Effects of core strengthening versus lower limb proprioceptive neuromuscular facilitation techniques on trunk function and balance in chronic stroke patients

Running title: Core strengthening vs. PNF techniques in chronic stroke

[1]Muhammad Hanif [2]Asma saman khan [3]Zohrain Tabassum [4]Nida Zahid [5]Ali Sufyan [6]Aqsa Majeed [7]Hanan Azfar

[1]MS NMPT [2]DPT [3]Doctor of physiotherapy [4]Masters in Orthopedic Manual therapy [5]Masters in public health [6]Masters in Pediatric Physical therapy [7]MS OMPT

Abstract:

Objective: To compare the effects of core the strengthening versus lower limb proprioceptive neuromuscular facilitation (PNF) techniques on trunk function and balance in chronic stroke patients.

Methods: The randomized controlled trial (RCT) took place at Itiefaq hospital & Riphah Rehabilitation Centre, Lahore, Pakistan. Participants consisted of individuals of both sexes aged between 40 and 70 who were suffering from chronic stroke (6 months to 2 years). Two groups were randomly assigned; Group A received a combination of core strengthening exercises with conventional treatment, while Group B underwent PNF therapy alongside conventional treatment. Outcome measures were evaluated using the Trunk Impairment Scale (TIS) and Berg Balance Scale (BBS).

Results: Out of 42 patients, there were 21 patients in each of the two groups. Between each group, scores for BBS and TIS showed statistically significant results, as evidenced by a p-value of <0.05. Within-group analysis revealed significant findings across all parameters. In contrast, the comparison between groups showed insignificant results for the TIS, as the p-value exceed 0.05. Between group results were significant in case of Berg Balance Scale ($p<0.05$).

Conclusion: The research concluded that applying core strengthening exercises and lower limb proprioceptive neuromuscular facilitation techniques enhanced the balance and trunk function in individuals with the chronic stroke.

Keywords: Stroke, Core strengthening exercises, Proprioceptive Neuromuscular Facilitation, Berg Balance Scale, Trunk Impairment Scale.

Introduction:

An essential source of morbidity and mortality in the world's healthcare systems is stroke. The common impairments after a stroke typically include rigidity, diminished strength, and reduced stability on the affected side, leading to challenges in maintaining a proper upright posture. The ensuing limitations have a significant detrimental effect on victims' productivity, independence, and their overall well-being.[1]

The trunk is thought of as the body's core pivot point, allowing it to maintain upright posture and accommodate changes in weight throughout static and dynamic postural changes. When a stroke affects only one side of the limbs, it also impacts both sides of the trunk muscles, leading to limitations in trunk rotation, walking difficulties, and balance issues. [2]. Thus, for many stroke patients, regaining trunk stability is a crucial rehabilitation objective. [3]

To conduct both ADL and instrumental ADL, core stability, or the body's ability to keep an upright stance, is vital. The deterioration of proprioceptive sensation or limb and trunk muscles paralysis causes imbalance in patients having hemiparetic stroke. Increased risk of falls and decreased mobility are associated with trunk stiffness, restricted balance, and reduced postural control in stroke patients. Due to this, they become dependent on others for their everyday activities and become disabled. The lumbopelvic-hip complex's capacity to protect the vertebral column from buckling and to retain its equilibrium after interruption is known as core stability. [4]

Patients who have had a stroke have more postural sway and trouble adjusting their equilibrium. They also cause the non-paretic lower leg to serve as the centre of gravity, leading to unbalanced posture, poor bodily balance, and a decreased capacity for lifting weight. The most crucial component for stroke victims who are hemiplegic is their ability to balance, and improving that capacity is the main aim of rehabilitation. [5]

Proprioceptive neuromuscular facilitation (PNF) is one technique used to enhance the capacity to balance in stroke patients (PNF). PNF triggers proprioceptors in the muscles and tendons, which enhances their abilities. [6]. It is typically used for early acute or subacute phase rehabilitation for neuromuscular reeducation to enhance motor function in stroke patients because it shows results on enhancing strength and endurance of muscles, coordination and range of motion(ROM) as well as alleviating pain, and improving stability. [7]

A PNF-based intervention has the ability to ameliorate motor function in the geriatric population suffering from chronic stroke, according to preliminary case studies. [8]. By using concentric, eccentric, and isometric contractions to facilitate, inhibit, strengthen, and relax muscle areas, PNF approaches support functional motions. The goal of techniques and treatments is to promote the response by eliciting the greatest amount of activity that can be accomplished with each voluntary effort and the greatest number of attempts of that activity. [9]

Stroke survivors have difficulty maintaining balance and control of their posture while standing upright due to their asymmetrical posture, irregular body imbalance, and failure of weight transfer [10]. The coordinated movement of multiple trunk muscles is important for trunk stability. In order to remain stable in actual locations, speeds, and diverse load conditions occurring on the spine, the muscles that are lateral, posterior, and anterior to the spine provide steady and strong contractility and work together to agreement. [11]

In accordance with the aforementioned research, trunk mobility exercises and the proprioceptive neuromuscular facilitation technique are equally helpful at enabling hemiplegic patients improve their trunk control. Although, no study has been done to compare the two interventions. Therefore, the purpose of this research was to contrast how trunk control exercises and the PNF (proprioceptive neuromuscular facilitation) technique affected hemiplegic individuals [12].The majority of research on stroke rehabilitation is focused on treating upper- or lower-extremity problems. Contrary to limb rehabilitation, trunk restoration is a relatively understudied topic in the field of stroke therapy.

The personalized treatment regimen was customized for each patient, focusing primarily on physical therapy such as muscle activation, stretching, passive movement, range-of-motion exercises for the side affected by hemiparesis, and walking up and down stairs. Additionally, occupational therapy and nursing care were included in the comprehensive plan. Secondly, task-directed movement and trunk activities that were incorporated into postural control were carried out. [13]

The stabilisation reverse PNF technique was used to carry out a trunk stability workout. With the help of alternate muscular contractions and static instruction, the Stabilizing Reverse Technique tries to stabilise posture. The therapist said, "Please hold," and the patient used manual resistance to complete isometric exercises. Upon successfully overcoming the therapist's resistance, the

patient was instructed to mirror the therapist's hand movements in opposite directions. Subsequently, the therapist would switch on the other hand. The therapist completed both PNF Levels I and II. By doing the PNF from in front of the patient, the therapist reduced their anxiety and kept them from falling. [14]

This study help researchers and clinicians to explore adherence to exercise recommendations to better assist in prescribing core strengthening treatment and conventional exercises that can be completed through the lifespan. This study will help to understand essential concepts of core strengthening and Proprioceptive neuromuscular facilitation with high amplitude multiple repetitions.

Materials and methods: -

Study design was Randomized Controlled Trial. Study was conducted at Riphah Rehabilitation center and Ittefaq Hospital, Lahore. Duration of study was 10 months after an approval of Synopsis Sample size was 42 calculated by using the epi-tool method taking trunk impairment scale as variable [2]. Total sample size was 42 after an addition of the attrition rate that was 10%.

Table 1: Sample size calculations

Mean 1	**10.92**
Mean 2	**13**
Variance	**5**
Confidence level	**0.95**
Power	**0.8**
Tails	**2**
Sample size 1 (n1)	**19**
Sample size 2 (n2)	**19**
Total sample size (both groups)	**38**
Attrition Rate	**10%**
Total sample size (both groups)	**42**

Non- Probability Consecutive sampling technique was used to recruit the individual for the study.

Study inclusion criteria were Chronic stroke patients (6 months to 2 years), patients with age ranges from 50 to 70 years, both male and female were included. Patient who can walk without support for 10 m [15]. The Exclusion criteria of study includes patients with respiratory illness Patients who are unable to understand the command, subjects having recurrent stroke were not included in study. Excluded subjects having severe spasticity or severe flaccidity in lower limbs and upper limbs. Major exclusion criterion includes subjects having neurological disorders: Parkinson' disease, multiple sclerosis, epilepsy, etc. [16]

Participants were recruited based on the previously mentioned criteria for inclusion exclusion, after which they were invited participate in the research study. Written informed consent was taken, both in English and Urdu language. Participants were allocated to treatment groups through a random lottery method. The study was single blinded in which subjects were masked related to treatment options available for other groups. Tools utilized for data collection include the Berge balance scale, which is employed to assess a patient's ability (or inability), serving to improve balance safety during the execution of various predetermined tasks. Scale consists of 14-item with each item consisting of five-points. The range of the scale used was from 0 to 4, where 0 represented the lowest level of function and 4 shows the highest level of function. It took approximately 20 minutes to finish. The Trunk Impairment Scale (TIS) was employed to calculate the motor impairment of the trunk post-stroke based on this scale. The individuals were divided into two distinct groups. Group A patients were given the core strengthening exercises in addition to the conventional treatment, which included a 15-minute cold pack, a 15-minute hot pack, and a 15-minute session of EMS.

Transverse abdominis, multifidus, paraspinals, quadratus lumborum, and obliques muscles was used as core strengthening muscles. Abdominal wall musculature was activated in first stage. Abdominal bracing was performed initially. Subjects attained Quadruped position. Alternate arms were lifted, gradually. Subjects were asked to lift an alternate leg and alternate arm/leg raises in order to activate multifidus muscle. For activation of and obliques and quadratus lumborum, side bridged were performed. Trunk curls in crook lying was performed. Patients were instructed to raise their upper trunk slightly (15°) from the examination table and maintain this position for 5 seconds. After the patient successfully completed 30 repetitions of each exercise with an 8-second

hold, the progression of exercises was induced. Normal diaphragmatic breathing should be maintained by each subject throughout the intervention. [17]

Patients in group B were provided with lower limb Proprioceptive Neuromuscular Facilitation (PNF) technique in addition to conventional treatment methods including Rhythmic initiation, slow reversal, stabilizing reversal, and combinations of isotones. In rhythmic initiation, patients progressed through voluntary relaxation, passive movements, movements assisted by an active individual, movements resisted actively, and finally, independent active movements. Subjects were directed verbally to set speed and rhythm of their movements**.** During the resistive phase, light tracking was used to facilitate movement. The time segment consists of 30 minutes, thrice week, over a 4-week period. 10-minute timeframe was employed. In slow reversal isotonic contractions of first agonists and then antagonists performed against resistance was performed initially. The stronger muscle groups were engaged before the weaker ones, allowing for a full range of motion in the limb. This routine was repeated for 30 minutes, three days a week, over a four-week period. Additionally, a 10-minute timeframe was allocated for each application of this technique. In stabilizing reversal, performing isotonic contractions by engaging first agonists, followed by the antagonist muscles against resistance was carried out. Limited range of motion was performed by limb. This was done for 10 minutes, five times a week, over a period of six weeks. In mixture of isotonic (agonist reversals, AR) Initially, the controlled shortening of the main muscles was resisted when moving through the range of motion. This was then followed by gradual lengthening of the muscles in a slow manner back to the starting position. Importantly, there is no relaxation period between these muscle contractions. The method is employed in activities focused on gravity adopting postures. It was found that most effective duration is 30 minutes per session, three times weekly over a span of four weeks. Specifically, the technique was taught for 10 minutes during each session [18]. Pre and post values were taken from both groups A and B, one at the start of the session (baseline) and other at the end of the session and effectiveness of an intervention were ruled out statistically at the end of the procedure. To measure the outcome of trials, Berg balance scale & Trunk impairment scale was used.

Data analysis procedure: -

Windows software, SPSS version 22 was used to analyze data. Statistical P value was 0.05. The data was subjected to a test of normality using the Shapiro-Wilk test, which resulted a P value of

less than 0.05, indicating that it was not distributed normally. The Percentage and frequency of descriptive statistics for socio-demographic were calculated. For between group comparisons**.** The Mann Whitney U test was employed to compute results. comparing within groups, Wilcoxon signed-rank test (non-parametric) was utilized for analyzing the results.

Results: -

Descriptive statistics: -

Table 2 shows the demographic statistics of the study. Group A with the core strengthening mean (SD) of the age was 58.80±4.51, the height was 166.9±9.38, the weight was 74.28±8.77, the BMI was 26.16±3.59, type of the stroke was 1.33±0.48, side of the stroke was 1.38±0.49 and days after the stroke was 1.33±0.57. In the group B of PNF mean (SD) of age was 59.47±6.3, the height was 168.89 ±10.22, the weight was 77.14±10.53, the BMI was 26.51±4.06, type of the stroke was 1.14±0.35, side of the stroke was 1.23±0.43 and days after the stroke was 1.52±0.67.

Table 2: Comparison of socio-demographics variables of two groups

Inferential statistics

Variables	Group A	Group B
	Mean (SD)	Mean (SD)
Age (Years)	58.80±4.51	59.47±6.33
Height (cm)	166.9±9.38	168.89 ±10.22
Weight (kg)	74.28±8.77	77.14±10.53
BMI	26.16±3.59	26.51±4.06
Type of stroke	1.33±0.48	1.14±0.35
Side of stroke	1.38±0.49	1.23±0.43
Days after stroke	1.33±0.57	1.52±0.67

Table 3 shows non-parametric (Wilcoxon signed rank test) within group analysis for group A (Interventional group) in which p value of interventional group in berg balance scale and trunk impairment scale was 0.000. That means the difference between both groups was significant.

Table 3: Within group (Non-parametric) Wilcoxon signed ranks test (Interventional group) Core strengthening

Variables	p-value	Z-value	R-value
BERG BALANCE SCALE	<0.001	4.032	0.879
TRUNK IMPAIRMENT SCALE	<0.001	4.030	0.879

Table 4 shows Wilcoxon signed rank test within group analysis for group B control group (PNF) in which p value of berg balance scale and trunk impairment scale was 0.000. That means the difference between both groups was significant.

Table 4: Within group (Non-parametric) Wilcoxon signed ranks test control group (PNF)

Variables	p-value	Z-value	R-value
BERG BALANCE SCALE	<0.001	4.029	0.879
TRUNK IMPAIRMENT SCALE	<0.001	4.028	0.878

Table 5: Non-parametric tests were applied to compare the two populations at pre-treatment and post treatment level. Both groups showed $p< 0.05$ at Berg balance scale and Trunk impairment scale. Non-parametric tests were utilized to compare groups. The Mann Whitney U test was employed at the baseline to contrast it with the final value in both groups. The P value of pre berg balance scale was 0.069 and that of pre trunk impairment scale was 0.348. The P value of the post berg balance scale was 0.102 and that of post trunk impairment scale was 0.518. There was the significant difference between two groups. Pre and post values were significantly improved when two groups were compared on the basis of Mann Whitney U test.

Table 5: Between groups (Non-parametric) Mann Whitney test (comparison on the baseline value)

Variables	Groups	N	Mean Rank	Median	z-value	p-value
Pre-berg balance scale	Group A	21	24.90	21.00	1.817	0.069
	Group B	21	18.10	19.00		
Pre-trunk impairment scale	Group A	21	13.26	9.00	0.939	0.348
	Group B	21	19.74	8.00		
Post-berg balance scale	Group A	21	18.43	40.00	1.636	0.102
	Group B	21	24.57	41.00		
Post-trunk impairment scale	Group A	21	22.71	19.00	0.646	0.518
	Group B	21	20.29	18.00		

Discussion: -

The findings of the current investigation aligned with a study carried out by Phan the Nguyen et al, researching the impact of PNF on enhancing balance and gait in individuals dealing with the chronic stroke. Significantly, an enhancement in balance and trunk mobility was observed. The results were significantly improved in both between and within the group as P value was <0.05. The major contributing reason of marked improvement was that 3 passive stretches was applied at the muscle for the time frame of 30 seconds. Patient performed 2 sets of 12 muscle stretches followed by performing shoulder lifting exercises at the end of the treatment plane. [19]

In conforming to that results, Pallavi Harjpal et al did research to check how PNF training helped in improving trunk mobility and balance in stroke patients. Study showed qualitative and significantly improved results in both within and between group assessment. Results showed p value was less than 0.05 because the strengthening and motor relearning program of an unaffected side was also performed. [20]

The study performed by Jung Ho Lee et al. supported the findings of the current research, which explored the impact of PNF techniques on enhancing functional activity, gait, and balance in individuals who have experienced a stroke. Significant differences ($p<0.05$) were observed in functional activity, gait, and balance when comparing the pre and post evaluations. The Results were significantly improved because PNF technique was used along with other therapeutic techniques i.e. tapping to improve the synergetic pattern in stroke patients. [21]

The Results of current study was following the results of Rakesh Pilkar et al who investigated the effects of core strengthening interventions on trunk function, mobility and balance after stroke. The trunk muscle response was improved on an application of the core strengthening program. The Reason of statistically improved results was that postural training was done along with an application of the core strengthening program. [22]

The results of current study were same as that of Dong Hoon Kim et al who find out the improved function of control of trunk and balance due to robot assisted trunk control training in stroke patients. The results were significantly improved because robotic trunk devices were used to improve the core strength. [23]

Conclusion: -

Research findings indicated that the application of exercises to strengthen the core and proprioceptive neuromuscular facilitation techniques on the lower limbs led to an enhancement in balance and trunk function for individuals dealing with the chronic stroke. The positive impact of both core strengthening and PNF techniques on trunk stability was observed. Hence, both technique proven to be efficient and effective techniques in improving functional level & balance of the trunk.

Limitations: -

- Time constraints meant that patients were only followed up for one month.
- Long-term outcomes were not assessed because we did not plan a follow-up after the intervention was stopped.
- Since the function of the damaged side muscles was tested, the results could not be compared to the unaffected side.
- Our conclusions may not be usual for patients with diverse areas because we only consider patients who are able to walk and stand.

Recommendations: -

More mobilization techniques can be added into study to see their effect or can be added with other intervention to see their combine effects. Clinicians are recommended to enable the usage of PNF along with core strengthening exercises & arrange different seminars and workshop regarding an application of above-mentioned techniques. The latent effects of frequency and amplitude on muscle function all across the body need to be investigated further. Alternative therapeutics' influence on stroke victims may be studied more in the future.

Conflict of interest: Authors revealed no competing interest.

Ethical approval: The research conducted at "Ripah International University" received approval from its institutional review board on July 6, 2022, under the registration number "S21C14G37029". Prior to the implementation of the intervention or data collection, all participants provided informed consent.

Use of AI: None

Authors' Contribution: MH and ASK were involved in developing and planning the study. ZT undertook the data collection, NZ and MG conducted the data analysis and interpretation. AM was responsible for drafting the article, while HA contributed the proofreading process. The final draft was thoroughly reviewed and approved by all authors to guarantee the manuscript's content and similarity index.

Funding: No funding was received for this study.

ACKNOWLEDGMENT:

We wish to express our gratitude to all individuals who willingly part in research. A special acknowledgment to our research supervisor for the invaluable direction and support provided throughout the research endeavor.

References: -

1. Winstein CJ, Stein J, Arena R, Bates B, Cherney LR, Cramer SC, et al. Guidelines for adult stroke rehabilitation and recovery: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. 2016;47(6):e98-e169.

2. Sharma V, Kaur J. Effect of core strengthening with pelvic proprioceptive neuromuscular facilitation on trunk, balance, gait, and function in chronic stroke. Journal of exercise rehabilitation. 2017;13(2):200.
3. Brown DA, LaCroix KL, Alhirsan SM, Capo-Lugo CE, Hennessy RW, Hurt CP. Designing User-Centered Technologies for Rehabilitation Challenge that Optimize Walking and Balance Performance. Neurorehabilitation Technology: Springer; 2022. p. 191-205.
4. Cabanas-Valdés R, Bagur-Calafat C, Girabent-Farrés M, Caballero-Gómez FM, Hernández-Valiño M, Urrutia Cuchi G. The effect of additional core stability exercises on improving dynamic sitting balance and trunk control for subacute stroke patients: a randomized controlled trial. Clinical rehabilitation. 2016;30(10):1024-33.
5. Felius R, Geerars M, Bruijn S, Wouda N, Van Dieën J, Punt M. Reliability of IMU-based balance assessment in clinical stroke rehabilitation. Gait & Posture. 2022;98:62-8.
6. Seo KC, Kim HA. The effects of ramp gait exercise with PNF on stroke patients' dynamic balance. Journal of physical therapy science. 2015;27(6):1747-9.
7. Schmid AA, Van Puymbroeck M, Altenburger PA, Dierks TA, Miller KK, Damush TM, et al. Balance and balance self-efficacy are associated with activity and participation after stroke: a cross-sectional study in people with chronic stroke. Archives of physical medicine and rehabilitation. 2012;93(6):1101-7.
8. Mustafa H, Harrison A, Sun Y, Pearcey GE, Follmer B, Nazaroff BM, et al. Five weeks of Yuishinkai karate training improves balance and neuromuscular function in older adults: a preliminary study. BMC Sports Science, Medicine and Rehabilitation. 2022;14(1):1-13.
9. Borowicz W, Ptaszkowski K, Murawska-Ciałowicz E, Rosińczuk J. Proprioceptive Neuromuscular Facilitation and Mirror Therapy Methods Are Comparable Methods of Rehabilitation after a First-Ever Ischemic Stroke: A Randomized Study. Sustainability. 2022;14(22):15246.
10. Shin B, Ham T, Gwak D, Lee K-m. Development of a vertical linear actuator with gravity compensation for long stroke. Microsystem Technologies. 2022:1-7.
11. Olczak A, Truszczyńska-Baszak A. Influence of the Passive Stabilization of the Trunk and Upper Limb on Selected Parameters of the Hand Motor Coordination, Grip Strength and Muscle Tension, in Post-Stroke Patients. Journal of Clinical Medicine. 2021;10(11):2402.
12. Moreno-Segura N, Martín-San Agustín R, García-Bafalluy S, Escriche-Escuder A. Effects of core training on trunk function, balance, and gait in stroke patients: A systematic review and meta-analysis of randomised controlled trials. Clinical Rehabilitation. 2022;36(12):1635-54.
13. Cui Z, Li Y, Huang S, Wu X, Fu X, Liu F, et al. BCI system with lower-limb robot improves rehabilitation in spinal cord injury patients through short-term training: a pilot study. Cognitive Neurodynamics. 2022:1-19.
14. HAH GAR. Rehabilitation Plan and Process of Patients after Stroke.

15. Srinayanti Y, Widianti W, Andriani D, Firdaus FA, Setiawan H. Range of Motion Exercise to Improve Muscle Strength among Stroke Patients: A Literature Review. International Journal of Nursing and Health Services (IJNHS). 2021;4(3):332-43.
16. Stein J, Katz DI, Black Schaffer RM, Cramer SC, Deutsch AF, Harvey RL, et al. Clinical performance measures for stroke rehabilitation: performance measures from the American Heart Association/American Stroke Association. Stroke. 2021;52(10):e675-e700.
17. Karthikbabu S, Ganesan S, Ellajosyula R, Solomon JM, Kedambadi RC, Mahabala C. Core Stability Exercises Yield Multiple Benefits for Patients With Chronic Stroke: A Randomized Controlled Trial. American Journal of Physical Medicine & Rehabilitation. 2022;101(4):314-23.
18. Mindouri AS, Kottaras A, Iakovidis P, Lytras D, Chatziprodromidou IP, Chasapis G. The efficacy of proprioceptive neuromuscular facilitation (PNF) in patients with stroke.
19. Nguyen PT, Chou L-W, Hsieh Y-L. Proprioceptive Neuromuscular Facilitation-Based Physical Therapy on the Improvement of Balance and Gait in Patients with Chronic Stroke: A Systematic Review and Meta-Analysis. Life. 2022;12(6):882.
20. Harjpal P, Qureshi I, Krishna Kovela R, Jain M. Efficacy of Bilateral Lower Limb Training over Unilateral to Re-educate Balance and Walking in Post-stroke Survivors: A Protocol for Randomized Clinical Trial. 2021.
21. Lee J-H. A study to investigate the difference in functional activity, gait, and balance of stroke patients according to treatment methods. 2022.
22. Pilkar R, Veerubhotla A, Ibironke O, Ehrenberg N. A Novel Core Strengthening Intervention for Improving Trunk Function, Balance and Mobility after Stroke. Brain Sciences. 2022;12(5):668.
23. Kim D-H, In T-S, Jung K-S. Effects of robot-assisted trunk control training on trunk control ability and balance in patients with stroke: A randomized controlled trial. Technology and Health Care. 2022(Preprint):1-10.

Figure 1: Consort Diagram

Consort flow diagram showing enrollment, allocation and progression of participants in study