RESEARCH PAPER

Influence of Transcranial Direct Current Stimulation on Hand Grip Strength and Quality of Life in Patients with Stroke

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ABSTRACT

Background: Upper-limb impairment after stroke may restrict hand function and quality of life. Transcranial direct current stimulation (tDCS) is a non-invasive method that might improve rehabilitation outcomes. However, its additional benefit when combined with functional task training remains unclear.

Objective: To examine the efficacy of tDCS in combination with functional task training on hand grip strength and quality of life in patients with stroke.

Methods: Sixty patients of both sexes with right hemispheric ischemic stroke and left-sided hemiparesis, ranging in age from 45 to 60 years, participated in this study. They were randomly allocated into two equal groups; group (A) and group (B). Hand grip strength and the Stroke-Specific Quality of Life Scale were utilized to evaluate all patients. Functional task training for upper-limb rehabilitation in addition to tDCS was administered to the study group (A). The same functional task training was applied to the control group (B). For four weeks, treatment was administered three sessions each week. For group (A), tDCS was applied at an intensity of 2 mA for thirty minutes. Both variables were evaluated before and after intervention.

Results: There were significant improvements in quality of life and hand grip strength in group (A) post treatment ($P<0.001$). In contrast, group (B) showed no statistically significant improvements in these outcomes ($P>0.05$). After treatment, group (A) demonstrated significantly better outcomes than group (B) in both assessed variables ($P<0.001$).

Conclusion: Adding tDCS to functional task training has a beneficial impact on improving hand grip strength and quality of life in patients with stroke.

Keywords: Stroke, Transcranial direct current stimulation, Functional task training, Hand grip strength, Quality of life.

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INTRODUCTION

Stroke is an acute neurological condition caused by cerebral ischemia or hemorrhage, resulting in injury to brain tissue. Its manifestations vary according to the location and severity of the lesion and may include sudden unilateral weakness or numbness, facial weakness, speech disturbance, visual symptoms, and impaired balance or coordination **[1]**.

Stroke represents a significant obstacle in global health. In 2021, approximately 11.9 million new strokes occurred worldwide, and 93.8 million people were living with stroke. Stroke was the 3rd prominent cause of mortality and disability combined globally. Its burden affects patients, caregivers, families, and healthcare systems. Hypertension, cigarette smoking, raised low-density lipoprotein cholesterol, raised fasting blood glucose, renal failure, obesity, lack of physical exercise, poor nutrition, air pollution, along with harmful alcohol consumption are all significant modifiable risk factors **[2]**.

Upper-extremity impairment is a frequent disabling consequence of stroke and may cause limitations of activities of daily living (ADL) and decrease quality of life (QOL). Stroke rehabilitation therefore emphasizes intensive, repetitive, and task-specific practice to improve functional performance and promote usage of the affected extremity during meaningful activities **[3]**.

Patients suffering from motor function impairment due to a stroke have limited treatment options. Functional motor learning (ML) approaches form the basis of most of such treatments. Although post-stroke motor rehabilitation commonly relies on motor-learning-based strategies, the available interventions do not always achieve optimal functional recovery. This has encouraged the investigation of adjunctive neuromodulation approaches that may enhance the effects of rehabilitation and support motor improvement after stroke **[4]**.

Neuromodulation techniques have gained increasing attention as adjuncts to conventional rehabilitation. The

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non-invasive transcranial direct current stimulation (tDCS) method modifies cortical excitability by applying a weak direct current via electrodes placed on the scalp. At commonly used stimulation parameters, tDCS is generally considered safe and feasible, with adverse effects usually mild and transient **[5]**.

Further research on the function of transcranial direct current stimulation (tDCS) in the rehabilitation of the upper limbs following a stroke is continuing. A recent meta-analysis of randomized controlled trials indicated that upper-limb motor function as well as ADL were moderately improved; however, the extent to which the improvement was observed varied among patient characteristics along with stimulation parameters **[6]**. Combining tDCS with functional task training may therefore provide a useful adjunctive approach by modulating cortical excitability while patients repeatedly practice purposeful hand activities **[7]**. Therefore, the purpose of this study was to examine the impact of tDCS in conjunction with task training in terms of the hand grip and QOL of stroke patients.

SUBJECTS AND METHODS

Study design

A case-control single-blinded, parallel-group pre- and post-study was carried out to investigate the effect of transcranial direct current stimulation combined with functional task training on hand grip strength and quality of life in patients with right hemispheric stroke. It took place at the Faculty of Physical Therapy's outpatient clinics, Cairo University. Data were gathered before and after intervention from November 2022 till October 2025 after approval of the Faculty of Physical Therapy Ethics Committee (No: P.T.REC/012/004189).

Participants

Sixty adult patients from both sexes with right hemispheric ischemic stroke and left-sided hemiparesis were included. Their ages varied from forty-five to sixty, and the duration of their illnesses varied from six months to eighteen months. The degree of upper-limb spasticity was mild, as determined by the Modified Ashworth Scale (MAS). Patients were chosen from the outpatient clinic of El Kasr El Ainy Hospital and Faculty of Physical Therapy, Cairo University. Exclusion criteria involved severe visual, cognitive, or language impairments, previous brain surgery, metallic implants in the brain, history of epilepsy or seizures, skin irritation at the stimulation site, inability to tolerate tDCS therapy, significant pre-stroke disability, major neurological or psychiatric disorders, severe pain, advanced systemic diseases, terminal illness, or current use of neuropsychotropic medications.

Sample size

This study comprised 60 patients, distributed into two equivalent groups.

Randomization

Patients were distributed randomly using the closed-envelope method into two equivalent groups. Group (A) was the study group and was given functional task training for upper-limb rehabilitation in addition to tDCS, whereas Group (B) was the control group and was given the same functional task training program without tDCS.

Assessment

1. Weight and height scale

All patients' heights and weights were measured using a weight and height scale. Prior to the study's execution, the participants' weight and height had been measured in order to calculate their body mass index (BMI).

2. Modified Ashworth Scale (MAS)

The Modified Ashworth Scale (MAS) was utilized to evaluate upper-limb spasticity and to identify patients with mild spasticity grades 1 or 1+. The scale was applied during the initial clinical assessment before enrolment in the study. Its reliability for the clinical assessment of muscle tone has been supported in the literature **[8]**.

3. Hand Grip Dynamometer

To measure grip strength, we used a handheld dynamometer (Grip X), a valid and reliable tool for assessing isometric forearm and hand muscular strength. The measurement was carried out in accordance with established protocols. The patient was seated with the back supported, the shoulder adducted and neutrally rotated, the elbow flexed at 90 degrees, the forearm in a neutral position, and the wrist placed between 0 and 15 degrees of ulnar deviation. The arm was not supported during the measurement. The dynamometer was adjusted to fit the patient's hand size and set to zero before each trial. The patient was instructed to squeeze the dynamometer maximally and then relax, without holding their breath. Three trials were performed for the affected hand, with brief rest periods between trials. The final score was calculated using the highest value of the three measurements, expressed in kilograms.

4. Stroke Specific Quality of Life scale (SS-QOL)

A patient-centered outcome measure called the Stroke Specific Quality of Life Scale (SS-QOL) is used for assessing the health-related QOL for patients with stroke. There are a total of 49 items that are divided across 12 categories, such as energy, family roles, mobility, self-care, function of the upper extremities, mood, as well as social involvement. The SS-QOL is a valid and reliable tool for evaluating QOL from the patient's perspective **[9]**. The SS-QOL scale is designed to be completed in around 15 minutes. Better functioning is indicated by higher scores. A total SS-QOL score and scores for individual domains are both produced by the SS-QOL. Both the domain scores and the summary score are calculated by taking the unweighted mean of the items that make up each domain **[10]**.

Interventions

1. Electrical stimulation device for transcranial direct current stimulation (tDCS)

The electrical stimulation device used to deliver transcranial direct current was the brain driver tDCS V2 Electrical stimulation device, which delivered a constant direct current at an intensity of 2 mA for 30 minutes.

All patients in both groups received the prescribed medication and participated in a rehabilitation program for upper limb recovery. The treatment protocol was conducted for four weeks, three sessions per week. In group A (study group), patients in this group received functional task training in addition to tDCS, which was applied according to the previously described protocol while in group B (control group), were given functional task training only without tDCS.

The tDCS equipment consisted of conductive rubber electrodes enclosed in perforated sponge pockets saturated with saline solution, cables connecting the electrodes to the tDCS device, elastic straps to stabilize the electrodes, sponges soaked in saline solution, and a measuring tape to locate the motor cortex area (M1) according to the International 10–20 system. The anode electrode was positioned over the ipsilesional primary motor cortex (M1), whereas the cathode electrode was placed over the contralateral supraorbital area. Stimulation was delivered with gradual ramp-up and ramp-down over 30 seconds. Before tDCS application, the skin was inspected for any pre-existing irritation. To increase conductance and reduce skin impedance, the hair was moved away from the stimulation site, and the skin surface was cleaned to remove any lotion, dirt, or oils, then dried well **[11].**

2. **Functional task training for upper limb**

During a physical therapy session, the patient will mostly focus on improving their trunk balance, sensorimotor skills, standing balance, walking, and retraining their muscles and cardiovascular system to perform at a higher effort. Occupational therapy sessions often focus on sensorimotor exercises to restore movement, balancing workouts (both sitting and standing), prehension exercises as well as mirror therapy. Functional task training for upper-limb rehabilitation included strengthening exercises for weak upper limb muscles mainly (shoulder flexors, elbow extensors and wrist extensors), stretching exercises for the affected upper limb muscles, weight shift exercises, balance training & trunk control exercises, neurodevelopmental (NDT) treatment activities to inhibit abnormal muscle tone and abnormal postural reflexes & to encourage the development of more normal postural control patterns, weight bearing activities, and unilateral weight bearing on full-extended arm and hand. Through various exercises performed on a ball, roll, and balance board from various positions, including supine, prone, sitting, along with standing, facilitation techniques aimed at enhancing righting and equilibrium reaction were employed to enhance postural mechanism. Teaching of protective reactions (saving reaction) was conducted to prevent subject from falling when balance is disturbed severely. As a form of proprioceptive training, approximation was performed slowly, regularly, and rhythmically on the upper and lower extremities, as well as the trunk, to help in spasticity control as well as joint mechanoreceptors stimulation. Strengthening exercises to the back and abdominal muscles were used to prevent spinal deformities and improve the trunk control. Stretching exercises were used to maintain the length and elastic recoil of all muscle which will be liable to be tight as pectoralis major, biceps brachii, wrist flexor and the shoulder internal rotators, elbow and wrist flexors, pronator and ulnar deviations of the upper limb **[3, 12]**.

Selected Hand Function Exercises

The functional task-training program included repetitive and task-oriented exercises selected to improve hand grip performance, grasping, object manipulation, and the performance of ADL. The difficulty of the exercises was progressively increased according to each patient's ability and level of improvement **[13].** The selected hand-function exercises included inserting cubes into wide-mouthed jars, inserting beans into wide-mouthed jars, and placing beans into a narrow-mouthed bottle, as well as fitting different shapes into their corresponding holes. Additional tasks involved manipulating clay to form small balls and rolls, drawing horizontal and vertical lines, and building towers starting with two or three cubes and gradually progressing up to ten cubes. The activities also included inserting a perforated ball onto a wooden cylinder, removing a sock from the heel to the toes, and practicing putting on and removing socks. Fine motor skills were further developed by picking up buttons of various sizes using a pincer grasp, repeatedly opening and closing scissors, using scissors to cut along thick lines drawn on paper, and cutting out simple shapes.

Statistical analysis

The descriptive statistics as well as t-test were used to compare the two groups (A and B) in terms of mean age, weight, height, BMI, in addition to duration of the illness. To compare each group's pre- and post-treatment measures, a dependent t-test was used. To compare pre- and post-treatment measurements of groups (A) and (B), an unpaired t-test was used. A significance level of $p<0.05$ was established for all statistical tests. All statistical analyses were conducted with IBM SPSS Statistics for Windows, version 19.0 **[14].**

RESULTS

No statistically significant difference was detected among the two studied groups regarding age, height, weight, BMI, SS-QOL, and hand grip strength (p=0.107, 0.310, 0.236, 0.833, 0.733, and 0.941 respectively) as represented in Table (1).

Table (1): General and clinical features pretreatment of the patients in both groups

Item	Study (GA)	Control (GB)	t-value	*p* value
	Mean ±SD	Mean ±S D		
Age (years)	54.36±4.03	56.13 ±4.158	1.66	0.107
Height (Cm.)	163.53±5.98	162.27±4.07	1.03	0.310
Weight (Kg.)	83.37±6.85	84.63±5.57	1.21	0.236
BMI/ (Kg/m^2)	26.83±2.36	27.21±2.45	0.17	0.833
Stroke Specific Quality of Life Scale	95.47±19.38	97.07±17.21	0.34	0.733
Hand Grip Strength	7.43±1.92	7.40±1.88	0.07	0.941

SD: standard deviation
P ≤ 0.05 = significant*

Table (2) shows that the study group (GA) demonstrated significant improvements in both measured outcomes after treatment. Stroke-specific quality of life increased markedly and hand grip strength improved significantly (both p=0.000).

In contrast, the control group (GB) showed no statistically significant improvements in SS-QOL or hand grip strength (p>0.05). Overall, the treatment applied to the study group was effective in significantly enhancing quality of life and hand grip strength compared with the control condition.

Table (3) shows that SS-QOL and hand grip strength were statistically significantly higher in the study group (GA) than in the control group (GB) after treatment (P<0.01).

Table (2): Comparison of the mean values of Stroke Specific Quality of Life Scale and Hand Grip Strength in both groups after treatment

Descriptive results				
	GA		GB	
Stroke Specific Quality of Life Scale	Pre treatment	Post treatment	Pre treatment	Post treatment
Mean±SD	95.47±19.38	163.67±22.74	97.07±17.21	98.90±15.31
Median	100	164	102	104
Minimum	49	120	55	60
Maximum	115	190	112	115
t-value	19.03		1.91	
Statistical p value (post treatment)	0.000**		0.066	
Hand Grip Strength				
Mean± SD	7.433±1.924	10.967±2.580	7.400±1.886	7.700±1.878
Median	8	10	8	8
Minimum	4	6	4	4
Maximum	10	15	10	11
t-value	6.91		1.61	
Statistical p value (post treatment)	.000**		0.119	

SD: standard deviation
P ≤ 0.05 = significant*

Table (3): Mean values of Stroke Specific Quality of Life Scale and Hand Grip Strength in both groups post treatment

Item	**Post treatment**			
	Study (GA)	**Control (GB)**	**t-value**	***p*- value**
	Mean±SD	**Mean±SD**		
Stroke Specific Quality of Life Scale	163.67±22.74	98.90±15.31	11.91	**0.00**
Hand Grip Strength	10.967±2.580	7.700±1.878	5.95	**0.00**

SD: standard deviation
P ≤ 0.05 = significant*

DISCUSSION

The integration of tDCS with traditional rehabilitation strategies has emerged as a promising approach in stroke recovery. Therefore, this study was carried-out to examine the impact of combining tDCS with functional task training on hand grip strength and QOL in patients suffering from subacute stroke. In the current study, sixty patients with right hemispheric ischemic stroke were randomized into two equivalent groups. The study group (A) was given functional task training for upper-limb rehabilitation as well as tDCS, whereas the control group (B) was given functional task training alone.

The patients aged from 45 to 60 years. This age range was selected to include middle-aged adults with stroke while minimizing the potential confounding effects of aging on upper limb recovery and treatment response. Although stroke incidence increases with advancing age, particularly after the age of 65 years [15], patients older than 60 years were excluded because joint and muscle function progressively decline with aging [16]. In addition, age-related differences in brain plasticity may affect recovery and treatment responses following cerebral ischemia, highlighting the importance of controlling the biological effects of aging when evaluating rehabilitation outcomes [17].

The duration of illness in the present study ranged from six to 18 months post-stroke. This interval was selected because spontaneous neurological recovery occurs mainly during the early months following stroke as a result of neuroplastic changes. After this period, recovery tends to stabilize, allowing the observed treatment outcomes to be attributed more accurately to the rehabilitation intervention rather than to spontaneous recovery [18].

Patients with right hemispheric ischemic stroke were selected to increase sample homogeneity and improve the specificity of the study. In addition, the right hemisphere has an essential role in visuospatial attention and higher cognitive functions, which are commonly affected following right hemispheric stroke [19].

Regarding the impact of tDCS in combination with functional task training on hand grip strength, there was a significant improvement in the study group (A) after treatment compared with that of the control group (B) ($P<0.001$). This indicates a positive effect of the combined intervention on voluntary hand muscle performance. This finding is in agreement with Grange et al. [20] who reported significant improvement in hand grip strength following intensive anodal tDCS combined with upper-limb rehabilitation, and Tang et al. [6] whose systematic review and meta-analysis demonstrated a beneficial effect of tDCS on upper-extremity motor function after stroke. The improvement in hand grip strength may be attributed to increased cortical excitability and enhanced synaptic plasticity in damaged perilesional tissue, which may facilitate motor learning and voluntary motor performance after stroke [21, 22]. tDCS may alter the resting membrane potential without directly generating action potentials. Using mechanisms referred to long-term potentiation as well as long-term depression, calcium ion channel activity may be modulated, which may strengthen neural pathways and support motor recovery [21, 26, 27].

Functional task training may also have contributed to the observed improvement in hand grip strength. Repetitive practice of meaningful, task-specific activities facilitates motor relearning and encourages the functional usage of the affected upper extremity during ADL. When combined with tDCS, this approach may enhance the effects of cortical stimulation by providing repeated opportunities to apply regained motor abilities during purposeful tasks [7, 25]. This explanation is supported by Llorens et al. [24] who reported clinically important enhancement in upper-limb motor function following combined tDCS and rehabilitation interventions in patients with stroke. These results suggest that tDCS may facilitate cortical reorganization and neuroplastic changes, thereby promoting motor relearning and enhancing the effectiveness of functional task training [28, 29].

Regarding the effect of transcranial direct current stimulation combined with functional task training on quality of life, there was a significant improvement in the SS-QOL score in the study group (A) after treatment compared with that of the control group (B) ($P<0.001$). This indicates a positive effect of the combined intervention on quality of life. This result is consistent with Tedla et al. [30] who reported improvement in quality of life following tDCS combined with rehabilitation in patients with subacute stroke, and an et al. [31] who found a significant increase in SS-QOL scores after tDCS combined with conventional occupational therapy.

However, despite these positive findings, the current results should be interpreted with caution in light of conflicting evidence in the literature. Some studies have reported limited or no additional benefit of tDCS when combined with conventional rehabilitation. A systematic review also found that tDCS did not consistently improve upper extremity function or muscle strength after stroke, suggesting that its clinical effects may vary across different contexts [32].

Moreover, variability in patient response represents an important challenge. The effects of tDCS may depend on individual factors such as lesion location, severity of impairment, and baseline cortical excitability. Patients with more severe motor deficits may demonstrate a limited response to stimulation, which may partly explain the variability in treatment outcomes across studies [23].

In addition, evidence suggests that the assumed polarity-specific effects of tDCS (anodal excitation and cathodal inhibition) may not always be consistent. Experimental findings have shown that increasing stimulation intensity or altering electrode configuration can reverse expected outcomes, highlighting the non-linear and complex nature of tDCS mechanisms [33].

Another point of debate concerns the durability of tDCS-induced improvements. Although short-term gains have been frequently reported, some longitudinal studies have not demonstrated sustained functional benefits. This suggests that the long-term effects of tDCS may vary and should be further investigated through extended follow-up periods [32].

Recent studies combining brain stimulation with exercise-based peripheral interventions have reported variable functional outcomes. These differences may be related to variations in treatment protocols, including electrode placement, electrode size, current intensity, sample size, and the site of cortical stimulation [32, 34].

The findings of this study indicated significant improvements in hand grip strength and quality of life following the application of tDCS combined with functional task training. These findings support the potential role of tDCS as an adjunctive intervention to enhance the effects of task-oriented rehabilitation in patients with subacute stroke.

The strengths of the current study include random allocation of participants and blinded outcome assessment. An additional advantage was the excellent adherence of the study group participants to the treatment schedule, with no reported adverse effects. Furthermore, the study investigated the effectiveness of combining tDCS with functional task training on hand grip strength and QOL in patients with subacute stroke. These findings may contribute to optimizing the rehabilitation of patients with upper limb deficits following stroke.

Limitations

This study has various limitations. 1st, the precise ischemic stroke subtype, such as lacunar infarction, cardioembolic infarction, or large-artery atherosclerosis, was not identified. In addition, the exact lesion location was not determined, which may have influenced the response to tDCS. 2nd, the findings may not be as generalizable due to the relatively limited sample size. 3rd, the follow-up period was insufficient to determine whether the observed improvements were maintained over time. Finally, other factors that may influence quality of life were not investigated. The improvement in hand grip strength following the combined tDCS and functional task training intervention supports its potential use as a feasible adjunctive approach for patients with subacute stroke and upper limb impairment.

Conclusion

In conclusion, the present study demonstrated significant improvements in hand grip strength and quality of life following the combination of tDCS with functional task training. However, the conflicting evidence reported in the literature highlights the need for cautious interpretation. Future studies should focus on optimizing stimulation parameters, identifying patient-specific predictors of response, and establishing the long-term efficacy of this combined intervention.

Conflict of interest

All authors have no conflicts of interest that are directly relevant to the content of this study.

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