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Effectiveness of Proprioceptive Neuromuscular Facilitation (PNF) Exercises in Upper Limb Motor Function Recovery in Patients with Stroke: A Randomized Clinical Trial

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Abstract

Stroke is a global epidemic as the most common brain disorders all over the world. Motor impairment is one of the most common challenging outcomes of upper extremity after stroke. Proprioceptive Neuromuscular Facilitation has been reported to have beneficial effects on different aspects in stroke survivors; how-ever, there is limited information about its effects on pain, upper limb motor function and fine motor activity, coordination and hand function. Therefore, our aim is to investigate the effectiveness of PNF exercise combined with conventional physiotherapy on enhancing upper limb motor function, fine motor activity, coordination, muscle tone and reducing pain in stroke patients and compare the findings to those of usual physiotherapy in stroke survivors. A single-center, parallel, assessor, and participant-blinded randomized clinical trial were conducted. A total of 68 stroke survivors were randomized to experimental group and control group. Both groups underwent 24 treatment sessions over six weeks The experimental group received proprioceptive neuromuscular facilitation patterns for the neck, trunk, scapula and upper extremity with conventional physiotherapy, whereas the control group received only conventional physiotherapy. This study conducted a pre-test (before the intervention) and a post-test (subsequent after the intervention) for each participant in both groups to evaluate the upper limb motor function, including pain, strength, coordination, fine motor activity and muscle tone before and after treatment. The primary outcome was the change in the Numeric Pain Rating Scale and Fugl–Meyer assessment for Upper Extremity scores and the secondary outcomes were the changes in Action Research Arm Test, Modified Ashworth scale. Statistically significant difference was obtained in favor of the between group. However, both groups showed significant improvement. The findings from this study provides strong evidence for the efficacy of PNF exercise in enhancing upper limb motor function, fine motor activity, coordination, muscle tone and reducing pain in stroke patients when combined with conventional rehabilitation. These results support the integration of PNF exercise into comprehensive stroke rehabilitation programs to optimize upper limb recovery and improve the overall quality of life for stroke survivors.

Keywords: Proprioceptive Neuromuscular Facilitation, Upper Limb Motor Function Recovery, Stroke, Clinical Trial.

Introduction

Stroke is a leading cause of death and disability globally, responsible for an estimated 5.5 million deaths annually (Feigin et al., 2022). According to the global burden of disease study 2019, stroke was the second-leading cause of death and the third-leading cause of disability and death in the world (Feigin et al., 2021). According to the World Health Organization, stroke accounted for more than 11 percent of all deaths in the world in 2017. Upper motor function deficit following stroke is a common form of stroke that has an impact on motor function and can have long-lasting consequences for the patient. Weakness, spasticity, and a lack of fine motor control are all symptoms of impairment in upper motor function that can make it difficult to carry out everyday activities (Feigin et al., 2022). Stroke patients with upper motor function deficit have been shown to benefit from early intervention and therapy. Motor function and impairment have been demonstrated to improve with interventions such constraint-induced movement therapy, robot-assisted therapy, and electrical stimulation. Proprioceptive neuromuscular facilitation is one option widely used in neuro rehabilitation for strengthening. PNF is a rehabilitation technique that utilizes specific techniques to facilitate or inhibit desired motor responses. It leverages the body's proprioceptive system, which provides information about body position and movement, to enhance muscle function and improve motor control. In Bangladesh, there is a paucity of rehabilitation centers where a person with a stroke can be provided with physiotherapy intervention. Different conventional intervention in stroke rehabilitation is used to mitigate muscle tone and enhance the functional activities in Bangladesh. Different clinical trials of other countries disclosed that the functional status of the upper limb is a significant focus

during the rehabilitation of a per-son with a stroke. Everyone's functional and disability status may be varied according to the determinants like age, gender, type, phases, and chronicity of stroke. PNF is a technique to produce functional movements after paralysis. PNF are applied to a person's muscles to contract in a sequence that allows performing tasks such as upper limb motor function, fine motor activity, Grasping, gripping, coordination, standing, and walking. PNF has evolved into an important therapeutic intervention that clinicians can use to help individuals who have had a stroke or a spinal cord injury regain their ability to stand, walk, reach, and grasp. With an expected growth in the aging population, it is likely that this technology will undergo important changes to increase its efficacy as well as its widespread adoption. However, PNF is not well established in Bangladesh while rehabilitating stroke patients. It is imperative to find out the efficacy of PNF on upper limb function while a physiotherapy management team works towards the improvement or the recovery of the functional and disability status of stroke patients; otherwise, physiotherapy is in-significant. Moreover, it is important to include PNF in general practice as there is limited use of PNF in the rehabilitation for people who have had a stroke. So, the study is intended to determine the effectiveness of PNF on upper limb motor functional recovery for people who have experienced a stroke.

Methodology

The study was single-centered, parallel, and single-blinded (participants) randomized clinical trial at Neurology Unit & Stroke Rehabilitation Unit, Physiotherapy Department at CRP in Dhaka, Bangladesh. Before done the group allocation, sample recruitment had completed in the clinic-based simple randomization sampling technique. After that group allocation had completed by computer-generated concealed allocation where both intervention groups followed in parallel number of participants via 1:1 ratio. The experimental group received proprioceptive neuromuscular facilitation patterns for the neck, trunk, scapula and upper extremity with conventional physiotherapy, whereas the control group received only conventional physiotherapy. This study conducted a pre-test (before the intervention) and a post-test (subsequent after the intervention) for each participant in both groups to evaluate the upper limb motor function, including pain, strength, coordination, fine motor activity and muscle tone before and after treatment. The study conducted at Neurology Unit & Stroke Rehabilitation Unit, Physiotherapy Department at CRP in Dhaka and Neurology unit of Physiotherapy and rehabilitation department at Jashore University of Science and Technology (JUST) in Bangladesh. This location was selected for the research due to CRP being the largest rehabilitation institute in South Asia, accommodating a significant number of stroke patients simultaneously. The G*power, version 3.1.9.7 (University of Kiel, Kiel, Germany) is used to identify the participant's numbers for this trial. It was performed to assess the efficacy of Proprioceptive Neuromuscular Facilitation in individuals with stroke using FMA-UE and ARAT ratings from a study. The calculation indicated that a sample size of 58 people per group was required to achieve 80% power for efficacy evaluation at a significance level (α) of 0.05. In order to cover the expected 20% dropout rate, the study required 70 (35 in each group) participants in total. However, we have selected 70 (35 in each group) participants to conduct the study (Kaminska & Sargsjane et al., 2024). The study sample comprised individuals who had experienced a stroke. The research engaged participants who voluntarily participated and completing selection criteria participant were recruited from the Neurology Unit and Stroke Rehabilitation Unit within the Physiotherapy Department at CRP in Dhaka and Neuro-physiotherapy unit of Physiotherapy and rehabilitation department at JUST. A baseline evaluation had been conducted on each eligible individual before initiating the initial therapy session. Once the evaluation was complete, participants had been randomly assigned based on this evaluation. Randomization was performed for treatment group selection after the baseline assessment. Those who consent to participate in the research and meet the eligibility requirements secretly allocated randomly to both groups in a 1:1 ratio using a website (https://www.graphpad.com/quickcalcs/randomize1/). The research assistant operated the randomization and didn't participate in the intervention or data-collecting process. Each participant's random assignment is contained within a confidential envelope. The investigator's documented data was obscured, and the unbiased research assistant was responsible for the envelopes. The independent research assistant chose an envelope following the baseline evaluation and subsequently disclosed to a certified physiotherapist the intervention assignment of the participants, utilizing a randomization process that also obscured the participant's group assignment from the physiotherapist. Participants, outcome evaluators, physiotherapists, and data statisticians were blinded in this study. While providing informed consent, the participants weren't informed about the group they had been assigned to but were informed about the suggested treatments as well as the same for the physiotherapist also. All outcomes were measured at baseline and after completing rehabilitation intervention for 24 sessions. Baseline data included socio-demographics like age, gender, occupation, BMI; health-related information e.g., types of strokes, affected side and history of comorbidities etc. Others Main outcomes of Pain, Upper extremity motor function, Wrist function, Hand function, Coordination, Fine motor activity of finger and Muscle tone of Upper extremity were measured by Numerical Pain Ratting Scale (NPRS), FUGL-MEYER Assessment Upper Extremity (FMA-UE), Action Research Arm Test (ARAT) and Modified Ashworth scale. The data collector conducted the pre-test examination through face-to-face interviews using an open-ended questionnaire, adhering to guidelines provided by a physiotherapist. Similarly, the post-test examination involved face-to-face interviews conducted by the same data collector, who recorded the responses to the questionnaire under the supervision and guidance of a physiotherapist. An independent screening team had supervised the treatment procedure, participant enrollment, and side effects. They had monitored data, conducted intermediate assessments, and reported any improvements to the therapy or technique to the ethical review board through the primary investigator.

Results

Demographic Information

The demographic analysis of the study provided significant insights among the participants. Among the 68 participants (34 per group), 58 completed the intervention as 10 participants had dropped out due to some conditions for non-research-related reasons study: 10 participant was discharged before the completion of the study. Finally, 58 participants were analyzed. The recruitment strategies for participants are given in methodological section. The experimental group and only Control groups' baseline and clinical characteristics were compared using the Mann-Whitney U test for continuous data and the Chi-square test for categorical variables, respectively. Age, gender, educational level, occupation, stroke type, duration of stroke, affected hemisphere, comorbidities were the baseline characteristics that were consistent for both experimental and control group (Table 1). The experimental group had an average age of 57.5 years (IQR=47.50 to 72.00) whereas the control group participants had an average age of 56.00 years (IQR=49.00 to 66.00). In experimental group 62.1% (18) of participants were male and 37.9% (11) were female. In the control group, 69.0 % (20) of participants were male, and 31.0 % (09) were female. In experimental group, educational status was primary 10.3%, SSC 24.1%, HSC 44.4%, graduation 20.7%, masters 3.4% of participants. In control group, educational status was primary 27.6%, SSC 20.7%, HSC 31.0%, graduation 13.8%, masters 6.9% of participants. In experimental group, occupational status were government service holder 20.7%, private service holder 17.2%, housewife 34.5%, and businessman 6.9% unemployed 20.7% of participants. In control group, educational status was government service holder 27.6%, private service holder 17.2%, housewife 24.1%, and businessman 10.3% unemployed 20.7% of participants.

Baseline: Demographic characteristics of the participants

Variable	Experimental Group %(n) (n=29)	Control group %(n) (n=29)	p value
Demographic Characteristics			
Age in years [Median (IQR)]	57.5 (47.50 to 72.00)	56 (49.00 to 66.00)	0.346[b]
Gender			
Male	62.1 (18)	69.0 (20)	0.449[a]
Female	37.9(11)	31.0 (9)	
Educational status			
Primary	10.3 (3)	27.6 (8)	0.802[a]
SSC	24.1 (7)	20.7 (6)	
HSC	44.4 (12)	31.0 (9)	
Graduate	20.7 (6)	13.8 (4)	
Masters or above	3.4 (1)	6.9 (2)	
Occupation			
Government service holder	20.7 (6)	27.6 (8)	0.836[a]
Private service holder	17.2 (5)	17.2 (5)	
Housewife	34.5 (10)	24.1 (7)	
Businessman	6.9 (2)	10.3 (3)	
Unemployed	20.7 (6)	20.7 (6)	
Monthly income BDT [Median (IQR)]	30000 BDT (24500 to 45000)	28000 BDT (21000 to 42500)	0.622[b]
Clinical Characteristics			
BMI [Meian (IQR)]	25.09 (22.35 to 27.25)	24.85 (22.68 to 26.54)	0.913[b]
Stroke type			
Ischemic stroke	62.1 (18)	55.2 (16)	0.428[a]
Hemorrhagic stroke	37.9 (11)	44.8 (13)	
Affected Side			
Right side	44.8 (13)	48.3 (14)	0.340[a]
Left side	55.2 (16)	51.7 (15)	

Duration of stroke			
< 3 Months			0.514[a]
3-6 months	62.1 (18)	65.5 (19)	
> 6months	37.9 (11)	34.5 (10)	
Comorbidities			
Diabetic mellitus	20.7 (6)	13.8 (4)	0.003[a]
Hypertention	34.5 (10)	37.9 (11)	
Both	31.0 (9)	27.6 (8)	
Heard Disease	6.9 (2)	10.7 (3)	
Kidney disease	3.4 (1)	6.9 (2)	
No	3.4 (1)	3.4 (1)	
[a]Pearson Chi-square Test; [b]Mann Whitney U test			

Participant's Clinical Characteristics

The clinical and changeable characteristics of participants for this study included BMI, Type of stroke, affected hemisphere, Duration of stroke, and presence of various comorbidities. First table represents the baseline clinical characteristics of the study participants. Among the all 58 participants, in experimental group average BMI of 29.09 (IQR=22.35 to 27.25) and whereas the control group participants had an average BMI of 24.45 (IQR=22.68 to 26.54) of participants. With these notable discrepancies, the BMI was not statistically significant (p= 0.913). Among the all 58 participants Ischemic type stroke 58.6%, hemorrhagic type stroke 41.4% in experimental group whereas the control group participants had an Ischemic stroke 58.6%, hemorrhagic stroke 41.4% of participants. In experimental group had right side affected 44.8%, left side affected 55.2% whereas the control group participants had an right side affected 48.3%, left side affected 51.7% of participants. In experimental group had duration of 3 to 6 months had 62.1%, more than 6 months 37.9% whereas the control group participants had duration of 3 to 6 months had 62.1% more than 6 months 37.9% of participants. In experimental group had diabetes mellitus 20.7%, hyper-tension 34.5%, both HTN and DM 31.00%, heard disease 6.9%, kidney disease 3.4 %, no disease 3.4%. whereas the control group participants had diabetes mellitus 13.8%, hyper-tension 37.9%, both HTN and DM 27.6%, heard disease 10.7%, kidney disease 6.9 %, no disease 3.4%. of participants.

Participant's clinical characteristics (within group comparison)

In within group comparison measurement by the Median (IQR) In this section discuss the both experimental and control group range with difference. In NPRS analysis by Median (IQR) in experimental group pre test 4 (3 to 4.50), post test 1 (1 to 2) and control group pre test 4 (3 to 4), post test 3(2 to 3). In FMA-UE (Shoulder and elbow) analysis by Median (IQR) in experimental group pre test 23 (20.50 to 25.50), post test 28(26 to 31) and control group pre test 23 (20 to 26), post test 25 (21 to 28). In FMA-UE (wrist) analysis by Median (IQR) in experimental group pre test 5 (4 to 5), post test 7 (6 to 7) and control group pre test 5 (3 to 6), post test 5 (3.50 to 6). In FMA-UE (Hand function) analysis by Median (IQR) in experimental group pre test 8 (7 to 9), post test 11 (9.50 to 12) and control group pre test 7 (5 to 9), post test 8 (6 to 10) In FMA-UE (coordination) analysis by Median (IQR) in experimental group pre test 3 (2 to 3), post test 4 (3 to 4) and control group pre test 3 (2 to 4), post test 3(2.50 to 4). In FMA-UE total analysis by Median (IQR) in experimental group pre test 38 (32.50 to 41), post test 48 (45 to 54.50) and control group pre test 38 (30.50 to 45), post test 39 (33.50 to 47). In ARAT (grasp) analysis by Median (IQR) in experimental group pre test 10 (8 to 12), post test 13 (10.50 to 14.50) and control group pre test 9 (5.50 to 10), post test 9 (6.50 to 10.50). In ARAT (grip) analysis by Median (IQR) in experimental group pre test 6 (6 to 8), post test 9 (8 to 10) and control group pre test 7 (5.50 to 8), post test 7 (5.50 to 8). In ARAT (pinch) analysis by Median (IQR) in experimental group pre test 9 (7 to 11.50), post test 12 (10 to 14) and control group pre test 9 (6 to 9.50), post test 9(6.50 to 10). In ARAT (gross movement) analysis by Median (IQR) in experimental group pre test 5 (6 to 6), post test 7 (6 to 7) and control group pre test 5 (4 to 6), post test 5 (4 to 6). In ARAT (total) analysis by Median (IQR) in experimental group pre test 29 (25 to 35.50), post test 41 (35 to 46) and control group pre test 29 (19.50 to 33), post test 31 (22.50 to 35.50). In MAS analysis by Median (IQR) in experimental group pre test 3 (2 to 3), post test 1 (1 to 2) and control group pre test 3 (2 to 3), post test 2 (6.50 to 10.50).

Within group and between group analysis

Numerical pain ratting scale (NPRS), Fugl-Meyer assessment upper extremity (FMA-UE), Action Research Arm Test (ARAT), Modified Ashworth Scale in Experimental group and control group

Outcome group	Baseline	After treatment	Within group Changes score		Between group after treatment Changes score	
	[Median (IQR)]	[Median (IQR)]	Z	p	Z	p
Numerical pain ratting scale (NPRS)						
Experimental group	4 (3 to 4.50)	1 (1 to 2)	4.832[b]	0.0001	4.599[d]	0.001
Control group	4 (3 to 5)	2 (1 to 3)	4.681[b]	0.0001		
Fugl-Meyer assessment upper extremity (FMA-UE)						
FMAUE-A (shoulder and elbow)						
Experimental group	23 (20.50 to 25.50)	28 (26 to 31)	4.747[c]	0.0001	3.358[d]	0.001
Control group	23 (20 to 26)	25 (21 to 28)	4.417[c]	0.0001		
FMAUE-B (Wrist)						
Experimental group	5 (4 to 5)	7 (6 to 7)	4.830[c]	0.0001	4.478[d]	0.001
Control group	5 (3 to 6)	5 (3.50 to 6)	2.449[c]	0.014		
FMAUE-C (Hand)						
Experimental group	8 (7 to 9)	11 (9.50 to 12)	4.790[c]	0.0001	4.565[d]	0.001
Control group	7 (5 to 9)	8 (6 to 10)	3.771[c]	0.0001		
FMAUE-D (Coordination)						
Experimental group	3 (2 to 3)	4 (3 to 4)	4.866[c]	0.0001	2.503[d]	0.012
Control group	3 (2 to 4)	3 (2.50 to 4)	3.162[c]	0.002		
FMAUE-Total (A-D)						
Experimental group	38 (32.50 to 41)	48 (45 to 54.50)	4.721[c]	0.0001	3.752[d]	0.001
Control group	38 (30.50 to 45)	39 (33.50 to 47)	4.587[c]	0.0001		
Action Research Arm Test						
ARAT- Grasp						
Experimental group	10 (8 to 12)	13 (10.50 to 14.50)	4.737[c]	0.0001	4.030[d]	0.001
Control group	9 (5.50 to 10.50)	9 (6.50 to 10.50)	4.264[c]	0.0001		
ARAT- Grip						
Experimental group	6 (6 to 8)	9 (7 to 10)	4.799[c]	0.0001	3.336[d]	0.001
Control group	7 (5.50 to 8)	7 (5.50 to 8)	4.359[c]	0.0001		
ARAT- Pinch						
Experimental group	9 (7 to 11.50)	12 (10 to 14)	4.781[c]	0.0001	3.811[d]	0.001
Control group	9 (6 to 11)	9 (6.50 to 12)	4.123[c]	0.0001		
ARAT- Gross movement						
Experimental group	5 (4 to 6)	7 (6 to 7)	4.853[c]	0.0001	4.611[d]	0.001
Control group	5 (4 to 6)	5 (4 to 6)	3.742[c]	0.0001		
ARAT-Total						
Experimental group	29 (25 to 35.50)	41 (35 to 46)	4.715[c]	0.0001	4.196[d]	0.001
Control group	29 (19.50 to 33)	31 (20.50 to 35)	4.658[c]	0.0001		
Modified Ashworth Scale						
Experimental group	3 (2 to 3)	1 (1 to 1)	4.774[b]	0.0001	2.846[d]	0.004
Control group	2 (2 to 3)	2 (1 to 2)	4.472[b]	0.0001		

a = Wilcoxon sign rank test; b = Based on positive rank; c = Based on negative rank; d =Mann-Whitney U test
Mann–Whitney U test; * P<.05, **P<.01, ***P<.001; Wilcoxon Test; * P<.05, **P<.01, ***P<.001

The mean difference test between groups, which employs the Mann-Whitney U Test for non-parametric data, comes next, aiding in assessing the significant difference between the control and experimental groups after the intervention. Statistical significance was determined at ($p < 0.05$). According to critical value of Z, for 95% confidence level z value is 1.96; in this study the researcher found in his study for 95% confidence level z value was 3.940 which is greater than 1.96 which indicates a significant change in between group results. Various outcomes examined showed a statistically significant improvement in the experimental group compared to the control group, underscoring the statistical significance difference.

Within-Group Comparison (Wilcoxon sign-ranked test): Experimental Group and Control group

The analysis focuses on the change in the Wilcoxon signed-rank test of the both Experimental Group and Control group

Formula of Wilcoxon sign-ranked test:

$$Z = \frac{W_x - \frac{n(n+1)}{4}}{\sqrt{\frac{n(n+1)(2n+1)}{24}}}$$

n = total number of participants

W_x = lowest value among positive and negative rank

Primary Outcomes

The primary outcome, pain was measured by Numeric Pain Rating Scale (NPRS) and Functional outcomes determined by the Fugl-Meyer Assessment for Upper Extremity (FMA-UE).

Numeric Pain Rating Scale (NPRS)

Above table described the comparison of participant's before (pre) and after (post) pain characteristics (NPRS) at within group analysis calculated z value were 4.832 ($p=0.001$) for experimental group and 4.681 ($p=0.001$) for control group. Both the z score greater than the standard z value 1.96 at 5% level of significance. So, we reject the null hypothesis of equality of two phase at $\alpha=0.05$ which means the reducing of pain characteristics is statistically significant for NPRS in within group analysis. It is revealed a significant decrease from the initial measurement to the both 1st and 24th session ($p=0.001$).

Fugl-Meyer Assessment Upper Extremity (FMA-UE)

FMA-UE the statistically significant differences were determined in patients upper limb motor functional recovery parameters of the experimental and control groups on Mann Whitney U and Wilcoxon sign rank test due to PNF exercise with conventional therapy vs only conventional therapy intervention. The Wilcoxon Signed Rank Test highlighted significant intra-group improvements for the experimental group across multiple outcome measures, demonstrating the effectiveness of the Proprioceptive Neuromuscular Facilitation intervention. The experimental group experienced significant and notable enhancements upper limb motor function (FMA-UE Shoulder and Elbow: $Z=4.747$, $p=0.0001$; FMA-UE Wrist: $Z=4.830$, $p=0.001$; FMA-UE Hand: $Z=4.790$, $p=0.001$; FMA-UE Coordination: $Z=4.866$, $p=0.001$ and FMA-UE: $Z=4.721$, $p=0.001$). The control group experienced significant and notable enhancements upper limb motor function (FMA-UE Shoulder and Elbow: $Z=4.417$, $p=0.0001$; FMA-UE Wrist: $Z=2.449$, $p=0.014$; FMA-UE Hand: $z=3.771$, $p=0.001$; FMA-UE Coordination: $Z=3.162$, $p=0.002$) and FMA-UE Total: $Z=4.587$, $p=0.001$). Participants in the experimental and control group showed highly significant improvement ($p<0.05$) in all upper limb motor functional recovery parameters and only control group Wrist function $p=0.014$ show significant. From table-2 it is revealed that all the traits are statistically significant for z value>1.96 at $\alpha=0.05$ level of significance in both experimental and control group. This means that using the PNF Exercise with conventional therapy is significantly more effective for improving upper limb motor function of patients with stroke.

Secondary Outcome

Action Research Arm Test (ARAT)

ARAT the statistically significant differences were determined in patients upper limb motor function and fine motor activity recovery parameters of the experimental and control groups on Mann Whitney U and Wilcoxon sign rank test due to PNF exercise with conventional therapy vs only conventional therapy intervention. The Wilcoxon Signed Rank Test results in Result highlighted significant intra-group improvements for the experimental group across multiple outcome measures, demonstrating the effectiveness of the Proprioceptive Neuromuscular Facilitation exercise. The experimental group experienced significant and notable enhancements upper limb motor performance, fine motor activity and coordination (ARAT Grasp: $Z=4737$, $p=0.001$; ARAT Grip: $Z=4.799$, $p=0.001$; ARAT Pinch: $Z=4.781$, $p=0.001$; Gross movement: $Z=4.853$, $p=0.001$) and ARAT Total: $Z=4.715$, $p= 0.001$). The control group enhancements upper limb motor function ((ARAT Grasp: $Z=4.264$, $p= 0.001$; ARAT Grip: $Z=4.359$, $p=0.001$; ARAT Pinch: $Z=4.123$, $p=0.001$; Gross movement: $Z=3.742$, $p=0.001$) and ARAT Total: $Z=4.658$, $p=0.001$). Participants in the experimental and control group showed highly significant improvement ($p<0.05$) in all upper limb motor performance, fine motor activity and coordination parameters. It is revealed that all the traits are statistically significant for Z value>1.96 at $\alpha=0.05$ level of significance in both experimental and control group. This means that using the PNF Exercise with conventional therapy is significantly more effective for improving upper limb motor function of patients with stroke.

Modified Ashworth Scale (MAS)

MAS the statistically significant differences were determined in patient's tome activity parameters of the experimental and control groups on Mann Whitney U and Wilcoxon sign rank test due to PNF exercise with conventional therapy vs only conventional therapy intervention. The Wilcoxon Signed Rank

Test highlighted significant intra-group improvements for the experimental group across multiple outcome measures, demonstrating the effectiveness of the Proprioceptive Neuromuscular Facilitation intervention. The experimental group experienced significant result in improve muscle tome (MAS Total: Z=4.786, p= 0.001). The control group enhancements in improve muscle tome (MAS Total: Z= 4.472, p= 0.001). Participants in the experimental and control group showed significant improvement ($p<0.05$) in muscle tone parameter. It is revealed that all the traits are statistically significant for Z value >1.96 at α=0.05 level of significance in both experimental and control group. This means that using both PNF Exercise with conventional therapy and only Conventional therapy is significant effective for improving upper limb motor function of patients with stroke.

Between group analysis: Experimental group and control group (Mann-Whitney U Test)

The mean difference test between groups, which employs the Mann-Whitney U Test for non-parametric data, comes next, aiding in assessing the significant difference between the control and experimental groups after the intervention. Statistical significance was determined at ($p<0.05$). According to critical value of Z, for 95% confidence level z value is 1.96; in this study the researcher found in his study for 95% confidence level z value was 3.940 which is greater than 1.96 which indicates a significant change in between group results. Various outcomes examined showed a statistically significant improvement in the experimental group compared to the control group, underscoring the statistical significance difference.

The formula of Mann-Whitney U test

$$U = n_1 n_2 + \frac{n_x(n+1)}{2} - T_x$$

Here,

- n_1 = the number of the subjects in trail group
- n_2 = the number of the subject in control group.
- T_x = the larger rank total.
- n_x = the number of the subjects of the group with larger rank total.

"The statistical approach to determining sample size was the power calculation. Statistical power is a measure of how likely the study was to produce a statistically significant result for a difference between groups of a given magnitude" (Hicks, 2009).

Primary Outcomes

The primary outcome, pain was measured by Numeric Pain Rating Scale (NPRS) and Functional outcomes determined by the Fugl-Meyer Assessment for Upper Extremity (FMA-UE).

Numeric Pain Rating Scale (NPRS)

Above table described the between group intervention comparison (post) pain characteristics (NPRS) at within group analysis calculated Z value 4.599 and p value 0.0001 z score greater than the standard z value 1.96 at 5% level of significance. So, we reject the null hypothesis at α=0.05 which means the reducing of pain characteristics is statistically significant for NPRS in between group analysis.

Fugl-Meyer Assessment Upper Extremity (FMA-UE)

FMA-UE the statistically significant differences were determined in patients upper limb motor functional recovery parameters of the experimental and control groups on Mann Whitney U and Wilcoxon sign rank test due to PNF exercise with conventional therapy vs only conventional therapy intervention. The Mann Whitney U Test highlighted significant between-group improvements for both experimental and control group across multiple outcome measures, demonstrating the effectiveness of the Proprioceptive Neuromuscular Facilitation exercise. The both group experienced significant and notable enhancements upper limb motor function (FMA-UE Shoulder and Elbow: Z=3.358, p=0.001; FMA-UE Wrist: Z=4.478, p=0.001). FMA-UE Hand: Z=4.565, p=0.001; FMA-UE Coordination: Z=2.503, p=0.012) and FMA-UE Total: Z=3.752, p=0.001). It is revealed that all the traits are statistically significant for Z value >1.96 at α=0.05 level of significance in both experimental and control group. This means that using the PNF Exercise with conventional therapy is significantly more effective for improving upper limb motor function of patients with stroke.

Secondary Outcome

Action Research Arm Test (ARAT)

ARAT the statistically significant differences were determined in patients upper limb motor function and fine motor activity recovery parameters of both experimental and control groups on Mann Whitney U and Wilcoxon sign rank test due to PNF exercise with conventional therapy vs only conventional therapy intervention. The Mann Whitney U Test results in Table 2 highlight significant between-group improvements for both experimental and control group across multiple outcome measures, demonstrating the effectiveness of the Proprioceptive Neuromuscular Facilitation intervention. The both group experienced significant and notable enhancements upper limb motor performance, fine motor activity and coordination (ARAT Grasp: Z=4.030, p=0.001; ARAT Grip: Z=3.336, p=0.001; ARAT Pinch: Z= 3.811, p=0.001; Gross movement: Z=4.611, p=0.001) and ARAT Total: Z=4.196, p= 0.001). So, Participants in both experimental and control group showed significant improvement ($p<0.05$) in all upper limb motor performance and fine motor activity of patients with stroke. From table-2 it is revealed that all the traits are statistically significant for z value >1.96 at α=0.05 level of significance in both experimental and control group. This means that using the PNF Exercise with conventional therapy is significantly more effective for improving upper limb motor function of patients with stroke.

Modified Ashworth Scale (MAS)

MAS the statistically significant differences were determined in patients upper extremity muscle tome parameters of the both experimental and control groups on Mann Whitney U and

Wilcoxon sign rank test due to PNF exercise with conventional therapy vs only conventional therapy intervention. The Mann Whitney U Test highlighted significant intra-group improvements for the experimental group across multiple outcome measures, demonstrating the effectiveness of the Proprioceptive Neuromuscular Facilitation intervention. The Mann Whitney U Test highlighted significant between-group improvements for both experimental and control group across multiple outcome measures, demonstrating the effectiveness of the Proprioceptive Neuromuscular Facilitation intervention. The both group experienced significant and notable enhancements of upper extremity muscle tome (MAS Total: $Z=2.846$, $p=0.004$). So, participants in both experimental and control group showed significant improvement ($p<0.05$) in all upper extremity muscle tome of patients with stroke. It is revealed that all the traits are statistically significant for z value>1.96 at $\alpha=0.05$ level of significance in both experimental and control group. This means that using the PNF Exercise with conventional therapy is significantly more effective for improving upper limb motor function of patients with stroke.

Discussion

A stroke is often associated with shoulder pain. In stroke patients with severe sensorimotor deficits, the occurrence increases from 18% in the first week to 29% after 1 month and to 47% after 6 months (Church C at el. 2006) At baseline, most of our participants were without shoulder pain. There was no significant change in shoulder pain within the groups during the 4-week pro-gram and no significant gain difference between either group. Electrical stimulation can be used to treat shoulder pain, but our stimulation protocol was not adjusted to this special objective. Furthermore, beneficial effects of PNF become obvious in participants who already have developed shoulder pain. Proprioceptive Neuromuscular facilitation is a modern scientific treatment approach which is evidenced based. Day by day it covers a vast area of medical science. For stroke patients, there are so many effective approaches are used worldwide. Among them PNF has been a popular approach. It has a vital component for improving many functional motor activities including upper limb function for stroke patient. It helped enhancing upper limb motor function, fine motor activity, coordination, muscle tone and reducing pain in stroke patients. It encouraged the patients to willing participate in the treatment session and dramatically outcome can be observed. The findings from this study provides strong evidence for the efficacy of PNF exercise in enhancing upper limb motor function, fine motor activity, coordination, muscle tone and reducing pain in stroke patients when combined with conventional rehabilitation. These results support the integration of PNF exercise into comprehensive stroke rehabilitation programs to optimize upper limb recovery and improve the overall quality of life for stroke survivors. Our study was performed with a small group of patients and group imbalances weakened the validity of the intergroup comparisons. Hence, the following conclusions have to be appraised in this context. In acute, severely affected stroke patients, our stimulation protocol does not induce superior improvements compared to the same amount of conventional upper extremity motor training. We assume that within normal rehabilitation conditions in our country, it would be necessary for people to continue FES themselves at home. This would probably require a simpler stimulation protocol. Based on our findings, further studies have to be carried out in at least 50 participants randomized to FES and conventional therapy, and additional dose-response studies with our protocol are necessary to identify the required minimum number of FES training sessions. The duration of treatment followed in this study was limited to 6 weeks. The evidence was that the rate of recovery in the relevant impairments and the recovery of function were highest during the period when active treatment was applied. However, as soon as this therapy was discontinued, the rate of recovery between groups was not equalized. While it is not possible to comment on how long the duration would normally be required, it can be hypothesized that any treatment should be continued until the patient achieves a threshold of function that can be built on by the patient and the therapist. Again, here is a need for much more work to elucidate the minimum duration of treatment. It is possible that the high attrition rate (nearly 30%) and the resultant reduction in the sample size may have also contributed in part to the lack of significance. Following this study, it is important to acknowledge certain limitations. The study has several limitations. The sample size was very small, so the result is difficult to generalize among whole population. Researcher has taken help from one assessor for data collection purpose, it may vary result. Data were collected one clinical setting CRP Savar, it can influence the result. Sometimes treatment sessions were interrupted due to public holiday mistaken in appointment schedule may interrupt the result. Therefore, the duration of the effect after the experimental intervention is unknown. Also, further research is needed to confirm the effectiveness of FES along with conventional physiotherapy for patients with stroke. The rehabilitation period was small only 8 week for total 24 sessions of intervention for the two groups that experimental group and control group. Similar studies with longer intervention time are required for conclusive results. However, the present study is meaningful because it suggests that simple FES therapy can improve hand functions of patients with stroke. Owing to limitations of the present study further studies are needed.

Conclusion

The result of the study has shown that the effectiveness of PNF along with conventional physiotherapy is superior to the conventional physiotherapy alone after twenty four sessions of treatment for patients with stroke. Considering the final assessment the all variables of upper limb motor function has been improved in both groups instead of some variables while comparing to the initial assessment where PNF along with conventional physiotherapy treatment group has found a greater benefit of the participants. PNF with usual therapy will add new knowledge to manage stroke patients. Improvement of upper limb motor function will reduce the burden of stroke patients as well as their families. Hopefully this research will update and include a new dimension in the rehabilitation process of stroke patients in Bangladesh.

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