begeleider: Student(e): Student(e):
09/12/19	Onderwerp op basis zoekstrategie	Promotor: Copromotor/Begeleider: Student(e): Student(e):
20/12/19	Beschikbare data + verzenden mails	Promotor: Copromotor/Begeleider: Student(e): Student(e):
31/01/20	Opnieuw verzenden mails	Promotor: Copromotor/Begeleider: Student(e): Student(e):
05/02/20	Clusters maken	Promotor: Copromotor/Begeleider: Student(e): Student(e):
14/02/20	Clusters maken	Promotor: Copromotor/Begeleider: Student(e): Student(e):
04/03/20	Clusters maken	Promotor: Copromotor/Begeleider: Student(e): Student(e):
11/03/20	Clusters maken	Promotor: Copromotor/Begeleider: Student(e): Student(e):
20/04/20	Bespreken statistiek	Promotor: Copromotor/Begeleider: Student(e): Student(e):
24/04/20	Bespreken statistiek	Promotor: Copromotor/Begeleider: Student(e): Student(e):

In te vullen door de promotor(en) en eventuele copromotor aan het einde van MP2:

Naam Student(e): Eva Bloemers Vanderstraeten Louwen **Datum:** 15/05/20

Titel Masterproef: The effectiveness of transcranial direct current stimulation tDCS in arm-hand function after stroke: A Systematic Review and Meta-Analysis

1) Geef aan in hoeverre de student(e) onderstaande competenties zelfstandig uitvoerde:
   - NVT: De student(e) leverde hierin geen bijdrage, aangezien hij/zij in een reeds lopende studie meewerkte.
   - 1: De student(e) was niet zelfstandig en sterk afhankelijk van medestudent(e) of promotor en teamleden bij de uitwerking en uitvoering.
   - 2: De student(e) had veel hulp en ondersteuning nodig bij de uitwerking en uitvoering.
   - 3: De student(e) was redelijk zelfstandig bij de uitwerking en uitvoering
   - 4: De student(e) had weinig tot geringe hulp nodig bij de uitwerking en uitvoering.
   - 5: De student(e) werkte zeer zelfstandig en had slechts zeer sporadisch hulp en bijsturing nodig van de promotor of zijn team bij de uitwerking en uitvoering.

Competenties	NVT	1	2	3	4	5
Opstelling onderzoeksvraag	O	O	O	O	O	O
Methodologische uitwerking	O	O	O	O	O	O
Data acquisitie	O	O	O	O	O	O
Data management	O	O	O	O	O	O
Dataverwerking/Statistiek	O	O	O	O	O	O
Rapportage	O	O	O	O	O	O

2) Niet-bindend advies: Student(e) krijgt toelating/geen toelating (schrappen wat niet past) om bovenvermelde Wetenschappelijke stage/masterproef deel 2 te verdedigen in bovenvermelde periode. Deze eventuele toelating houdt geen garantie in dat de student geslaagd is voor dit opleidingsonderdeel.

3) Deze wetenschappelijke stage/masterproef deel 2 mag wel/niet (schrappen wat niet past) openbaar verdedigd worden.

4) Deze wetenschappelijke stage/masterproef deel 2 mag wel/niet (schrappen wat niet past) opgenomen worden in de bibliotheek en docserver van de UHasselt.

Datum en handtekening Student(e)	Datum en handtekening promotor(en)	Datum en handtekening Co-promotor(en)
15/05/20		
15/05/20		

Verklaring op Eer

Ondergetekende, student aan de Universiteit Hasselt (UHasselt), faculteit Revalidatiewetenschappen aanvaardt de volgende voorwaarden en bepalingen van deze verklaring:

1. Ik ben ingeschreven als student aan de UHasselt in de opleiding Revalidatiewetenschappen en kinesitherapie, waarbij ik de kans krijg om in het kader van mijn opleiding mee te werken aan onderzoek van de faculteit Revalidatiewetenschappen aan de UHasselt. Dit onderzoek wordt beleid door prof. Dr. Raf Meesen en kadert binnen het opleidingsonderdeel: wetenschappelijke stage/masterproef deel 2. Ik zal in het kader van dit onderzoek creaties, schetsen, ontwerpen, prototypes en/of onderzoeksresultaten tot stand brengen in het domein van neurologische revalidatie (hierna: "De Onderzoeksresultaten").

2. Bij de creatie van De Onderzoeksresultaten doe ik beroep op de achtergrondkennis, vertrouwelijke informatie[1], universitaire middelen en faciliteiten van UHasselt (hierna: de "Expertise").

3. Ik zal de Expertise, met inbegrip van vertrouwelijke informatie, uitsluitend aanwenden voor het uitvoeren van hogergenoemd onderzoek binnen UHasselt. Ik zal hierbij steeds de toepasselijke regelgeving, in het bijzonder de Algemene Verordening Gegevensbescherming (EU 2016-679), in acht nemen.

4. Ik zal de Expertise (i) voor geen enkele andere doelstelling gebruiken, en (ii) niet zonder voorafgaande schriftelijke toestemming van UHasselt op directe of indirecte wijze publiek maken.

5. Aangezien ik in het kader van mijn onderzoek beroep doe op de Expertise van de UHasselt, draag ik hierbij alle bestaande en toekomstige intellectuele eigendomsrechten op De Onderzoeksresultaten over aan de UHasselt. Deze overdracht omvat alle vormen van intellectuele eigendomsrechten, zoals onder meer – zonder daartoe beperkt te zijn – het auteursrecht, octrooirecht, merkenrecht, modellenrecht en knowhow. De overdracht geschiedt in de meest volledige omvang, voor de gehele wereld en voor de gehele beschermingsduur van de betrokken rechten.

6. In zoverre De Onderzoeksresultaten auteursrechtelijk beschermd zijn, omvat bovenstaande overdracht onder meer de volgende exploitatiewijzen, en dit steeds voor de hele beschermingsduur, voor de gehele wereld en zonder vergoeding:

   - het recht om De Onderzoeksresultaten vast te (laten) leggen door alle technieken en op alle dragers;
   - het recht om De Onderzoeksresultaten geheel of gedeeltelijk te (laten) reproduceren, openbaar te (laten) maken, uit te (laten) geven, te (laten) exploiteren en te (laten) verspreiden in eender welke vorm, in een onbeperkt aantal exemplaren;

[1] Vertrouwelijke informatie betekent alle informatie en data door de UHasselt meegedeeld aan de student voor de uitvoering van deze overeenkomst, inclusief alle persoonsgegevens in de zin van de Algemene Verordening Gegevensbescherming (EU 2016/679), met uitzondering van de informatie die (a) reeds algemeen bekend is; (b) reeds in het bezit was van de student voor de mededeling ervan door de UHasselt; (c) de student verkregen heeft van een derde zonder enige geheimhoudingsplicht; (d) de student onafhankelijk heeft ontwikkeld zonder gebruik te maken van de vertrouwelijke informatie van de UHasselt; (e) wettelijk of als gevolg van een rechterlijke beslissing moet worden bekendgemaakt, op voorwaarde dat de student de UHasselt hiervan schriftelijk en zo snel mogelijk op de hoogte brengt.

- het recht om De Onderzoeksresultaten te (laten) verspreiden en mee te (laten) delen aan het publiek door alle technieken met inbegrip van de kabel, de satelliet, het internet en alle vormen van computernetwerken;
- het recht De Onderzoeksresultaten geheel of gedeeltelijk te (laten) bewerken of te (laten) vertalen en het (laten) reproduceren van die bewerkingen of vertalingen;
- het recht De Onderzoeksresultaten te (laten) bewerken of (laten) wijzigen, onder meer door het reproduceren van bepaalde elementen door alle technieken en/of door het wijzigen van bepaalde parameters (zoals de kleuren en de afmetingen).

De overdracht van rechten voor deze exploitatiewijzen heeft ook betrekking op toekomstige onderzoeksresultaten tot stand gekomen tijdens het onderzoek aan UHasselt, eveneens voor de hele beschermingsduur, voor de gehele wereld en zonder vergoeding.

Ik behoud daarbij steeds het recht op naamvermelding als (mede)auteur van de betreffende Onderzoeksresultaten.

7. Ik zal alle onderzoeksdata, ideeën en uitvoeringen neerschrijven in een "laboratory notebook" en deze gegevens niet vrijgeven, tenzij met uitdrukkelijke toestemming van mijn UHasseltbegeleider Prof. Dr. Raf Meesen.

8. Na de eindevaluatie van mijn onderzoek aan de UHasselt zal ik alle verkregen vertrouwelijke informatie, materialen, en kopieën daarvan, die nog in mijn bezit zouden zijn, aan UHasselt terugbezorgen.

Gelezen voor akkoord en goedgekeurd,

Naam: Eva Bloemers

Adres: Voetbalstraat 19, 3580 Beringen

Geboortedatum en –plaats : 12/11/1997, Antwerpen

Datum: 18/05/2020

Handtekening: 

Verklaring op Eer

Ondergetekende, student aan de Universiteit Hasselt (UHasselt), faculteit Revalidatiewetenschappen en Kinesitherapie aanvaardt de volgende voorwaarden en bepalingen van deze verklaring:

1. Ik ben ingeschreven als student aan de UHasselt in de opleiding revalidatiewetenschappen en kinesitherapie, waarbij ik de kans krijg om in het kader van mijn opleiding mee te werken aan onderzoek van de faculteit revalidatiewetenschappen en kinesitherapie aan de UHasselt. Dit onderzoek wordt beleid door Prof. Dr. Raf Meesen en kadert binnen het opleidingsonderdeel wetenschappelijke stage/masterproef deel 2. Ik zal in het kader van dit onderzoek creaties, schetsen, ontwerpen, prototypes en/of onderzoeksresultaten tot stand brengen in het domein van neurowetenschappen (hierna: "De Onderzoeksresultaten").

2. Bij de creatie van De Onderzoeksresultaten doe ik beroep op de achtergrondkennis, vertrouwelijke informatie[1], universitaire middelen en faciliteiten van UHasselt (hierna: de "Expertise").

3. Ik zal de Expertise, met inbegrip van vertrouwelijke informatie, uitsluitend aanwenden voor het uitvoeren van hogergenoemd onderzoek binnen UHasselt. Ik zal hierbij steeds de toepasselijke regelgeving, in het bijzonder de Algemene Verordening Gegevensbescherming (EU 2016-679), in acht nemen.

4. Ik zal de Expertise (i) voor geen enkele andere doelstelling gebruiken, en (ii) niet zonder voorafgaande schriftelijke toestemming van UHasselt op directe of indirecte wijze publiek maken.

5. Aangezien ik in het kader van mijn onderzoek beroep doe op de Expertise van de UHasselt, draag ik hierbij alle bestaande en toekomstige intellectuele eigendomsrechten op De Onderzoeksresultaten over aan de UHasselt. Deze overdracht omvat alle vormen van intellectuele eigendomsrechten, zoals onder meer – zonder daartoe beperkt te zijn – het auteursrecht, octrooirecht, merkenrecht, modellenrecht en knowhow. De overdracht geschiedt in de meest volledige omvang, voor de gehele wereld en voor de gehele beschermingsduur van de betrokken rechten.

6. In zoverre De Onderzoeksresultaten auteursrechtelijk beschermd zijn, omvat bovenstaande overdracht onder meer de volgende exploitatiewijzen, en dit steeds voor de hele beschermingsduur, voor de gehele wereld en zonder vergoeding:

   - het recht om De Onderzoeksresultaten vast te (laten) leggen door alle technieken en op alle dragers;
   - het recht om De Onderzoeksresultaten geheel of gedeeltelijk te (laten) reproduceren, openbaar te (laten) maken, uit te (laten) geven, te (laten) exploiteren en te (laten) verspreiden in eender welke vorm, in een onbeperkt aantal exemplaren;

[1] Vertrouwelijke informatie betekent alle informatie en data door de UHasselt meegedeeld aan de student voor de uitvoering van deze overeenkomst, inclusief alle persoonsgegevens in de zin van de Algemene Verordening Gegevensbescherming (EU 2016/679), met uitzondering van de informatie die (a) reeds algemeen bekend is; (b) reeds in het bezit was van de student voor de mededeling ervan door de UHasselt; (c) de student verkregen heeft van een derde zonder enige geheimhoudingsplicht; (d) de student onafhankelijk heeft ontwikkeld zonder gebruik te maken van de vertrouwelijke informatie van de UHasselt; (e) wettelijk of als gevolg van een rechterlijke beslissing moet worden bekendgemaakt, op voorwaarde dat de student de UHasselt hiervan schriftelijk en zo snel mogelijk op de hoogte brengt.

- het recht om De Onderzoeksresultaten te (laten) verspreiden en mee te (laten) delen aan het publiek door alle technieken met inbegrip van de kabel, de satelliet, het internet en alle vormen van computernetwerken;
- het recht De Onderzoeksresultaten geheel of gedeeltelijk te (laten) bewerken of te (laten) vertalen en het (laten) reproduceren van die bewerkingen of vertalingen;
- het recht De Onderzoeksresultaten te (laten) bewerken of (laten) wijzigen, onder meer door het reproduceren van bepaalde elementen door alle technieken en/of door het wijzigen van bepaalde parameters (zoals de kleuren en de afmetingen).

De overdracht van rechten voor deze exploitatiewijzen heeft ook betrekking op toekomstige onderzoeksresultaten tot stand gekomen tijdens het onderzoek aan UHasselt, eveneens voor de hele beschermingsduur, voor de gehele wereld en zonder vergoeding.

Ik behoud daarbij steeds het recht op naamvermelding als (mede)auteur van de betreffende Onderzoeksresultaten.

7. Ik zal alle onderzoeksdata, ideeën en uitvoeringen neerschrijven in een "laboratory notebook" en deze gegevens niet vrijgeven, tenzij met uitdrukkelijke toestemming van mijn UHasseltbegeleider Prof. Dr. Raf Meesen.

8. Na de eindevaluatie van mijn onderzoek aan de UHasselt zal ik alle verkregen vertrouwelijke informatie, materialen, en kopieën daarvan, die nog in mijn bezit zouden zijn, aan UHasselt terugbezorgen.

Gelezen voor akkoord en goedgekeurd,

Naam: Vanderzande Laurens

Adres: Overdemerstraat 30 3511 Kuringen

Geboortedatum en –plaats : 25/07/1997 te Hasselt

Datum: 25/05/20

Handtekening:

COVID-19 Addendum - Masterproef 2

Gelieve dit document in te laten vullen door de promotor en ingevuld toe te voegen aan je masterproef.

Naam promotor(en)
Raf Meesen
Caroline Strouwen
Naam studenten
Eva Bloemers
Laurens Vanderzande

1) Duid aan welk type scenario is gekozen voor deze masterproef:

☒ scenario 1: masterproef bestaat uit een meta-analyse - masterproef liep door zoals voorzien
☐ scenario 2: masterproef bestaat uit een experiment - masterproef liep door zoals voorzien
☐ scenario 3: masterproef bestaat uit een experiment - maar een deel van de voorziene data is verzameld
☐ 3A: er is voldoende data, maar met aangepaste statische procedures verder gewerkt
3B: er is onvoldoende data, dus gewerkt met een descriptieve analyse van de aanwezige data
☐ scenario 4: masterproef bestaat uit een experiment - maar er kon geen data verzameld worden
☐ 4A: er is gewerkt met reeds beschikbare data
☐ 4B: er is gewerkt met fictieve data

2) Geef aan in hoeverre de student(e) onderstaande competenties zelfstandig uitvoerde:

- NVT: De student(e) leverde hierin geen bijdrage, aangezien hij/zij in een reeds lopende studie meewerkte.
- 1: De student(e) was niet zelfstandig en sterk afhankelijk van medestudent(e) of promotor en teamleden bij de uitwerking en uitvoering.
- 2: De student(e) had veel hulp en ondersteuning nodig bij de uitwerking en uitvoering.
- 3: De student(e) was redelijk zelfstandig bij de uitwerking en uitvoering
- 4: De student(e) had weinig tot geringe hulp nodig bij de uitwerking en uitvoering.
- 5: De student(e) werkte zeer zelfstandig en had slechts zeer sporadisch hulp en bijsturing nodig van de promotor of zijn team bij de uitwerking en uitvoering.

Competenties	NVT	1	2	3	4	5

Opstelling onderzoeksvraag	☐	☐	☐	☐	☒	☐
Methodologische uitwerking	☐	☐	☐	☐	☒	☐
Data acquisitie	☐	☐	☐	☐	☐	☒
Data management	☐	☐	☐	☐	☐	☒
Dataverwerking/Statistiek	☐	☐	☐	☐	☐	☒
Rapportage	☐	☐	☐	☐	☒	☐

Datum
25/05/2020

Inschrijvingsformulier verdediging masterproef academiejaar 2019-2020,
Registration form jury Master's thesis academic year 2019-2020,

Gegevens student:
Information student:

Faculteit/School: **Faculteit Revalidatiewetenschappen**
Faculty/School: ***Rehabilitation Sciences***

Stamnummer: **1540793**
Student number

Naam student: **Bloemers Eva**
Name student

Opleiding/*Programme*: **2 ma revalid. & kine kinderen**

Gegevens masterproef
Information Master's thesis

Titel van Masterproef/*Title of Master's thesis:* The effectiveness of transcranial direct current stimulation tDCS in arm-hand function after stroke: A Systematic Review and Meta-Analysis

Wijziging*/Change:* ……

Promotor(en): Prof. Dr. Raf Meesen
Supervisor(s)
Wijziging*/Change:* ……

Copromotor(en): Dr. Carolien Strouwen
Co-supervisor(s)
Wijziging*/Change:* ……

Externe promotor(en):
External supervisor(s)
Wijziging*/Change:* ……

Externe co-promotor(en) :
External co-supervisor(s)
Wijziging*/Change:* ……

In geval van samenwerking tussen studenten, naam van de medestudent(en): Laurens Vanderzande
In case of group work, name of fellow student(s)
Wijziging*/Change:* ……

Wijzigingen gegevens masterproef
Changes information Master's thesis

In te vullen door student
To be filled out by the student

Wijziging gegevens masterproef:
Change information Master's thesis:

● Geen
None
o Ja, de wijzigingen werden in bovenstaand luik "Gegevens masterproef" aangebracht
Yes, the changes are put in in the "Information Master's thesis" section above

In te vullen door promotor(en)
To be filled out by the supervisor(s)

De wijzigingen in bovenstaand luik "Gegevens masterproef" worden door de promotor
The changes in the "Information Master's thesis" section above are by the supervisor
o goedgekeurd.
approved
met uitzondering van:……
with exception of
o afgekeurd.
disapproved

o De scriptie is vertrouwelijk (wordt niet opgenomen in bib)
Thesis confidential (not available in library)

Datum en handtekening
student
Date and signature
student
14/05/2020

Datum en handtekening
promotor(en)
Date and signature
supervisor(s)

Verdediging
Jury

In te vullen door de promotor(en)
To be filled out by the supervisor(s)

De promotor(en) geeft (geven) de student(en) het niet-bindend advies om de bovenvermelde masterproef in de bovenvermelde periode:
The supervisor(s) give(s) the student(s) the non-binding advice
o te verdedigen;
to defend the aforementioned Master's thesis within the aforementioned period of time;
o de verdediging is openbaar.
in public
o de verdediging is niet openbaar.
not in public
o niet te verdedigen
not to defend the aforementioned Master's thesis within the aforementioned period of time.

Optie: in te vullen door de student:
Option: to be filled out by the student:

In tegenstelling tot het niet-bindend advies van de promotor(en) wenst de student de bovenvermelde masterproef in de bovenvermelde periode:
In contrast to the non-binding advice put forward by the supervisor(s), the student wishes:
o niet te verdedigen.
not to defend the aforementioned Master's thesis within the aforementioned period of time.
● wel te verdedigen.
to defend the aforementioned Master's thesis within the aforementioned period of time.

Datum en handtekening student
Date and signature student
14/05/2020

Datum en handtekening promotor(en)
Date and signature supervisor(s)

Inschrijvingsformulier verdediging masterproef academiejaar 2019-2020,
Registration form jury Master's thesis academic year 2019-2020,

Gegevens student:
Information student:

Faculteit/School: **Faculteit Revalidatiewetenschappen**
Faculty/School: ***Rehabilitation Sciences***

Stamnummer: **1541032**
Student number

Naam student: **Vanderzande Laurens**
Name student

Opleiding/*Programme*: **2 ma revalid. & kine musc.**

Gegevens masterproef
Information Master's thesis

Titel van Masterproef/*Title of Master's thesis:*

Wijziging/*Change:* The effectiveness of transcranial direct current stimulation tDCS in arm-hand function after stroke: A Systematic Review and Meta-Analysis

Promotor(en):
Supervisor(s)
Wijziging/*Change:* Prof. Dr. Raf Meesen

Copromotor(en):
Co-supervisor(s)
Wijziging/*Change:* Dr. Caroline Strouwen

Externe promotor(en):
External supervisor(s)
Wijziging/*Change:* .....

Externe co-promotor(en) :
External co-supervisor(s)
Wijziging/*Change:* .....

In geval van samenwerking tussen studenten, naam van de medestudent(en): Eva Blaemers
In case of group work, name of fellow student(s)
Wijziging/*Change:* .....

Wijzigingen gegevens masterproef
Changes information Master's thesis

In te vullen door student
To be filled out by the student

Wijziging gegevens masterproef:
Change information Master's thesis:

- ● Geen
  None
- o Ja, de wijzigingen werden in bovenstaand luik "Gegevens masterproef" aangebracht
  Yes, the changes are put in in the "Information Master's thesis" section above

In te vullen door promotor(en)
To be filled out by the supervisor(s)

De wijzigingen in bovenstaand luik "Gegevens masterproef" worden door de promotor
The changes in the "Information Master's thesis" section above are by the supervisor

- o goedgekeurd.
  approved
  met uitzondering van:.....
  with exception of
- o afgekeurd.
  disapproved

- o De scriptie is vertrouwelijk (wordt niet opgenomen in bib)
  Thesis confidential (not available in library)

Datum en handtekening student
Date and signature student
18/05/20

Datum en handtekening promotor(en)
Date and signature supervisor(s)

Verdediging
Jury

In te vullen door de promotor(en)
To be filled out by the supervisor(s)

De promotor(en) geeft (geven) de student(en) het niet-bindend advies om de bovenvermelde masterproef in de bovenvermelde periode:
The supervisor(s) give(s) the student(s) the non-binding advice
o te verdedigen;
to defend the aforementioned Master's thesis within the aforementioned period of time;
o de verdediging is openbaar.
in public
o de verdediging is niet openbaar.
not in public
o niet te verdedigen
not to defend the aforementioned Master's thesis within the aforementioned period of time.

Optie: In te vullen door de student:
Option: to be filled out by the student:

In tegenstelling tot het niet-bindend advies van de promotor(en) wenst de student de bovenvermelde masterproef in de bovenvermelde periode:
In contrast to the non-binding advice put forward by the supervisor(s), the student wishes:
o niet te verdedigen.
not to defend the aforementioned Master's thesis within the aforementioned period of time.
o wel te verdedigen.
to defend the aforementioned Master's thesis within the aforementioned period of time.

Datum en handtekening
student
Date and signature
student

Datum en handtekening
promotor(en)
Date and signature
supervisor(s)

Van: Raf MEESEN <raf.meesen@uhasselt.be>
Onderwerp: Antw: Inschrijvingsformulier MP 2
Datum: 18 mei 2020 om 09:05:42 CEST
Aan: Eva Bloemers <eva.bloemers@student.uhasselt.be>, Laurens Vanderzande <laurens.vanderzande@student.uhasselt.be>, Carolien Strouwen <carolien.strouwen@uhasselt.be>

Eva,
Graag iedereen in cc houden,

Gunstig advies

Mvg

Op vr 15 mei 2020 om 15:53 schreef Eva Bloemers <eva.bloemers@student.uhasselt.be>:
Beste

In bijlage het inschrijvings- en inventarisatieformulier voor masterproef deel 2. Graag uw advies.

Mvg
Eva Bloemers
2e ma REKI
1540793

--

Professor Raf Meesen
Associate Professor, Neuroplasticity and Movement Control
Head, Neurologic Rehabilitation research group
Chairman, Rehabilitation Sciences and Physiotherapy Master program
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