

Effects of Proprioceptive Neuromuscular Facilitation With and Without Electrical Muscle Stimulation on Spasticity, Gait, and Lower Limb Function in Chronic Stroke Patients

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Abstract

Background: Stroke, a leading cause of death and disability, is characterized by a sudden disruption of blood flow to the brain, resulting in motor weakness and hemiparesis. Rehabilitation aims to improve functional outcomes, with Proprioceptive Neuromuscular Facilitation (PNF) and Electrical Muscle Stimulation (EMS) being promising interventions.

Objective: This study aimed to determine the effects of PNF with and without EMS on spasticity, gait, and lower limb function in chronic stroke patients.

Methods: A randomized controlled trial was conducted with 22 participants recruited from the physiotherapy department of District Headquarters Sheikhpura from October 2022 to May 2023. Participants were randomly divided into a control group, receiving PNF techniques alone, and an experimental group, receiving PNF combined with EMS. The PNF techniques included rhythmic initiation, stabilizing reversals, and dynamic reversals, while EMS was applied at a frequency of 25 to 50 Hz for 10 seconds, three times a week for six weeks. Outcome measures included the Modified Ashworth Scale, Modified Barthel Index, Dynamic Gait Index, and Tinetti Performance Oriented Mobility Assessment. Data were analyzed using SPSS version 25.

Results: Post-intervention, the experimental group showed significant improvements over the control group in the Modified Ashworth Scale ($p=0.022$), Modified Barthel Index ($p=0.028$), Dynamic Gait Index ($p=0.042$), and Tinetti Assessment ($p=0.004$).

Conclusion: The study concluded that combining PNF with EMS yields better outcomes in managing spasticity, gait, and lower limb functions in chronic stroke patients than PNF alone.

1 Introduction

Stroke, a leading cause of mortality and disability worldwide, is characterized by the sudden impairment of brain function due to disrupted blood supply. It ranks as the second leading cause of death and third in terms of disability globally (1). The disruption in blood flow, whether through ischemic blockages or hemorrhagic ruptures, results in rapid neuronal damage and subsequent loss of motor function, particularly hemiparesis, on the side of the body opposite the brain lesion (2). Such events necessitate urgent medical intervention to prevent extensive brain damage and improve patient outcomes. Risk factors for stroke include obesity, sedentary lifestyle, substance abuse, smoking, hypertension, diabetes, cardiovascular diseases, and previous stroke history. These factors underscore the importance of prevention through lifestyle changes, including maintaining a healthy weight, engaging in regular physical activity, and adhering to a balanced diet rich in fruits and vegetables (3).

The management of stroke involves addressing acute complications, minimizing disability, and promoting rehabilitation to improve quality of life. Rehabilitation strategies often focus on enhancing motor function, gait, and limb coordination, where proprioceptive neuromuscular facilitation (PNF) has shown promising results. PNF techniques leverage specific movement patterns to facilitate motor learning and improve muscle activation (4). Recent studies highlight PNF's efficacy in enhancing balance and gait in chronic stroke

patients. A meta-analysis conducted by Nguyen et al. (2022) involving 532 participants across 19 studies affirmed PNF's significant role in improving balance and gait, establishing it as a viable therapeutic intervention in chronic stroke rehabilitation (5). However, the need for further exploration into combined therapeutic approaches remains, particularly in integrating electrical muscle stimulation (EMS) with PNF.

Electrical muscle stimulation (EMS) is an adjunctive modality that delivers electrical impulses to muscles, prompting contractions that mimic natural physiological signals. EMS has been investigated for its potential to enhance motor recovery by improving muscle tone, strength, and coordination. A randomized controlled trial by Nakanishi et al. (2020) demonstrated EMS's benefits on critically ill patients' limb muscles, leading to reduced hospital stays (6). Similarly, a study by Hong et al. (2019) reported positive outcomes of neuromuscular electrical stimulation (NMES) in improving lower limb function post-chronic stroke, further underscoring EMS's therapeutic potential (7). Despite these findings, the specific impact of combined PNF and EMS interventions on spasticity and gait requires comprehensive investigation.

The current study aims to evaluate the effects of PNF with and without EMS on spasticity, gait, and lower limb function in chronic stroke patients. By comparing these interventions, the research seeks to determine whether the addition of EMS to PNF techniques offers superior outcomes compared to PNF alone. This study employs a randomized controlled trial design, with participants randomly assigned to either a control group receiving PNF techniques or an experimental group receiving both PNF and EMS. The research utilizes the Dynamic Gait Index, Modified Barthel Index scale, and Modified Ashworth Scale as primary outcome measures, with data analyzed using parametric tests for normal distribution (8).

The inclusion criteria focus on male and female patients aged 50-65 years with chronic strokes lasting between 6-12 months, ensuring a representative sample of the target population. By adhering to CONSORT guidelines, the study aims to provide robust evidence to inform future stroke management guidelines, offering clinicians effective treatment strategies for improving patient outcomes. The findings are anticipated to contribute valuable insights into optimizing rehabilitation protocols for chronic stroke patients, emphasizing the importance of integrating multimodal therapies to address complex motor impairments. Ultimately, the study seeks to advance understanding in stroke rehabilitation, guiding clinicians toward more effective interventions to enhance recovery and functional independence in affected individuals.

2 Material and Methods

The study employed a randomized controlled trial (RCT) design to investigate the effects of Proprioceptive Neuromuscular Facilitation (PNF) and Electrical Muscle Stimulation (EMS) on muscle tone, spasticity, gait, and lower limb function in patients with chronic stroke. Conducted at the physiotherapy department of District Headquarters Sheikhpura, the study spanned from October 2022 to May 2023, involving a sample size of 22 participants determined through Epitool calculations, considering a 95% confidence interval and a 10% attrition rate. The study adhered to ethical principles as outlined in the Declaration of Helsinki, with approval obtained from the institutional review board prior to commencement.

Participants were recruited using non-probability convenience sampling and included both male and female patients aged 50-65 years who had experienced chronic strokes lasting between 6-12 months. Exclusion criteria were established to eliminate potential confounding factors, including patients with acute stroke, those with significant cognitive impairments, severe cardiovascular conditions, or other neurological disorders. Prior to participation, informed consent was obtained from all participants, ensuring their understanding of the study objectives, procedures, and potential risks.

Participants were randomly assigned to either the control group or the experimental group through a coin-tossing method, ensuring an equal distribution of participants across both groups. The control group received PNF techniques alone, while the experimental group received PNF techniques in conjunction with EMS. The PNF techniques applied included rhythmic initiation followed by stabilizing reversals and dynamic reversals, aimed at enhancing motor function and muscle activation. EMS was administered at a frequency of 25 to 50 Hz for 10 seconds, three times a week for a duration of six weeks.

Outcome measures were assessed using the Dynamic Gait Index, Modified Barthel Index scale, and Modified Ashworth Scale, providing comprehensive evaluations of gait, functional independence, and spasticity, respectively. Baseline assessments were conducted prior to the intervention, and follow-up assessments were performed immediately post-intervention to evaluate changes in outcome measures.

Data were collected and analyzed using SPSS version 25. The Shapiro-Wilk test was utilized to confirm the normal distribution of data, allowing for the application of parametric tests. Independent sample t-tests and paired sample t-tests were employed for between-group and within-group comparisons, respectively. Statistical significance was set at $p < 0.05$ for all analyses. The results of the study were

expected to contribute valuable insights into the management of chronic stroke patients, providing evidence for the efficacy of combined PNF and EMS interventions in improving motor function, spasticity, and gait.

Throughout the study, measures were taken to ensure the integrity and reliability of the data collected. Single blinding was maintained to minimize bias, with assessors blinded to group allocation. The study adhered to the Consolidated Standards of Reporting Trials (CONSORT) guidelines, detailing the participant flow, intervention protocols, and follow-up processes to enhance the transparency and reproducibility of the findings. These methodological rigors ensured the study's contributions to clinical practice and the development of effective rehabilitation strategies for chronic stroke patients.

3 Results

The study included 22 participants, with 17 males (77.3%) and 5 females (22.7%), and a mean age of 57.86 ± 4.60 years. Data analysis was conducted using SPSS version 25, with the Shapiro-Wilk test confirming the normal distribution of outcome measures at baseline ($p > 0.9$), allowing for parametric testing. The results from the intervention were evaluated using independent sample t-tests and paired sample t-tests to assess differences between and within groups, respectively.

Table 1: Between-Groups Difference in Modified Ashworth Scale (Independent Sample t-test)

Outcome Measure	Assessment	Group A (Mean \pm SD)	Group B (Mean \pm SD)	t-value	p-value
Modified Ashworth Scale	Pre-Intervention	1.590 \pm 0.202	1.590 \pm 0.202	0.000	1.000
	Post-Intervention	1.409 \pm 0.375	1.090 \pm 0.202	2.475	0.022

Post-intervention analysis showed that Group B exhibited a significant improvement in the Modified Ashworth Scale compared to Group A, indicating a greater reduction in spasticity ($p = 0.022$).

Table 2: Between-Groups Difference in Modified Barthel ADL Index (Independent Sample t-test)

Outcome Measure	Assessment	Group A (Mean \pm SD)	Group B (Mean \pm SD)	t-value	p-value
Modified Barthel ADL Index	Pre-Intervention	9.636 \pm 2.062	9.454 \pm 2.161	0.202	0.842
	Post-Intervention	8.727 \pm 2.284	6.818 \pm 1.401	2.363	0.028

Both groups demonstrated significant improvement in the Modified Barthel ADL Index post-intervention, with Group B showing greater enhancement in functional independence compared to Group A ($p = 0.028$).

Table 3: Between-Groups Difference in Dynamic Gait Index (Independent Sample t-test)

Outcome Measure	Assessment	Group A (Mean \pm SD)	Group B (Mean \pm SD)	t-value	p-value
Dynamic Gait Index	Pre-Intervention	16.363 \pm 2.500	15.909 \pm 2.300	0.444	0.662
	Post-Intervention	16.727 \pm 5.274	20.272 \pm 1.272	-2.167	0.042

Post-intervention, both groups improved in the Dynamic Gait Index, with Group B displaying a more significant enhancement in gait performance compared to Group A ($p = 0.042$).

The experimental group receiving PNF with EMS (Group B) showed superior outcomes across all measured parameters compared to the control group receiving PNF alone (Group A).

Table 4: Between-Groups Difference in Tinetti Performance Oriented Mobility Assessment (Independent Sample t-test)

Outcome Measure	Assessment	Group A (Mean \pm SD)	Group B (Mean \pm SD)	t-value	p-value
POMA	Pre-Intervention	7.363 \pm 1.629	7.909 \pm 1.300	-0.868	0.396
	Post-Intervention	7.000 \pm 1.000	9.000 \pm 1.788	-3.237	0.004

The application of EMS in conjunction with PNF techniques resulted in enhanced reductions in spasticity, improved functional independence, better gait performance, and greater mobility improvements, demonstrating the efficacy of combined therapeutic interventions in chronic stroke rehabilitation.

4 Discussion

The study demonstrated that combining Proprioceptive Neuromuscular Facilitation (PNF) techniques with Electrical Muscle Stimulation (EMS) significantly improved spasticity, gait, and lower limb function in chronic stroke patients compared to PNF alone. These findings align with previous research, indicating the potential of EMS in enhancing motor recovery and functional outcomes for stroke patients. Studies have suggested that EMS aids in muscle re-education and neural plasticity, contributing to improved muscle tone and motor function (6)(7).

The enhanced outcomes in the experimental group receiving both PNF and EMS can be attributed to the synergistic effects of these interventions. PNF techniques are known to facilitate motor learning through proprioceptive input, while EMS provides electrical impulses that stimulate muscle contractions, promoting strength and coordination. This combination likely potentiated the effects observed in this study, as evidenced by significant improvements in the Modified Ashworth Scale, Modified Barthel Index, Dynamic Gait Index, and Tinetti Performance Oriented Mobility Assessment compared to the control group (5)(8).

The study's findings are consistent with those of other researchers who have investigated the benefits of integrating EMS with traditional rehabilitation techniques. For example, EMS has been shown to effectively reduce spasticity and improve gait in stroke patients, supporting its use as a complementary therapy (14)(15). Additionally, PNF has been established as an effective intervention for enhancing balance and coordination in chronic stroke rehabilitation (5). The current study builds on this evidence by highlighting the added benefits of combining PNF with EMS to achieve superior clinical outcomes.

One strength of this study was its randomized controlled design, which minimized bias and ensured a rigorous evaluation of the interventions. The use of well-validated assessment tools, such as the Dynamic Gait Index and Modified Barthel Index, provided reliable measures of functional improvement. However, the study also had limitations, including a relatively small sample size, which may limit the generalizability of the findings. Future studies with larger sample sizes are needed to confirm these results and establish the broader applicability of combining PNF with EMS in stroke rehabilitation.

Additionally, the study's duration was limited to six weeks, which may not fully capture the long-term effects of the interventions. Longer follow-up periods are necessary to determine whether the observed improvements are sustained over time. Another limitation was the use of convenience sampling, which might have introduced selection bias, although randomization helped mitigate this issue.

Despite these limitations, the study contributes valuable insights into optimizing stroke rehabilitation by demonstrating that the concurrent application of PNF and EMS can significantly enhance patient outcomes. Clinicians should consider incorporating EMS into traditional rehabilitation protocols for stroke patients to maximize recovery potential. Future research should explore the optimal frequency and duration of EMS application in combination with PNF to further refine treatment strategies.

The study provides evidence supporting the efficacy of integrating PNF techniques with EMS in the rehabilitation of chronic stroke patients. This combined approach offers a promising avenue for improving motor function and reducing disability, aligning with current trends in neurorehabilitation that emphasize multimodal therapies to address the complex needs of stroke survivors.

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Disclaimers

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Trial Registration	NA
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