# EFFECT OF TRANSCRANIAL DIRECT STIMULATION ON COGNITION IN CHILDREN WITH ATTENTION DEFICIT HYPERACTIVE DISORDER: SYSTEMATIC REVIEW

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**Absract**

**Background:** The use of Transcranial Direct Current stimulation (tDCS) in cognition improvement in children with attention deficit hyperactivity disorder is new, and thus the scientific evidence for its effectiveness needs to be evaluated through a systematic review. **Objective:** To provide updated evidence-based guidance for tDCSeffects on cognition in children with attention deficit hyperactivity disorder. **Data synthesis**: Six studies included 133 participants in total. Best evidence synthesis was applied to summarize the outcomes, which were memory performance, intrinsic alertness, performing time and commission errors. **Conclusion:** the available data demonstrated the efficacy of tDCS as a new modality on cognition in children with attension deficit hyperactivity disorder has an immediate and short term effect on improving cognition .Further studies are still needed, especially those involving both neurophysiological and functional evaluations and to cover further domain on attension deficit hyperactivity disorder.

**Keywords:**
transcranial direct current stimulation, tDCS, cognition, attention deficit hyperactivity disorder, ADHD, children and adolescents.

## Introduction:

Attention deficit hyperactivity disorder (ADHD) is a childhood onsetpsychatric disorder which is characterized by developmentally inappropriate levels of inattention, impulsivity and hyperactivity (DSM-IV). In ADHD cognitive control, the ability to control sensory processes and actions in a goal-directed manner (Bunge et al., 2002)[1] is severely compromised, affecting motor, emotional and cognitive domains ( Wodka et al., 2007) [2]. ADHD patients are particularly impaired in different aspects of inhibition control, namely interference control, the suppression of task irrelevant, competing stimuli and response inhibition, the suppression of a prepotent response. Interference control has been effectively investigated using the Flanker task (Eriksen and Eriksen, 1974)[3] and the Simon task (Simon, 1990) [4], which has been shown to provide a reliable measurement of this cognitive ability (Wöstmann et al., 2013) [5]. In both tasks participants have to indicate the category of a target stimulus by a right or a left button press. In the Flanker task, the target is surrounded by distracting stimuli which must be ignored in order to give the right response. In the Simon task, the target stimulus is presented either on the left or on the right side. In this case, the position must be ignored to give the right response.

So far, ADHD patients have shown higher error rates and slower reaction times compared to healthy controls (Mullane et al., 2009).[6]

Successful interference control has been associated with the integrity of the right inferior frontal gyrus (rIFG) (Luks et al., 2010[7]; Zhu et al., 2010[8]). In children and adolescents with ADHD various studies have revealed structural (Sowell et al., 2003 [9]; Durston et al., 2004) [10] as well as functional alterations (Aron and Poldrack, 2005) [11] in the rIFG. For example during a Simon task, unmedicated ADHD patients showed less activity in the rIFG compared to healthy controls (Rubia et al., 2011) [12] whereas ADHD patients medicated with methylphenidate did not differ from healthy controls (Lee et al., 2010) [13]. Thus, increasing activity of the rIFG seems to facilitate interference control. Transcranial direct current stimulation (tDCS) is a non-invasive tool for modulating cortical excitability. To conduct tDCS a weak current is passing through the scalp mostly via two conductive rubber electrodes in sponges soaked in saline solution or covered with conductive gel. The modulation of cortical excitability depends on the polarity of electrodes. In general, the positively charged anode increases cortical excitability while the negatively charged cathode decreases it (Nitsche and Paulus, 2000) [14]. This modulation is due to a modification of the resting membrane potential in regions of current flow (Stagg and Nitsche, 2011) [15]. TDCS when applied for 30 min induces prolonged effects after the end of stimulation (Nitsche and Paulus, 2001) [16]. Studies showed tDCS induced improvements of symptom severity already in different psychiatric and neurologic disorders, for example depression (Kalu et al., 2012) [17], schizophrenia (Brunelin et al., 2012) [18], stroke (Chang et al., 2015) [19] and dyslexia (Heth and Lavidor, 2015) [20]. Castellanos and Proal (2012) suggested that tDCS may also be of therapeutic use for ADHD, especially due to its beneficial effect on larger scale networks (Keeser et al., 2011) [21]. The development of non-pharmaceutical treatment approaches is particularly relevant in ADHD, since even though many patients benefit from medical treatment, a substantial number report remarkable side effects and parents as well as children and adolescents often wish for alternative treatment strategies (Halperin and Healey, 2011) [22]. Effects of stimulant treatment persist only for the time of active medication (Chronis et al., 2003) [23], whereas beneficial effects of repetitive tDCS have been reported to last for several month (Cohen Kadosh et al., 2010) [24]. Even though tDCS has been predominantly employed in adults, studies in children and adolescents have confirmed that this method is also well tolerated and save in younger age groups (Mattai et al., 2011[25]; Andrade et al., 2014[26]; Moliadze et al., 2014[27]; Krishnan et al., 2015) [28].

Studies testing modulatory effects of tDCS in ADHD are, however, sparse. Using oscillatory tDCS during slow wave sleep, Prehn-Kristensen et al. (2014) [29] demonstrated an improvement of declarative memory performance on the next day as well as improved reaction times in a go/nogo task in children with ADHD (Munz et al., 2015) [30].

**Purpose**:

The purpose of this study is to systematically review the clinical effectiveness of transcranial direct current stimulation on cognition in children and adolescents with attention deficit hyperactivity disorder.

**Methods:**

**Search strategy:**

This study included studies that examine the effect of transcranial direct stimulation current on cognition in children and adolescents with attention deficit hyperactivity disorder. Literature search was performed independently by the three authors using an inclusive electronic literature search of Cochrane library, Pubmed, Physiotherapy Evidence Database (Pedro) Web of Science, Google scholar databases from their earliest records to February 2019, using a number of key words: Transcranial Direct Stimulation current, attention deficit hyperactivity disorder, cognition, children, adolescents. These key words were used individually and/or were combined. All references from the selected articles were also cross-checked by the authors to identify relevant studies that may have been missed in the search.

**Study selection:**

Before the beginning of the study selection procedures,duplicated searches were excluded by two authors. independently reviewed the studies for eligibility based on title and abstract. Studies deemed potentially eligible by at least one author then thefull text versions were retrieved and independently screened by two authors to determine whether they met inclusion criteria. Disagreement between the two authors in any stage was resolved by discussion until consensus was reached or, where necessary, the third author made the final decision.

**Eligibility criteria:**

The inclusion criteria for studies to be included in this systematic review were as follows: participants inthe study were children and adolescents who had ADHD and were aged between 7.2 and 17 years old; the outcome measures used in the study were related to cognition, such as memory performance, alertness, performing time in addition to behavior and selective attention; and the study was written in English. Studies were excluded if the participants had oppositional defiant disorder, conduct disorder, any psychiatric abnormalities, average intelligence quotient (IQ < 85), profound memory impairment or self-reported sleep-disturbances; if the study notpublished as a full text article.

**Data-extraction and management:**

Data were extracted by one author and checked by an other one through a self-made extractionform. Disagreements between the two reviewers were resolved by discussion until consensus was reached.Key details of each study were extracted using the specific data extraction format. The format includes:research design, participants, eligibility criteria, intervention, outcomes of interest and results of each study.

**Assessment of methodological quality:**

Two reviewers independently assessed the methodological quality of the included studies,according to the Physiotherapy Evidence Data base (PEDro) scale Appendix (1). The PEDro scale is a validmeasure of the methodological quality of clinical trials and is based on the Delphi list developed byVerhagen et al [31].The scale is used to rate studies from 0–11 according to following 11 methodologicalcriteria: specified eligibility criteria, random allocation, concealed allocation, baseline comparability,blinded subjects, blinded therapists, blinded assessors, adequate follow-up, intention-to-treat analysis,between group comparisons, and point estimates and variability. Each item was scored as 1 (yes) or 0 (no).The studies were ranked as 'high quality' if their score is 7, studies with a score of 5 or 6 were considered of'moderate quality' and those with a score of 4 or less were deemed of 'poor quality' [32, 33]. PEDro scores were not used as inclusion/exclusion criteria, but rather as a basis for data-analysis and to discuss the strengths and weaknesses of studies.

**Data collection and analysis:**

We used the standard methods ofthe Cochrane Collaboration. Tworeview authors searched for and considered trials for inclusion, evaluated methodological quality and extracted data independently. Differences in interpretation were resolved by discussion with the third review author.

**Quality assessment:**

We conducted quality assessment according to the methods described in section six of the Cochrane Handbook for Systematic Reviews of Interventions (Handbook 2007). We considered four major sources of potential bias and methods of avoidance when assessing the trial quality:

(1) selection bias - blinding of randomization;

(2) performance bias - blinding of intervention;

(3) attrition bias - complete follow-up;

(4) detection bias - blinding of outcome assessment.

A quality rating was assigned to each trial for the criterion of blinding of randomization as follows: (A) adequate, (B) unclear, (C) inadequate, or (D) not used. A quality rating of (A) yes, (B) can't tell, or (C) no, was assigned to the other quality components (completeness of follow-up and blinding of outcome assessment). High quality trials were defined as those receiving an A rating for blinding of randomization (central computerizedrandomizationservice or sealed opaque envelopes). The quality assessment rating included in the Table of 'Characteristics of Included Studies' refers to blinding of randomization (allocation concealment) only.

**Data synthesis and analysis:**

Descriptiveanalysis was used to represent the extracted data from the selected studies.

**R E S U L T S**

Flow of studies through the review:

The literature search identified a total of 2400 potentially relevant articles. After the removal of duplicates(n= 168), rejection based on title and abstract (n=1247), and inclusion and exclusion criteria (n=6). were included for the quality assessment and best evidence synthesis.

**Types of participants**

A total of 140 children were randomized in the six included trialsinvestigating ADHD.Participant recruitment and inclusion criteria varied between thefive trials; Alexander 2014 [34] included 24 participants aged from 10 to 14 years old, Manuel 2015 [35]recruited 14 participants with age from 11 to 13.7 years old,Vahid 2017[36] included 25 participants aged from 7.2 to 12.3 years old, Carolin 2016 [37] included 42 participants aged from 13 to 17 years old. Theprimary diagnosis for enrolled participants is attention deficit hyperactivity disorder. Alexander 2014 [38] and Manuel 2015 [39]; participants met the diagnostic criteria for ADHD according to DSM-IV-TR. in Vahid 2017 [40]; diagnosed with ADHD according to the diagnostic and statistical manual of mental disorders. Carolin 2016[41]; met the diagnostic criteria for ADHD according to DSM-IV.

**Types of interventions**

The type of interventions is the same in all the studies; tDSC. There are just little different in procedure, time, duration and intensity. two studies( Alexander 2014 ) and ( Manuel 2015 ) were applied during sleep.

**Types of outcome measures**

Some studies have the same type of outcome measures; (Vahid, 2017) and (Sotnikova 2017)used Go/No-go task to measure the effect tDCS on memory performance. To measure inhibitory control and response inhibition; ( Vahid 2017 ) used N-Back test and WCST. Moreover, ( Carolin 2016 ) used Flanker Task to measure interference control.

**Discussion**

Transcranial direct current stimulation is probably beneficial for improving cognition in children and adolescents with attention deficit hyperactivity disorder. The main objective of this review was to critically evaluate articles that demonstrate this assumption. Combining all outcome measures of all studies, transcranial direct current stimulation intervention generally demonstrated strong effects in improving cognitive abilities in children and adolescents with attention deficit hyperactivity disorder, in addition to reduction of clinical symptoms of ADHD;

inattention, hyperactivity and impulsivity. It helps in improvement of working memory, intrinsic alertness, inhibitory control and interference control.

## A U T H O R S ' C O N C L U S I O N S

### Implications for practice

The results of this review provide sufficient evidence to

guide clinical practice on the use of tDCS in children and adolescents with ADHD symptoms.

Although concern for the safety of tDCS in children and adolescentshas been reported, possible adverse effects of tDCS could beevaluated.

Available data from seven reviewed studies demonstrated the efficacy of transcranial direct current stimulation as a new modality in improving cognition and clinical symptoms in children and adolescents with ADHD with immediate and short term effect.

### Implications for research

Further RCTs are required to assess long lasting effect of tDCS in improving cognition and reducing clinical symptoms in children with ADHD. Further trials are required to know and assess the exact washout period to be available to researchers that want to do accumulating studies. Costs also needto be considered.

## C H A R A C T E R I S T I C S O F S T U D I E S

### Characteristics of included studies [ordered by study ID]

### Alexander 2014

| | |
|---|---|
| **Methods** | **Blinding of randomisation - yes**<br>**Blinding of intervention - yes**<br>**Blinding of outcome measure - unclear**<br>**Complete follow-up – yes** |
| **Participants** | **24 cildren; 12 normal, 12 with ADHD**<br>**Main diagnosis: ADHD**<br>**Age: 9-14 years old**<br>**Conducted in: sleep laboratory (children with ADHD), at home (normal children)** |
| **Interventions** | **A double-blind crossover study with two groups:**<br>**Study group and control group ( sham stimulation).**<br>**Each of the two techniques are performed during sleep.** |

| | |
|---|---|
| **outcomes** | **Memory performance** |

**Manuel 2015**

| | |
|---|---|
| **Methods** | **Blinding of randomisation - yes**<br>**Blinding of intervention - yes**<br>**Blinding of outcome measure - yes**<br>**Complete follow-up - yes** |
| **Participants** | **14 children with ADHD**<br>**Main diagnosis: ADHD**<br>**Age: 10-14 years**<br>**Conducted in a sleep lab** |
| **intervention** | **A randomzied double-blind cross-over with one study group:**<br>**Transcranial direct current stimulation**<br>**Sham stimulation**<br>**Each of them were performed during non-rapid eye movement sleep** |
| **outcomes** | **Reaction time**<br>**Motor memory**<br>**Alertness**<br>**Behavioral inhibition**<br>**Sleep parameters** |

**Vahid 2017**

| | |
|---|---|
| **methods** | **Blinding of randomisation - unclear**<br>**Blinding of intervention - yes**<br>**Blinding of outcome measure - unclear**<br>**Complete follow-up – yes** |
| **participants** | **25 children**<br>**Main diagnosis: ADHD**<br>**Age: 7.2-12.3 years**<br>**Conducted in: not mentioned** |
| **intervention** | **A randomized double-blind sham controlled cross-over study of two** |

| | |
|---|---|
| | **groups:**<br>**Anodal, cathodal and sham tDCS**<br>**Cathodal, anodal and sham tDCS** |
| **outcomes** | **Ihibitory control**<br>**Response inhibition**<br>**Working memory performance**<br>**Cognitive flexibility**<br>**Planning**<br>**Task-switching abilities** |

**Breitling 2016**

| | |
|---|---|
| **methods** | **Blinding of randomisation - no**<br>**Blinding of intervention - no**<br>**Blinding of outcome measure - no**<br>**Complete follow-up – yes** |
| **participants** | **46 male; 21 normal, 21 with ADHD**<br>**Main diagnosis: ADHD**<br>**Age: 13-17 years**<br>**Conducted in: not mentioed** |
| **intervention** | **A randomized control trial with two groups (study and control):**<br>**Anodal, cathodal and sham tDCS**<br>**Each participant in both groups received all of them separated by at least one week.** |
| **Outcomes** | **Interference control** |

**Sotnikova 2017**

| | |
|---|---|
| **Methods** | **Blinding of randomisation - unclear**<br>**Blinding of intervention - yes**<br>**Blinding of outcome measure - yes**<br>**Complete follow-up – yes** |
| **Participants** | **16 adolescents (13 boys, 3 girls)** |

| | |
|---|---|
| | **Main diagnosis: ADHD**<br>**Age: 12-16 years**<br>**Conducted in: not mentioned** |
| **Intervention** | **A double-blind sham-controlled study with two groups**<br>**First group: was firstly treated with tDCS and then with sham stimulation**<br>**Second group: received treatment in the reverse order**<br>**The time between both stimulation sessions was at least 2 weeks.** |
| **Outcomes** | **Working memory**<br>**Behavioral changes:**<br>**Reaction time**<br>**Reaction time variability**<br>**Omission errors**<br>**Accuracy**<br>**False alarms** |

**Cornelia 2017**

| | |
|---|---|
| **Methods** | **Blinding of randomisation - unclear**<br>**Blinding of intervention - yes**<br>**Blinding of outcome measure - yes**<br>**Complete follow-up – yes** |
| **Participants** | **15 adolescents (12 male, 3 female)**<br>**Main diagnosis: ADHD**<br>**Age: 12-16 years**<br>**Conducted in: the Department of Child and Adolescent Psychatry, Psychosomatic and Psychotherapy of the Philips-University in Marburg, Germany.** |
| **Intervention** | **A randomized double-blinded sham-controlled crossover study with One group; received both anodal tDCS as well as sham stimulation on five consecutive days with a washout period of 2 weeks.** |
| **Outcomes** | **Changes of the parents' version of a German adaptive ADHD Diagnostic Checklist, FBB-ADHD from baseline to 7 days after the end of stimulation.**<br>**Working memory performance** |

**Characteristics of excluded studies [ordered by study ID]**

| | |
|---|---|
| | |

| **study** | **Reason for exclusion** |
|---|---|
| **Cosmo Camila, 2015** | **Participants didn't match the included age** |

1-Bunge, S. A., Dudukovic, N. M., Thomason, M. E., Vaidya, C. J., and Gabrieli, J. D. (2002). Immature frontal lobe contributions to cognitive control in children: evidence from fMRI. Neuron 33, 301-311. doi: 10.1016/S0896-6273(01)00583-9.

2-Wodka, E. L., Mahone, E. M., Blankner, J. G., Larson, J. C., Fotedar, S., Denckla, M. B., et al. (2007). Evidence that response inhibition is a primary deficit in ADHD. J. Clin. Exp. Neuropsychol. 29, 345–356. doi: 10.1080/13803390600678046.

3-Eriksen, B. A., and Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. Percet. Psychophys. 16, 143-149. doi : 10.3758/BF03203267.

4-Simon, J. R. (1990). "The effects of an irrelevant directional cue on human information processing," in Stimulus-Response Compability, eds R. W. Proctor and T. G. Reeve (Amsterdam: Elsevier), 31–86.

5-Wöstmann, N. M., Aichert, D. S., Costa, A., Rubia, K., Moller, H. J., and Ettinger, U. (2013). Reliability and plasticity of response inhibition and interference control. Brain Cogn. 81, 82–94. doi: 10.1016/j.bandc.2012.09.010.

6-Mullane, J. C., Corkum, P. V., Klein, R. M., and McLaughlin, E. (2009). Interference control in children with and without ADHD: a systematic review of Flanker and Simon task performance. Child Neuropsychol. 15, 321–342. doi: 10.1080/09297040802348028.

7-Luks, T. L., Oliveira, M., Possin, K. L., Bird, A., Miller, B. L., Weiner, M. W., et al. (2010). Atrophy in two attention networks is associated with performance on a Flanker task in neurodegenerative disease. Neuropsychologia 48, 165–170. doi: 10.1016/j.neuropsychologia.2009.09.001.

8-Zhu, D. C., Zacks, R. T., and Slade, J. M. (2010). Brain activation during interference resolution in young and older adults: an fMRI study. Neuroimage 50, 810–817. doi: 10.1016/j.neuroimage.2009.12.087.

9-Sowell, E. R., Thompson, P, M., Welcome, S, E., Henkenius, A. L., Toga, A. W., and Peterson, B. S. (2003). Cortical abnormalities in children and adolescents with attention-deficit hyperactivity disorder. Lancet 362, 1699-1707. doi : 10.1016/S0140-66736(03)14842-8.

10-Durston, S., Hulshoff Pol, H. E., Schnack, H. G., Buitelaar, J. K., Steenhuis, M. P., Minderaa, R. B., et al. (2004). Magnetic resonance imaging of boys with attention-deficit/hyperactivity disorder and their unaffected siblings. J. Am. Acad. Child Adolesc. Psychiatry 43, 332–340. doi: 10.1097/00004583-200403000-00016.

11-Aron, A. R., and Poldrack, R. A. (2005). The cognitive neuroscience of response inhibition: relevance for genetic research in attention-deficit/hyperactivity disorder. Biol. Psychiatry 57, 1285–1292. doi: 10.1016/j.biopsych.2004.10.026.

12-Rubia, K., Halari, R., Cubillo, A., Smith, A. B., Mohammad, A. M., Brammer, M., et al. (2011). Methylphenidate normalizes fronto-striatal underactivation during interference inhibition in medication-naive boys with attention-deficit hyperactivity disorder. Neuropsychopharmacology 36, 1575–1586. doi: 10.1038/npp.2011.30.

13-Lee, Y. S., Han, D. H., Lee, J. H., and Choi, T. Y. (2010). The effects of methylphenidate on neural substrates associated with interference suppression in children with ADHD: a preliminary study using event related fMRI. Psychiatry Investig. 7, 49–54. doi: 10.4306/pi.2010.7.1.49.

14-Nitsche, M. A., and Paulus, W. (2000). Excitability changes induced in the human motor cortex by weak transcranial direct current stimulation. J. Physiol. 527(Pt 3), 633–639. doi: 10.1111/j.1469-7793.2000.t01-1-00633.x.

15-Stagg, C. J., and Nitsche, M. A. (2011). Physiological basis of transcranial direct current stimulation. Neuroscientist 17, 37–53. doi: 10.1177/1073858410386614.

16-Nitsche, M. A., and Paulus, W. (2001). Sustained excitability elevations induced by transcranial DC motor cortex stimulation in humans. Neurology 57, 1899–1901. doi: 10.1212/WNL.57.10.1899.

17-Kalu, U. G., Sexton, C. E., Loo, C. K., and Ebmeier, K. P. (2012). Transcranial direct current stimulation in the treatment of major depression: a meta-analysis. Psychol. Med. 42, 1791–1800. doi: 10.1017/S0033291711003059.

18-Brunelin, J., Mondino, M., Gassab, L., Haesebaert, F., Gaha, L., Suaud-Chagny, M. F., et al. (2012). Examining transcranial direct-current stimulation (tDCS) as a treatment for hallucinations in schizophrenia. Am. J. Psychiatry 169, 719–724. doi: 10.1176/appi.ajp.2012.11071091.

19-Chang, M. C., Kim, D. Y., and Park, D. H. (2015). Enhancement of cortical excitability and lower limb motor function in patients with stroke by transcranial direct current stimulation. Brain Stimul. 8, 561–566. doi: 10.1016/j.brs.2015.01.411.

20-Heth, I., and Lavidor, M. (2015). Improved reading measures in adults with dyslexia following transcranial direct current stimulation treatment. Neuropsychologia 70, 107–113. doi: 10.1016/j.neuropsychologia.2015.02.022.

21-Keeser, D., Meindl, T., Bor, J., Palm, U., Pogarell, O., Mulert, C., et al. (2011). Prefrontal transcranial direct current stimulation changes connectivity of resting-state networks during fMRI. J. Neurosci. 31, 15284–15293. doi: 10.1523/JNEUROSCI.0542-11.2011.

22-Halperin, J. M., and Healey, D. M. (2011). The influences of environmental enrichment, cognitive enhancement, and physical exercise on brain development: can we alter the developmental trajectory of ADHD? Neurosci. Biobehav. Rev. 35, 621–634. doi: 10.1016/j.neubiorev.2010.07.006.

23-Chronis, A. M., Pelham, W. E. Jr., Gnagy, E. M., Roberts, J. E., and Aronoff, H. R. (2003). The impact of late-afternoon stimulant dosing for children with ADHD on parent and parent-child domains. J. Clin. Child Adolesc. Psychol. 32, 118–126. doi: 10.1207/S15374424JCCP3201_11.

24-Cohen Kadosh, R., Soskic, S., Iuculano, T., Kanai, R., and Walsh, V. (2010). Modulating neuronal activity produces specific and long-lasting changes in numerical competence. Curr. Biol. 20, 2016–2020. doi: 10.1016/j.cub.2010.10.007.

25-Mattai, A., Miller, R., Weisinger, B., Greenstein, D., Bakalar, J., Tossell, J., et al. (2011). Tolerability of transcranial direct current stimulation in childhood-onset schizophrenia. Brain Stimul. 4, 275–280. doi: 10.1016/j.brs.2011.01.001.

26-Andrade, A. C., Magnavita, G. M., Allegro, J. V., Neto, C. E., Lucena Rde, C., and Fregni, F. (2014). Feasibility of transcranial direct current stimulation use in children aged 5 to 12 years. J. Child Neurol. 29, 1360–1365. doi: 10.1177/0883073813503710.

27-Moliadze, V., Schmanke, T., Andreas, S., Lyzhko, E., Freitag, C. M., and Siniatchkin, M. (2014). Stimulation intensities of transcranial direct current stimulation have to be adjusted in children and adolescents. Clin. Neurophysiol. 126, 1392–1399. doi: 10.1016/j.clinph.2014.10.142.

28-Krishnan, C., Santos, L., Peterson, M. D., and Ehinger, M. (2015). Safety of noninvasive brain stimulation in children and adolescents. Brain Stimul. 8, 76–87. doi: 10.1016/j.brs.2014.10.012.

29-Prehn-Kristensen, A., Munz, M., Goder, R., Wilhelm, I., Korr, K., Vahl, W., et al. (2014). Transcranial oscillatory direct current stimulation during sleep improves declarative memory consolidation in children with attention-deficit/hyperactivity disorder to a level comparable to healthy controls. Brain Stimul. 7, 793–799. doi: 10.1016/j.brs.2014.07.036.

30-Munz, M. T., Prehn-Kristensen, A., Thielking, F., Mölle, M., Göder, R., and Baving, L. (2015). Slow oscillating transcranial direct current stimulation during non-rapid eye movement sleep improves behavioral inhibition in attention-deficit/ hyperactivity disorder. Front. Cell. Neurosci. 9:307. doi: 10.3389/fncel.2015.00307.

31-Verhagen AP, Vet HCW de, Bie RA de, Kessels AGH, Boers M, Bouter LM, et al. (1998). The

Delphi list: a criteria list for quality assessment of randomized clinical trials for conducting systematic

reviews developed by Delphi consensus. J Clin Epidemiol.;51(12):1235–41.

32-Dario AB, Cabral AM, Almeida L, Ferreira ML, Refshauge K, Simic M, et al. (2017).. Effectiveness

of telehealth-based interventions in the management of non-specific low back pain: a systematic review

13with meta-analysis. Spine J. 17(9):1342–51.

33- Lemes ÍR, Ferreira PH, Linares SN, Machado AF, Pastre CM, Netto J (2016). Resistance training reduces systolic blood pressure in metabolic syndrome: a systematic review and meta-analysis of randomised controlled trials. Br J Sports Med.;50(23):1438–42. 19- Sackett DL, Strauss SE, Richardson WS, et al. (2000). Evidence-Based.

34-Prehn-Kristensen, A., Munz, M., Göder, R., Wilhelm, I., Korr, K., Vahl, W., ... & Baving, L. (2014). Transcranial oscillatory direct current stimulation during sleep improves declarative memory consolidation in children with attention-deficit/hyperactivity disorder to a level comparable to healthy controls. Brain stimulation, 7(6), 793-799.

35- Munz, M. T., Prehn-Kristensen, A., Thielking, F., Mölle, M., Göder, R., & Baving, L. (2015). Slow oscillating transcranial direct current stimulation during non-rapid eye movement sleep improves behavioral inhibition in attention-deficit/hyperactivity disorder. Frontiers in cellular neuroscience, 9, 307.

36- Nejati, V., Salehinejad, M. A., Nitsche, M. A., Najian, A., & Javadi, A. H. (2017). Transcranial direct current stimulation improves executive dysfunctions in ADHD: implications for inhibitory control, interference control, working memory, and cognitive flexibility. Journal of attention disorders, 1087054717730611.

37- Breitling, C., Zaehle, T., Dannhauer, M., Bonath, B., Tegelbeckers, J., Flechtner, H. H., & Krauel, K. (2016). Improving interference control in ADHD patients with transcranial direct current stimulation (tDCS). Frontiers in cellular neuroscience, 10, 72.

38- Prehn-Kristensen, A., Munz, M., Göder, R., Wilhelm, I., Korr, K., Vahl, W., ... & Baving, L. (2014). Transcranial oscillatory direct current stimulation during sleep improves declarative memory consolidation in children with attention-deficit/hyperactivity disorder to a level comparable to healthy controls. Brain stimulation, 7(6), 793-799.

39- Munz, M. T., Prehn-Kristensen, A., Thielking, F., Mölle, M., Göder, R., & Baving, L. (2015). Slow oscillating transcranial direct current stimulation during non-rapid eye movement sleep improves behavioral inhibition in attention-deficit/hyperactivity disorder. Frontiers in cellular neuroscience, 9, 307.

40- Nejati, V., Salehinejad, M. A., Nitsche, M. A., Najian, A., & Javadi, A. H. (2017). Transcranial direct current stimulation improves executive dysfunctions in ADHD: implications for inhibitory control, interference control, working memory, and cognitive flexibility. Journal of attention disorders, 1087054717730611.

41-Breitling, C., Zaehle, T., Dannhauer, M., Bonath, B., Tegelbeckers, J., Flechtner, H. H., & Krauel, K. (2016). Improving interference control in ADHD patients with transcranial direct current stimulation (tDCS). Frontiers in cellular neuroscience, 10, 72.