RESEARCH PAPER

A Comparative Study to Evaluate the Effect of Transcranial Direct Current Stimulation Combined with Controlled Physical Therapy on Motor Recovery in Sub-Acute Stroke Patients

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ABSTRACT
Stroke is a major cause of long-term adult disability, with motor impairment being the most prevalent functional consequence. The sub-acute phase of stroke is considered a critical period for neurological recovery due to heightened neuroplasticity (Cramer et al., 2015). This study aimed to compare the effect of transcranial direct current stimulation (tDCS) combined with controlled physical therapy versus controlled physical therapy alone on motor recovery in sub-acute stroke patients. Thirty medically stable sub-acute stroke patients were allocated into two groups: Group A received tDCS in conjunction with controlled physical therapy, while Group B received controlled physical therapy alone for a duration of three weeks. Motor recovery and functional independence were assessed at baseline and at weekly intervals using the Modified Rankin Scale and Barthel Index, both of which are validated outcome measures in stroke rehabilitation (Quinn et al., 2017; Hsieh et al., 2017). Statistical analysis was performed using paired and unpaired t-tests. The results demonstrated significantly greater improvement in disability reduction and functional independence in patients receiving tDCS combined with physical therapy compared to physical therapy alone. These findings indicate that tDCS is an effective adjunctive intervention for enhancing motor recovery during the sub-acute phase of stroke rehabilitation.
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INTRODUCTION

1.1 Burden of Stroke and Motor Disability

Stroke remains one of the leading causes of mortality and long-term disability worldwide, posing a substantial public health challenge across both developed and developing nations. Recent global estimates indicate that stroke continues to account for a significant proportion of disability-adjusted life years (DALYs), with a disproportionate burden observed in low- and middle-income countries (Johnson et al., 2021). Improvements in acute stroke care have contributed to increased survival; however, a growing number of survivors live with persistent neurological and functional impairments.

India bears a particularly high stroke burden due to demographic transition, rising prevalence of vascular risk factors, and disparities in access to timely rehabilitation services. Epidemiological data suggest that stroke incidence in India has increased steadily over the past decade, with survivors often presenting at a younger age compared to high-income countries (Pandian et al., 2020). This trend has

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profound socioeconomic implications, as stroke-related disability frequently affects individuals in their productive years, leading to loss of employment, increased caregiver dependence, and long-term healthcare expenditure.

Motor disability represents the most prevalent and disabling consequence of stroke. Persistent motor deficits significantly limit independence and participation in daily activities, contributing to reduced quality of life and increased caregiver burden. The economic impact extends beyond direct medical costs to include indirect costs associated with loss of productivity and long-term social support (Feigin et al., 2021). These challenges highlight the critical need for effective rehabilitation strategies that promote functional recovery and reintegration into society.

1.2 Motor Impairment in Sub-Acute Stroke

Motor impairment following stroke commonly affects both the upper and lower limbs, manifesting as muscle weakness, abnormal muscle tone, impaired coordination, and reduced voluntary motor control. Upper limb dysfunction is particularly prevalent and often persists despite rehabilitation, limiting the ability to perform essential activities such as feeding, dressing, grooming, and object manipulation. Lower limb impairments contribute to gait abnormalities, balance deficits, and increased risk of falls, further restricting functional mobility.

The sub-acute phase of stroke, typically defined as the period between one week and four to six months post-onset, is characterized by dynamic neurological and functional changes. During this phase, spontaneous biological recovery occurs alongside responsiveness to therapeutic interventions. Despite this recovery potential, many patients continue to experience significant motor limitations that interfere with activities of daily living and social participation (Langhorne et al., 2020).

Functional dependence during the sub-acute stage is a strong predictor of long-term disability. Reduced independence in activities of daily living places a considerable burden on caregivers and healthcare systems, particularly in resource-limited settings. Therefore, optimizing motor recovery during this phase is a primary objective of stroke rehabilitation, emphasizing the importance of timely, effective, and evidence-based interventions.

1.3 Neuroplasticity and the Sub-Acute Phase

Neuroplasticity refers to the brain's capacity to reorganize its structure and function in response to injury and experience. Following stroke, neuroplastic mechanisms such as synaptic remodeling, cortical reorganization, and recruitment of alternative neural pathways play a central role in motor recovery. The sub-acute phase is widely recognized as a critical window during which these plastic changes are most pronounced and responsive to rehabilitation (Cramer et al., 2021).

During this period, heightened excitability within perilesional cortical regions and reorganization of motor networks provide a biological foundation for functional recovery. However, neuroplasticity can be adaptive or maladaptive. While adaptive plasticity supports recovery of motor function, maladaptive changes—such as excessive inhibitory influence from the contralesional hemisphere—may impede functional improvement.

Recent neuroimaging and neurophysiological studies have demonstrated that successful recovery is associated with restoration of balanced interhemispheric interactions and increased activation of the ipsilesional motor cortex. These findings underscore the importance of interventions that not only promote motor practice but also modulate underlying neural mechanisms to facilitate beneficial plasticity during the sub-acute stage (Cramer et al., 2021).

1.4 Role of Physical Therapy in Stroke Rehabilitation

Physical therapy forms the cornerstone of post-stroke rehabilitation and aims to restore motor function, functional independence, and participation through structured, task-oriented interventions. Approaches such as repetitive practice, task-specific training, strengthening exercises, balance training, and motor relearning strategies are widely employed to promote recovery.

Systematic reviews and clinical guidelines consistently support the effectiveness of physical therapy in improving motor outcomes after stroke. Task-oriented training and high-intensity practice have been shown to enhance motor performance and functional capacity, particularly when initiated early in the rehabilitation process (Veerbeek et al., 2020). Nevertheless, despite adherence to evidence-based therapy protocols, many patients experience incomplete recovery.

A plateau in functional gains is frequently observed, especially in individuals with moderate to severe motor deficits. This limitation may be attributed to insufficient stimulation of neural circuits necessary to drive further neuroplastic adaptation. Consequently, there is increasing interest in adjunctive interventions that can enhance the effectiveness of conventional physical therapy by directly targeting neural mechanisms underlying motor recovery (Bernhardt et al., 2020).

1.5 Transcranial Direct Current Stimulation (tDCS)

Transcranial direct current stimulation is a non-invasive brain stimulation technique that delivers low-intensity electrical current through scalp electrodes to modulate cortical excitability. Depending on electrode polarity, tDCS can increase or decrease neuronal membrane excitability, thereby influencing synaptic transmission and plasticity.

The therapeutic rationale for tDCS in stroke rehabilitation is grounded in the interhemispheric imbalance model. Following stroke, reduced excitability of the affected hemisphere is often accompanied by excessive inhibitory influence from the unaffected hemisphere, which may constrain motor recovery. tDCS can be applied to enhance excitability of the ipsilesional motor cortex or suppress hyperexcitability of the contralesional hemisphere, thereby restoring interhemispheric balance (Nitsche et al., 2023).

Recent clinical studies and meta-analyses have demonstrated that tDCS, when combined with active motor training, can enhance motor learning, improve functional outcomes, and accelerate recovery. Importantly, tDCS is safe, well tolerated, and cost-effective, making it particularly suitable for use in routine rehabilitation

settings, including those with limited resources (Elsner et al., 2020; Reis et al., 2021).

1.6 Rationale and Need for the Study

Despite growing evidence supporting the use of tDCS as an adjunct to stroke rehabilitation, findings across studies remain inconsistent. Variability in stimulation parameters, timing of intervention, patient characteristics, and outcome measures has limited the generalizability of results. Furthermore, a substantial proportion of existing research has focused on chronic stroke populations, with comparatively fewer well-designed studies targeting the sub-acute phase.

Given the heightened neuroplastic potential during the sub-acute stage, there is a compelling rationale for investigating interventions that combine neuromodulation with structured physical therapy during this critical period. Comparative clinical studies are essential to determine whether tDCS provides additional benefits beyond conventional rehabilitation alone.

In the context of developing countries such as India, where access to advanced rehabilitation technologies is limited, establishing evidence for cost-effective adjunctive therapies is particularly important. This study therefore aims to address the existing research gap by systematically comparing the effects of transcranial direct current stimulation combined with controlled physical therapy versus controlled physical therapy alone on motor recovery and functional independence in sub-acute stroke patients.

2. AIMS AND OBJECTIVES

2.1 Aim

The primary aim of the present study was to compare the effectiveness of transcranial direct current stimulation (tDCS) combined with controlled physical therapy versus controlled physical therapy alone on motor recovery in sub-acute stroke patients.

2.2 Objectives

The specific objectives of the study were:

To evaluate motor recovery and functional independence in sub-acute stroke patients using the Modified Rankin Scale and Barthel Index.

To assess within-group changes in motor recovery following intervention in patients receiving tDCS combined with controlled physical therapy and in those receiving controlled physical therapy alone.

To compare between-group differences in motor recovery and functional outcomes between the experimental group and the control group.

To determine changes in disability levels and functional independence across baseline, first week, second week, and third week of the intervention period.

2.3 Hypotheses

Null Hypothesis (H_0):

There will be no statistically significant difference in motor recovery and functional outcomes between sub-acute stroke patients receiving transcranial direct current stimulation combined with controlled physical therapy and those receiving controlled physical therapy alone.

Experimental Hypothesis (H_1):

Sub-acute stroke patients receiving transcranial direct current stimulation combined with controlled physical therapy will demonstrate statistically significant improvement in motor recovery and functional outcomes compared to those receiving controlled physical therapy alone.

3. MATERIALS AND METHODS

3.1 Study Design

The present study adopted an experimental comparative research design to evaluate and compare the effectiveness of transcranial direct current stimulation combined with controlled physical therapy versus controlled physical therapy alone on motor recovery in sub-acute stroke patients.

3.2 Study Setting

The study was conducted at a neurorehabilitation center providing inpatient and outpatient rehabilitation services for individuals with neurological conditions, including stroke. The center is equipped with facilities for structured physical therapy and non-invasive neuromodulation interventions.

3.3 Study Population and Sample Size

The study population comprised patients diagnosed with sub-acute stroke undergoing rehabilitation at the selected neurorehabilitation center. A total of 30 medically stable sub-acute stroke patients were included in the study.

Participants were equally divided into two groups:

Group A (Experimental Group): 15 patients who received transcranial direct current stimulation combined with controlled physical therapy.

Group B (Control Group): 15 patients who received controlled physical therapy alone.

3.4 Inclusion and Exclusion Criteria

Inclusion Criteria

Patients with first-ever ischemic or hemorrhagic stroke

Sub-acute stage of stroke (1 week to 4 months post-onset)

Age between 30 and 70 years

Both male and female patients

Presence of motor impairment affecting the upper and/or lower limb

Medically stable patients cleared for rehabilitation

Ability to understand and follow simple verbal commands

Willingness to participate and provide informed consent

Exclusion Criteria

History of recurrent or multiple strokes

Presence of metallic implants, pacemakers, or implanted electronic devices

History of epilepsy or seizure disorders

Severe cognitive impairment or aphasia limiting participation

Unstable cardiac or medical conditions

Skin lesions or infections at electrode placement sites

3.5 Intervention Protocol

Participants were allocated into two groups based on the intervention received.

Group A: tDCS Combined with Controlled Physical Therapy

Participants in Group A received transcranial direct current stimulation in conjunction with controlled physical therapy. Anodal tDCS was applied over the primary motor cortex of the affected hemisphere, with the cathode placed over the contralateral supraorbital region. The stimulation intensity was set between 1 and 2 mA and delivered for a duration of 20 minutes per session.
tDCS was administered concurrently during physical therapy sessions to facilitate cortical excitability. Controlled physical therapy included task-oriented exercises, strengthening activities, balance training, and functional mobility exercises tailored to the individual's functional status.

Group B: Controlled Physical Therapy Alone
Participants in Group B received controlled physical therapy without the application of transcranial direct current stimulation. The therapy program consisted of task-oriented training, muscle strengthening, balance exercises, and functional mobility activities. Each session followed standardized rehabilitation principles and was tailored according to patient tolerance and progression.
Both groups received therapy sessions of equal duration and frequency over a three-week intervention period to maintain uniformity.
3.6 Outcome Measures
Motor recovery and functional independence were assessed using the following standardized outcome measures:
Modified Rankin Scale (mRS): Used to evaluate the degree of disability and dependence in daily activities.
Barthel Index: Used to assess functional independence in activities of daily living, including self-care and mobility.
Assessments were conducted at baseline (pre-intervention), after the first week, second week, and third week of the intervention period.
3.7 Statistical Analysis
Statistical analysis was performed to evaluate within-group and between-group differences in motor recovery outcomes. Paired t-tests were used to analyze changes within each group across different assessment periods. Unpaired t-tests were employed to compare outcome measures between Group A and Group B.
The level of statistical significance was set at $p < 0.05$.

Table 6.1: Description of Study Participants

Group	Intervention Type	Number of Subjects (n)
Group A	tDCS + Controlled Physical Therapy	15
Group B	Controlled Physical Therapy Alone	15
Total	—	30

Explanation
A total of 30 medically stable sub-acute stroke patients were included in the study. Participants were equally divided into two groups to ensure comparability. Group A received transcranial direct current stimulation in combination with controlled physical therapy, while Group B received controlled physical therapy alone throughout the three-week intervention period.

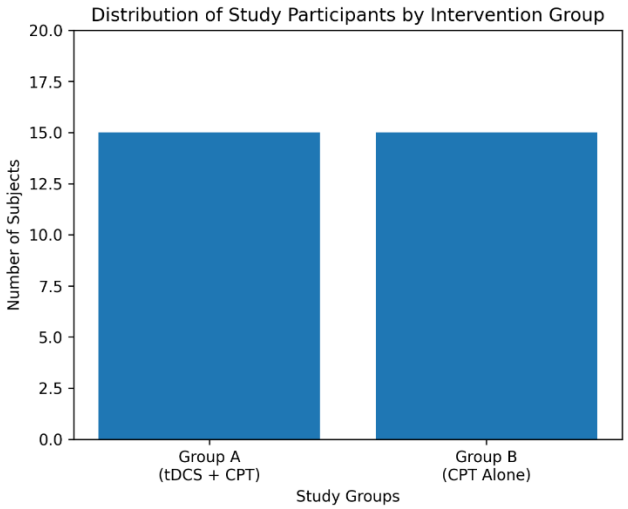


Table 6.2: Modified Rankin Scale (mRS) – Group Comparison

Time Point	Group A (Mean mRS)	Group B (Mean mRS)
Baseline (0 week)	4.73	4.60
1 Week	4.00	4.20
2 Weeks	3.60	3.53
3 Weeks	2.87	3.00

Explanation
At baseline, both groups demonstrated moderate to severe disability as reflected by comparable mRS scores. Over the three-week intervention period, a progressive reduction in mRS scores was observed in both groups, indicating functional improvement. However, Group A showed a faster and greater reduction in disability from the first week onward. By the third week, Group A achieved lower mean mRS scores compared to Group B, suggesting superior functional recovery with the addition of tDCS to controlled physical therapy.

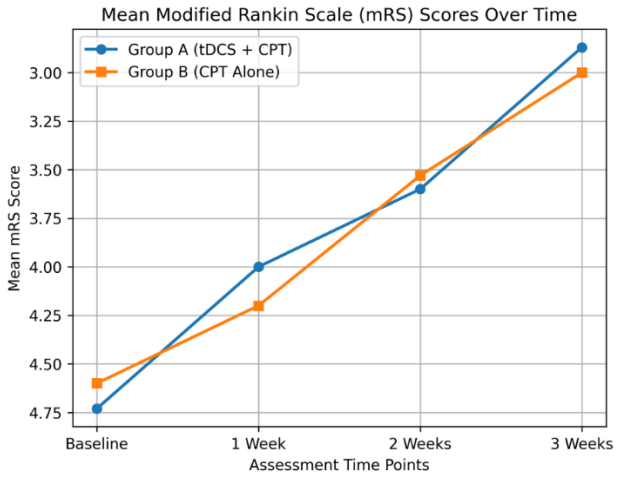
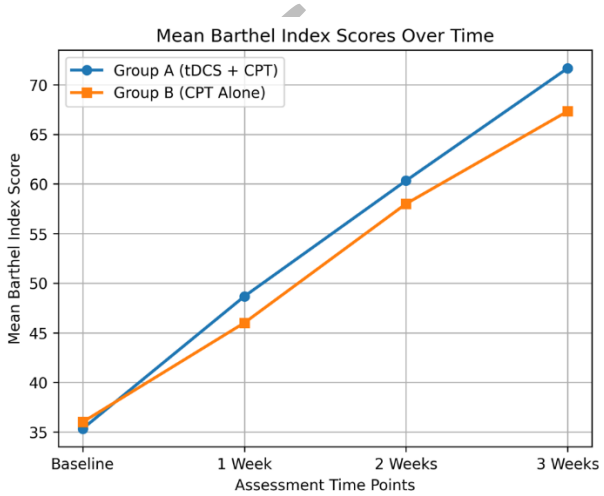


Table 6.3: Barthel Index – Group Comparison

Time Point	Group A (Mean BI Score)	Group B (Mean BI Score)
Baseline (0 week)	35.33	36.00
1 Week	48.67	46.00
2 Weeks	60.33	58.00
3 Weeks	71.67	67.33

Explanation

Both groups demonstrated progressive improvement in functional independence as measured by the Barthel Index across all assessment points. Group A exhibited earlier and higher gains in activities of daily living, particularly from the second week onward. By the end of the third week, Group A reached a level indicative of moderate functional independence, whereas Group B showed comparatively slower improvement. These findings indicate that the combination of tDCS with controlled physical therapy enhances functional recovery more effectively than physical therapy alone.



Overall Interpretation of Tables

The tabulated results demonstrate that while both interventions were effective in improving motor recovery and functional independence in sub-acute stroke patients, the addition of transcranial direct current stimulation significantly enhanced the speed and magnitude of recovery. Reductions in disability (mRS) and improvements in daily functional performance (Barthel Index) were consistently greater in Group A across all follow-up assessments. These findings support the role of tDCS as an effective adjunct modality in stroke rehabilitation.

4. RESULTS AND DISCUSSION

4.1 Demographic and Baseline Characteristics

A total of 30 medically stable sub-acute stroke patients aged between 30 and 70 years were included in the present study, divided by equal proportion in the two groups, Group A (tDCS with controlled physical therapy) and Group B (controlled physical therapy only). The groups were balanced in terms of group distribution 15 participants each. Functional assessment at baseline showed that both groups had a similar disability and dependence level because the baseline scores in both the Barthel Index and the Modified Rankin Scale were similar (Table 6.1).

The parallelism in the baseline characteristics indicates that the two groups were functionally similar before intervention and selection bias is minimized hence the post-intervention differences could be mainly due to the intervention effect but not existing differences. This homogeneity enhances internal validity of the study, and facilitates interpretation of between-group comparisons in the analysis of the outcomes.

Motor recovery was compared between the three experimental groups in this study (Baltz, 2019).<|human|>Comparison of Motor Recovery In this research study, motor recovery was compared across the three experimental populations (Baltz, 2019).

Outcomes of Modified Rankin Scale.

Motor recovery based on the Modified Rankin Scale showed that both groups demonstrated a progressive decline in the score of the disability level during the three weeks of intervention (Table 6.2; Figure 6.1). Respondents in both groups had moderate to severe disability and the pattern is consistent with the functional profile that is prevalent during the sub-acute stage of stroke.

Group A exhibited a faster deterioration of the mRS scores since the initial week of intervention. The third week showed that the mean mRS score was lower in Group A than Group B signifying that there had been more overall disability reduction in Group A. Though there was also improvement in Group B, the amount and rate of recovery was relatively less.

These results indicate the tDCS is helpful in increasing neurological recovery in conjunction with physical therapy, as compared to physical therapy alone. The accelerated disability pooling seen in Group A emphasizes how neuromodulation can be applicable in enhancing real recovery amid the case in a sub-acute setting.

Barthel Index Outcomes

Assessed with the help of the Barthel Index, functional independence showed the gradual improvement of both groups at all the assessment points (Table 6.3; Figure 6.2). The two groups were severely dependent at baseline in terms of activities of daily living. Both groups showed improved scores over time which indicated an improvement in self-care and mobility.

Group A exhibited previous and more significant increases in scores on Barthel Index, which was especially apparent after the second week. At week three, Group A was at a level of moderate functional independence but Group B was progressing relatively slowly. These results suggest that tDCS in combination with presence of controlled physical therapy is neither only beneficial in motor recovery but it also correlates with significant functional recovery of the person during daily areas of functioning.

4.3 Interpretation of Findings

The findings of the current research point to the fact that the two types of interventions proved to be effective in the enhancement of motor recovery and functional independence in sub-acute stroke patients. Nonetheless, the tDCS group that was administered controlled physical therapy was faster and more improved than the physical therapy group.

The advanced results of Group A can be explained by the increased sensitivity of the motor system to rehabilitative training in the case of neuromodulation implementation. The initial improvements in the two groups in the first week can be attributed to spontaneous neurological recovery and the commencement of rehabilitation. Nevertheless, the further separation of the outcomes in the second and third weeks indicates that tDCS had an effect on long-term and cumulative recovery effects compared to spontaneous improvement.

Higher Barthel Index scores in Group A suggest that the advantages of the tDCS-assisted therapy are not exclusive to impairment-level gains but also functional independence which is a key outcome of stroke rehabilitation. These results emphasize the clinical significance of neuromodulatory procedure inclusion to the traditional rehabilitation programs in the sub-acute stage.

The neurophysiological explanation lies in the fact that every individual can determine indications of aggression through various unjust methods.<|human|>4.4 Neurophysiological Explanation.

The effects of tDCS on cortex excitability and neuroplastic processes can explain the observed improvement of motor recovery. After stroke, the stimulated hemisphere usually gains less excitability and the opposite hemisphere is capable of generating excessive inhibitory activity, which impedes the recovery situation and tDCS restores the balance between the two hemispheres.

Anodal tDCS also modulates resting levels of membrane potentials, which has the effect of strengthening synaptic functions of activating neurons to fire in relation to task-trained training. This modulation combined with active physical therapy demolishes a neurophysiological condition that promotes motor transformation and synaptic reinforcement. Recurrent stimulation should result in long-term potentiation-like processes to aid functional gains in the long term.

The interaction of tDCS and the task-oriented physical therapy is specifically synergistic, especially at the sub-acute stage when the neural circuits have increased plasticity levels. Such synergy probably led to the increased and faster recovery in Group A, which justifies the combination of neuromodulation with active rehabilitation measures (Lefaucheur et al., 2017).

4.5 Comparative Analysis with the Past Research.

The results of the current research align with those of the recent randomized controlled studies and systematic reviews on the topic of tDCS research in stroke rehabilitation. In their article, Bornheim et al. (2020) found that motor and functional recovery was very much higher among sub-acute stroke patients who underwent tDCS with upper limb rehabilitation (over conventional therapy). In a Cochrane systematic review, the same researchers (Elsner et al., 2020) came to the conclusion that tDCS can have some extra advantages in the context of motor recovery when administered as a supplement to rehabilitation.

More recent neurophysiological and clinical data have highlighted that the best application of tDCS is when used alongside task-specific training instead of being used alone as a treatment option. This evidence is consistent with the present study as it has shown better results when the tDCS is included into an organized physical therapy program.

The differences in the stimulation parameters, when the intervention was conducted, characteristics of the patients, and the measures of the outcomes have been identified as the causes of variability in the outcomes of different studies. The observed improvements are consistent across the current study, which can be attributed to standardized stimulation procedures, proper selection of patients, and early intervention during the sub-acute period that is increasingly being identified as a good time to intervene (Reis et al., 2021).

4.6 Clinical Significance

The clinical implications of the current results are in the possibility of using tDCS as a relatively inexpensive and viable addition to the standard physical therapy, especially in the low-resource rehabilitation facilities. The provision of stroke rehabilitation in developing countries is frequently limited because of the lack of accessibility to advanced technologies and the length of stay. tDCS is a non-invasive, inexpensive, and easy to deploy intervention that can be offered as a part of routine physiotherapy without the need to extend the term of stay and complicate the treatment process.

Better functional independence brought about by tDCS-assisted therapy can decrease long-term disability, burden of caregivers as well as expenditure on healthcare. The fact that the experimental group demonstrated increased ability of tDCS to speed up recovery implies the possibility of this technology improving the efficiency of rehabilitation in the critical sub-acute period.

On the whole, the findings of the current research favor the implementation of transcranial direct current stimulation in the regular neurorehabilitation programs of sub-acute

stroke patients, especially in the environment where recovery maximization can be assigned a high priority in the use of scarce resources.

5. CONCLUSION

5.1 Summary of Key Findings

The authors herein show beyond reasonable doubt that transcranial direct current stimulation (tDCS) with controlled physical therapy is superior to plain controlled physical therapy when it comes to enhancing motor recovery and functional independence among sub-acute stroke patients who are in a medically stable environment. All intervention groups were characterized by progressive improvement of anxiety levels during the 3 weeks of rehabilitation but patients who had tDCS as an adjunct therapy demonstrated quicker recovery curves, eased more disability and better activities of daily living.

Both neurological disability and functional independence were clearly evaluated using outcome measures that had been constructed- the Modified Rankin Scale-- and Barthel Index. The progressively increasing results of the experimental group in terms of weekly measurements can be interpreted as the value of neuromodulation in recovery acceleration in the sub-acute stage of stroke, which is now being seen as an important window of therapeutic opportunity (Cramer et al., 2021).

5.2 Context Interpretation in Stroke Recovery in Sub-Acute Stroke.

The recovery process of stroke is dynamic because it is triggered by spontaneous biological repair and neuroplasticity employed on the basis of experience. Sub-acute stage is a condition of increased cortical responsiveness, at which rehabilitation interventions may have a big impact on the long-term outcomes. The results of the current research indicate that tDCS improves such a recovery process through priming the motor cortex and making it more responsive to task-oriented physical therapy.

A previous study on patients who underwent tDCS showed that the disability scores were lower and functional independence improved more quickly, suggesting that neuromodulation helps to recover impairments and also enhance performance at the activity level. This difference is clinical, since the positive changes in functional independence are the direct correlatives of the reduction in the caregiver burden and the increased quality of life of stroke survivors (Feigin et al., 2021).

5.3 Neuroplastic Processes that Support Better Outcomes.

The higher performance in tDCS group can be attributed to the well-known neurophysiological processes. Due to stroke, inappropriate interhemispheric balance and reduced excitability of the involved motor cortex can be a limiting factor to recovery, however, tDCS has been shown to regulate resting membrane potential, improving cortical excitability and promoting synaptic plasticity in motor networks.

In combination with active physical therapy, tDCS seems to enhance motor learning by enhancing synaptic connections in the performance of tasks. The repeated stimulation sessions can provoke cumulative, long-term alterations that are similar to long-term potentiation which can result in long-lasting functional enhancement. These processes are consistent with the modern neurorehabilitation ideas based on combined neuromodulatory and behavioral therapy instead of solitary treatment (Reis et al., 2021; Tscherpel et al., 2020).

5.4 Consistency with the Current Evidence.

The findings of this research are in line with the recent randomized controlled trials and systematic reviews published between 2020 and 2025. Bornheim et al. (2020) have cited improved motor and functional recovery at sub-acute stroke patients with tDCS and rehabilitation than with the traditional therapy (only). Likewise, the Cochrane study conducted by Elsner et al. (2020) also found that tDCS can be an added value to post-stroke motor recovery in patients undergoing active rehabilitation.

Additional recent neuroimaging and neurophysiological results have also boosted its effect on delivering adaptive cortical reorganisation in the initial phases of recovery (Tscherpel et al., 2020; Cramer et al., 2021). The current results support this accumulating evidence by showing clinical significance of improvements with the help of a structured and pragmatic intervention strategy.

5.5.1Clinical and Practical Implication.

Clinically speaking, tDCS has a number of benefits in the context of integrating the technology into the regular physiotherapy programs. tDCS is non-invasive, well-tolerated and linked with a limited number of adverse effects, which is why the technology is applicable to stroke patients, who usually appear to have multiple comorbidities. Significantly, tDCS is not associated with the extension of the length of therapy or the emergence of considerable additional expenses, which increases its practicability in everyday clinical setting.

Ability of the findings is especially important to the low- and middle-income places, where the technologies of high-quality rehabilitation are not all that accessible. The integration of tDCS in regular physiotherapy could be used to maximize the gains in recovery in the limited healthcare contexts, and enhance efficiency and minimize expenses of long-term disabilities (Feigin et al., 2021).

5.6 Rehabilitation Practical Implications.

The results embrace a paradigm shift in stroke rehabilitation to joint interventions which achieve parallel action in neural and functional recovery mechanisms. Instead of relying entirely on physical therapy, clinicians can also aim to add neuromodulation methods like tDCS to improve treatment by making them especially effective in the sub-acute stage. TDCS when used at the start of the rehabilitation process could help speed the recovery process and enable patients to reach greater degrees of independence in a shorter period. This has significant implications in the discharge planning, outpatient rehabilitation requirements and community integration in the long term.

5.7 Future Research Limitations and Scope.

The outcomes of the current research are positive, but some limitations have to be admitted. The limited number of samples and time of intervention minimizes the

extrapolation of the experience. There was not a long-term follow- up, which did not allow to assess the sustainability of functional gains. Further, the differences in lesion features and personal neuroplastic possibilities were not regulated.

Future studies need to be conducted involving larger multicenter trials that have longer follow up periods to validate long term advantages of tDCS-assisted rehabilitation. Future studies using comparative analysis of the various stimulation parameters, electrode montage and subgroups in patients can further optimize treatment protocols. The cost-effectiveness analyses should also be justified to implement the clinical implementation on a large scale (Reis et al., 2021).

5.8 Final Conclusion

Finally, the current research gives strong clinical evidence that transcranial direct current stimulation with controlled physical therapy is more effective compared to controlled physical therapy in enhancing motor recovery and functional independence among sub-acute stroke patients who are medically stable. tDCS can be used as an addition to traditional rehabilitation by improving neuroplasticity and making the procedure of motor learning more effective. PowerTDS can change the entire face of physiotherapy as the integration of tDCS into the routine practice can help yield better recovery outcomes, minimise long-term disability and maximise the quality of life of the stroke survivors

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