Research Article

Efficacy of Transcranial Direct Current Stimulation and Mirror Therapy for Rehabilitation of Spastic Quadriplegic Cerebral Palsy-A pilot Study

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Abstract

Background: Advancements in medical science, including Transcranial Direct Current Stimulation (tDCS) and Mirror Therapy (MT), are being utilized to treat Cerebral Palsy (CP), a non-progressive condition that impacts neuromuscular development.

Objective: To compare the effects of tDCS and MT for rehabilitation of spastic quadriplegic CP

Methods: A Double-Blind Randomized Clinical Trial(IRCT20231227060542N1) was conducted at the Department of Physical Therapy, Ghurki Hospital, Lahore, Pakistan. Thirty CP patients were randomly assigned by sealed envelopes to three equal groups: Group A (tDCS, MT), and routine Physical Therapy (RPT)), Group B (tDCS and RPT), and Group C (MT and RPT). Participants underwent tDCS with MT for 30 minutes per session, five times weekly for two weeks. RPT was also provided for 20 minutes per session, five times weekly for 10 weeks". Motor development (MD) was assessed using the Shoaib Sensorimotor Development Tool (SMDT), motor control (MC) by Fugl-Meyer Assessment (UE, LE), and Muscle Performance(MP) by isokinetic dynamometer at baseline, after two weeks, and after ten weeks of follow-up.

Results: Group A demonstrated a more significant impact on rehabilitation in terms of motor development, motor control, and muscle performance compared to Groups B and C, based on mean comparisons after two and ten weeks. There was a statistically significant difference between the groups in MD (P = 0.01), MC (P = 0.02), and MP (P = 0.04).

Conclusion: Transcranial direct current stimulation, either alone or in combination, has a more consistent impact on the rehabilitation of spastic quadriplegic cerebral palsy patients

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Introduction

Brain damage from any source, whether prenatal, intranatal, or postnatal, results in a compromised blood supply to the brain, which causes cerebral palsy (CP), a non-progressive condition that affects a patient's motor performance in terms of gross and fine motor, sensory, and social interaction with disturbed reflexes. The newborn is predisposed to disability as a result of these anatomical and physiological damages, which affect mobility and postural functions and cause social deprivation.[1] Children with cerebral palsy exhibit neuro-

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muscular abnormalities, including abnormal muscle tone, decreased strength, and motor control, leading to functional limitations in posture, movement, balance, and coordination.[2] Spastic quadriplegic cerebral palsy affects four limbs and the trunk, affecting the motor cortex, with common presentations in Pakistani children.[3]

Different countries have different rates of cerebral palsy (CP), although most report two cases for every 1000 live births.[4] According to research, it is 3 out of 1000 in India[5] and 1.22 out of 1000 live births in Khyber Pakhtunkhwa, Pakistan.[6] Multiple factors can affect the baby's development prenatal (low birth weight and placental anomalies), postnatal (meconium aspiration, vacuum extraction, and breech delivery), and perinatal (seizures, respiratory distress syndrome, hypoglycemia, meningitis, and sepsis).[7] Functional limitations in children with cerebral palsy (CP) include decreased strength, motor coordination issues, and spasticity. These impairments affect posture, balance, and motor coordination, leading to difficulties in walking and fine motor activities with impaired motor control.

Stimulus-specific training, mirror therapy, electrical stimulation, and tactile treatments are essential habilitation methods for cerebral palsy.[8] The degree of arousal in a three-dimensional plane may be greatly increased using the physio ball while performing exercises for trunk muscle activation and have an immediate effect. Because of the surface's instability, there are postural disruptions that increase muscular reflexes and help to maintain good posture.[9] Mirror neurons, a part of the premotor cortex and inferior parietal cortex become active when viewed through a mirror. Mirror therapy, where patients look at their upper or lower extremities in the mirror, may increase motor cortex activity.[10]

Technological advancements in medical sciences have led to the development of non-invasive brain stimulation techniques, such as transcranial direct current stimulation (TDCS), which can directly activate the central nervous system to improve motor performance and reorganize neuronal connections under the notion of top-to-bottom intervention.[11] Anodal tDCS, a technique involving two electrodes, has shown promising results in children with cerebral palsy (CP) and stroke by improving balance and gait parameters.[12] Mirror therapy is a method used to assist children with cerebral palsy. It involves using a mirror to improve the function of the upper and lower limbs, based on the theory of neuroplasticity. This technique indirectly stimulates the central nervous system through peripheral neuromuscular activity, aiming to enhance overall functional recovery through a bottom-to-top rehabilitation approach.[13] Reflex inhibitory patterns, goal-directed functional training, context-focused treatment, manual training, constraint-induced movement therapy, and home exercise regimens are among the most popular rehabilitation strategies that fall under the domain of routine physical therapy. Furthermore, reflex inhibitory patterns and goal-directed functional training were combined to achieve that aim.[14]

Neuroplasticity is a crucial concept in addressing the neuromuscular development of stroke and CP patients. A range of interventions, including mirror therapy, transcranial direct current stimulation, and routine physical therapy, have been demonstrated to be successful in addressing motor development in "holism" domains, highlighting the gap among existing literature. To improve the functional, structural, and emotional status of spastic quadriplegic cerebral palsy patients, researchers are investigating novel aspects of rehabilitation approaches. The objective of this study is to determine the efficacy of transcranial direct current stimulation and mirror therapy for the rehabilitation of spastic quadriplegic cerebral palsy. As a result, this vulnerable population of CP can be improved in the context of development, which directly uplifts their quality of life, makes them valuable members of our society, and improves the mental health status of their parents too.

Methods

From December 2023 to January 2024, Thirty children with spastic quadriplegic CP, aged 3 to 7 years from both genders,[15] were enrolled in a single-center, double-blind (patient and assessor) randomized clinical trial conducted at Ghurki Hospital, Lahore, Pakistan. The trial was registered in the Iranian Registry of Clinical Trials (IRCT20231227060542N1) and formally approved by the Ethical Committee of the University of Lahore (REC-UOL-185-12-2023). Written consent was obtained from all patients or their guardians. Patients who could walk independently or with assistance (Levels I, II, and III on the Gross Motor Function Classification System (GMFCS),[16] had a tone of less than or equal to 2 on the modified Ashworth scale, and could comprehend orders or use augmentative communication[17] were included. Children with ataxic and athetoid cerebral palsy, a history of neurosurgery or cancer, orthopedic deformities, seizure history, or metal implants in the skull were excluded. Ten children each were allocated to Group A (tDCS, MT, RPT), Group B (TDCS, RPT), or Group C (MT, RPT) using the sealed envelopes in a 1:1:1 ratio. The trial was conducted following the CONSORT guidelines (Figure I)

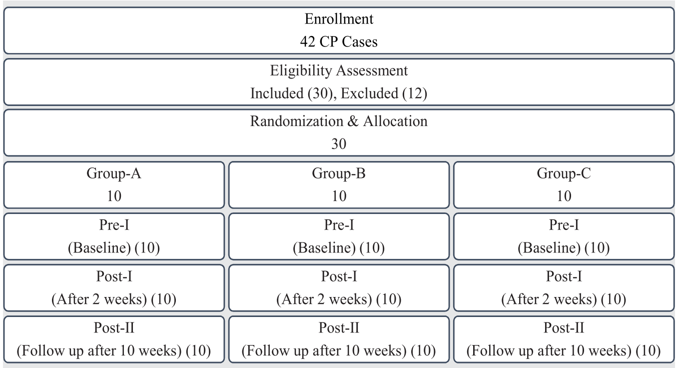

Figure 1: *Consort Diagram*

A 30-minute session of tDCS with 2 mA intensity was administered, with 15 minutes dedicated to the right-sided extremities and 15 minutes to the left-sided extremities. According to the International 10-20 System, the cathode electrode was placed on the left supraorbital region and the anode electrode on the right primary motor cortex (M1) for left-sided extremities, and vice versa for right-sided extremities. A wireless, rechargeable device (Segal Stim by Framed Company) was used, with 6-centimeter sponge electrodes moistened with physiological saline. During the session, the patient needed to maintain a comfortable sitting position.

Mirror therapy was applied for 30 minutes, with 15 minutes dedicated to each side of the extremities by concealing the extremities of one side behind a 35×35 centimeters mirror and mirroring the other side's extremities. The upper extremity mirror therapy program included pronation, supination, wrist flexion, finger flexion, and elbow flexion.[18] The lower extremity program included ball rolling, rocker-board, and pedaling.[19] Movements were repeated 20 times per set, with a total of 10 sets, and 2 minutes of rest between sets.

Routine Physical Therapy involves goal-directed functional training and reflex inhibitory patterns for rehabilitation. This approach targets muscle performance and control, adjusting activities based on the patient's capabilities. Reflex inhibitory patterns regulate body reflex actions, including protection, feeding, initiating movement, and maintaining balance. In children with CP, these reflexes can be diminished or exaggerated. The therapy is conducted five days a week for 20 minutes each session, from the start of treatment to follow-up.

Patients with cerebral palsy were given ten sessions of transcranial Direct Current Stimulation and Mirror Therapy, each session lasting 30 minutes in total, with 15 minutes dedicated to each side (left and right). An autonomous assessor evaluated the patients' motor development using the Shoaib-Sensorimotor Development Tool (SMDT) with a reliability of 0.977, motor control using the Fugl-Meyer Assessment for Upper Extremities (FMA-UE) and Lower Extremities (FMA-LE) questionnaire with a reliability of 0.86, 0.935, and muscle performance (elbow flexion) using an isokinetic dynamometer.[20,21] Assessments were conducted at baseline, after 10 sessions (two weeks), and ten weeks post-treatment as a follow-up.

Results

SPSS version 26 was used to analyze the data. The normality of the data was assessed using Shapiro-Wilk tests. Categorical and continuous variables were presented as percentages and mean values, respectively. Repeated measures ANOVA was used to compare the means among groups and the Bonferroni test was performed for group-wise comparisons.

Table 1: *Demographics*

Variables	Group A (10)	Group B (10)	Group C (10)	Total (30)
	n (%)	**n (%)**	**n (%)**	**n (%)**
Age				
Mean ± SD	4.5 ± 0.64	4.71±1.01	4.41±0.92	4.54±0.86
Gender				
Male	4 (13)	5 (17)	7 (23)	16 (53)
Female	6 (20)	5 (17)	3 (10)	14 (47)
Tone on MAS				
Grade 1	2 (6)	1 (3)	2 (6)	4 (15)
Grade 1+	4 (14)	4 (14)	3 (9)	11 (37)
Grade 2	4 (14)	5 (17)	5 (17)	14 (48)
GMFCS Level				
Level I	3 (10)	1 (3)	2 (6)	6 (19)
Level II	3 (10)	2 (6)	2 (6)	7 (22)
Level III	4 (14)	7 (24)	6 (21)	17 (59)

Out of 30 CP patients, the mean age and standard deviation for Group A were 4.5 ± 0.641 years, for Group B were 4.2 ± 0.387 years, and for Group C were 4.4 ± 0.920 years. There were 53% males and 47% females. (Table -1)

Between-group comparison of Motor development, motor control, and muscle performance The results of repeated measures ANOVA showed significant diffe-

Table 2: *Between-group comparison of MD, MC, and MP*

Variables	Assessment Intervals	Group-A (TDCS+MT+RPT)	Group-B (TDCS+RPT)	Group-C (MT+RPT)	P value
		Mean±SD	Mean±SD	Mean±SD	
Motor Development	Baseline	24.55±3.54	25.55±3.43	25.35±3.51	0.06
	After 2 weeks	26.05±3.83	25.75±3.54	26.35±3.83	0.02*
	After 10 weeks	27.50±4.00	28.00±4.04	26.50±4.00	0.01*
Motor Control	Baseline	33.35±4.04	33.95±5.83	34.05±4.04	0.08
	After 2 weeks	43.09±3.04	44.45±3.83	41.65±3.04	0.06
	After 10 weeks	55.65±2.04	50.05±2.50	51.25±2.75	0.02*
Muscle Performance	Baseline	6.25±5.43	6.10±4.41	6.41±5.32	0.06
	After 2 weeks	8.50±3.04	8.60±4.04	7.90±4.05	0.05
	After 10 weeks	12.54±2.83	11.76±2.04	11.54±2.83	0.04*

"" indicates statistically significant*

Table 3: *Group-wise Comparison of MD, MC, and MP*

Variables	Timeline	(I) Rx-Groups	(J) Rx-Groups	Mean Difference (I-J)	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Motor Development	Baseline	A	B	10.9	0.27	-4.97	26.77
		B	C	-9.5	0.41	-25.37	6.37
		C	A	-1.4	1.00	-17.27	14.47
	After 2 weeks	A	B	11.5	0.04*	-2.81	25.81
		B	C	-8.8	0.39	-23.11	5.51
		C	A	-2.7	1.00	-17.01	11.61
	After 10 weeks	A	B	11.3	0.02*	-3.76	26.36
		B	C	-0.9	0.03*	-24.06	6.06
		C	A	4.8	0.04*	-17.36	12.76
Motor Control	Baseline	A	B	17.5	0.30	-8.83	43.83
		B	C	-12.8	0.68	-39.13	13.53
		C	A	-4.7	1.00	-31.03	21.63
	After 2 weeks	A	B	13.5	0.07	-8.72	43.72
		B	C	-13	0.65	-39.22	13.22
		C	A	-4.5	1.00	-30.72	21.72
	After 10 weeks	A	B	4.1	0.03*	-3.17	11.37
		B	C	5.3	0.01*	-8.67	5.87
		C	A	-2.7	0.04*	-9.97	4.57
Muscle Performance	Baseline	A	B	3.5	0.64	-3.52	10.52
		B	C	-1.3	1.00	-8.32	5.72
		C	A	-2.2	1.00	-9.22	4.82
	After 2 weeks	A	B	3.5	0.64	-3.52	10.52
		B	C	-1.3	1.00	-8.32	5.72
		C	A	-2.2	1.00	-9.22	4.82
	After 10 weeks	A	B	3.5	0.01*	-3.52	10.52
		B	C	-1.3	0.02*	-8.32	5.72
		C	A	-2.2	0.04*	-9.22	4.82

"" indicates statistically significant*

rences in mean motor development scores between groups A, B, and C after the 2^{nd} and 10^{th} weeks. At baseline, there were no significant differences in motor development (MD), motor control (MC), and muscle performance (MP) scores. However, after 2 weeks, a significant change in mean MD was noted (P=0.02). Moreover, after ten weeks, there were statistically significant differences in mean scores for MD, MC, and MP, with P-values of 0.01, 0.02, and 0.04, respectively. (Table-2)

Group-wise Comparison of MD, MC, and MP:

Group-wise comparison of motor development, motor control, and muscle performance indicates that there was no significant change at baseline between the three groups. After 10 weeks, there were statistically significant differences in MD between groups A-B, B-C, and C-A, with P-values of 0.02, 0.03, and 0.04, respectively. For MC, significant differences were noted between groups A-B, B-C, and C-A, with P-values of 0.03, 0.01, and 0.04, respectively. Regarding MP of elbow flexion, significant differences were also noted between groups A-B, B-C, and C-A, with P-values of 0.01, 0.02, and 0.04, respectively. (Table-3)

Discussion

The results of this study provide important new information on the potential of tDCS and mirror therapy as innovative, non-invasive therapeutic modalities. By comparing top-down and bottom-up stimulation of the neuromuscular system in individuals with various brain activity deficits, the study showed significant improvements in neuromuscular development, motor control, and muscle performance across all groups. Additionally, when these therapies were administered in combination, the results were more profound compared to when each therapy was given alone.

While CP symptoms have been effectively managed using conventional rehabilitation techniques, this review highlights the noteworthy safety and tolerability of tDCS. Consistent with previous research, it indicates that tDCS is a well-tolerated, non-invasive brain stimulation method. This implies that tDCS can be used without causing significant pain or adverse effects, making it a desirable option for individuals with CP, including children.[22]

The beneficial effects of tDCS on motor development were consistent with previous research suggesting that tDCS can improve motor learning and recovery in various neurological conditions. These effects are believed to result from tDCS-induced alterations in cortical excitability and plasticity in the motor cortex, directly impacting CP patients' involvement in their daily tasks and activities.[15]

tDCS had a positive impact on reducing spasticity in CP patients, which enhances their motor development, control, and muscle performance. This improvement directly influences their daily tasks, socialization, sensory development, and gait, leading to a better quality of life. The favorable effects of tDCS on various metrics highlight its potential to improve functional outcomes. One of the review's main conclusions is the understanding that the beneficial effects of tDCS can complement existing rehabilitation programs, rather than replace traditional physical therapy.[23]

For post-stroke patients, using tDCS in conjunction with mirror therapy (MT) offers a promising neurorehabilitation strategy for improving upper limb motor performance, movement effectiveness, and daily function.[24] tDCS appears to enhance daily function and hand movement control when applied sequentially before MT, suggesting it could be an effective technique in future clinical use.[25] The current study found similar results, showing that combining tDCS and MT for motor development leads to better muscle performance and control.

Regarding the weaknesses of this study, the practicality of treatment time posed a significant challenge, as CP children often had behavioral issues, tantrums, and hospital phobia, making adherence to the treatment sessions difficult. Additionally, while routine physical therapy exercises were provided to parents for follow-up, the quality of care given by parents is uncertain and raises concerns.

The limited number of studies on tDCS and mirror therapy in cerebral palsy (CP) patients necessitates further investigation to validate their effects in larger populations and to understand long-term impacts and best practices. Pediatric rehabilitation using these techniques has shown safety and improvements in motor development, control, muscular function, gait, tone, and balance. However, additional clinical studies are needed to standardize processes and confirm long-term benefits.

Conclusion

Transcranial direct current stimulation, either alone or in combination, has a more consistent impact on the rehabilitation of spastic quadriplegic cerebral palsy patients in the context of motor development, motor control, and muscle performance.

Ethical Approval: The Research Ethical Committee, the University of Lahore approved the study vide letter Ref No: REC-UOL-185-12-2023.

Conflict of Interest: The authors declare no conflict of interest.

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Authors' Contribution:

SW: Conception & design, acquisition of collection, drafting of article, critical revision for important intellectual content, final approval

AA: Critical revision for important intellectual content, final approval

JBG: Analysis & interpretation of data

AH: Analysis & interpretation of data

MT: Final approval

AN: Acquisition of data

References

1. Rani M, Waqas S, Asim HM, Tariq M, Javaid A. Effectiveness of Vestibular Stimulation on Balance Using Swing Therapy in Children with Hypotonic Cerebral Palsy. Annals of KEMU. 2022;28(1).
2. Afzal N, Waqas S, Tariq M, Javaid A, Asim HM. Translation and Validation Scale for Assessment and Rating of Ataxia in Urdu Language for Cerebral Palsy Patients. PJMHS. 2022;16(09):58-.
3. Palsi PÇS. Cerebral palsy in Pakistani children: A hospital based survey. Cukurova Med J. 2014;39(4):705-11.
4. Pashmdarfard M, Amini M, Mehraban AH. Participation of Iranian cerebral palsy children in life areas: a systematic review article. Iran J Child Neurol. 2017; 11(1): 1.
5. Salazar Fajardo JC, Kim R, Gao C, Hong J, Yang J, Wang D, et al. The effects of tDCS with NDT on the improvement of motor development in cerebral palsy. J Mot Behav. 2022;54(4):480-9.
6. Ahmad A, Akhtar N, Ali H. Prevalence of cerebral palsy in children of district Swabi, Khyber Pakhtunkhwa-Pakistan. KMUJ. 2017;9(2).82-91
7. McIntyre S, Taitz D, Keogh J, Goldsmith S, Badawi N, Blair E. A systematic review of risk factors for cerebral palsy in children born at term in developed countries. Dev Med Child Neuro. 2013;55(6):499-508.
8. Auld ML, Russo R, Moseley GL, Johnston LM. Determination of interventions for upper extremity tactile impairment in children with cerebral palsy: a systematic review. Dev Med Child Neurol 2014;56(9):815-32.
9. Lucas BR, Elliott EJ, Coggan S, Pinto RZ, Jirikowic T, McCoy SW, et al. Interventions to improve gross motor performance in children with neurodevelopmental disorders: a meta-analysis. BMC pediatr. 2016;16:1-16.
10. Park E-j, Baek S-h, Park S. Systematic review of the effects of mirror therapy in children with cerebral palsy. J Phys Ther Sci. 2016;28(11):3227-31.
11. Saleem GT, Crasta JE, Slomine BS, Cantarero GL, Suskauer SJ. Transcranial direct current stimulation in pediatric motor disorders: a systematic review and meta-analysis. Arch Phys M. 2019;100(4):724-38.
12. Thair H, Holloway AL, Newport R, Smith AD. Transcranial direct current stimulation (tDCS): a beginner's guide for design and implementation. Front Neurol. 2017;11(1):641.
13. Araneda R, Herman E, Delcour L, Klöcker A, Saussez G, Paradis J, et al. Mirror movements after bimanual intensive therapy in children with unilateral cerebral palsy: A randomized controlled trial. Dev Med Child Neurol. 2022;64(11):1383-91.
14. Novak I, Mcintyre S, Morgan C, Campbell L, Dark L, Morton N, et al. A systematic review of interventions for children with cerebral palsy: state of the evidence. Dev Med Child Neurol. 2013;55(10):885-910.
15. Salazar Fajardo JC, Kim R, Gao C, Hong J, Yang J, Wang D, et al. The effects of tDCS with NDT on the improvement of motor development in cerebral palsy. J Mot Behav. 2022;54(4):480-9.
16. Radwan A, Eltalawy HA, Abdelziem FH, Macaluso R, O'Brien MK, Jayaraman A. Effect of Transcranial Direct Current Stimulation versus Virtual Reality on Gait for Children with Bilateral Spastic Cerebral Palsy: A Randomized Clinical Trial. Child. 2023;10(2):222.
17. Kara OK, Yardimci BN, Sahin S, Orhan C, Livanelioglu A, Soylu AR. Combined effects of mirror therapy and exercises on the upper extremities in children with unilateral cerebral palsy: a randomized controlled trial. Dev neurorehabili. 2020;23(4):253-64.
18. Cho H-S, Cha H-g. Effect of mirror therapy with tDCS on functional recovery of the upper extremity of stroke patients. J Phy Ther Sci. 2015;27(4):1045-7.
19. Arya KN, Pandian S, Kumar V. Effect of activity-based mirror therapy on lower limb motor-recovery and gait in stroke: A randomised controlled trial. Neuropsychol Rehabil. 2019;29(8):1193-210.

20. Hernandez ED, Galeano CP, Barbosa NE, Forero SM, Nordin Å, Sunnerhagen KS, et al. Intra-and inter-rater reliability of Fugl-Meyer assessment of upper extremity in stroke. J Rehabil Med. 2019;51(9):652-9.
21. Hernández ED, Forero SM, Galeano CP, Barbosa NE, Sunnerhagen KS, Murphy MA. Intra-and inter-rater reliability of Fugl-Meyer Assessment of Lower Extremity early after stroke. Braz J Phys. 2021;25(6):709-18.
22. Begemann MJ, Brand BA, Ćurčić-Blake B, Aleman A, Sommer IE. Efficacy of non-invasive brain stimulation on cognitive functioning in brain disorders: a meta-analysis. Psychol Med. 2020;50(15):2465-86.
23. Elnaggar RK, Mahmoud WS, Alsubaie SF, Abd El-Nabie WA. Effectiveness of a multi-modal exercise program incorporating plyometric and balance training in children with hemiplegic cerebral palsy: a three-armed randomized clinical trial. Phy Occup ther Pedi. 2022;42(2):113-29.
24. Vlotinou P, Tsiptsios D, Karatzetzou S, Kalogirou G, Stefas E, Aggelousis N, et al. Transcranial Direct Current Stimulation in Conjunction with Mirror Therapy for Upper Extremity Rehabilitation in Chronic Stroke Patients. Maedica. 2022;17(1):169.
25. Liao W-w, Chiang W-c, Lin K-c, Wu C-y, Liu C-t, Hsieh Y-w, et al. Timing-dependent effects of transcranial direct current stimulation with mirror therapy on daily function and motor control in chronic stroke: a randomized controlled pilot study. J Neuroeng Rehabil. 2020; 17(1):1-11.