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COMPARATIVE EFFECTIVENESS OF CONSTRAINT-INDUCED MOVEMENT THERAPY AND MIRROR THERAPY COMBINED WITH NEUROMUSCULAR ELECTRICAL STIMULATION FOR IMPROVING HAND FUNCTION IN INDIVIDUALS WITH CHRONIC STROKE

[1*]Korukonda Venkata Surya Prakash, [2]Pilli Akshaya Madhuri

[1]Principal/ Professor, Kakinada SIMS College of Physiotherapy, Kakinada.
[2]Assistant Professor MPT Neurology, Kakinada SIMS College of Physiotherapy, Kakinada.

***Corresponding Author: Korukonda Venkata Surya Prakash**

Principal/ Professor, Kakinada SIMS College of Physiotherapy, Kakinada.

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ABSTRACT

Background: Upper limb impairment is one of the most common and disabling consequences of stroke, significantly affecting functional independence and quality of life. Constraint-Induced Movement Therapy (CIMT) and Mirror Therapy (MT), when combined with Neuromuscular Electrical Stimulation (NMES), are widely used rehabilitation strategies to improve hand function following stroke. However, evidence comparing the effectiveness of these combined interventions remains limited. **Objective:** To compare the effectiveness of Constraint-Induced Movement Therapy combined with Neuromuscular Electrical Stimulation and Mirror Therapy combined with Neuromuscular Electrical Stimulation in improving hand function among individuals with chronic stroke. **Methods:** A quasi-experimental study was conducted among 30 individuals with chronic stroke aged 18–65 years who presented with impaired hand function. Participants were allocated into two groups using convenience sampling. Group A (n = 15) received Constraint-Induced Movement Therapy combined with Neuromuscular Electrical Stimulation, whereas Group B (n = 15) received Mirror Therapy combined with Neuromuscular Electrical Stimulation. Both groups underwent 15 treatment sessions over three weeks (five sessions per week). Outcome measures included the Modified Ashworth Scale (MAS) for spasticity and the Box and Block Test (BBT) for manual dexterity. Paired t-test and independent t-test were used for within-group and between-group analyses, respectively, with a significance level of p & lt; 0.05. **Results:** Thirty participants completed the study. Group A demonstrated a significant reduction in spasticity, with Modified Ashworth Scale scores improving from 3.33 ± 0.72 to 2.46 ± 1.06 (p = 0.0137). Both groups demonstrated improvement in hand function following intervention. However, between-group comparisons showed no statistically significant differences in Modified Ashworth Scale or Box and Block Test scores based on the available data. **Conclusion:** Both Constraint-Induced Movement Therapy combined with Neuromuscular Electrical Stimulation and Mirror Therapy combined with Neuromuscular Electrical Stimulation demonstrated clinical improvements in hand function among individuals with chronic stroke. Based on the available statistical findings, no significant difference was observed between the two intervention groups. Further randomized controlled studies with larger sample sizes are recommended to confirm these findings.

KEYWORDS: Stroke; Constraint-Induced Movement Therapy; Mirror Therapy; Neuromuscular Electrical Stimulation; Hand Function; Upper Limb Rehabilitation; Neuroplasticity.

INTRODUCTION

Stroke is one of the leading causes of mortality and long-term disability worldwide, placing a substantial burden on individuals, families, and healthcare systems. It is defined as the sudden onset of neurological dysfunction resulting from an interruption of cerebral blood flow due to either vascular occlusion or hemorrhage. Ischemic stroke accounts for nearly 80% of all stroke cases, whereas hemorrhagic stroke constitutes the remaining proportion. Depending on the location and severity of the lesion, stroke may result in varying degrees of motor, sensory, cognitive, perceptual, and communication impairments.[1,2]

Upper limb dysfunction is one of the most disabling consequences of stroke, with approximately 80–87% of survivors experiencing weakness or paralysis of the affected arm during the acute stage. Although spontaneous neurological recovery occurs in many patients, a considerable proportion continue to have impaired upper extremity function several months after stroke. Persistent deficits in hand function restrict independence in activities of daily living, limit participation in social and occupational roles, and reduce overall quality of life.[1,5,6]

Several modifiable and non-modifiable factors contribute to the occurrence of stroke. Hypertension remains the most significant risk factor, while obesity, physical inactivity, smoking, unhealthy dietary habits, diabetes mellitus, and dyslipidemia further increase the risk. Age, family history, psychological stress, and other lifestyle-related factors also influence stroke incidence.[3]

Motor impairment following stroke commonly presents as hemiparesis or hemiplegia accompanied by spasticity, impaired coordination, reduced dexterity, muscle weakness, and abnormal movement patterns. These impairments often interfere with reaching, grasping, object manipulation, and other functional hand activities required for independent living. Consequently, restoration of upper limb function remains one of the primary objectives of neurological rehabilitation.[2,4]

Recovery after stroke is largely dependent on neuroplasticity, which refers to the ability of the central nervous system to reorganize its structure and function in response to injury and repetitive motor practice. Functional recovery is facilitated through cortical reorganization, strengthening of existing neural pathways, formation of new synaptic connections, and motor relearning. Rehabilitation interventions that emphasize repetitive, task-specific practice are known to enhance these neuroplastic changes and improve motor performance.[10]

Among the various rehabilitation approaches, Constraint-Induced Movement Therapy (CIMT) has been widely used to improve upper limb function after stroke. CIMT is based on overcoming learned non-use by restricting the unaffected upper limb while encouraging intensive practice with the affected limb during functional activities.

Repetitive use of the paretic limb promotes cortical reorganization and contributes to improvements in motor control and functional independence.[14]

Mirror Therapy (MT) has also gained considerable attention as a rehabilitation strategy for upper limb recovery. During mirror therapy, the reflection of the unaffected limb performing movements creates the visual illusion that the affected limb is moving normally. This visual feedback activates the mirror neuron system and motor cortical areas, thereby facilitating motor relearning and enhancing upper limb function.[11]

Another commonly used intervention in stroke rehabilitation is Neuromuscular Electrical Stimulation (NMES). NMES applies electrical impulses to peripheral motor nerves to produce muscle contractions, thereby improving muscle activation, reducing spasticity, increasing strength, and facilitating voluntary movement. When combined with functional rehabilitation techniques, NMES may further enhance motor recovery by providing additional sensory input and promoting neuroplastic adaptation.[15,16]

Previous studies have demonstrated the individual effectiveness of CIMT, Mirror Therapy, and NMES in improving upper limb function after stroke.[11,14–16] However, limited evidence is available comparing the effectiveness of Constraint-Induced Movement Therapy combined with Neuromuscular Electrical Stimulation and Mirror Therapy combined with Neuromuscular Electrical Stimulation in individuals with chronic stroke. A direct comparison of these interventions may provide valuable evidence to guide clinical decision-making and optimize rehabilitation outcomes.

Therefore, the present study aimed to compare the effectiveness of Constraint-Induced Movement Therapy combined with Neuromuscular Electrical Stimulation and Mirror Therapy combined with Neuromuscular Electrical Stimulation in improving hand function among individuals with chronic stroke.

MATERIALS AND METHODS

Study Design: A quasi-experimental study was conducted to compare the effectiveness of Constraint-Induced Movement Therapy (CIMT) combined with Neuromuscular Electrical Stimulation (NMES) and Mirror Therapy (MT) combined with Neuromuscular Electrical Stimulation in improving hand function among individuals with chronic stroke.

Study Setting: The study was conducted in the Outpatient Department of Kakinada SIMS College of Physiotherapy, Kakinada.

Study Duration: The study was carried out over a period of three weeks.

Participants: A total of 45 post-stroke subjects were screened for eligibility. Of these, 30 participants who fulfilled the inclusion criteria were recruited after obtaining written informed consent. Participants were allocated into two groups using the convenience sampling method.

Group A (n = 15): Constraint-Induced Movement Therapy combined with Neuromuscular Electrical Stimulation.
Group B (n = 15): Mirror Therapy combined with Neuromuscular Electrical Stimulation. All participants completed the intervention protocol, and no dropouts were reported.

Inclusion Criteria
- Age between 18 and 65 years.
- Clinically diagnosed with stroke.
- Stroke onset of more than six months.
- Upper extremity motor dysfunction with impaired hand function.
- Mini-Mental State Examination (MMSE) score ≥25 with no cognitive impairment.
- First-ever episode of stroke.
- Both male and female participants.

Exclusion Criteria
- Visual impairment.
- Other neurological disorders.
- Musculoskeletal disorders affecting the upper limb.
- Hemineglect.
- Neoplasm or carcinoma.
- Severe cognitive impairment.

Outcome Measures
Modified Ashworth Scale (MAS): Spasticity was assessed using the Modified Ashworth Scale, a reliable clinical measure of resistance to passive movement.[17]

Box and Block Test (BBT): Manual dexterity was assessed using the Box and Block Test, which measures gross manual dexterity.[18]

Statistical Analysis: Statistical analysis was performed using IBM SPSS Statistics version 21.0 and Microsoft Excel 2007. Descriptive statistics were expressed as mean ± standard deviation (SD). The paired Student's t-test was used to compare pre- and post-intervention outcomes within each group, whereas the independent Student's t-test was used to compare outcome measures between groups. A p-value < 0.05 was considered statistically significant.

RESULTS
A total of 45 individuals with chronic stroke were screened for eligibility. Among them, 30 participants fulfilled the inclusion criteria and were enrolled in the study. Participants were allocated into Group A (Constraint-Induced Movement Therapy with Neuromuscular Electrical Stimulation; n = 15) and Group B (Mirror Therapy with Neuromuscular Electrical Stimulation; n = 15) using convenience sampling. All participants completed the three-week intervention protocol, and no dropouts were reported.

Modified Ashworth Scale (MAS): Within-group analysis demonstrated a significant reduction in spasticity in Group A, with the mean MAS score decreasing from 3.33 ± 0.72 at baseline to 2.46 ± 1.06 following intervention (p = 0.0137), indicating a statistically significant improvement. Within-group analysis of Group B also showed improvement in MAS scores following intervention; however, the complete statistical values were not available for reporting.

The baseline comparison between groups showed no statistically significant difference in MAS scores (Group A: 3.33 ± 0.72; Group B: 3.33 ± 0.61; p = 1.000), indicating that both groups were comparable before treatment. Similarly, post-intervention comparison revealed no statistically significant difference between the groups (Group A: 2.46 ± 1.06; Group B: 2.46 ± 0.74; p = 1.000).

Box and Block Test (BBT): The mean Box and Block Test score in Group A improved from 44.20 ± 10.60 at baseline to 60.20 ± 12.08 following intervention, indicating improvement in manual dexterity.

In Group B, the mean BBT score increased from 40.80 ± 6.72 to 59.73 ± 10.38 after intervention. The reported within-group p-value was 0.2327.

Comparison of baseline BBT scores between the groups showed no statistically significant difference (p = 0.3040). Likewise, comparison of post-intervention scores demonstrated no statistically significant difference between the two intervention groups (p = 0.6873).

Overall, both intervention groups demonstrated improvement in hand function following three weeks of rehabilitation. Participants who received Constraint-Induced Movement Therapy combined with Neuromuscular Electrical Stimulation showed significant improvement in spasticity as measured by the Modified Ashworth Scale. Improvements in manual dexterity were observed in both groups based on the Box and Block Test.

However, between-group comparisons did not demonstrate statistically significant differences for either outcome measure, suggesting that both intervention protocols produced comparable outcomes within the study period.

DISCUSSION
The present study compared the effectiveness of Constraint-Induced Movement Therapy (CIMT) combined with Neuromuscular Electrical Stimulation (NMES) and Mirror Therapy (MT) combined with Neuromuscular Electrical Stimulation (NMES) in improving hand function among individuals with chronic stroke. Hand function was assessed using the Modified Ashworth Scale (MAS) and the Box and Block Test (BBT) before and after a three-week intervention

program.

The findings of the present study demonstrated improvement in hand function following both intervention protocols. Within-group analysis showed a statistically significant reduction in spasticity in Group A, indicating that CIMT combined with NMES effectively improved upper limb motor performance. Although participants in Group B also demonstrated improvement following the intervention, the available statistical data did not demonstrate a statistically significant within-group difference. Furthermore, between-group comparisons revealed no statistically significant differences in either the Modified Ashworth Scale or the Box and Block Test scores, suggesting that both interventions produced comparable outcomes during the three-week treatment period.

Constraint-Induced Movement Therapy is based on the principle of overcoming learned non-use by restraining the unaffected upper limb while encouraging repetitive use of the affected upper limb during functional activities. Intensive task-oriented practice promotes cortical reorganization and neuroplasticity, thereby improving voluntary motor control and functional performance following stroke.[23] Neuromuscular Electrical Stimulation further facilitates motor recovery by increasing sensory input, enhancing muscle activation, improving voluntary muscle contraction, and reducing spasticity through repeated stimulation of peripheral motor nerves.[24]

The findings of the present study are consistent with those reported by Taub et al., who demonstrated that CIMT improves upper limb motor recovery by promoting repetitive use of the affected extremity and facilitating cortical reorganization.[20,24] Similarly, Bonifer et al. reported significant improvements in upper extremity function following Constraint-Induced Movement Therapy in individuals with chronic stroke.[15]

Participants who received Mirror Therapy combined with NMES also demonstrated improvement in hand function. Mirror Therapy provides visual feedback by creating the illusion of normal movement of the affected limb, thereby activating the mirror neuron system and motor cortex. This visual feedback facilitates motor relearning and enhances upper limb recovery following stroke.[11,22] Previous studies by Yavuzer et al., Gurbuz et al., and Ezendam et al. similarly reported improvements in upper extremity motor function following Mirror Therapy, supporting its effectiveness as a rehabilitation intervention after stroke.[11,22,28]

Neuromuscular Electrical Stimulation has been widely used as an adjunct to conventional rehabilitation because it enhances muscle strength, reduces spasticity, improves voluntary motor control, and promotes functional recovery through increased sensory stimulation and cortical reorganization.[16,21,26] Since NMES was administered in both intervention groups, the improvements observed in the present study may have been influenced by the therapeutic effects of electrical stimulation in addition to the rehabilitation techniques.

Although both intervention groups demonstrated improvements in hand function, no statistically significant differences were observed between the groups based on the available data. These findings suggest that both CIMT combined with NMES and Mirror Therapy combined with NMES may be beneficial rehabilitation approaches for improving upper limb function in individuals with chronic stroke. The absence of statistically significant differences between the groups may be attributed to the relatively small sample size, convenience sampling, the short intervention duration of three weeks, and the common use of NMES in both treatment groups.

Clinical Implications: The findings of this study suggest that both Constraint-Induced Movement Therapy combined with Neuromuscular Electrical Stimulation and Mirror Therapy combined with Neuromuscular Electrical Stimulation can be incorporated into stroke rehabilitation programs to improve hand function. The choice of intervention may depend on patient characteristics, therapist expertise, rehabilitation goals, and available clinical resources.

Limitations: The present study has several limitations. The sample size was relatively small, which may have reduced the statistical power to detect differences between the interventions. Participants were recruited using convenience sampling, limiting the generalizability of the findings. The intervention period was limited to three weeks, and no long-term follow-up was conducted to evaluate the sustainability of treatment effects. In addition, only the Modified Ashworth Scale and Box and Block Test were used to assess hand function.

Recommendations for Future Research: Future studies should employ randomized controlled trial designs with larger sample sizes and longer follow-up periods to further evaluate the comparative effectiveness of these interventions. The inclusion of additional outcome measures assessing activities of daily living, quality of life, and patient-reported functional outcomes may provide a more comprehensive understanding of upper limb recovery following stroke.

CONCLUSION

The present quasi-experimental study compared the effectiveness of Constraint-Induced Movement Therapy (CIMT) combined with Neuromuscular Electrical Stimulation (NMES) and Mirror Therapy (MT) combined with Neuromuscular Electrical Stimulation (NMES) in improving hand function among individuals with chronic stroke. Both intervention protocols demonstrated improvements in hand function following three weeks of rehabilitation. Participants who received CIMT combined with NMES showed significant improvement in spasticity, while improvements in manual dexterity were observed in both groups. However, between-group analysis did not reveal statistically significant differences in the outcome measures. These findings suggest that both CIMT combined with NMES and Mirror Therapy combined with NMES are beneficial rehabilitation approaches for improving hand function in individuals with chronic stroke. Further randomized controlled trials with larger sample sizes and longer follow-up periods are recommended to validate these findings.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this study.

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ETHICAL APPROVAL

Ethical approval for this study was obtained from the Institutional Ethics Committee of Kakinada SIMS College of Physiotherapy prior to the commencement of the study.

Written informed consent was obtained from all participants before their inclusion in the study.

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