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NEURAL SYMPHONY: HARMONIZING TRANSCRANIAL DIRECT CURRENT STIMULATION (TDCS) FOR POST-STROKE COGNITIVE RESURGENCE - A NARRATIVE EXPLORATION

Physiotherapy & Rehabilitation

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ABSTRACT

Neurocognitive deficits post-stroke is a pervasive repercussion of stroke, adversely affecting key cognitive faculties, including executive function, memory, and attention. Transcranial Direct Current Stimulation (tDCS) is a non-intrusive technique that modulates brain activity without the need for surgical intervention. This review consolidates current literature to critically examine the effectiveness of tDCS in ameliorating cognitive deficits associated with PSCI. Although numerous studies suggest promising outcomes, particularly in augmenting executive function and overall cognition, its efficacy in enhancing memory and attentional processes remains ambiguous. Variability in stimulation protocols, patient demographics, and study methodologies further complicates the interpretation of results. Given the escalating interest in tDCS as a rehabilitative modality, a rigorous and systematic review is imperative to delineate its therapeutic value, highlight existing research gaps, and inform future investigations aimed at optimizing its clinical application in post-stroke cognitive rehabilitation.

KEYWORDS

cognition, narrative review, neuroplasticity, NIBS, stroke, transcranial direct current stimulation (tDCS)

INTRODUCTION

Neurocognitive deficits post-stroke encompasses cognitive deficits of any degree, irrespective of their origin, identified following a confirmed stroke event (1). Neurocognitive deficits post-stroke manifests with varying intensity. Around sixty percent of stroke survivors face deficits within a year, with its predominance peaking in the acute phase post-stroke. Remarkably, around 20% of individuals with mild PSCI achieve full cognitive restitution, with the highest probability of recovery occurring in the immediate aftermath of the cerebrovascular insult (2).

Lesions affecting the sovereign cerebral hemisphere and disruptions within the prefrontal–subcortical network may precipitate deficits in executive functioning. In cases of a singular large cortico-subcortical brain ischemic lesion, acute cognitive decline may occur if it affects a region crucial for cognition. Damage to the constituents of the Papez circuit may induce strategic infarction dementia (3).

NIBS methods like Repetive Transcranial Magnetic Stimulation (rTMS) and transcranial electrical stimulation (TES) modulate brain function, Influences understanding, thinking, emotions, motor abilities, and other brain processes. These interventions have demonstrated efficacy in both healthy individuals and patients (4). Neuroenhancement refers to the augmentation of fundamental cognitive processes within the brain beyond natural learning, encompassing mechanisms involved in perception, attention, conceptualization, memory, reasoning, and motor function (5). The public views neuroenhancement as both a promising development and a cause for concern (6).

Neuroplasticity forms the core mechanism regulating various cognitive and behavioral functions in both normal and pathological conditions, including memory formation, learning, and neural restoration. It represents the lasting transformation of neuronal structure and connectivity in response to experiential influences. Extensively investigated in cellular and animal models, synaptic plasticity—characterized by extended neuronal excitation, prolonged synaptic weakening—involves the dynamic modulation of synaptic strength through enhancement or attenuation of neural connections (7). By leveraging the principles of synaptic extended neuronal excitation and enduring synaptic suppression, non-invasive tDCS has the potential to optimize performance across various cognitive domains. Notably, these neuromodulatory processes are particularly effective when the targeted cognitive functions actively recruit the stimulated brain region (8).

Anodal cortical neuromodulation, a NIBS method, induces brain plasticity by applying weak currents across the scalp. The primary effect involves the polarization of neuronal membranes, which is contingent on the orientation of the electrical field and leads to either an augmentation of neural responsiveness and activity (9). After a short duration of stimulation, distinct neuroplastic after-effects emerge. Recent evidence suggests that increasing anodal tDCS intensity to 3 mA for 20 minutes significantly enhances therapeutic efficacy compared to conventional protocols (10).

This study delved into the impact of transcranial direct current stimulation (tDCS) on cognitive rehabilitation in stroke survivors through an extensive analysis of existing scholarly literature. The foremost objective was to critically appraise the efficacy of tDCS as a neuro-modulatory intervention for enhancing cognitive function in this demographic. By integrating insights from prior empirical research, the study endeavoured to delineate both the therapeutic advantages and inherent constraints of Anodal cortical neuromodulation in alleviating post-stroke cognitive deficits. Additionally, it aimed to uncover existing lacunae in the literature, thereby providing a foundational framework for future inquiries focused on optimizing cortical neuromodulation as a precision-driven therapeutic modality for cognitive restoration in stroke-affected individuals.

MATERIAL AND METHODS

Study Design

This study sought to scrutinize the potency of transcranial direct current stimulation as a therapeutic modality to enhance cognitive recovery in stroke survivors by synthesizing existing research on its effectiveness.

Eligibility Criteria

This study was structured using the PICOS framework to ensure methodological rigor: **P** represents "stroke-affected individuals," **I** investigate "the utilization of Transcranial Direct Current Stimulation (tDCS)," **C** examines "placebo interventions or conventional therapeutic approaches," **O** evaluates "cognitive metrics such as attentional capacity, memory retention, and executive processing," and **S** encompasses "randomized controlled trials and clinical studies" as the principal research designs.

This comprehensive review exclusively examined full-text trials published in English that explored the influence of neurostimulation on various cognitive domains. Research articles published in other languages or those that did not assess the efficacy of tDCS in cognitive outcomes were omitted from the analysis

Sources Of Research

A comprehensive search was conducted across PubMed, Google Scholar, Embase, and Scopus databases to identify clinical trials and studies on treatments for PSCI between January 2017 and February 2024.

Search Strategy
The search strategy incorporated keywords such as "PSCI," "tDCS," "Cognition," "Stroke," and "non-invasive brain stimulation."

RESULTS

Literature Search And Characteristics Of The Included Studies
Our analysis revealed that anodal cortical neuromodulation has primarily been applied to cognitive rehabilitation. Initially, 143 studies were identified as potentially relevant following the database search. Following the removal of duplicate records, a full-text screening of articles was conducted, ultimately identifying eight studies that met the screening benchmarks.

Ultimately, eight studies were included in the review: three addressing overall cognition, two focusing on executive function, one examining attention, and one exploring memory.

Effect Of tDCS On Attention In PSCI
To evaluate the instantaneous effects of anodal cortical neuromodulation on attentional performance in individuals with cognitive deficits following a stroke, five randomized controlled trials (RCTs) were analyzed, comprising 170 patients who underwent tDCS and 80 assigned to control groups. Neurostimulation did not yield a significantly different effect on attentional performance when compared to sham treatment or absence of stimulation (11,12).

Effect Of tDCS On Executive Function In PSCI
To delve into the prompt effects of anodal cortical neuromodulation on executive function in individuals with cognitive deficits following a stroke. Analysis of eight RCTs and one review, including 166 tDCS-treated and 137 control patients, showed greater executive function improvement with tDCS than with sham or no intervention. Subgroup analysis indicated that dorsolateral prefrontal cortex (DLPFC) stimulation led to the most significant gains (SMD = 1.63, 95% CI = 0.27–2.98), while only one study targeted the temporal lobe (12–15).

Effect Of tDCs On Memory In PSCI
The instantaneous impact of tDCS on cognitive retention in individuals with cognitive dysfunction secondary to stroke was assessed across four randomized controlled trials (RCTs), involving 80 patients who received cortical neuromodulation and 65 in control groups. Findings from three RCTs indicated no notable variation in mnemonic enhancement between those who underwent cortical neuromodulation and those subjected to sham stimulation or no intervention. However, one RCT reported discernible improvements in memory performance following a tDCS regimen of four sessions per week over four weeks (12,16).

Effect of tDCS On Overall Cognition In PSCI
This study analysed eleven randomized controlled trials (RCTs) involving a cohort of 200 participants who underwent neurostimulation to enhance cognitive function. Findings revealed that individuals with stroke-related cognitive dysfunction who received cortical neuromodulation exhibited greater improvements in overall cognitive performance immediately post-treatment compared to those in the sham or non-intervention groups (13–15,17).

DISCUSSION

This review primarily sought to evaluate research exploring the application of tDCS in modulating cognitive domains among individuals recovering from stroke. Additionally, it aimed to critically appraise the existing evidence on the effectiveness of neurostimulation in augmenting cognitive functions in stroke survivors.

Growing interest within both clinical and academic domains has highlighted cortical neuromodulation as a promising intervention for neurological and cognitive impairments. Distinct from conventional electrical stimulation techniques, tDCS is a non-invasive neuromodulatory approach that regulates cortical activity through the application of a low-intensity, steady electrical current.

Liya Zhang et al. (2024) investigated neurostimulation, motor-cognitive intervention, and their combined effect on PSCI. The integrated approach showed superior efficacy in enhancing cognitive function, suggesting its safety and potential as a holistic intervention for PSCI patients (12). Yinan Ai et al. explored catechol-O-methyltransferase (COMT) and BDNF gene variants' influence on PSCI and their interaction with cortical neuromodulation. tDCS improved cognition, with COMT genotype affecting efficacy, while BDNF had no significant impact. Tailored tDCS interventions for PSCI based on genetic profiles show promise for personalized treatment approaches (18).

Zhao Yue et al. explored a new cortical neuromodulation model combined with cognitive training for stroke-induced unilateral neglect (UN). Single-site and multi-site cortical neuromodulation both significantly improved UN symptoms, encouraging further investigation into their distinct therapeutic potentials (19).

In 2022, Myoung-Hwan Ko et al. assessed remotely supervised cortical neuromodulation (RS-tDCS) with cognitive training in chronic stroke patients with cognitive impairment. Real RS-tDCS group showed significant K-MoCA score improvements versus sham, particularly in those with lower baseline K-MoCA or left hemisphere lesions. High adherence (98.4%) and safety indicate RS-tDCS as a viable home-based post-stroke cognitive rehabilitation approach (15).

Table 1: Overview: Transcranial Direct Current Stimulation (tDCS) treatment study characteristics.

Sr. No	First author	Study Type	Study Sample	Intervention	Outcome	Intervention Period & Intensity	Result	Analysis
1.	Liya Zhang, et al. (2024)	Randomized control trail.	90 patients with PSCI	tDCS and motor cognitive intervention.	MoCA Scale and the LOTCA	5 session per week for 4 weeks.	MoCA and LOTCA scores improved significantly in all groups post-treatment.	tDCS combined with motor-cognitive intervention is safe and enhances PSCI patients' cognitive function.
2.	Yinan Ai, et al. (2023)	Randomized control trail.	76 subjects with PSCI.	tDCS and COMT	MoCA and BDST	5 sessions per week for 2 weeks.	tDCS group demonstrated superior improvement in MoCA and BDST compared to sham.	Study suggests COMT Val158Met affects prefrontal tDCS efficacy in cognition.
3.	Yue Zhao, et al. (2023)	Randomized control trail.	30 stroke patients with UN.	Congnitive training with tDCS.	Deviation index and Behavioral Inattention Test.	5 session per week for 2 weeks.	Treatment groups exhibited significant score improvements across all tests compared to controls.	Single-site and multi-site tDCS both improve UN and cognitive function post-stroke.
4.	Myoung-Hwan Ko, et al. (2022)	A Randomized control trail.	26 subjects with chronic stroke with cognitive impairment.	tDCS and RS-tDCS	Boston Naming Test, Trail Making Test, K-MoCA	5 sessions per week for 4 weeks.	Real group showed significant K-MoCA improvement, contrasting with sham.	RS-tDCS benefits moderate cognitive decline patients.
5.	Minmin	C trail.	60 patie	iTBS and	LOTCA and	5 session per week	Cognitive	Combining iTBS

	Chu, et al. (2022)		nts with PSCI.	tDCS	MBI	for 6 weeks.	performance exhibited enhancement across all three groups of individuals with post-stroke neurocognitive impairment following six weeks of intervention.	Combining iTBS and tDCS with cognitive training enhances cognitive function and quality of life in PSCI patients compared to cognitive training alone.
6.	Zhengtao Wang, et al. (2022)	Pilot Randomized control study	24 patients with PSEI.	Anodal tDCS	TMT-A, TMT-B, and digital span test.	7 days for 4 weeks. Intensity- 2 mA	The experimental group showed superior clinical scale results compared to the control group, with notable differences in the following aspects.	Anodal tDCS improves executive function in PSEI patients, associated with increased theta power in the affected area.
7.	Knut K Kolskår, et al. (2021)	A Randomized control trail.	54 subjects with stroke.	Computerized cognitive training (CCT) combined with transcranial direct current stimulation (tDCS)	fMRI, MMSE	two stimulations per week for 4 weeks.	Collectively, these findings indicate substantial adaptive improvements in targeted cognitive exercises following training.	This study demonstrated enhanced proficiency across all trained tasks, though transcranial direct current stimulation (tDCS) provided no discernible supplementary advantage.
8.	Yuan-Wen Liu, et al. (2021)	A Randomized control trail.	50 subjects with executive function impairement.	tDCS with Cognitive training	WCST, SCWT, DST, MMSE, MoCA	5 sessions per week over a span of 4 weeks.	tDCS group significantly outperformed sham-tDCS group.	Combining tDCS with cognitive training significantly improved executive function.

PSCI= Post Stroke Cognitive Impairment, tDCS= Transcranial Direct Current Stimulation, MoCA= Montreal Cognitive Assessment, LOCTA= Loewenstein Occupational Therapy Cognitive Assessment, COMT= catechol-O-methyltransferase, BDST= Backward digit span test, UN= Unilateral neglect, iTBS= Intermittent Theta-Burst Stimulation, MBI= Modified Barthel Index, PSEI= Post Stroke Executive Impairment, TMT= Trail Making Test, WCST= Wisconsin Card Sorting Test, SCWT= Stroop Color Word Test, DST= Digit Symbol test, MMSE= Mini-Mental State Examination.

Zhengtao Wang et al. innovatively examined cortical neuromodulation impact on post-stroke executive impairment (PSEI) using EEG. Real tDCS improved executive function versus sham, supported by neuropsychological assessments. Enhanced theta power in the left central area correlated with improved performance, suggesting cortical neuromodulation modulates brain activity to benefit PSEI (20).

In their 2021 double-blind trial, Knut K Kolskår et al. studied chronic stroke patients combining computerized cognitive training (CCT) with left dorsolateral prefrontal cortex-targeted cortical neuromodulation While cognitive performance improved, no additional benefits were observed over CCT alone, and no clear association emerged between gains and fMRI-measured brain activation changes (21).

In their 2021 RCT, Yuan-Wen Liu et al. explored neurostimulation combined with cognitive training in stroke patients. Significant enhancements in executive function and daily living activities were evident in the real-stimulation group, underscoring the efficacy of this combined intervention (22).

CONCLUSION

Recent study evidence suggests that combining tDCS with cognitive training can help post-stroke patients improve their cognitive function. Although neurostimulation has demonstrated potential in enhancing higher-order cognitive processing, overall cognitive abilities, and visuospatial proficiency. Its effect on memory and concentration is unknown, however a few studies have suggested that it can improve both. Further high-quality research is required for the advancement of treatment techniques for post-stroke cognitive impairment, particularly in the memory and attention component.

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