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TRANSCRANIAL DIRECT CURRENT STIMULATION ASSOCIATED WITH PHYSIOTHERAPEUTIC REHABILITATION IN PATIENTS WITH NEUROLOGICAL SEQUELAE

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ABSTRACT

Introduction: Transcranial direct current stimulation (tDCS) is an innovative approachfor the treatment of neurological injuries. Objective: This study aimed to investigate the benefits of combining physiotherapeutic intervention with tDCSto improve functionality, balance, and pain levelsin patients with neurological sequelae. ***Methodology:*** Thisoriginal, experimental study includednine patients with neurological sequelae: two with adult ataxic cerebral palsy, four with stroke sequelae, two with spinal cord injury sequelae, and one with cerebral palsy. The participants underwent 8 to 20 tDCS sessions combined with functional training and physiotherapeutic rehabilitation to improve motor function, balance, motor coordination, and pain management. Pre- and post-intervention assessments included the Timed Up and Go test, the Fulg-Meyer scale for the upper limbs, and the visual analog scale (VAS) for pain. Statistical analysis was performed using Student's *t*-test, with a significance level of $p = 0.05$, using GraphPad Prism 8. ***Results:*** The results showedsignificant benefits, including improved upper limb function in patients with stroke sequelae, reduced pain in patients with spinal cord injury, improved balance in patients with Parkinson's disease, and enhanced motor coordination in patients with ataxic cerebral palsy. ***Conclusion:*** Our findings suggest that tDCS,when combined with physiotherapeutic intervention,is effective in improving function, balance, motor coordination, and reducing pain in patients with neurological sequelae.

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INTRODUCTION

Low-intensity electrical stimuli can elicit significant therapeutic responses in the brains of patients with neurological diseasesequelae[1]. Neuromodulation can be achieved through transcranial direct current stimulation (tDCS), transcranial alternating current stimulation (tACS), transcranial pulsed current stimulation (tPCS), and transcranial random noise stimulation (tRNS)[2]. Purely continuous stimulation (DCS mode) involves the application of a direct current signal that flows unidirectionally from positive to negative and vice versa. This current is prolonged (tDCS, ≤ 2 mA) to enhance cortical excitability and modulate brain activity[2]. This type of electrical stimulation has been used in the rehabilitation of various neurological conditions, including depression, epilepsy, Parkinson's disease, movement disorders, stroke sequelae, Alzheimer'sdisease and memory impairments, autism, choreas, and athetoses[3,4]. In the study by Alekseichuk et al. (2019)[1], the authors observed that transcranial electrical stimulation (TES) stimulates neural tissue in the brain, synchronizes neural networks, and induces neuromodulation. Therefore, when combined with neurofunctional rehabilitation, both transcranial magnetic stimulation (TMS) and TES exhibit notable neurophysiological effects. Transcranial direct current stimulation (tDCS) is a neuromodulation technique used to stimulate the brain. When combined with physiotherapeutic rehabilitation, it aims to enhance treatment outcomes and restore function in patients with neurological sequelae[5]. In this context, the objective of this study was to investigate the benefits of combining physiotherapeutic intervention with tDCSto improve functionality, balance, motor coordination, and pain sensitivity in patients with neurological sequelae.

METHODS

For this purpose, an original experimental study was conducted with nine patients with neurological sequelae from different conditions, including two with cerebellar ataxia–adult cerebral palsy, two with spinal cord injuries, four with stroke, and one with Parkinson's disease. In order to assess functional independence, coordination, and functionality in patients with stroke and cerebellar ataxia–adult cerebral palsy, the Fugl-Meyer Upper Limb Scale was used. For patients with spinal cord injury sequelae, the visual analog scale (VAS)for pain assessment was applied, while the Timed Up and Go(TUG) test was used to evaluate balance and gait speed in the patient with Parkinson's disease. Between8 and 20 sessions of tDCSwere performed, alongside physiotherapeutic functional training to improve the patients' functional neurological status. The TUGtest is a simple assessment used to evaluate balance, gait speed, and even the degree of fall risk in patients. During the test, the patientsareinstructed to stand up from a chair, walk 3 meters to an obstacle, return to the chair, and sit back down. The faster they complete the task, the better their performance[6]. TheFugl-Meyer Upper Limb Scale evaluates upper limb mobility and functionality and comprises five dimensions: motor control, range of motion, sensitivity, pain, and balance. Each item is scored on a three-level scale, with a total possible score of 100 points[7]. FortDCS,the tDCSmode was set to 1–2mA,with electrodes positioned parallel to the cranial bones at specific points based on the 10/20 electroencephalogram (EEG) system and the expected benefits for each patient. The stimulation lasted 20 minutes, as shown in Table 1.

Table 1. tDCSapplication coordinates and treatment protocols

Patient	Neurological Disease	tDCS Points	# Sessions	Combined Physiotherapeutic Intervention
Patient A	Cerebellar Ataxia (PC)	Czand Oz	20	Functional training for hand motor coordination
Patient B	Cerebellar Ataxia(PC)	Czand Oz	20	Functional training for hand motor coordination
Patient C	Hemisection of the cervical spinal cord at the C5-T1level	2 cm behind C3 and C4	8	Desensitization of the upper and lower limbs
Patient D	Laminectomy and radiculotomy at the C5-T1level	2 cm behind C3 and C4	20	Desensitization of the upper and lower limbs
Patient E	Stroke sequelae	C3 and C4	12	Functional motor coordination training with the upper limbs
Patient F	Stroke sequelae	C3 and C4	15	Functional motor coordination training with the upper limbs
Patient G	Stroke sequelae	C3 and C4	20	Functional motor coordination training with the upper limbs
Patient H	Stroke sequelae	C3 and C4	20	Functional motor coordination training with the upper limbs
Patient I	Parkinson's Disease	Oz andCz	8	Gait and body balance training

Table 2. Mean values of the Fugl-Meyerscale parameters for the patient with cerebellar ataxia before and after tDCS

Fugl-Meyer Scale Parameters	Initial Result	Final Result
I	*4*	*4*
II	*9*	*18*
III	*3*	*6*
IV	*3*	*6*
V	*1*	*1*
B– Wrist	*5*	*8*
C– Hand	*7*	*10*
D	*0*	*2*
H	*10*	*12*
J-Passivejointmovement	*24*	*24*
J-Joint pain	*24*	*24*

*p<0.05. Paired Student's t-test.

tDCSwas integrated into physiotherapeutic functional training, targeting specific aspects and parameters for improvement, which varied for each patient based on their therapeutic objectives[5,8]. The patients with neurological sequelae were assessed before and after the therapeutic intervention and tDCSsessions. For the statistical analysis, a paired Student's t-test was performed, considering a significance level of p =0.05, using GraphPad Prism 8software.

RESULTS

A total of nine patients with neurological sequelae from different pathologies were evaluated: two with cerebellar ataxia–adult cerebral palsy,two with spinal cord injuries, four with stroke, and one with Parkinson's disease. The application of tDCSin Patient A, a 50-year-old male with ataxic-type cerebral palsy, who receivedtDCSat pointsCzand Oz, resulted in significant improvement in functionality, as assessed by the Fugl-Meyerscale (see Table 2). The paired Student's t-test showed a significant difference (p = 0.0162). In Patient B, a 40-year-old female with neurological sequelae and ataxic-type cerebral palsy, who received tDCSat points Czand Oz, significant improvement in functionality was also observed, as assessed by the Fugl-Meyerscale (see Table 3), with a p-value of 0.0116. The assessment of pain levels in Patient C, who exhibited sequelae from cervical spinal cord hemisection at the C5-T1 level and received tDCSat points located2 cm behindC3 and C4, showed a significant decrease after the 8th tDCS session, as shown in Figure 1. In Patient D, who presented with sequelae from laminectomy and radiculotomy at the C5-T1level, a decrease in pain levels was also observed, as shown in Figure 1. The results for Patient E, who had stroke sequelae and received tDCSin the upper limb control regions (C3 and C4), showed an improvement in upper limb motor function after 12 sessions, with a p-value of 0.0102. Patient F, who exhibited stroke sequelae and upper limb motor incoordination, showed an improvement in upper limb motor coordination after 15tDCSsessions, with a p-value of 0.0123in the paired Student's t-test. Data from Patient G, who had stroke sequelae, showed a significant difference between the initial and final assessments after 20 sessions of tDCS, with a p-value of 0.0025. The evaluation of Patient H, who had stroke sequelae, did not show significant differences in mean Fugl-Meyer scale values, with a p-value of 0.718.

PatientI, who had Parkinson'sdisease and received 8 sessions of tDCS, showed an improvement in gait speed on the TUG test. At the beginning of the sessions, they took 18 seconds to cover the 3-meter distance, and by the end of the sessions, they took12 seconds.

DISCUSSION

The research data demonstrated a significant improvement in motor coordination and upper limb function in patients with cerebellar ataxia–adult cerebral palsy. These patients underwent combined treatment with tDCS and physiotherapeutic functional training for the upper limbs.

Table 3. Mean values of the Fugl-Meyerscale parameters for Patient Bwith ataxic cerebral palsy before and after tDCS

Fugl-Meyer Scale Parameters	Initial Result	Final Result
I	*4*	*4*
II	*10*	*19*
III	*4*	*8*
IV	*4*	*8*
V	*1*	*2*
B– Wrist	*6*	*10*
C– Hand	*6*	*12*
D	*1*	*2*
H	*11*	*12*
J–Passivejointmovement	*24*	*24*
J–Joint pain	*24*	*24*

**p*<0.05 – Paired Student's t-test.

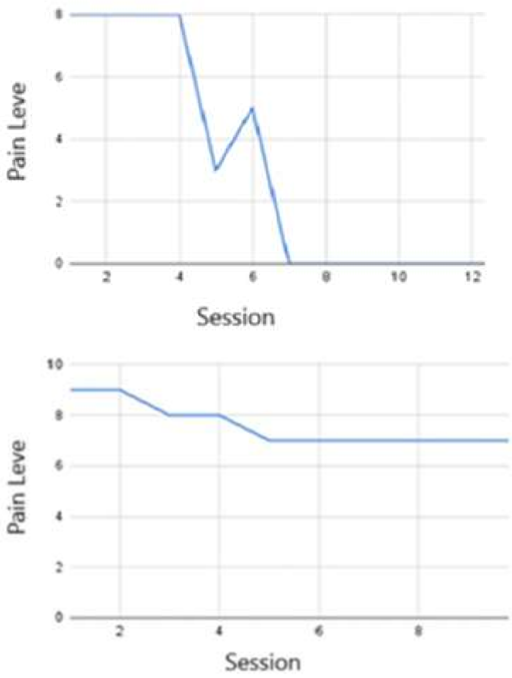

Figure 1. Mean VAS pain assessment scores in Patients C and D after the tDCSsessions

The neuromodulation protocol–usingan anode at point Oz and a cathode at Cz, with 20 sessions of 2 mA stimulation for 20 minutes per session, three times a week–significantly enhanced their motor control. It is important to note that these patients were born with brain alterations, and previous physiotherapeutic interventions had been exhausted in attempts to improve their chronic conditions.In this context, tDCS emerges as an innovative therapeutic strategy, offering new hope and meaningful improvements for these individuals. Similarly, in the study by Mendonça et al. (2021)[9],a patient with cerebellar ataxia for 10 years showed significant improvements in gait speed and balance after receiving physiotherapeutic rehabilitation combined with tDCS(2 mA, 20 minutes per session, with the anode at the inion) for two weeks, with daily sessions. The results from patients with spinal and radicular injuries, who experienced high levels of pain at the beginning of the treatment, showed a significant reduction in pain after 8 sessions. Patient C achieved complete pain relief, while Patient D showed a reduction in pain intensity after 8 tDCS sessions. The intervention lasted 20 minutes per session at 2 mA, with the anode positioned 2 cm behindC3 and the cathode 2 cm behind C4, across 8 to 20 sessions, three times a week. The adopted physiotherapeutic intervention involved desensitization of the hands and feet to stimulate ascending fibers that conduct nerve impulses to the somesthetic areas of the brain. According toLima *et al.* (2007)[10], neuropathic pain, caused by nervous system injuries, is chronic but can be alleviated through transcranial electrical stimulation, a non-invasive technique that neuromodulates brain connections and provides significant benefits for patients. The patients with stroke sequelae showed significant improvements in motor coordination, functionality, motor performance, and strength of the paralyzed upper limbs, as evidenced by the statistically significant difference in Fugl-Meyer scale scores before and after the intervention. Between12 and 20 sessions of tDCSwere conducted, each lasting 20 minutes, at 2 mA, with the anode positioned at C3 and the cathode at C4 (motor areas of the brain). Anode and cathode placement variedbased on the hemisphere of brain injury, with the anode positioned over the affected hemisphere and the cathode over the unaffected hemisphere, three times a week. During the application of TES, the physiotherapeutic intervention was combined with functional and therapeutic exercises to improve mobility, functionality, and strengthin the paralyzed upper limbs of the patients. In the study by lsner *et al.* (2020)[11], variability in tDCS outcomes was observed in stroke patients. However, significant variability in protocols was noted, with many studies not incorporating physiotherapeutic intervention. Gait speed and balance training combined with tDCSfor 20 minutes at 2 mA, with the anode at Oz and the cathode at Cz, three times a week, benefited the patients by reducing the time required to complete the3-meter Timed Up and Go (TUG) test.These findingsalign with the study by Fiório *et al.* (2021)[12],which reported improvements in gait speed and balance in a patient with Parkinson'sdisease after 20 sessions of gait training and tDCS (20 minutes per sessionat 2 mA, with the anode at Cz). Thus, the present study identified improvements in various therapeutic parameters in patients with neurological sequelae through the combined use of tDCS and physiotherapeutic intervention. These findings provide new therapeutic perspectives for these patients, contributing to enhanced functionality, balance, coordination, and pain reduction, ultimatelyimproving their quality of life.

CONCLUSION

This study demonstrated significant benefits, including improved upper limb functionality in patients with stroke sequelae,pain reduction in patients with spinal cord injuries,enhanced balance in patients with Parkinson'sdisease,and improved motor coordination in patients with ataxic cerebral palsy. It can be concluded that tDCS, when combined with physiotherapeutic intervention, was effective in improving aspects related to functionality, balance, motor coordination, and pain reduction in patients with neurological sequelae.

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REFERENCES

Alekseichuk I, Falchier AY, Linn G, et al. Electric field dynamics in the brain during multi-electrode transcranial electric stimulation. Nat Commun. 2019; 10:2573.doi:10.1038/s41467-019-10581-7.

Alves JM, Júnior PF, Monteiro AC, et al. Osefeitos do treinamentoneurológiconasfunçõesmotoras de pacientes com isquemia cerebral. Revista Neurociências. 2021;29:1–19. doi:10.34024/ rnc.2021.v29.11550.

Bretan O, Silva Júnior JE, Ribeiro OR, et al. Risk of falling among elderly persons living in the community: assessment by the Timed up and go test. Braz J Otorhinolaryngol. 2013;79(1):18–21.doi:10.5935/1808-8694.20130004.

Evancho A, Tyler WJ, McGregor K. A review of combined neuromodulation and physical therapy interventions for enhanced neurorehabilitation. Front Hum Neurosci. 2023; 21(17):1151218. doi: 10.3389/fnhum.2023.1151218.

Fiório FB, Canzi CL, Canzi CL, et al. Efeitos da estimulaçãoelétricatranscranianaassociadaaotreino de marchaemesteira no equilíbrio de indivíduos com doença de parkinson / Effects of transcranial electric stimulation associated with treadmill training on the balance of individual with parkinson's disease. *Brazilian Journal of Development.* 2021;7(12):113306–113317.doi:10.34117/bjdv7n12-219.

Fregni F, Freedman S, Pascual-Leone A. Recent advances in the treatment of chronic pain with non-invasive brain stimulation techniques. The Lancet Neurology.2017;6:188–191.doi:10.1016/S1474-4422(07)70032-7.

Guidetti M, Arlotti M, Bocci T, et al. Electric Fields Induced in the Brain by Transcranial Electric Stimulation: A Review of In Vivo Recordings. Biomedicines. 2022; 20; 10(10):2333.doi:10.3390/biomedicines10102333.

Huang Y, Liu AA, Lafon B, et al. Measurements and models of electric fields in the in vivo human brain during transcranial electric stimulation. eLife. 2017; 6:e18834.doi:10.7554/eLife.18834.

Lima MC, Ribeiro M, Batistella LR, et al. Estimulação cerebral para tratamento de dorneuropática. Psicologia: Teoria e Prática. 2007;9(2):142–149.

Lsner B, Kugler J, Pohl M, et al. Transcranial direct current stimulation (tDCS) for improving activities of daily living, and physical and cognitive functioning, in people after stroke. Cochrane Database of Systematic Reviews. 2020; 11:1–259.doi:10.1002/14651858.CD009645.pub4.

Mendonça MS, Goulardins JB, Souza CO, et al. Aplicaçãosimultânea de estimulaçãotranscranianaporcorrentecontínuacerebelaranódica para reabilitação do equilíbriona ataxia cerebelar: relato de caso. Rev Pesqui Fisioter. 2021;11(2):427–434. http://dx.doi.org/10.17267/2238-2704rpf.v11i2.3636

Živanović M, Bjekić J, Konstantinović U, et al. Effects of online parietal transcranial electric stimulation on associative memory: a direct comparison between tDCS, theta tACS, and theta-oscillatory tDCS. Sci Rep. 2022;12:14091.doi:10.1038/s41598-022-18376-5.

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