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Effectiveness Of Proprioceptive Neuromuscular Facilitation (PNF) Exercises Of Pelvis Versus Lateral Weight Shifting Exercises On Trunk Motor Control And Balance Among Post-Stroke Patients

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abstract
Background: *Stroke, a common neurological disorder resulting in a major cause of disability. Trunk control is a major prerequisite for stable balance and gait functions post stroke and it requires appropriate sensorimotor ability.*
Objective: *The objective is to find out the effectiveness of Proprioceptive Neuromuscular Facilitation exercises versus Lateral Weight Shifting exercises in post stroke patients on improving trunk control and balance. A total of 42 subjects, Group A - 21 subjects received Pelvic PNF exercises and Group B - 21 subjects received lateral weight shifting exercises 30 minutes / session / day for 5 days / week for 4weeks and in addition received conventional therapy for 60 minutes respectively.*
Outcome Measures: *Trunk Impairment Scale (TIS) and Tinetti Performance – Oriented Mobility Assessment (POMA).*
Results: *The calculated 't' value for Trunk Impairment Scale (TIS) in groups A and B, using the paired 't' test were 13.47 and 14.04; (P<0.05), and post-test score comparison between the groups using independent 't' test, were 3.46 (P<0.05). The calculated 't' value for Tinetti Performance – Oriented Mobility Assessment (POMA) in group A and B, using the paired 't' test were 18.24 and 15.91; (P<0.05), and post-test score comparison between the groups using independent 't' test, were 2.35 (P<0.05).*
Conclusion: *The results reveals that pelvic proprioceptive neuromuscular facilitation exercises were more effective than the lateral weight shifting exercises in improving the trunk motor control, balance, and gait functions in stroke patients.*
Keywords: *Lateral Weight Shifting, Trunk Control, Proprioceptive Neuromuscular Facilitation (PNF), Stroke, Trunk Impairment Scale (TIS).*

INTRODUCTION

Stroke, a prevalent neurological condition and a leading cause of adulty disability [1]. It poses a important health challenge, requiring continuous and comprehensive rehabilitation efforts [2]. Stroke morbidity rate is estimated about 73/100,000 population in India [3]. Hemiparesis is a muscle weakness of the body on one half of face, trunk, upper extremity, and lower extremity respectively [4]. Sensorymotor impairments of trunk affects functional performance following a stroke [5]. Stroke patients experience impairment in trunk muscles on both sides of their bodies [6]. In addition to the weakness of the muscles of the hemiplegic limbs, trunk muscles also exhibit impairment in multi-direction even after a unilateral stroke [7, 8].
An adequate level of trunk stability is required for balance and lower extremity functions for activities of daily living and higher-level tasks. The abdominal muscles require a stable attachment at the pelvis, thorax, or central aponeurosis, depending on the direction and which region of the trunk is being moved for optimal function [10]. The trunk is connected to the pelvis by which they together support the extensor movements. Pelvic motion is driven by the trunk muscles, as the pelvis movement patterns relies on the

extent of trunk motion [9]. The pelvic region allows the body to sustain momentum and adapt to shifts in weight playing a crucial factor in both static and dynamic postural adjustments [11]. Biomechanically, pelvic movement cannot occur without corresponding motion in the spine, as they are interconnected and the range of motion in pelvis and its movement patterns is influenced by the degree of movement in the lower spine [12].

The Pelvic Proprioceptive Neuromuscular Facilitation (PNF) facilitates the control of trunk and lower extremity motion and provide mobility and stability to trunk. Pelvis is regarded as a key point controlling and maintaining a proper pattern of gait. In addition, through principles of irradiation, these diagonal patterns help in improving functional activities of trunk and indirectly treat the functional impairments of the upper trunk & cervical areas [13].

Selective weight shifting ability in sitting and standing is essential to achieve basic functional tasks. Optimal postural adjustments with appropriate segmental alignment are achieved by training reaching in sitting or standing position. Improvements in motor control of trunk, proprioception, static balance, and dynamic balance is achieved by weight-shifting activities trained in sitting position in patients affected by stroke [14]. Balance in static sitting, balance during dynamic activities in sitting, and coordination of movements in sitting post stroke is assessed by the Trunk Impairment Scale (TIS), a 4-point ordinal scale, with high reliability, validity, and responsiveness [15, 16].

The Tinetti Performance Oriented Mobility Assessment (POMA), has two subtests - balance and gait, components which provides a brief and reliable evaluation of both static balance functions and dynamic balance functions. Balance components comprise sitting statically, standing ability from sitting, and balance while standing, gait components include initiation of gait, tracking the path while walking, missed steps, turning, and timed walking [17].

The study aims to investigate the effects of proprioceptive neuromuscular facilitation exercises of pelvis compared to lateral weight shifting exercises on motor control of trunk, balance, and gait functions in patients post-stroke, and to determine which intervention is more effective.

METHODOLOGY

A total of 42 hemiparetic participants were assigned to any one of the two treatment groups, group A and group B, using convenience sampling technique, in this pretest-posttest, comparative study design. Study participants were recruited from PSG Stroke Rehabilitation Centre (SRC), Physical Medicine and Rehabilitation (PMR) department, PSG Hospitals, Coimbatore. The criteria for inclusion were first-onset of unilateral stroke in both males and females, right and left middle cerebral artery infarct, 35 - 60 years of age, trunk impairment score 10 - 16 out of 23, post stroke duration 5 – 45 days, able to sit for 30 seconds without any support on bed with their feet touching the ground, not received any PNF treatment since 4 weeks, able to ambulate for a distance of 10 meters with or without walking aids, able to understand and follow verbal instructions and willingness to participate by providing informed consent. Exclusion criteria were, aphasia, other neurological and musculoskeletal disorders, mini mental scale < 20, history of major trauma for maximum of 6 months duration, medically unstable patients, and uncontrolled hypertension. 21 participants in Group A underwent 30 minutes session pelvic proprioceptive neuromuscular facilitation exercises along with 60 minutes conventional therapy and 21 participants in Group B underwent 30 minutes of lateral weight shifting exercises along with 60 minutes conventional therapy, for 5 days / week for 4weeks respectively.

Interventions

Pelvic Proprioceptive Neuromuscular Facilitation Exercises: For four weeks (five days per week), participants underwent three 10-minute PNF sessions—rhythmic initiation, slow (dynamic) reversal, and stabilizing reversal—with rest periods tailored to their comfort. All exercise was performed on the affected side with patient in side-lying position with hips at 100° flexion and knees at 45° flexion to promote anterior pelvic elevation and posterior pelvic depression. The therapist stood behind each patient; hands aligned with the pelvic movement plane: on the anterior superior iliac spines for elevation (cue: "pull up") and on the ischial tuberosities for depression (cues: "push down" and "sit into my hands"). After the patient achieved voluntary relaxation, rhythmic initiation progressed from passive to assisted, then active-resisted, and finally active movements. Slow reversal consisted of successive concentric contractions of the stronger

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agonists immediately followed by the weaker antagonists, whereas stabilizing reversal used alternating isotonic contractions against enough resistance to allow only minimal motion. Throughout, PNF procedural principles of position, manual contact, lumbrical grip, stretching, resistance, and verbal commands were followed.

Lateral Weight Shift Exercises: (i) Seated with Support: The patient is seated on a plinth with their feet providing a wide base of support on the floor. A table is placed in front of them at elbow height, providing a stable surface to rest their elbows. With their head in a neutral position, the patient performed 10 repetitions of lumbar flexion and extension. Next, patient used their unaffected arm to move a cone across the table, from the unaffected to the affected side, 10 times. They do this without shifting their base of support. Then, they move the same cone forward and backward on the table 10 times, again without changing their base of support. To increase the challenge, the patient uses their unaffected arm to reach for and place hoops over cones on the table. This is done from the unaffected to the affected side, and they are encouraged to reach as far as possible, which requires a change in their base of support. They repeat this 10 times. The patient finally does another 10 repetitions of lumbar flexion and extension. (ii) Reaching Without Support & Sit-to-Stand: The table is then removed, and the patient is asked to reach for hoops placed on the unaffected side of the plinth. This exercise requires a significant shift in their base of support and is repeated 10 times. Afterward, the patient reaches up to place the hoops on a stand in front of them that is at a height requiring a full arm extension. This is repeated 10 times. The entire procedure is then repeated with the stand positioned on the affected side for 10 repetitions. The table is returned, and the patient places their hands on it for support while performing 10 repetitions of sit-to-stand. (iii) Activating the Affected Side: The patient uses their affected hand to move cones on the table from the unaffected side to the affected side 10 times. Finally, they use their affected hand to move the cones forward and backward on the table 10 times, staying within their base of support. All these exercises were carried out for 5 days per week for 4 weeks.

Conventional Therapy: Functional exercises and task-oriented exercises for upper and lower extremities (Bed mobility training - turning, rolling, lying to sitting to lying; Balance training; Mobility training (sitting to standing to sitting, walking); Upper limb training (lifting, reaching, grasping, releasing). Participants in both groups underwent 60 minutes of conventional exercise therapy sessions for 5 days per week for 4 weeks.

Outcome Measures

Trunk Impairment Scale (TIS) to assess the trunk motor control and Tinetti Performance - Oriented Mobility Assessment (POMA) Scale to assess the static and dynamic balance respectively.

Method of Data Collection and Analysis

The Trunk Impairment Scale (TIS), Tinetti Performance - Oriented Mobility Assessment (POMA) Scale scores were obtained with a time duration of 30-40 minutes per patient. The collected data were analyzed using a paired 't'-test to assess changes in outcome measures from pretest to posttest within the group and independent 't' test was employed to analyze and compare changes between the groups A and B. Analysis of data was done using the SPSS software version 16.0.

RESULTS

The data of 42 stroke patients were evaluated and the values of mean, standard deviation, percentage were found out.

Table 1 represents the gender distribution of patients with 46 men and 12 women representing 76.2 % and 23.8 % respectively.

Table 1. Descriptive Statistics of Gender Distribution of Patients

GENDER OF PATIENTS	COUNT	PERCENTAGE (%)
MALE		
Group A	17	40.48 %
Group B	15	35.72 %
FEMALE		

Group A Group B	4 6	9.52 % 14.28 %
TOTAL	42	100 %

Table 2 displays the descriptive statistics for the study participants in both the groups for mean. Age, height, weight BMI, duration, and side of hemiparesis.

Table 2. Descriptive Characteristics of Stroke and Outcome Measures of Patients

Variables	**Mean and Standard Deviation (SD)**	
	Group A	**Group B**
AGE	53 ± 6.1	56 ± 5.8
BMI	26.34 ± 4.2	27.76 ± 3.6
DURATION	27 ± 13.24	29 ± 11.12
RIGHT SIDE HEMIPARESIS	12	11
LEFT SIDE HEMIPARESIS	09	10

Table 3 presents the Trunk Impairment Scale scores for participants in groups A and B, indicating a difference in the pre and post treatment mean score for the experimental group 7.05 and for the control group 4.81 respectively. Calculated 't' value from the paired 't' test for groups A and B were very significant with values of 13.47 and 14.04 respectively, P<0.05. Between group comparison for the post-treatment score for groups A and B were very significant with a calculated 't, value of 3.46, P<0.05.

Table 3. Trunk Impairment Scale (TIS) comparison pre & post treatment between group A and group B

Trunk Impairment Scale (TIS)	**Group A**	**Group B**	**Post test comparison between Group A and Group B**
Pre-treatment score	11.14 ± 1.0	11.23 ± 1.1	
Post-treatment score	18.19 ± 2.2	16.04 ± 1.8	
't' value	13.47	14.04	3.46
P value	<0.05	<0.05	<0.05

Table 4 presents the Tinetti Performance-Oriented Mobility Assessment (POMA) scores for participants in groups A and B, indicating a difference in the pre and post treatment mean score for the experimental group 4.95 and for the control group 3.57 respectively. Calculated 't' value from the paired 't' test for groups A and B were very significant with values of 18.24 and 15.91 respectively, P<0.05. Between group comparison for the post-treatment score for groups A and B were significant with a calculated 't' value of 2.35, P<0.05.

Table 4. Tinetti Performance-Oriented Mobility Assessment (POMA) comparison pre & post treatment between group A and group B

Tinetti Performance-Oriented Mobility Assessment (POMA)	**Group A**	**Group B**	**Post test comparison between Group A and Group B**
Pre-treatment score	15.52 ± 1.6	15.23 ± 1.8	
Post-treatment score	20.47 ± 2.4	18.80 ± 2.2	
't' value	18.24	15.91	2.35
P value	<0.05	<0.05	<0.05

The results from the statistical analysis shows that the pelvic proprioceptive neuromuscular facilitation exercises were more effective when compared to lateral weight shifting exercises on improving trunk motor control and balance among stroke patients.

DISCUSSION

Most studies in rehabilitation of stroke focuses on functional recovery of upper limb and lower limbs. Our focus was in regaining the motor control of trunk and the present study aimed at finding the effects of Proprioceptive Neuromuscular Facilitation (PNF) exercises of pelvis on motor control of trunk, and balance in patients post-stroke. Improvements in trunk motor control, balance, and gait functions as assessed using Trunk Impairment Scale (TIS) and Tinetti Performance-Oriented Mobility Assessment (POMA), noted in both the groups, which were statistically significant. The improvements were much higher and statistically significant in the group which received PNF therapy and conventional physiotherapy than the group which received lateral weight shifting exercises and conventional physiotherapy.

The improvements in lateral weight shift exercises group which is a form of selective trunk training could be because of repetitive and intense training of the participants in which they did exercises in which trunk lateral bending were incorporated to touch the plinth with elbow & returning to the start position with trunk erect. Above implemented exercises focus on selective movements of the trunk which improved the overall coordination and strength of the trunk and pelvic muscles. The improvement in stroke patient's muscular strength and functions, which enhances functional motor recovery, results from multiple mechanisms such as engaging in motor skills practice which enhances sensorimotor representation, affecting both cortical and subcortical levels, ultimately influencing spinal motor-neuron pools resulting in an increased recruitment and firing rates within these pools [18].

Results from a review on trunk training after stroke stated that selective-trunk training may be beneficial for improvements in the trunk function, standing balance and walking ability post stroke with more beneficial effects observed in walking ability across many trails. The review emphasizes the importance of consistently integrating trunk training into clinical practice for individuals with stroke during the subacute phase (2 weeks – 6 months), as well as during the chronic phase (> 6 months) [19].

The pelvic proprioceptive neuromuscular facilitation exercises resulted in stimulation of the proprioceptors thereby facilitating the neuromuscular control mechanism and optimizing trunk motor control improvements. Functional recovery in stroke patients following pelvic PNF therapy is because it induces affected extremity usage voluntarily to the maximum potential, there by promoting the affected side and unaffected side symmetry by using diagonal movements [20]. Facilitation of neuromuscular system is achieved by irradiation induced by combination of many factors such as movement patterns, stretch application, and maximal resistance application.

Verheyden et al., noted that enhancement of trunk functions had a positive impact on performance of speech, breath, upper limb, balance, and gait functions. The Trunk Impairment Scale (TIS) is an effective tool for assessing impairments in trunk motor control in post-stroke patients. One of its key advantages is that it assesses patients in a sitting position, which is feasible during the acute phase after a stroke. Additionally, the TIS allows for tracking progress and aids in planning subsequent therapy in various stages [21].

The present study found out improvements in the performance of trunk as measured using Trunk Impairment Scale (TIS) in terms of balance in static sitting, balance during dynamic activities in sitting, coordination in sitting activities, maintaining and changing the postures and in gait which are measured by the ability to perform movements such as symmetrical rotation of trunk, trunk flexion-extension, trunk lateral flexion, and trunk rotational movement [22]. The pelvic proprioceptive neuromuscular facilitation exercises group showed more statistically significant improvements than the lateral weight shift exercises group.

This is attributed to the performance of pelvic diagonal pattern movements using rhythmic initiation, slow reversal and stabilizing reversal techniques which normalized the trunk muscles tone on the affected side, lengthening of the contracted tissues, relaxation of the hypertonic muscles, initiation of trunk movements on affected side, strengthening weak muscles, and improving the pelvis motor control [23]. Knott and Voss stated this as "hidden potentials" for recovering patients [24]. Neuro-physiological mechanism such as autogenic inhibition, reciprocal inhibition, and stress relaxation is primarily responsible for increasing the

trunk range of motion, motor control of trunk and neuromuscular efficiency [25]. This finding is further corroborated by a study conducted by Benecke et al., where the authors noted that increased sensory input signals from peripheral regions in the PNF position resulted in alterations in pyramidal tract excitation and the descending final common motor pathways when compared to other positions [26].
Stroke patients usually have asymmetrical movement of pelvis with little or no lower trunk control affecting balance and gait [27]. The results for the balance and gait functions measured using Tinetti Performance-Oriented Mobility Assessment (POMA) showed a significant statistical improvement in the pelvic proprioceptive neuromuscular facilitation exercise group than the lateral weight shift exercises group, suggesting that the functions of muscles when performing pelvic proprioceptive neuromuscular facilitation exercises were like the functional movements while performing various activities or tasks of daily living. There was a carryover effect in static and dynamic balance from the improvements in trunk motor control by initiating movement from a proximal to distal direction with pelvic diagonal pattern exercises. The improvements in the gait components for step symmetry and heel contact while walking was little to moderate in participants who received pelvic proprioceptive neuromuscular facilitation exercises whereas the participants in the trunk lateral weight shift exercise group show little to moderate improvements in step symmetry, heel contact while walking, trunk sway and gait deviations while walking. Thus, pelvic anterior elevation and posterior depression which is an integral pattern when considering gait swing along with various techniques of PNF such as rhythmic initiation, slow reversal, and stabilizing reversal, facilitated trunk and influenced the lower extremity functions [12, 20] in our study. This aligns with the research findings by Trueblood et al., in which PNF-based resistance exercises for pelvic movements targeted at lower trunk muscles led to improvements in walking among participants in the early phase of stroke recovery [28].
Absence of long-term patient follow up to assess any carry over effects for intervention was one of the studies limitations and no outcome tools were employed in this study to measure the weight distribution symmetry and truncal asymmetry. Future randomized control trail with large number of participants using outcome tools such as Isokinetic Dynamometer, Electromyography and Force plate sensors can be carried out to find out quantifiable improvements in trunk motor control and in balance and gait functions.

CONCLUSION

Incorporating pelvic proprioceptive neuromuscular facilitation exercise interventions during stroke rehabilitation has a beneficial effect by positively impacting motor control of trunk, balance in static sitting, balance during activities in dynamic sitting, and gait functions in stroke-affected patients. The results from the study recommends that Proprioceptive Neuromuscular Facilitation exercises can be added to the rehabilitation protocol to accelerate functional recovery.

CONFLICT OF INTEREST

The authors declare that there are no potential conflicts of interest that might have impacted the research presented in this paper.

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