Protocols for transcranial direct current stimulation combined with motor training administered to neurological patients: systematic review

Protocolos para estimulação transcraniana por corrente contínua combinada com treinamento motor administrado a pacientes neurológicos: revisão sistemática

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Lorraine Barbosa Cordeiro
Master's student in Human Movement and Rehabilitation
Institution: Universidade Evangélica de Goiás (UNIEVANGÉLICA)
Address: Anápolis - GO, Brasil
E-mail: fisiolorraine@gmail.com

Jamile Benite Palma Lopes
PhD in Health Sciences
Institution: Associação de Pais e Amigos dos Excepcionais (APAE) de Taquaritinga
Address: Taquaritinga – SP, Brasil
E-mail: jamilepalma@yahoo.com.br

Rodolfo Borges Parreira
PhD in Health Sciences
Institution: Centro de Medicina Esportiva e Performance (CEMEP)
Address: Londrina – PR, Brasil
E-mail: rodolfo@institutosalgado.com.br

Daniela Rosana Pedro Fonseca
Master in Physical Education
Institution: Universidade Paulista - campus Goiânia
Address: Goiânia – GO, Brasil
E-mail: fonseca.dandri@gmail.com

Natália de Almeida Carvalho Duarte
Post PhD in Human Movement and Rehabilitation
Institution: Universidade Evangélica de Goiás (UNIEVANGÉLICA)
Address: Anápolis - GO, Brasil
E-mail: natycarvalho_fisio@hotmail.com

Cláudia Santos Oliveira
PhD in Health Sciences
Institution: Universidade Evangélica de Goiás (UNIEVANGÉLICA)
Address: Anápolis - GO, Brasil
E-mail: csantos.neuro@gmail.com
ABSTRACT
Transcranial direct current stimulation (tDCS) is a promising tool for patients with neurological disorders. The objective of the present study was to analyze whether there is standardization in the literature regarding the choice of protocols regarding the assembly of electrodes, intensity of electric current and number of sessions of tDCS performed alone or specially in combination with motor training for neurological patients. Following the PRISMA statement, the study was registered in the PROSPERO database (CRD42019128005), considering articles published up to January 2023. The search strategy followed the guidelines of the Cochrane Collaboration. A total of five hundred twenty-three articles were retrieved from the databases, thirteen of which were included in this systematic review. All were randomized clinical trials involving neurological patients – seven involved the pediatric population with cerebral palsy and six involved the adult population (five comprised of stroke survivors and one comprised of patients with Parkinson’s disease). The literature regarding the use of non-invasive neuromodulation, such as Transcranial Direct Current Stimulation, is not yet conclusive. Variability in protocols revealed a lack of standardization. On the other hand, standardization was found among studies involving the pediatric population regarding current intensity and application time.

Keywords: transcutaneous electric stimulation, neurology, nervous system disease.

RESUMO
A estimulação transcraniana por corrente contínua (tDCS) é uma ferramenta promissora para pacientes com distúrbios neurológicos. O objetivo do presente estudo foi analisar se há padronização na literatura quanto à escolha de protocolos relativos à montagem de eletrodos, intensidade da corrente elétrica e número de sessões de ETCC realizadas isoladamente ou especialmente em combinação com treinamento motor para pacientes neurológicos. Seguindo a declaração PRISMA, o estudo foi registrado no banco de dados PROSPERO (CRD42019128005), considerando artigos publicados até janeiro de 2023. A estratégia de pesquisa seguiu as diretrizes da Colaboração Cochrane. Um total de quinhentos e vinte e três artigos foram recuperados dos bancos de dados, treze dos quais foram incluídos nesta revisão sistemática. Todos eram ensaios clínicos randomizados envolvendo pacientes neurológicos - sete envolviam a população pediátrica com paralisia cerebral e seis envolviam a população adulta (cinco eram sobreviventes de AVC e um era composto por pacientes com doença de Parkinson). A literatura sobre o uso de neuromodulação não invasiva, como a Estimulação Transcraniana por Corrente Contínua, ainda não é conclusiva. A variabilidade nos protocolos revelou uma falta de padronização. Por outro lado, foi encontrada uma padronização entre os estudos envolvendo a população pediátrica com relação à intensidade da corrente e ao tempo de aplicação.

Palavras-chave: estimulação elétrica transcutânea, neurologia, doenças do sistema nervoso.

1 INTRODUCTION
The use of non-invasive neuromodulation techniques has been widely studied in recent years. Such techniques have been gaining prominence in the national and international literature, with encouraging results regarding rehabilitation for neurological disorders. The main forms of
brain stimulation are transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (tDCS) [1], the latter of which has advantages over other transcranial stimulation techniques, such as low cost, application versatility and minimal adverse events [2,3]. Transcranial direct current stimulation is a non-invasive neuromodulatory technique that has the ability to modulate the excitability of the neuronal membrane via a low intensity direct monophasic electrical current (1 to 2 mA) applied to the scalp using sponge electrodes over a pre-specified target area [4,5].

These neuromodulation effects vary according to electrode polarity, with increased cortical excitability below the anode electrodes and decreased electrical activity below the cathode electrodes. Such effects have been widely studied in human beings due to a baseline research that provided us with enough information to prove all the neurophysiological effects of the technique. The first study on the application of tDCS in acute ischemia, for example, provided us with a basis for understanding this mechanism, in addition to highlighting the importance of mastering the pathophysiology of the health condition to improve the safety and efficacy of the technique [6]. With tDCS, part of the electrical current that flows from the electrodes penetrates the skull, reaching cortical structures and causing an alteration in the membrane potential. The effects provided by stimulation occur due to the movement of electrons that flow from the anodal (positive) to cathodal (negative) electrode, resulting in different effects on biological tissues [6] with few side effects reported in the literature, such as itching, redness and a burning sensation below the electrode region as well as headache, which is generally mild and with no long-term impact [5].

The placement of the electrodes conventionally follows the 10-20 international system of electroencephalography (EEG) as reference, knowledge of which is extremely important to the identification of the target area to achieve the desired therapeutic objectives [6-8]. The current density (relationship between current intensity and electrode size) of sponge electrodes must also be considered. The larger the electrode, the lower the current density, therefore, the less focal the stimulus. That is, smaller electrodes spread the current less, therefore increasing the current density favoring the stimulus focus a little more. A higher current density may result in an increase in the perception of pain to the stimulus, and for this reason, this parameter must be carefully evaluated according to the population to be studied. [9]. Electrode placement depends on the hypothesis being tested and the task employed. The task must recruit neurons in the target
region to enable the observation of changes related to stimulation. Therefore, the placement of the reference electrode is based on the direction of the current as well as patient comfort and safety [10].

Transcranial direct current stimulation is used as complementary therapy in rehabilitation protocols and may be combined with physiotherapy for both adults and children with neurological disorders [11]. The combination of the technique of transcranial direct current stimulation with training of a motor task performed simultaneously has been showing promise, where it is suggested that neuromodulation is capable of optimizing the effects obtained by physical therapies [11,12]. The most widely treated conditions described in the literature are cerebral palsy [12], stroke [13] and Parkinson's disease [14]. Understanding the neurophysiology of each disease and its neuromotor impairments is important to the planning of neuromodulatory therapy. Moreover, the standardization of ideal treatment protocols is necessary and should consider all variables of each neurological condition.

Therefore, the aim of the present study was to analyze whether standardization is found in the literature regarding the choice of protocols in terms of electrode montage, intensity of the electrical current and the number of sessions of tDCS performed alone or specially in combination with motor training for neurological patients.

2 MATERIALS AND METHODS

This present review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA statement) and was registered in the PROSPERO database (CRD42019128005).

2.1 ELIGIBILITY CRITERIA

The following criteria were used for the selection of articles: 1) Population: Neurological patients, with no restrictions regarding age; 2) Intervention: use of tDCS focusing on motor rehabilitation combined with motor training; 3) Comparison: montage protocols; 4) Outcome: Description of tDCS montage protocols and areas stimulated; 5) Study: randomized clinical trials.
2.2 INFORMATION SOURCES

The PubMed (National Library of Medicine), Scopus and Web of Science databases were searched for relevant articles published in English and Portuguese up to January 2023. No restriction was imposed regarding the year of publication and no other filters or limits applied.

2.3 SEARCH STRATEGY

Searches of the databases were conducted between March 2022 to January 2023 using the following search strategy: “Transcranial Direct Current Stimulation” OR “tDCS” AND “Nervous System Diseases” AND ”Neurological Diseases” AND “Motor Activity” OR “Motor Area” OR "Motor Cortex" AND "Double Blind Randomized".

2.4 ARTICLE SELECTION AND DATA EXTRACTION

Two independent reviewers (LBC and BOS) examined the titles and abstracts of the articles retrieved from the electronic databases. Cases of a divergence of opinion between the reviewers were resolved by consulting a third reviewer to make the final decision. After preselecting articles based on the abstracts and titles, the reviewers analyzed the full texts and excluded duplicates. A form was used to list the reasons for the exclusion.

Two reviewers extracted the data of interest from all studies included in the review using a custom data extraction table created in Microsoft Excel. The data were presented in the form of narrative synthesis, with numbers and codes for the results section. The following data were extracted: (a) metadata – authorship and year of publication; (b) population characteristics – age, central nervous system disease, clinical characteristics; (c) tDCS parameters – electrode montage, intensity, electrode size, control, number and duration of sessions; d) intervention; e) assessment methods; f) results.

3 RESULTS

A total of 523 articles were retrieved from the electronic databases based on the descriptors. After screening, 33 duplicates were excluded, leaving 490 articles, 448 of which articles were excluded after reading the abstract. Among the remaining 42 articles, 29 were excluded after (Fig. 1).
Figure 1. Overview of article selection process.

Legend: Flowchart of the study.
Source: authors.

3.1 METHODOLOGICAL QUALITY

Methodological quality was appraised using the PEDro Scale (Table 1). The PEDro scale is based on a description of the study structure and includes items related to randomization, blinding, design analysis and statistics. The average PEDro score was 8.9 points (range: 7 to 10 of 11 points). Thus, all studies were considered to have good methodological quality.

All studies were randomized trials, but one failed to report the generation of the randomization sequence [18]. Most trials failed to blind the therapists [18, 19, 21-25, 27, 28] and three did not blind the raters [16, 26, 27].
Table 1. Appraisal of methodological quality using PEDro scale.

<table>
<thead>
<tr>
<th>Eligibility Criteria</th>
<th>Alisar et al., 2019&lt;sup&gt;16&lt;/sup&gt;</th>
<th>Bornheim et al., 2020&lt;sup&gt;17&lt;/sup&gt;</th>
<th>Dehem et al., 2018&lt;sup&gt;18&lt;/sup&gt;</th>
<th>Duarte et al., 2014&lt;sup&gt;19&lt;/sup&gt;</th>
<th>Gillick et al., 2018&lt;sup&gt;20&lt;/sup&gt;</th>
<th>Grecco et al., 2014&lt;sup&gt;21&lt;/sup&gt;</th>
<th>Grecco et al., 2014&lt;sup&gt;22&lt;/sup&gt;</th>
<th>Lazzari et al., 2015&lt;sup&gt;23&lt;/sup&gt;</th>
<th>Lazzari et al., 2017&lt;sup&gt;24&lt;/sup&gt;</th>
<th>Liorens et al., 2021&lt;sup&gt;25&lt;/sup&gt;</th>
<th>Moura et al., 2017&lt;sup&gt;26&lt;/sup&gt;</th>
<th>Yao et al., 2020&lt;sup&gt;27&lt;/sup&gt;</th>
<th>Yotnuengnit et al., 2018&lt;sup&gt;28&lt;/sup&gt;</th>
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<tr>
<td>Yes</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Concealed Allocation</td>
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<td>Allocation comparability</td>
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<td>Yes</td>
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<td>Yes</td>
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<td>Yes</td>
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<tr>
<td>Blinding of Subjects</td>
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<td>Yes</td>
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<td>Blinding of therapists</td>
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<td>No</td>
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<tr>
<td>Blinding of Assessors</td>
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<td>More than 85% follow-up</td>
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<td>Intention-to-treat</td>
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<td>Yes</td>
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<td>Yes</td>
<td>Yes</td>
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<td>Yes</td>
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<td>Analysis Inter-group</td>
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<td>Comparison Measures of variability</td>
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<td>Yes</td>
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</tr>
</tbody>
</table>

Legend: Physiotherapy Evidence Scale – PEDro.
Source: authors.
3.2 DESCRIPTION OF STUDY CHARACTERISTICS

The characteristics of the articles included in the present review are summarized in Table 2. All studies were randomized clinical trials. Seven involved children with cerebral palsy (CP) [19, 20-24, 26]. Five involved adult stroke survivors [16-18, 25, 27]. One study involved adults with Parkinson's disease [28].
<table>
<thead>
<tr>
<th>Study information</th>
<th>Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td>Condition</td>
</tr>
<tr>
<td>Alisar et al., 2019&lt;sup&gt;16&lt;/sup&gt;</td>
<td>Stroke.</td>
</tr>
<tr>
<td>Bornheim et al., 2020&lt;sup&gt;17&lt;/sup&gt;</td>
<td>Acute stroke.</td>
</tr>
<tr>
<td>Dehem et al., 2018&lt;sup&gt;18&lt;/sup&gt;</td>
<td>Chronic stroke.</td>
</tr>
<tr>
<td>Duarte et al., 2014&lt;sup&gt;19&lt;/sup&gt;</td>
<td>Cerebral palsy.</td>
</tr>
<tr>
<td>Study Authors (Year)</td>
<td>Diagnosis</td>
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<td>Gillick et al., 2018</td>
<td>Cerebral palsy</td>
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<td>Grecco et al., 2014</td>
<td>Cerebral palsy</td>
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<td>Grecco et al., 2014</td>
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<td>Lazzari et al., 2015</td>
<td>Cerebral palsy</td>
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<td>Lazzari et al., 2017</td>
<td>Cerebral palsy</td>
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<tr>
<td><strong>Lioren et al., 2021</strong>&lt;sup&gt;25&lt;/sup&gt;</td>
<td>Post-stroke.</td>
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<tr>
<td><strong>Moura et al., 2017</strong>&lt;sup&gt;26&lt;/sup&gt;</td>
<td>Cerebral palsy.</td>
</tr>
<tr>
<td><strong>Yao, 2020</strong>&lt;sup&gt;27&lt;/sup&gt;</td>
<td>Ischemic stroke.</td>
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<tr>
<td><strong>Yotnuengnit, 2018</strong>&lt;sup&gt;28&lt;/sup&gt;</td>
<td>Parkinson Disease.</td>
</tr>
<tr>
<td>CG: sham tDCS + physical therapy.</td>
<td>Manager used to evaluate gait parameters.</td>
</tr>
</tbody>
</table>

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Legends: tDCS: transcranial direct current stimulation; min.: minute; TMS: transcranial magnetic stimulation; mA: milliampere; cm: centimeter; cm²: square centimeter; min: minute; GE: experimental group; CG: control group; RAT: robot-assisted therapy; FMUE: Fugl-Meyer upper extremity section; FIM: Functional Independence Measure; BSSR: Brunnstrom Stages of Stroke Recovery; VR: virtual reality; ARAT: Action Research Arm Test; BI: Barthel Index; CIMT: constraint-induced movement therapy; MAE: minor adverse event; FMLE: Fugl-Meyer lower extremity section; SIS: Stroke Impact Scale; HADS: Hospital Anxiety and Depression Scale.

Source: authors.
3.3 CHARACTERISTICS OF ELECTRODE MONTAGE AND ADMINISTRATION OF TDCS

3.3.1 Cerebral palsy

Seven studies included in the present review [19, 20-24, 26] administered tDCS to children with cerebral palsy. To evaluate static and dynamic balance in this population, the authors of three studies [19, 23, 24] positioned the anode over C3/C4 (primary motor cortex) and a cathode over the contralateral supraorbital region. Stimulation was administered over 10 days with a current of 1 mA during twenty minutes of training using electrodes measuring 25 cm². Duarte et al. (2014) [19] evaluated the effects of tDCS combined with tDCS gait training on static and dynamic balance, whereas Lazzari et al. (2015) [23] and Lazzari et al. (2017) [24] evaluated the effects of tDCS combined with virtual reality training on balance.

Grecco et al., [21] evaluated the effects of 10 sessions of anodal tDCS over the primary motor cortex, with the cathode positioned over the contralateral supraorbital region. A current of 1 mA was administered by electrodes measuring 25 cm², for 20 minutes during simultaneous treadmill gait training. The outcomes of interest were kinematic gait variables, gross motor function and functioning. In the same year, Grecco et al. [22], evaluated the effect of a single session of tDCS on immediate changes in spatiotemporal gait variables and static balance, stimulating the primary motor cortex region for 20 minutes at a current of 1 mA (electrodes measuring 25 cm²), with the cathode positioned in the contralateral supraorbital region.

Evaluating the kinematics of upper limb movements, Moura et al. [26], positioned the anode over the primary motor cortex and the cathode in the contralateral supraorbital region. A current of 1 mA was administered using electrodes measuring 25 cm² during upper limb training in a total of ten sessions.

3.3.2 Stroke

Five studies included in the present review [16-18, 25, 27] administered tDCS to stroke survivors. The studies by Alisar et al. [16] and Dehem et al. [18], focused on the upper limbs. Alisar et al. [16], investigated the effects of 15 sessions of bilateral stimulation of the primary motor cortex combined with physical therapy and occupational therapy on upper limb motor function. The anode was positioned over C3 (ipsilesional hemisphere) and the cathode was positioned over C4 (hemisphere contralateral to injury). A current of 2 mA was administered by
electrodes measuring 22 cm² for 30 minutes. Dehem et al. [18] evaluated upper limb dexterity using a similar montage (anode positioned over ipsilesional C3 and cathode positioned over contralesional C4) with a current of 1 mA combined with robot-assisted therapy. One session was performed for 20 minutes with electrodes measuring 35 cm².

Bornheim et al. [17] investigated the effects of five sessions of tDCS combined with physical therapy and occupational therapy on functional and sensory outcomes in the first year after the onset of stroke. The anode was positioned over the ipsilesional primary motor cortex and cathode was positioned in the contralateral supraorbital region (C3/Fp2 or C4/Fp1). A current of 2 mA was administered for 20 minutes with electrodes measuring 25 cm².

Liores et al. [25] investigated the effect of anodal tDCS combined with a virtual reality intervention on sensory-motor function. The anode was positioned over the ipsilesional primary motor cortex (M1; C3 or C4 for left or right hemiparesis) and the cathode was positioned in the contralateral supraorbital region (Fp2 or Fp1 for left or right hemiparesis). A current of 2 mA was administered for 20 minutes with electrodes measuring 25 cm² in a total of 25 sessions.

Yao et al. [27] evaluated upper limb function and quality of life in a study involving 10 sessions of tDCS combined with a virtual reality intervention. The cathode was positioned over the primary motor cortex (M1) and the anode was positioned in the contralateral region. A current of 2 mA was administered for 20 minutes with electrodes measuring 35 cm².

3.3.3 Parkinson’s disease

One study included in the present review [28] involved the administration of tDCS to individuals with Parkinson’s disease. The authors evaluated the effects of tDCS combined with physical therapy on locomotion. The anode (35 cm².) was positioned over Cz, which corresponds to the lower limb motor cortex, and the cathode (35 cm²) was positioned in the supraorbital area on the forehead. The treatment protocol entailed six 30-minute sessions.

4 DISCUSSION

The use of non-invasive neuromodulation, more specifically transcranial direct current stimulation, has been widely studied in recent years, with a significant number of recent publications on the subject.
Studies with methodological quality and real scientific evidence are needed for the technique to be applied safely and with important functional therapeutic results. The tDCS technique is relatively simple but the key to successful therapy is an understanding of neurophysiological aspects, such as the pathophysiology of the condition, compromised areas of the brain, neuromotor impairment and the adaptive or maladaptive plasticity. Moreover, different protocols are needed for populations in different age groups due to differences in anthropometric characteristics as well as the behavior and interaction of the current with the target tissue.

In general, the intensity of the electrical current used to perform tDCS is 2 mA for the adult population. A lower current of 1 mA is used for the pediatric population [29]. Moreover, the data referring to this population are a somewhat less divergent, with similar rehabilitation protocols found in the literature.

Most studies involving the use of tDCS on children with CP with a mean age range of four to twelve years employed the 10-20 electroencephalography system as reference for locating the points to be stimulated. Stimulation was administered with an intensity of 1 mA for 20 minutes with electrodes measuring 25 cm² [19, 21, 24, 26]. The most common protocol was five sessions per week for two weeks (total of ten sessions). At the end of the protocol, improvements were found in the spatiotemporal and kinematic gait variables, static and dynamic balance and functioning. Some studies report that the therapeutic effects are enhanced by the use of the combination of techniques [19, 21, 22]. Protocols involving a single session of tDCS also found improvements in static balance and gait velocity in children with CP, however the effects were not maintained for more than 20 minutes after the end of the stimulation [22, 23].

Most studies involving the use of tDCS on stroke survivors with a mean age range of 18 to 80 years used the 10-20 electroencephalography system as reference to locate the points to be stimulated [16, 18]. Only one study used the induction of the motor evoked potential response by transcranial magnetic stimulation [27]. Most studies administered stimulation at an intensity of 2 mA [16, 17, 25, 27] with a variation in the duration ranging from 20 [18, 25, 27] to 30 minutes using electrodes of different sizes, such as 22 cm² [16], 25 cm² [17, 25] and 35 cm² [18, 27]. Considering the number of sessions of the studies there is no standardization: 15 sessions [16], 5 sessions [17] a single session [18], 25 sessions [25] and 10 sessions [27]. At the end of the protocol, improvements were found in upper extremity function [16], motor functions and somatosensory functions [17], upper limb motor function [25], upper limb motor impairment,
functioning and quality of life [27]. The protocol involving a single tDCS session also led to improvements in hand dexterity and arm movements [18].

A study involving the use of tDCS administered to individuals with Parkinson’s disease [28] aged 40 to 80 years used the 10-20 electroencephalography system as reference for locating the points to be stimulated and administered the current at an intensity of 2 mA using electrodes measuring 35 cm² for 30 minutes. At the end of the six-session protocol, improvements in gait speed and an increase in step length were observed.

The use of tDCS has become increasingly frequent, with promising results in the field of neurology. When aligned with the neurophysiological and neuromotor characteristics of each condition, this method has demonstrated encouraging effects for the clinical practice of rehabilitation. However, it is important to bear in mind that despite being easy to administer, tDCS has its complexity and must be properly aligned with the therapeutic objectives, with the careful consideration of adverse effects. The current must be adapted to the pediatric population, who have different neuroanatomical characteristics compared to adults. Thus, a current of lower intensity, such as 1 mA, is capable of generating neurophysiological effects in children similar to a current of 2 mA administered to adults [29]. In general, 20-minute sessions are capable of generating the desired therapeutic effects [17-27].

As a limitation of the study, we highlight the difficulty of accessing some articles with full text, limiting the selection of studies to be included.

The literature regarding the use of non-invasive neuromodulation, such as Transcranial Direct Current Stimulation, is not yet conclusive and represents a scientific gap. The combined use of tDCS with specific motor training according to the therapeutic objective and the target area must be more widely studied to generate evidence that justifies the use of the technique in clinical practice.

Further studies are needed for the definition of the ideal protocol for each condition and population. Long-term follow-up is also needed to enable the determination of whether the benefits are maintained over time. The modulation of cortical excitability provided by tDCS should be the focus of study, with the inclusion of specific tests that can provide reliable parameters and information on the physiological effects involved.
5 CONCLUSIONS

This review found evidence supporting the use of tDCS in adult patients. However, the variability in the protocols revealed a lack of standardization. In contrast, standardization was found among the studies involving the pediatric population in terms of current intensity and application time.

Although the technique is relatively simple to apply, all parameters of noninvasive neuromodulation must be well controlled to avoid possible biases in research and the therapeutic results obtained. The findings of this review provide important information to guide future studies involving adequate protocols and methodological quality.

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REFERENCES


Stagg, C.J.; Antal, A.; Nitsche, M.A. Physiology of transcranial direct current stimulation. The journal of ECT 2018; 34:3, 44-152. doi: 10.1097/YCT.0000000000000510


Simis, M. et al. tDCS in the Context of Rehabilitation. In: Transcranial Direct Current Stimulation in Neuropsychiatric Disorders. Springer Cham 2021; 653-663. DOI: 10.1007/978-3-030-76136-3_34


Lazzari, R.D. et al. Effect of a single session of transcranial direct-current stimulation combined with virtual reality training on the balance of children with cerebral palsy: a randomized,
controlled, double-blind trial. Journal of physical therapy science, 2015, 27.3: 763-768. https://doi.org/10.1589/jpts.27.763


