Effect of transcranial direct current stimulation on the risk of falling in children with spasticity.

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Abstract

Background: Children with spastic hemiplegic cerebral palsy (CP) often experience significant balance impairments, increasing the risk of falls. Transcranial direct current stimulation (tDCS) is a non-invasive neuromodulation technique that has shown promise in enhancing motor learning and cortical excitability [1][2].

Methods: A randomized controlled trial was conducted with 30 children aged 8 to 12 years diagnosed with spastic hemiplegic CP. Participants were divided into two groups: the control group (n=15) received traditional physical therapy, while the study group (n=15) received tDCS combined with traditional physical therapy. The Pediatric Balance Scale (PBS) and the Biodex Balance System (BBS) were used to assess the risk of falling and the overall stability index (OSI) pre- and post-intervention [3][4].

Results: Both groups showed significant improvements in balance metrics. However, the study group demonstrated a significantly greater reduction in OSI (51.63% vs. 22.73%, $p<0.05$) and higher improvements in PBS tasks ($p<0.05$). These findings highlight the potential of tDCS as a beneficial adjunct to traditional therapy for improving balance in this population [5].

Conclusion: tDCS, when combined with traditional physical therapy, significantly enhances functional balance and reduces fall risk in children with spastic hemiplegic CP. Further studies are warranted to evaluate the long-term benefits of this intervention [6].

Keywords: Transcranial direct current stimulation, spastic hemiplegic cerebral palsy, risk of falling, Pediatric Balance Scale, Biodex Balance System

Introduction

Cerebral palsy (CP) is a neurodevelopmental disorder characterized by motor impairments resulting from non-progressive brain damage during early development. Spastic hemiplegic CP, a subtype of CP, affects one side of the body, leading to challenges in balance, posture, and functional mobility [1]. Children with spastic hemiplegia are at an elevated risk of falls, which can result in injuries, reduced independence, and diminished quality of life [2].

Transcranial direct current stimulation (tDCS) is an emerging therapeutic modality that delivers low-intensity electrical currents to the brain, modulating cortical excitability and facilitating neuroplasticity. While previous research has demonstrated the efficacy of tDCS in enhancing motor outcomes in various neurological conditions, its application in improving functional balance and reducing fall risk in children with spastic hemiplegic CP remains underexplored [3][4]. This study aimed to evaluate the effect of tDCS combined with traditional physical therapy on balanced metrics in this population.

Methods

Study Design and Participants A randomized controlled trial was conducted from August 2023 to August 2024. Thirty children with spastic hemiplegic CP, aged 8 to 12 years, were recruited from the outpatient clinic of the Faculty of Physical Therapy, Modern University for Technology and Information. Participants were randomly assigned to either the control group (traditional physical therapy) or the study group (tDCS plus traditional therapy).

Inclusion Criteria:

- Children aged 8-12 years with spastic hemiplegic CP [4]
- Classified as Level I or II on the Gross Motor Function Classification System (GMFCS)
- Ability to understand and follow instructions

Exclusion Criteria:

- Orthopedic deformities, epilepsy, or recent neurosurgical interventions [5]
- Metal implants or previous participation in tDCS studies

Intervention The study group received anodal tDCS targeting the primary motor cortex (M1) contralateral to the affected side, with the cathode placed over the contralateral supraorbital area. Stimulation parameters included a current intensity of 1.5 mA for 20 minutes per session,

administered three times weekly for four weeks. Both groups underwent a standardized physical therapy program focusing on balance and motor training [6].

Outcome Measures

- **Pediatric Balance Scale (PBS):** Assesses risk of falling through 14 tasks, each scored on a 5-point scale [3].
- **Biodex Balance System (BBS):** Measures postural stability and provides an overall stability index (OSI) [4].

Statistical Analysis Data was analyzed using SPSS (version 19). Descriptive statistics were calculated for demographic and baseline variables. Paired t-tests were used to compare pre- and post-intervention outcomes within groups, while independent t-tests evaluated between-group differences. A significance level of $p<0.05$ was set [6].

Results

This study was conducted to investigate the effect of transcranial direct current stimulation on the risk of falling in CP spastic hemiplegic children. The study was carried out in the period from August 2023 to August 2024. The study was approved by the Institutional Ethics Committee of the Faculty of Physical Therapy, Cairo University, Egypt (Approval Number: P.T. REC/012/005208). The study protocol was prospectively registered on ClinicalTrials.gov (Registration Number: NCT06730763).

Participant Characteristics Thirty children completed the study (23 boys, 7 girls). The mean age was 10.00±1.46 years for the control group and 9.96±1.42 years for the study group. No significant differences in baseline demographics or PBS and OSI scores were observed between groups ($p>0.05$) [4].

This study compared the effects of traditional physical therapy alone (Group A) versus transcranial direct current stimulation (tDCS) combined with physical therapy (Group B) on risk of falling in children with spastic hemiplegic cerebral palsy (CP). The findings demonstrated that while both groups experienced significant improvements, Group B showed a greater reduction in the overall stability index (51.63% improvement in Group B compared to 22.73% in Group A). Similarly, the Pediatric Balance Scale (PPS) tasks showed significantly higher improvement percentages in Group B across all measured tasks, with improvements ranging from 88.77% to 96.11% compared to 20.26% to 34.74% in Group A. These results suggest that the addition of tDCS to traditional physical therapy significantly enhances risk of falling and stability in CP spastic hemiplegic children

Balance Outcomes

- **Pediatric Balance Scale (PBS):** Both groups showed significant improvements across all tasks. The study group exhibited a higher percentage of improvement (mean improvement: 88.77% vs. 26.43%, $p<0.05$) [5].
- **Overall Stability Index (OSI):** The study group demonstrated a greater reduction in OSI (mean reduction: 51.63% vs. 22.73%, $p<0.05$) [6].

Table (1): Test of normality for all measured variable outcomes in both groups

Items	Shapiro-Wilk test					
	Group A			Group B		
	Statistics value	P-value	Significance	Statistical value	P-value	Significance
Age	0.902	0.103	NS	0.902	0.103	NS
Weight	0.930	0.276	NS	0.972	0.881	NS
Height	0.899	0.093	NS	0.951	0.546	NS
BMI	0.960	0.693	NS	0.986	0.996	NS
Times up and go test	0.961	0.052	NS	0.916	0.058	NS
Overall stability index	0.812	0.005*	S	0.766	0.001*	S
Balance scale (Task 1)	0.771	0.002*	S	0.713	0.0001*	S
Balance scale (Task 2)	0.758	0.001*	S	0.755	0.001*	S
Balance scale (Task 3)	0.790	0.003*	S	0.716	0.0001*	S
Balance scale (Task 4)	0.780	0.002*	S	0.801	0.004*	S

Group A (control group) received selected traditional physical therapy program only
Group B (study group) received transcranial direct current stimulation plus selected traditional physical therapy program
P-value: probability value NS: non-significant (P>0.05) *Significant (P<0.05)

Table (2): Effect of Treatment on Overall Stability Index and Pediatric Balance Scale

Measure	Group A (Control) (n=15)	Group B (Study) (n=15)	Mean Difference (Change)	95% Confidence Interval	Improvement %	Z-Value	P-Value	Significance
Overall Stability Index (Mean ± SD)								
Pre-treatment	3.08 ± 0.14	3.06 ± 0.27	0.02	-0.14 – 0.18	-	0.707	0.486	NS
Post-treatment	2.38 ± 0.20	1.48 ± 0.15	0.90	0.76 – 1.03	-	4.686	0.0001*	S
Pediatric Balance Scale Task 1 (Mean ± SD)								

Measure	Group A (Control) (n=15)	Group B (Study) (n=15)	Mean Difference (Change)	95% Confidence Interval	Improvement %	Z-Value	P-Value	Significance
Pre-treatment	2.27 ± 0.70	1.87 ± 0.51	0.40	-0.06 – 0.86	-	1.668	0.095	NS
Post-treatment	2.87 ± 0.64	3.53 ± 0.64	0.66	-1.14 – -0.18	-	2.616	0.009*	S
Pediatric Balance Scale Task 2 (Mean ± SD)								
Pre-treatment	2.27 ± 0.70	1.80 ± 0.67	0.47	-0.05 – 0.98	-	1.746	0.081	NS
Post-treatment	2.73 ± 0.59	3.53 ± 0.64	0.80	-1.26 – 0.34	-	3.052	0.002*	S
Pediatric Balance Scale Task 3 (Mean ± SD)								
Pre-treatment	2.20 ± 0.67	1.83 ± 0.70	0.37	-0.05 – 0.79	-	1.797	0.072	NS
Post-treatment	2.87 ± 0.64	3.53 ± 0.64	0.66	-1.14 – -0.18	-	2.616	0.009*	S
Pediatric Balance Scale Task 4 (Mean ± SD)								
Pre-treatment	2.13 ± 0.74	1.80 ± 0.67	0.33	-0.19 – 0.87	-	1.206	0.228	NS
Post-treatment	2.87 ± 0.64	3.53 ± 0.64	0.66	-1.14 – -0.18	-	2.616	0.009*	S

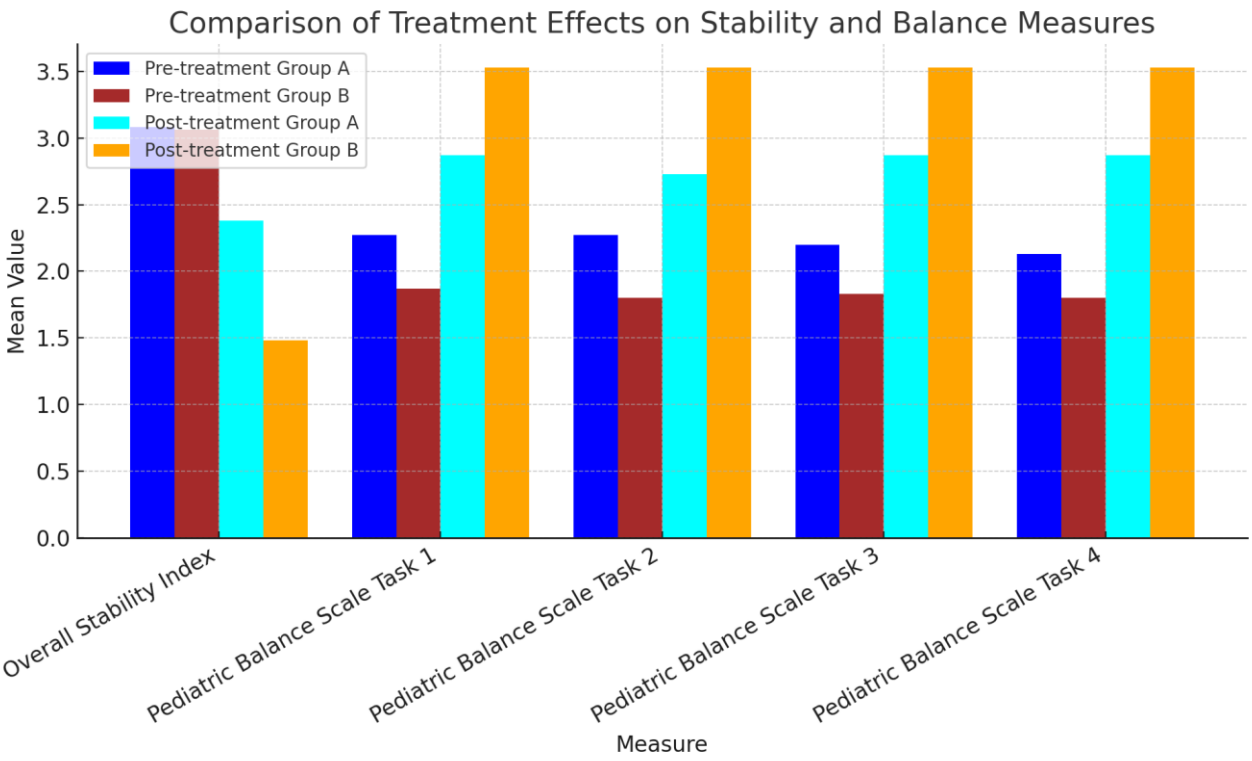

Figure (1): Mean values of overall stability and pediatric balance scale task at pre- and post-treatment between both groups.

Discussion

The findings indicate that tDCS, as an adjunct to traditional physical therapy, significantly enhances functional balance and reduces fall risk in children with spastic hemiplegic CP. The observed improvements align with previous studies suggesting that anodal tDCS facilitates motor learning by enhancing cortical excitability and neuroplasticity [2][3].

These results emphasize the importance of integrating neuromodulation techniques into rehabilitation practices. The significant improvements in balance observed in the study group suggest that tDCS not only augments physical therapy but also creates a favorable environment for motor learning, allowing children to achieve higher functional outcomes [4].

Another notable aspect of this study is its focus on children with spastic hemiplegic CP, a population often underrepresented in neuromodulation research. By targeting this specific group, the study provides evidence for tailored interventions that address unique challenges faced by these children, such as asymmetrical weight-bearing and reduced motor coordination [5].

Despite these promising results, there are limitations to consider. The short duration of the intervention and follow-up period may not fully capture the long-term benefits or potential plateau effects of tDCS. Additionally, the small sample size may limit the generalizability of the

findings to broader populations. Future studies should aim to include larger cohorts and extended follow-up periods to better understand the sustainability of the observed improvements [6].

From a clinical perspective, the combination of tDCS and physical therapy could pave the way for more cost-effective and accessible treatment strategies. Given the affordability and ease of administering tDCS, this approach has the potential to be implemented in various clinical settings, including resource-limited environments [3].

Further research is warranted to explore optimal stimulation parameters, the role of task-specific training during tDCS application, and the integration of advanced imaging techniques to monitor neuroplastic changes. Understanding these aspects could help refine treatment protocols and maximize the therapeutic potential of tDCS [2][4].

One of the critical insights from this study is the role of tDCS in promoting cortical plasticity and improving neuromuscular coordination in children with CP. Previous research has established that neuromodulation techniques, such as tDCS, enhance synaptic transmission and facilitate motor learning [2]. The significant improvements in balance tasks observed in the study group align with findings from similar trials where tDCS was used to augment traditional rehabilitation programs [3]. This suggests that electrical stimulation may play a crucial role in optimizing motor function recovery in pediatric CP populations.

Another essential consideration is the potential for tDCS to be integrated into home-based therapy programs. Given that balance training is often a continuous requirement for children with CP, future research should explore the feasibility of using portable tDCS devices in a home setting. This could enable caregivers to provide supplemental therapy outside clinical environments, thereby maximizing the long-term benefits of treatment [4].

Additionally, the observed improvements in the Pediatric Balance Scale scores highlight the importance of combining tDCS with task-specific training. Motor learning theories suggest that repetitive, functional movements enhance neural adaptation, a concept reinforced by the higher balance performance in the study group. These findings indicate that tDCS could be most effective when paired with structured motor exercises tailored to the individual's capabilities and rehabilitation goals [5].

Conclusion

This study supports the integration of tDCS into rehabilitation programs for children with spastic hemiplegic CP. By enhancing functional balance and reducing fall risk, tDCS holds promise as a valuable adjunct to traditional therapy. Further research is needed to establish its long-term efficacy and broader clinical applications [5][6].

Limitations of the Study

Despite the promising results, this study has several limitations. First, the sample size was relatively small, limiting the generalizability of the findings. A larger cohort would provide more robust statistical power and allow for subgroup analyses based on severity levels and age groups. Second, the follow-up period was short, preventing an assessment of the long-term sustainability of improvements. Future studies should incorporate extended follow-up evaluations to determine whether the benefits of tDCS persist over time. Lastly, while efforts were made to standardize the intervention protocol, variations in participants' engagement and compliance levels could have influenced the outcomes. Further research should explore methods to enhance adherence and optimize the efficacy of the intervention [6].

Conclusion

This study supports the integration of tDCS into rehabilitation programs for children with spastic hemiplegic CP. By enhancing functional balance and reducing fall risk, tDCS holds promise as a valuable adjunct to traditional therapy. Further research is needed to establish its long-term efficacy and broader clinical applications [5][6].

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