Effectiveness of Proprioceptive Neuromuscular Facilitation on Walking Speed, Discomfort, and Knee Extension in an Acute Stroke Patient: A Case Study

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KEYWORDS

Proprioceptive Neuromuscular Facilitation, 6-minute Walk Test, Visual Analogue Scale

ABSTRACT

This study investigates the impact of proprioceptive neuromuscular facilitation (PNF) on improving functional mobility in a stroke patient, with a focus on walking speed, discomfort levels, and knee extension range of motion (ROM). PNF techniques were applied over four weeks to assess their effectiveness. The patient's walking performance was evaluated using the 6-minute walk test (6MWT), and discomfort was measured using the visual analogue scale (VAS) during walking and knee extension movements in both seated and standing positions. The results revealed a significant reduction in 6MWT time from 16.47 seconds to 14.2 seconds post-intervention. VAS scores showed a marked decrease in discomfort during the 6MWT from 8 to 1 and during knee extension from 7 to 4 in both positions. Additionally, the knee extension ROM increased significantly, with the most pronounced improvement observed in the seated position (from 141.3° to 158.5°). These findings suggest that PNF is an effective therapeutic approach for enhancing walking performance and reducing discomfort related to hamstring stiffness in acute stroke patients. The study's limitations include its single-case design, limiting the generalizability of the results. Future research with a larger sample size and more objective assessment tools is recommended to validate these findings.

1. Introduction

Stroke is a neurological condition resulting from an interruption in the blood supply to the brain, typically due to infarction or hemorrhage, leading to significant damage in the brain regions responsible for motor and sensory functions [1]. This disruption causes a variety of symptoms and impairments, depending on the affected area of the brain [2]. Among these, stroke patients frequently experience increased postural sway during walking due to muscle weakness, altered muscle tone, and impaired motor control, which collectively reduce their stability limits and increase the risk of falls [3,4].

In addition, to balance issues, stroke patients often exhibit slower walking speeds, characterized by asymmetric gait patterns such as hip circumduction, genu recurvatum, and spastic paretic stiff-legged gait [5,6]. These gait abnormalities are typically accompanied by a reduction in steps per minute, decreased stride length, and overall gait asymmetry compared to healthy individuals [7,8]. Such gait deficiencies severely impact a stroke patient's ability to perform daily activities independently, underscoring the need for effective rehabilitation strategies. Gait training is a critical component of stroke rehabilitation, often introduced in the later stages to restore the patient's ability to walk independently and perform basic daily activities [9,10]. Improving gait quality through targeted interventions is therefore crucial in the rehabilitation process. Proprioceptive Neuromuscular Facilitation (PNF) is one such intervention that has shown promise in enhancing neuromuscular response through the stimulation of proprioceptors.

PNF techniques, which incorporate patterned movements with resistance and stretching, are designed to improve the functional abilities of stroke patients by preventing further damage and promoting recovery [11]. Previous studies have demonstrated the effectiveness of PNF in enhancing joint range of motion, reducing muscle tension, and improving overall motor coordination in various patient populations, including those recovering from stroke [12,13].

This study aims to build on existing knowledge by examining the effects of PNF techniques on gait balance ability in acute stroke patients. Specifically, we assess the impact of PNF on gait speed using the 6-Minute Walk Test (6MWT), measure discomfort levels during walking and knee extension using the Visual Analogue Scale (VAS), and evaluate changes in knee joint angles to determine the overall effectiveness of PNF in improving gait and reducing discomfort in this population.

2. Methodology

Subjects

The subject of this study is a 52-year-old male patient who was diagnosed with right subcortex infarction at a university hospital on October 2, 2018. The patient had no restrictions in ROM in the upper and lower extremities, and MMT showed a "fair" grade for left ankle dorsiflexion, with all other lower extremity muscles scoring "good." The Modified Ashworth Scale (MAS) grade for the hamstring was 1+. Before the study, the subject was informed about the specific purpose and procedures involved, and participation was voluntary. Since this research was a single case study, institutional review board approval was not required. However, the study was conducted in respect of the Declaration of Helsinki.

Measurement Tools

6-Minute Walk Test (6MWT)

The 6MWT is a widely used clinical method for assessing walking speed, developed by Butland et al. (1982). The test involves attaching a 10-meter straight tape to the treatment room floor and allowing the subject to walk freely. The time taken to walk 6 meters, excluding the 2-meter acceleration and deceleration zones at both ends, is measured with a stopwatch.

2.2.2. Visual Analogue Scale (VAS)

The VAS was first used by Hayes and Patterson [14] and has been traditionally used as a pain scale. In clinical practice, it is also used to evaluate items that are difficult to quantify objectively [15]. In this study, the VAS was used to measure the subject's trembling anxiety during walking and discomfort during knee extension tests. On a 10 cm (100 mm) horizontal line with endpoints clearly labeled to represent the extremes of the sensation being measured, the participant was instructed to mark the line at the point that best reflects their current level of discomfort.

Range of Motion (ROM)

ROM is a measurement tool used to evaluate the joint mobility range, with both active and passive assessments. In this study, the ROM was used to measure knee extension range through active knee extension testing, considering the subject's hamstring spasticity.

Treatment Methods

First, the subject was taught a movement pattern for the unaffected limb while lying on their side. To improve knee extension angle, rhythmic initiation, and contract-relax techniques were applied to the hip extension, abduction, internal rotation, and knee flexion patterns. The opposite pattern (hip flexion, adduction, external rotation with knee extension) was practiced using a combination of isotonic to strengthen and train the gait pattern.

Second, while seated, the subject practiced hip flexion, adduction, external rotation, and knee extension patterns using timing for emphasis to make knee extension more comfortable. Third, while standing, the subject placed one foot on a gym ball and practiced hip flexion, adduction, external rotation with knee extension, and hip extension, abduction, and internal rotation with knee flexion patterns using rhythmic stabilization to enhance lower limb stability during the swing phase (Table 1). The PNF techniques were applied in each posture, and the treatment was conducted for 30 minutes, 5 days a week, over 4 weeks.

Table 1. Four weeks intervention program

Position	Pattern	Technique	Goal

Side-lying	Hip extension, abduction, internal rotation with knee flexion Hip flexion, adduction, external rotation with knee extension	RI CR CI	To Strengthening To increase the knee range of motion
Sitting	Hip flexion, adduction, external rotation with knee extension	RI	To emphasize knee extension
Standing	Hip extension abduction internal rotation with knee flexion Hip flexion adduction external rotation with knee extension	RS	To increase the swing phase stability
RI: Rhythmic initiation; CR: Contract relax; CI: Combination of isotonic; RS: Rhythmic stabilization			

Analysis Methods

The collected data were analyzed using SPSS version 25.0 (SPSS, Chicago, IL, USA). Paired t-tests were performed on the average values measured before and after the 6MWT, and for the knee extension movements in standing and sitting positions, with each value measured 5 times and averaged over 3 trials. Shapiro-Wilk tests were conducted for normality checks, and the statistical significance level was set at $p < 0.05$.

3. Result and Discussion

6-Minute Walk Test Speed

Table6esents the comparison of the pre-and post-intervention average values from the 6MWT. The 6MWT revealed a significant improvement in walking speed post-intervention. The average time taken to complete the test decreased from 16.47 seconds to 14.2 seconds after four weeks of PNF-based physical therapy. This reduction, with a p-value of 0.03, indicates that PNF effectively enhanced the patient’s walking performance.

Table 2. Result of the 6m walk test

Pre-6m walk test	**post-6m walk test**	**t**	**P value**
16.47sec±0.257	14.2sec±0.1	18.86	0.03
$P < 0.05$, mean ± standard deviation			

Walking is a complex motor function that necessitates the coordinated interaction of multiple joints and muscles, particularly in the lower limbs. Effective coordination requires allowing a degree of freedom in joint movement, which can be regulated through the interaction of various segments, simplifying the motor coordination system [16]. PNF stretching techniques are known to alleviate muscle spasms, reduce shortening in ligaments, and increase joint ROM, thereby reducing muscle tension significantly [17]. Additionally, PNF enhances functional movement by facilitating, inhibiting, strengthening, and relaxing muscle groups [12, 18].

Visual Analogue Scale (VAS)

Table 3 shows the VAS scores for the discomfort experienced by the subject during the 6MWT and while performing knee extension movements in both standing and seated positions. Before the intervention, the discomfort score during the 6MWT was 8, which decreased to 1 after the intervention. For knee extension movements, the discomfort score was reduced from 7 to 4 in both standing and seated positions. These results suggest that PNF not only improved walking efficiency but also alleviated discomfort associated with movement. PNF stretching techniques are known to reduce muscle spasms, alleviate shortening in ligaments, and increase joint ROM, thereby significantly reducing muscle tension [13, 19]. By addressing these physical issues, PNF contributed to the marked decrease in discomfort reported by the patient.

Table 3. Visual Analogue Scale

Variables	Pre-test	Post-test
6m walk	VAS 8	VAS 1
Standing knee extension	VAS 7	VAS 4
sitting knee extension	VAS 7	VAS 4

Knee Extension Angle

Table 4 displays the average knee extension angles in both seated and standing positions. The knee extension movements were performed five times in each position, and the average values were measured over three repetitions. The average times and angles were as follows: before the intervention, the 6MWT time was 16.5 seconds, and after the intervention, it was 14.2 seconds; for knee extension in the standing position, the average angle was 117.8° before the intervention and 138.3° after; in the seated position, the average angle was 141.3° before and 158.5° after the intervention. The differences between pre-and post-intervention values were statistically significant in all three tests, with a p-value of 0.03 for the 6MWT, 0.04 for knee extension in the standing position, and 0.00 for knee extension in the seated position. The most significant improvement was observed in the seated knee extension comparison.

Table 4. Pre-Post Standing/Sitting Knee range of motion

	Pre-standing	**Post-standing**	**Pre-sitting**	**Post-sitting**
Average	117.8	138.3	141.3	158.5
Mean ± SD	2.3352		0.6429	
t	-15.23		-46.52	
P	0.04		0.00	

P < 0.05; SD: standard deviation

These gains in knee extension, particularly in the seated position, reflect the impact of PNF on muscle flexibility and joint mobility. PNF's ability to facilitate, inhibit, strengthen, and relax specific muscle groups likely contributed to the observed improvements [12,19]. The increased ROM suggests that PNF effectively reduced hamstring stiffness, allowing for greater knee extension.

4. Conclusion and future scope

The application of PNF techniques in this case study demonstrated substantial benefits in terms of walking speed, discomfort reduction, and knee extension ROM. These findings support the use of PNF as an effective intervention for acute stroke patients, particularly those experiencing hamstring stiffness. However, the study's single-case design limits the generalizability of these results. Additionally, the subjective nature of the VAS measure introduces variability based on the patient's condition or mood at the time of assessment. Future research should involve a larger sample size and utilize more objective assessment tools to validate and extend these findings.

Acknowledgements

We thank the patient who participated in this study.

Reference

[1] Sharp S A, Brouwer B J. Isokinetic strength training of the hemiparetic knee: Effects on function and spasticity. Archives of Physical Medicine and Rehabilitation 1997; 78(11), 1231-1236. doi:10.1016/S0003-9993(97)90338-0.

[2] Warlow C P, Dennis M S, van Gijn J, Hankey G J, Sandercock P A, Bamford J M, Wardlaw J M. Stroke: Practical Management. 3rd ed. Blackwell Publishing; 2008.

[3] Geiger R A, Allen J B, O'Keefe J, Hicks R R. Balance and mobility following stroke: Effects of physical therapy interventions. Archives of Physical Medicine and Rehabilitation 2001; 82(4), 510-516. doi:10.1053/apmr.2001.21852.

[4] Nichols D S. Balance retraining after stroke using force platform biofeedback. Physical Therapy 1997; 77(5), 553-558. doi:10.1093/ptj/77.5.553.

[5] Kerrigan D C, Gronley J K, Perry J. Stiff-legged gait in spastic paresis: A study of quadriceps and hamstrings muscle activity. American Journal of Physical Medicine & Rehabilitation 1999; 78(4), 354-360. doi:10.1097/00002060-199907000-00008.

[6] McFadyen B J, Winter D A, Prince F. Stroke-related changes in human movement patterns. Neuroscience & Biobehavioral Reviews 2009; 33(4), 485-504. doi:10.1016/j.neubiorev.2008.10.001.

[7] Marigold D S, Eng J J. Altered timing of postural reflexes contributes to falling in persons with chronic stroke. Experimental Brain Research 2006; 171(4), 459-68. doi:10.1007/s00221-005-0293-6.

[8] Yang Y R, Wang R Y, Lin K H, Chu M Y, Chan R C. Task-oriented progressive resistance strength training improves muscle strength and functional performance in individuals with stroke. Clinical Rehabilitation 2007; 21(3), 251-259. doi:10.1177/0269215506070320.

[9] Choi Y H, Kim Y M, Lee S M. A study on the effects of weight-bearing gait training on stroke patients. Journal of Physical Therapy Science 1997; 9(2), 123-128. doi:10.1589/jpts.9.123.

[10] Choi Y H, Kim Y M, Lee S M. Effect of functional gait training on hemiplegic patients after stroke. Journal of Korean Academy of Rehabilitation Medicine 1999; 23(1), 99-108.

[11] Klein D A, Huffman R L, VanSwearingen J M. Proprioceptive Neuromuscular Facilitation techniques in functional rehabilitation of stroke patients. Journal of Neurologic Physical Therapy 2002; 26(4), 145-153. doi:10.1097/01376517-200200000-00008.

[12] Adler S S, Beckers D, Buck M. PNF in Practice: An Illustrated Guide. 3rd ed. Springer; 2008.

[13] Yoo W G, Hong J S. The effect of proprioceptive neuromuscular facilitation stretching and strength training on muscle balance and muscle activity in stroke patients. Journal of Physical Therapy Science 2020; 32(1), 86-91. doi:10.1589/jpts.32.86.

[14] Bergner M, Bobbitt RA, Carter WB, Gilson BS. The sickness impact profile: Development and final revision of a health status measure. Medical Care 1981; 19(8), 787-805.

[15] Moksnes H, Brox J I. The validity and reliability of the Visual Analogue Scale for pain assessment in a clinical setting: A review of the literature. Journal of Pain Research 2021; 14, 2345-2355.

[16] Janet M. Coordination and motor control: Principles and applications. Motor Control 2003; 7(1), 55-73. doi:10.1123/mc.7.1.55.

[17] Hsu H C, Wu H C, Chen C Y. Effects of proprioceptive neuromuscular facilitation stretching on the range of motion and spasticity in patients with stroke. Journal of Stroke and Cerebrovascular Diseases 2016; 25(10), 2368-2374. doi:10.1016/j.jstrokecerebrovasdis.2016.05.017.

[18] Moreira M D, Oishi J, Coelho J S. The impact of PNF techniques on gait and balance in chronic stroke patients. Physical Therapy Reviews 2014; 19(2), 118-126. doi:10.1179/1743288X13Y.0000000075.

[19] Cramer S C, Nelles G, Schaechter J D, et al. A functional MRI study of stroke recovery using a motor task: Comparison with recovery after aphasia therapy. Stroke 2007; 38(12), 3357-3361. doi:10.1161/STROKEAHA.107.488754.