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Comparison of CIMT with PNF versus NMES with PNF to improve Upper Limb Function in Hemiparetic Patients

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ABSTRACT

Background: Stroke frequently results in motor and sensory deficits leading to functional dependence. After a stroke, upper-limb weakness is prevalent throughout the different phases of recovery, impacting daily activities and QoL. Current rehabilitation approaches have incorporated evidence-based techniques to enhance upper limb recovery. Proprioceptive neuromuscular facilitation (PNF) employs particular movement patterns to aid the improvement of muscle function and strength in stroke patients. Constraint-induced movement therapy (CIMT) is an extensively researched strategy for treating upper-limb deficits following stroke, demonstrating improvements in motor function with forced-shift paradigms. Additionally, Neuromuscular electrical stimulation (NMES) has been shown to improve motor control by facilitating recovery of volitional movement. Although the individual therapies have proven effective, the comparative effect of the combination therapies has yet to be explored. Hence, our study aims to compare the effectiveness of CIMT with PNF versus NMES with PNF in enhancing upper-limb function in hemiparetic patients.

Methods: The comparative study was done with 30 stroke patients. The patients aged 50-70 in the sub-acute stage of stroke with MAS <3, GCS = 15 were included in the study. The patients were randomly divided into Group A and Group B, receiving CIMT with PNF and NMES with PNF, respectively. UEFI & FMA- UE were used as outcome measures to assess both groups at baseline and after 8 weeks of intervention.

Results: To analyze the difference between UEFI and FMA-UE across both groups, a paired t-test was applied. Both groups showed significant improvement, but group B showed comparatively better improvement with $p<0.0001$

Conclusion: Neuromuscular electrical stimulation with PNF is an effective therapy for enhancing UL function post-stroke.

Keywords: CIMT, PNF, NMES, UEFI, FMA-UE, Stroke.

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INTRODUCTION

A stroke is a sudden onset of neurological signs and symptoms, followed by a restriction in cerebral blood flow. This disruption leads to acute deprivation of oxygen and essential nutrients to brain tissues, ultimately causing neuronal injury or death and subsequent functional impairments. The WHO describes stroke as an "acute onset of neurological dysfunction of the brain due to abnormality in cerebral circulation" [1]. Owing to its high incidence and associated socioeconomic consequences, stroke poses a public health challenge that necessitates comprehensive, systematic, and long-term rehabilitation strategies to optimize functional outcomes and Quality of Life (QoL) for patients. Stroke results in both motor and sensory impairments, with upper limb dysfunction representing one of the most disabling outcomes due to its direct impact on ADLs. It is widely acknowledged that 87% of motor deficits in the upper limbs develop in the early stages, and these impairments often persist, limiting daily activities despite conventional rehabilitation. Such deficits are usually characterized by weakness, loss of motor control, abnormal muscle tone, and restricted joint range of motion, resulting in difficulties with upper-limb function for purposeful tasks. Hence, the restoration and enhancement of upper limb motor functions have become a central goal in stroke rehabilitation. To address these deficits in upper-extremity motor capabilities, a variety of therapies and treatment methods have been used [2].

Among these interventions, Constraint-Induced Movement Therapy (CIMT) is the most extensively researched rehabilitation method. It includes resisting the good arm and focusing on goal-oriented training [3]. CIMT is grounded in the concept of "learned non-use," which involves restraint of the unaffected limb and forced use of the affected limb. Through repetitive, meaningful task-oriented practice and forced use, it promotes neuroplasticity reorganization, resulting in measurable improvements in motor function and functionality of the affected limb [4].

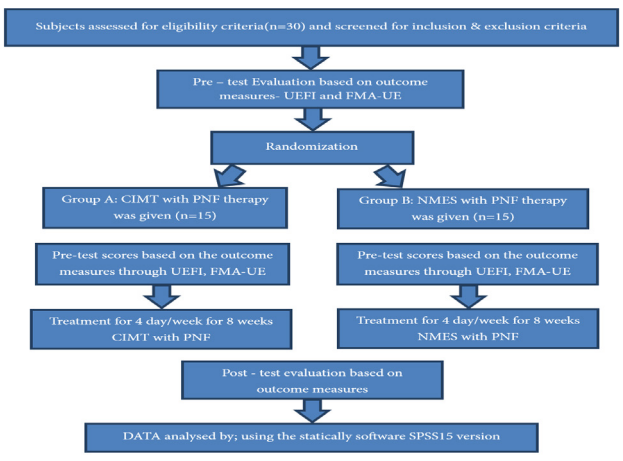
Proprioceptive neuromuscular facilitation (PNF), on the other hand, is an approach that incorporates specific, well-defined movement patterns that help enhance muscle strength, coordination, and function [5]. PNF enhances movement synchronization and boosts overall motor control by using diagonal and spiral movement patterns that simulate natural, functional movements that integrate multiple joints and muscle groups, facilitating coordinated movement [6]. By emphasizing proprioceptive input, manual resistance, and graded facilitation techniques, PNF improves the synchronization of muscle activation and overall motor control, thereby supporting the relearning of organized, purposeful movement patterns in stroke patients.

According to previous research, Neuromuscular electrical stimulation (NMES) has also gained significance as a therapeutic modality due to its capacity to influence both peripheral and central components of motor function. It not only promotes sensorimotor function but also results in brain plasticity [7]. NMES involves the application of electric currents via surface electrodes to evoke muscle contractions in paretic muscles, resulting in muscle activation, strength, and endurance. Improvements in motor function of paretic muscles, including decreased spasticity, strengthened muscles, and improved joint range of motion, have been observed with the application of NMES in stroke patients [8]. When combined with task-specific training, NMES may further enhance functional gains.

Given these complementary mechanisms and potential synergistic effects, the primary objective of our study is to compare the effects of CIMT and PNF & NMES on upper-limb function in Patients with Hemiparesis.

METHODOLOGY

Before the recruitment of patients in this comparative study, ethical clearance [SGRR/IEC/43/22] was obtained from SGRR Institute of Medical and Health Sciences, and the trial was registered under registration no. CTRI/2023/09/057193. A total of 30 patients (sample size calculated using WINPEPI software with a 5% significance level) aged 50-70, in the sub-acute stage of stroke with MAS <3 & GCS = 15, were included in the study. The patients with hemiparesis because of any other diseases or trauma, medically unstable, psychiatric problem, any orthopedic pathological condition and fracture, other peripheral and CNS dysfunction, Global aphasia, Uncooperative patients, Cognitive impairments, Visual field defect or neglect syndrome were excluded. Informed consent was obtained from all patients and their relatives. The patients were referred from the Physiotherapy OPD of SGRR SMI Hospital, Patel Nagar, Dehradun. A detailed briefing is provided to family members about the purpose and methods of the study. The patients were randomly assigned to Group A and Group B using a lottery by the primary investigator. Group A received CIMT with PNF, whereas Group B received NMES with PNF. Both groups underwent their respective exercise protocols, 4 days per week for 8 weeks; each session lasting 45 min [9]. UEFI and FMA-UE were used as outcome measures to assess both groups at initial assessment before the treatment and at the end of 8 weeks of intervention.



Flowchart 1: Flowchart showing the research process of the study

RESULTS

The sample size was calculated using the software, with a 10% exclusion rate and a 5% significance level, resulting in 30. The data were analyzed using SPSS version 20. To analyze the difference between UEFI and FMA-UE for Groups A and B, a paired t-test was applied.

The demographic distribution of Age and Gender showed that the mean age of the participants was 58.73 and 63.53 for Group A and Group B, respectively. The average gender distribution showed that Group A and Group B had 10 and 9 (males), while 5 and 6 (females), respectively (Table 1).

Within-group analysis showed significant improvement in pre- & post-intervention UEFI & FMA-UE scores for both groups, with $p < 0.0001$ (Table 2, 3). Graph 1 showed the pre-post scores of UEFI & FMA-UE for Group A, while Graph 2 showed the pre-post scores of UEFI & FMA-UE for Group B.

The results of Group A and Group B showed significant differences. After comparing the mean UEFI differences between the two groups, the mean UEFI difference for Group A is 7.6, and for Group B it is 10.73. This result shows that Group B is more effective in UEFI than Group A (Table 4). On the other hand, comparing the mean differences between Group A and Group B in FMA-UE, Group A showed 9.73, and Group B showed 14.8, indicating that Group B is more effective in FMA-UE than Group A (Table 5).

Table 1: Age and Gender Distribution for Groups A and B

Demographics	Age (Mean ± SD)	Gender	
		Male (n)	Female (n)
GROUP A	58.73 ± 5.65	10	5
GROUP B	63.53 ± 4.86	9	6

The table shows that the mean age of the participants for both groups was 58.73 ± 5.65 and 63.53 ± 4.86, respectively.

Table 2: Within-group differences of UEFI and FMA-UE scores for Group A

Group A		Mean	SD	SEM	95% CI		t-value	df	p-value
					Lower	Upper			
UEFI	pre - post	-7.60000	.91026	.23503	-8.10408	-7.09592	-32.337	14	.000
FMA -UE	pre - post	-9.73333	2.25093	.58119	-10.97985	-8.48681	-16.747	14	.000

The difference between pre- and post-values for UEFI and FMA-UE in group A has shown a significant improvement, with $p < 0.000$.

Table 3: Within-group differences of UEFI and FMA-UE scores for Group B

Group B		Mean	SD	SEM	95% CI		t-value	df	p-value
					Lower	Upper			
UEFI	pre - post	-10.73333	3.23964	.83647	-12.52738	-8.93928	-12.832	14	.000
FMA-UE	pre - post	-14.80000	3.64887	.94214	-16.82068	-12.77932	-15.709	14	.000

The difference between pre- and post-values for UEFI and FMA-UE in group B has shown a significant improvement, with $p < 0.000$.

Table 4: Comparison between Group A and B of post scores of UEFI

UEFI	Mean	SD	SEM	95% CI		t-value	df	p-value
				Lower	Upper			
APOST - BPOST	-3.60000	3.04256	.78558	-5.28491	-1.91509	-4.583	14	.000

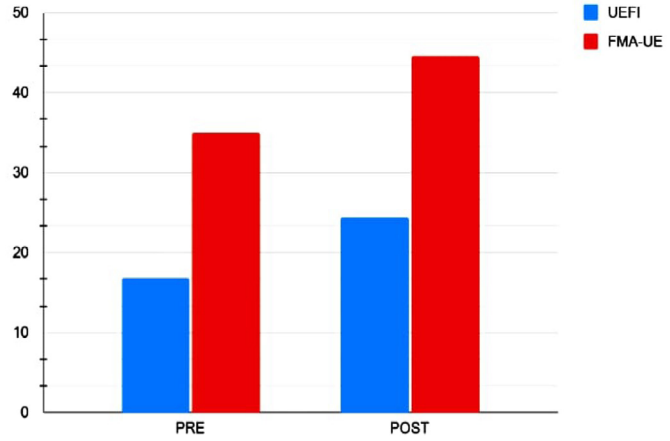
The difference between the two groups for UEFI is significant, with a mean difference of 3.60 ± 3.04

Table 5: Comparison between Group A and B of post scores of FMA-UE

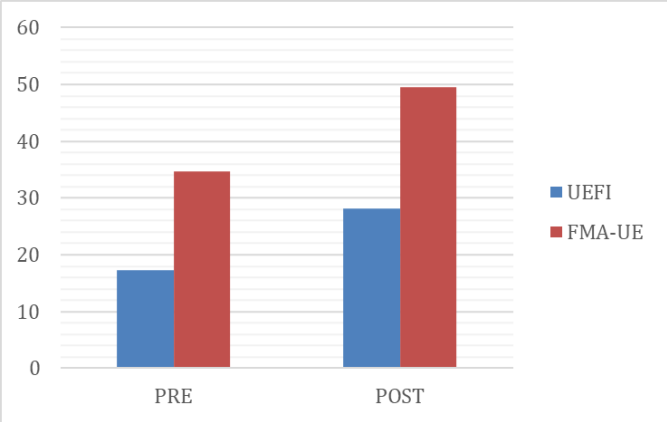
FMA-UE	Mean	SD	SEM	95% CI		t- value	df	p-value
				Lower	Upper			
APOST - BPOST	-7.60000	.91026	.23503	-8.10408	-7.09592	-32.337	14	.000

The difference between the two groups for FMA-UE is significant, with a mean difference of 7.60 ± 0.91

Graph 1: Pre- Post-Intervention Scores of UEFI and FMA-UE within Group A



Graph 2 – Pre- & Post-Intervention Scores of UEFI and FMA-UE within Group B



DISCUSSION

The present study evaluated the comparative effectiveness of Constraint-Induced Movement Therapy (CIMT) versus Proprioceptive Neuromuscular Facilitation (PNF) and Neuromuscular Electrical Stimulation (NMES) with PNF in patients with hemiparesis. Thirty participants were randomly assigned to two groups and were assessed using the Upper Extremity Functional Index (UEFI) and Fugl-Meyer Assessment for Upper Extremity (FMA-UE). Both groups demonstrated improvements after 8 weeks of intervention; however, Group B (NMES + PNF) showed greater gains. Specifically, the mean difference in UEFI was 7.6 in Group A (CIMT + PNF) compared to 10.73 in Group B, while FMA-UE improvements were 9.73 and 14.8, respectively. These results indicate that NMES combined with PNF produced greater improvements in upper-extremity motor function and overall functional activity.

The findings of this study highlight that while CIMT with PNF has therapeutic benefits, the combination of NMES with PNF is superior in enhancing functional recovery. The results partially align with earlier work by Muhammad Aliyu Abba et al. (2020), who demonstrated that CIMT led to significant improvement in FMA scores among stroke patients, suggesting its potential as an effective intervention [9]. Similarly, P. Singh et al. (2013) reported improved functional activity following a two-week CIMT program. However, the present study suggests that NMES may be more effective than CIMT when both are paired with PNF, possibly because NMES directly activates motor units and provides external facilitation to impaired muscles [10].

Support for NMES effectiveness is consistent with findings by Shu-Shyuan Hus et al. (2010), who reported that NMES improved functional activity as measured by the Action Research Arm Test (ARAT). The observed improvements in the current study further reinforce the role of NMES in post-stroke rehabilitation [11]. In addition, the role of PNF in enhancing strength and range of motion has been demonstrated by Kayla B. Hindle et al. (2012), supporting its inclusion in multimodal rehabilitation approaches [12].

The measurement tools used in this study also have strong validity and reliability in stroke rehabilitation. The UEFI has been reported as a reliable patient-reported outcome measure in musculoskeletal and neurological dysfunctions (Bert M. Chewsworth et al., 2014). Similarly, the FMA-UE has shown high reliability and responsiveness, as evidenced by Heesoo Kim et al. (2014), making it a suitable outcome measure for upper extremity functional assessment [13,14].

The current findings suggest important theoretical implications for stroke rehabilitation. NMES may facilitate cortical reorganization by enhancing neuroplasticity through repeated motor-unit activation, thereby accelerating recovery of voluntary movement. PNF, when paired with NMES, provides additional proprioceptive input and facilitates functional tasks, creating a synergistic effect that enhances motor relearning. This combination appears to be more effective than CIMT with PNF, which relies heavily on patient-driven practice and may be limited by fatigue and compliance issues.

Clinically, these findings indicate that NMES combined with PNF may be a more effective rehabilitation strategy for improving UL function in hemiparetic patients. Theoretical models of neuroplasticity and motor learning are supported by these results, as external stimulation coupled with functional movement appears to optimize recovery. Future research should investigate long-term outcomes, larger sample sizes, and the integration of NMES+PNF with other evidence-based therapies to establish comprehensive rehabilitation protocols.

CONCLUSION

Neuromuscular electrical stimulation and PNF therapy were found to be more effective in improving functional independence in post-stroke patients with upper-limb impairment. It concluded that using NMES along with PNF as a treatment approach for patients in the sub-acute phase of stroke can help in early and efficient regaining of upper limb functions.

REFERENCES

[1] Muniyar KD, Darade SB. Effect of Swiss Ball Training and Conventional Physiotherapy to Improve Balance and Mobility in Post-Stroke Patients. International Journal of Physiotherapy and Research. 2018 Aug 11;6(4):2813–22.

[2] Harris JE, Eng JJ. Strength Training Improves Upper-Limb Function in Individuals with Stroke. Stroke. 2010 Jan;41(1):136–40.
[3] Kwakkel G, Veerbeek JM, van Wegen EEH, Wolf SL. Constraint-induced Movement Therapy after Stroke. The Lancet Neurology. 2015 Feb;14(2):224–34.
[4] Abdullahi A, Truijen S, Umar NA, Useh U, Egwuonwu VA, Van Criekinge T, et al. Effects of Lower Limb Constraint-Induced Movement Therapy in People With Stroke: A Systematic Review and Meta-Analysis. Frontiers in Neurology. 2021 Mar 23;12.
[5] Areas GPT, Borghi-Silva A, Lobato AN, Silva AA, Freire Jr RC, Areas FZS. Effect of upper extremity proprioceptive neuromuscular facilitation combined with elastic resistance bands on respiratory muscle strength: a randomized controlled trial. Brazilian Journal of Physical Therapy. 2013 Dec;17(6):541–6.
[6] Tedla J, Devika R, Sangadala. Proprioceptive Neuromuscular Facilitation Techniques in Adhesive capsulitis: a Systematic Review and meta-analysis. 2019 Jun.
[7] Hsu SS, Hu MH, Wang YH, Yip PK, Chiu JW, Hsieh CL. Dose-Response Relation Between Neuromuscular Electrical Stimulation and Upper-Extremity Function in Patients With Stroke. Stroke. 2010 Apr;41(4):821–4.
[8] Yun GJ, Chun MH, Park JY, Kim BR. The Synergic Effects of Mirror Therapy and Neuromuscular Electrical Stimulation for Hand Function in Stroke Patients. Annals of Rehabilitation Medicine. 2011;35(3):316.
[9] Abba M, Muhammad A, Badaru U, Abdullahi A. Comparative Effect of constraint-induced Movement Therapy and Proprioceptive Neuromuscular Facilitation on Upper Limb Function of Chronic Stroke Survivors. Physiotherapy Quarterly. 2020;28(1):1–5.
[10] Singh P, Pradhan B. Study to assess the effectiveness of modified constraint-induced movement therapy in stroke subjects: A randomized controlled trial. Ann Indian Acad Neurol . 2013 Apr-Jun;16(2):180–184.
[11] Hu M, Hsu S, Luh J, Wang Y, Yip P, Hsieh C. Dosage of neuromuscular electrical stimulation: Is it a determinant of upper limb functional improvement in stroke patients? Journal of Rehabilitation Medicine. 2012;44(2):125–30.
[12] Hindle K, Whitcomb T, Briggs W, Hong J. Proprioceptive Neuromuscular Facilitation (PNF): Its Mechanisms and Effects on Range of Motion and Muscular Function. Journal of Human Kinetics. 2012 Mar 1;31(1):105–13.
[13] Chesworth BM, Hamilton CB, Walton DM, Benoit M, Blake TA, Bredy H, et al. Reliability and Validity of Two Versions of the Upper Extremity Functional Index. Physiotherapy Canada. 2014 Jul;66(3):243–53.
[14] Kim H, Her J, Ko J, Park D, Woo JH, You Y, et al. Reliability, Concurrent Validity, and Responsiveness of the Fugl-Meyer Assessment (FMA) for Hemiplegic Patients. Journal of Physical Therapy Science. 2012;24(9):893–9.