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Combined Effect of Pelvic Proprioceptive Neuromuscular Facilitation and Core Strengthening on Trunk Control, Balance, and Gait in Individuals with Paraplegia

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ABSTRACT

Background: Paraplegia causes substantially reduced motor and sensory functions in the lower limbs and insufficient control over the trunk and pelvis. Regulating one's trunk and pelvis is essential for balance and gait. However, among people with paraplegia, poor trunk and pelvic control is a crucial risk factor for immobility and a worsened quality of life (QoL). Despite conventional methods for enhancing trunk and pelvic control, there is a lack of standardized techniques to improve trunk and pelvic control for SCI patients. So, the present study aims to evaluate the combined effects of pelvic proprioceptive neuromuscular facilitation and core strengthening on trunk control, balance, and gait in paraplegic patients.

Methods: A quasi-experimental study involving 17 participants (13 males, 4 females) with subacute paraplegia having the neurological level of injury (T6-T12) with ASIA Impairment Scale (ISNCSCI) grades B and C. Intervention was given to the participants for 45 minutes per session, five times/week for four weeks. Before and after the intervention, the participant's performance was assessed using the trunk control test for SCI, the Berg Balance Scale, the SCI-FAI, and the Walking Index for Spinal Cord Injury II (WISCI).

Results: After four weeks of intervention, the comparison between the pre-and post-intervention outcomes of the Trunk Control Test (p=0.001), BBS (p=0.001), SCI-FAI (p=0.001), and WISCI (p=0.001) showed significant differences.

Conclusion: The current study concluded that pelvic PNF combined with core strengthening effectively improved trunk control, balance, and gait in subacute paraplegic patients. Both interventions are safe to perform.

Keywords: Balance, core strengthening, gait, paraplegia, proprioceptive neuromuscular facilitation.

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INTRODUCTION

Paraplegia is a worldwide healthcare issue that leads to mortality and morbidity [1]. Approximately 20,000 new cases are recorded annually in Haryana, India, with 60 to 70 percent of the poor, young, and primary income producers in their families [2]. Youthful males between 20 and 35 make up most SCI patients [3]. The well-being (QoL) and sovereignty of paraplegic individuals are severely compromised by the restriction in activities caused by poor sitting balance, which is essential to implement daily activities and vocational tasks [4]. Traumatic and non-traumatic SCI are considered debilitating states with motor, sensory, bowel, and autonomic dysfunctions, with a prevalence of paraplegia varying between 18% and 91.97% [5]. In developing countries, higher numbers of paraplegic cases have been reported as compared to people with quadriplegia [6].

Previous prognostic studies show that the components of sitting balance are crucially missing in patients with spinal cord trauma [7]. Although physiotherapy interventions for trunk-pelvic control for individuals with SCI were neglected in past literature, pelvic Proprioceptive Neuromuscular Facilitation (PNF) helps stimulate muscle and joint proprioceptors to improve pelvic stability for maintaining trunk control, balance, and gait in individuals suffering from spinal cord injuries [8]. The trunk and pelvic muscles form the core musculature, which helps maintain spinopelvic stability. It includes anterior abdominal muscles, posterior paraspinal muscles, and the diaphragm, which acts as a roof. In contrast, the musculature of the pelvis and hip girdle constitute the base of the core musculature [9]. Recent research has demonstrated that the central nervous system begins the contraction of the multifidus and abdominal muscles in a feed-forward way before the prime mover of the lower limb for spinal stability [10]. Following contralateral weight shifting, the transverse abdominis is the first muscle that typically contracts during lower limb motions [3]. According to studies, paraplegic individuals who acquire core training have improved static and dynamic balance [11].

Individuals with SCI are frequently given systemic pharmacological treatment for paraplegia, which includes corticosteroids, gangliosides, and neurobions like methylprednisolone, sodium succinate, cyanocobalamin, and nicotinamide. These medications can potentially cause side effects like nausea, vomiting, withdrawal seizures, and hallucinations, and no single drug has been proven effective in all patients [12]. As part of a long-term regimen alongside surgical and pharmaceutical therapies, rehabilitation has been recognized as essential in trunk and pelvic control therapy. Enhancing trunk and pelvic control will enable patients to perform ADLs, including transfers, dressing, restroom use, and working independently [12].

Pelvic proprioceptive neuromuscular facilitation and core strengthening are currently used to improve trunk and pelvic control among those with neurological conditions like stroke. Pelvic proprioceptive neuromuscular facilitation refers to a collection of fundamental methods that strengthen and increase the flexibility of the neuraxis and musculature and move joints slowly and rhythmically to stimulate the spinal column and peripheral nerves [13]. The PNF method's principal objective is to use the neurophysiological concepts of the sensorimotor system for the physical assessment and therapy of neuromuscular disorders. This technique provides therapists with a helpful tool for identifying and treating neuromuscular dysfunctions.

We hypothesize that adding pelvic proprioceptive neuromuscular facilitation to core strengthening will assist paraplegic patients in improving their core stability to achieve trunk control and controlled motion to enhance balance and gait.

METHODS

1. Participants

This single-group pretest-posttest quasi-experimental study was accomplished at the Maharishi Markandeshwar Institute of Medical Sciences and Research, Mullana-Ambala, between June 2022 and March 2023. Eighteen patients were subsequently enrolled after receiving approval from the institution's research and ethical committee (Maharishi Markandeshwar Institute of Medical Sciences and Research #IEC/2022/2230). According to the inclusion and exclusion criteria, we enrolled 18 people with paraplegia with traumatic SCI in our research. Following their agreement to participate in the study, the individuals were chosen from the institute's rehabilitation department. One individual was left out (after four days of therapy owing to their incapacity to finish the trial). In contrast, the other 17 participants (15 incomplete and two complete spinal cord injuries) completed the intervention. According to the inclusion/exclusion criteria, each participant received the intervention.

Both males and females between 20 and 60 years of age, a person with spinal column trauma between T6 and T12 levels according to the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) to subside autonomic dysreflexia, individuals with both traumatic and non-traumatic spinal cord injuries, those who are oriented and alert, and those who have complete or incomplete paraplegia; those with non-progressive SCI and who provided informed consent were recruited for the study [13]. Individuals with any form of cognitive impairment, any form of cardiac dysfunction, any form of neurological disability, those with musculoskeletal disorders of the upper and lower extremities, those with traumatic brain injury, recent onset or worsening neurological signs, and those who did not consent for follow-up were eliminated from the research.

2. Intervention

All subjects received thorough explanations of the trial and comprehensive patient information sheets. All participants in the research provided their written, informed permission. The Clinical Trials Registry-India (CTRI/2022/09/045965) was used for the research protocol.

The International Spinal Cord Injury Core Data Set form, ISNCSCI, was used to assess the neurological level of the SCI, and an evaluation proforma was used to gather demographic information, neurological findings, and pre-intervention characteristics (Table 1).

The physiotherapy management focused on improving trunk and pelvic control, which should help improve balance and gait in paraplegic individuals. The pre-intervention assessment was performed using the Trunk Control Test for SCI to examine trunk and pelvic control, the Berg Balance Scale (BBS) to examine balance, the Walking Index for Spinal Cord Injury II (WISCI), and the Spinal Cord Injury Functional Ambulation Inventory (SCI-FAI) to examine the gait of paraplegic individuals. Therefore, the participants who had complete or incomplete paraplegia received pelvic PNF with core strengthening, which consists of an anterior elevation-posterior depression movement pattern for pelvic PNF and quadruped tummy tuck-in and medicine ball rotations for core strengthening, followed by prevention of secondary complications.

Pelvic Proprioceptive Neuromuscular Facilitation

The movement pattern used was anterior elevation and posterior depression on either side. The subjects were told to lie on their sides with their knees bent at a 45° angle and both hips flexed at an angle of 100°. A cushion supported the neck at a 30° angle (Figs. 1A, 1B). The therapist faced the subject's head while standing behind them. The therapist's hands were placed on the anterior iliac spine for anterior elevation and the ischial tuberosity for posterior depression. After the lengthening of the targeted muscles but before the subject's accessory movements, a stretch was performed. The use of resistance produced fluent and well-coordinated motions. The therapist also assisted whenever the subject requested it. The patients were given precise and desired orders to promote desirable pelvic motions. The instructions "pull up" and "push down" or "sit into my hands" were employed to encourage pelvic elevation and depression, which is seen anterior-posteriorly.

The intervention comprises the core components of PNF, including manual touch, posture, resistance, and vocal directions. The three principal approaches applied for intervention were slow reversal, agonistic reversals, and rhythmic initiation. The succession was as follows: rhythmic initiation, slow reversal, and agonistic reversal, each for 10 minutes, with a 2-minute rest interval between every approach. The timing was kept via stopwatch [13]. Each session involved pelvic PNF with a movement pattern alternating between anterior elevation and posterior depression. It lasted 30 minutes and occurred five times a week for four weeks. After that, rhythmic initiation, slow reversals, and agonistic reversals were performed for 10 minutes each, with a 2-minute break between each technique [13].

Core Strengthening

In this study, core strengthening focused on the transverse abdominis muscle and involved medicine ball rotation (Fig. 1D). In the quadruped position, the individual was instructed that they should carry out a tummy tuck-in along with tilting their pelvis posteriorly (Fig. 1C). The therapist maintained the pelvis in a neutral position to prevent an imbalance in the participant's posture. In each session, we instructed the patient to perform a tummy tuck in a quadruped position for ten repetitions x 2 sets with a 30-second hold. A medicine ball rotation was given for 3-5 minutes. The interventions were performed for over four weeks; five sessions of 15 minutes each were performed, making a total of 45 minutes of intervention per session [14].

Participants in a previous study on hemiplegics also indicated positive results and long-lasting benefits in the trunk and pelvic control with pelvic PNF and core strengthening, which also factored into the decision to extend this intervention for future studies [9].

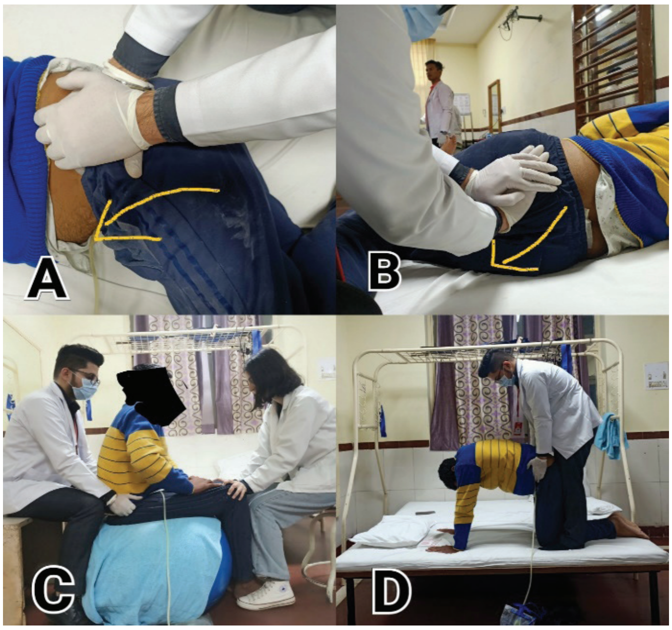

Figure1: 1A: Anterior Elevation; 1B: Posterior Depression; 1C: Quadruped Tummy Tuck-in; 1D: Medicine Ball Rotations. Arrows depict the direction of the force.

3. Outcome measures

The outcome measure to determine the neurological level of injury (NLI) was the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI). Pre- and post-intervention assessments were based on trunk control tests for SCI, Berg Balance Scale (BBS), Spinal Cord Injury Functional Ambulation Inventory (SCI-FAI), and Walking Index for Spinal Cord Injury II (WISCI).

3.1 International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI)

The ISNCSCI is a classic scale to identify the neurological level of injury (NLI) and confirm whether the patient is suffering from an incomplete or complete spinal cord injury [15].

3.2 Trunk Control Test for SCI

The trunk control test is a 13-item scale that measures the static and dynamic equilibrium of the patient to assess the stability and tendency of the trunk and pelvic control to carry out activities with the upper and lower limbs. The scoring is performed on a scale of 0-2 (where 0 denotes not done and four denotes done without support). The total score for 13 items is 24. The scale has good reliability (α=0.979) [16].

3.3 Walking Index for Spinal Cord Injury II (WISCI)

The WISCI is a numeric scale that measures the amount and type of assistance (along with orthoses and supporting devices like walkers, crutches, etc.). There are 20 levels of WISCI, out of which Level 0 denotes full assistance, and Level 20 denotes no assistance. The levels are assessed based on four parameters: devices, braces, assistance, and patient-reported comfort level. The scale has good reliability (α=0.982) [17].

3.4 Spinal Cord Injury Functional Ambulation Inventory (SCI-FAI)

The SCI-FAI is a universally accepted functional outcome scale to measure gait in patients with SCI. The SCI-FAI is a 4-item scale that includes various parameters to assess ambulatory function among spinal cord injury patients. The total score for four items is 39. The scale has good reliability (α=0.960) [18].

3.5 Berg Balance Scale (BBS)

The BBS was initially created to assess balance in elderly and SCI patients, but it has now been applied to a wide range of patients. It consists of 14 items, all scored between 0 and 4, adding to a maximum rating between 0 and 56; a higher score denotes better balance. The internal consistency for the scale is α=0.98 [19].

4. Statistical Analyses

Using IBM SPSS version 29.0 (IBM Corp., Armonk, NY, USA), the data were all analyzed. The data are introduced in the median (interquartile range). The Shapiro-Wilk Test was used to inspect the normal distribution among the measurements [13]. Wilcoxon signed-rank test was accustomed for within-group analysis. A p-value of ≤0.05 was used to determine statistical significance, and the confidence interval's value was 95%.

RESULTS

The study had a total of 17 participants. The research population's demographic characteristics are summarized in Table 1. As summarized in Table 2 and Figure 2, our findings revealed significant differences within pre- and post-intervention scores of the Trunk Control Test for trunk control, the Berg Balance Scale (BBS) for balance, the Spinal Cord Injury Functional Ambulation Inventory (SCI-FAI), and the Walking Index for Spinal Cord Injury II (WISCI) for gait.

Table 1: Demographic details of the participants

Characteristic	Participants
Age (year)	40.94±13.65*
Time since injury (months)	2.85±2.22*
Gender	
Males	13
Females	4
Neurological Level	
T6	4
T7	3
T8	3
T9	4
T10	-
T11	2
T12	1
AIS	
AIS A	-
AIS B	4
AIS C	13
AIS D	-

AIS: American Spinal Injuries Association

*Mean ± Standard Deviation

Table 2: Comparison of difference between pre-and post-intervention scores

Variables	Pre-Intervention [Median (IQR)]	Post-Intervention [Median (IQR)]	Z-value	p-value
TCT	4.000 (4.50)	9.000 (5.50)	-3.646	0.001*
WISCI	1.000 (1.00)	2.000 (1.00)	-3.900	0.001*
SCI-FAI	4.000 (4.00)	9.000 (6.50)	-3.575	0.001*
BBS	0.000 (2.50)	5.000 (6.00)	-3.532	0.001*

IQR: Interquartile Range; *p≤0.05

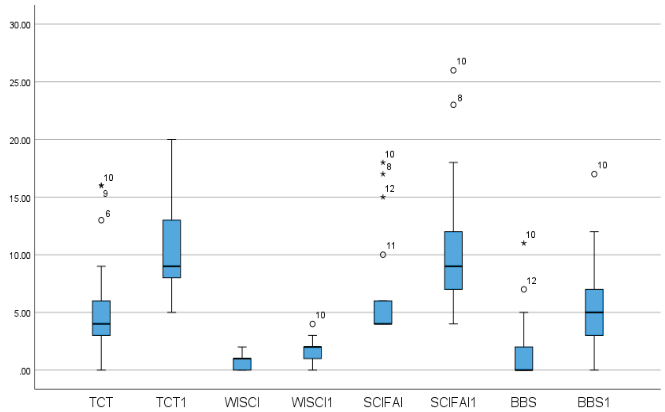

Fig.2: Box and Whiskers plot showing Median (IQR) of the Trunk Control Test (TCT), Walking Index for Spinal Cord Injury (WISCI), Spinal Cord Injury Functional Ambulation Inventory (SCI-FAI), and Berg Balance Scale (BBS) between pre-and post-intervention scores.

*TCT: Trunk Control Test (Pre); TCT1: Trunk Control Test (Post); WISCI: Walking Index for Spinal Cord Injury (Pre); WISCI1: Walking Index for Spinal Cord Injury (Post); SCI-FAI: Spinal Cord Injury Functional Ambulation Inventory (Pre); SCI-FAI1: Spinal Cord Injury Functional

Ambulation Inventory (Post); BBS: Berg Balance Scale (Pre); BBS1: Berg Balance Scale (Post).

DISCUSSION

This is the first study to show how core strengthening and pelvic proprioceptive neuromuscular facilitation (PNF) improve trunk control, balance, and gait in people with paraplegia. According to the ASIA impairment scale (ISNCSCI), the patients were suffering from incomplete paraplegia at the T6-T12 neurological level of injury. Our study showed improvements in trunk control, balance, and gait after administering pelvic PNF and core strengthening for four weeks. In a previous study, the same intervention, i.e., pelvic PNF combined with core strengthening, was given to chronic stroke patients for four weeks, whereafter significant improvements were observed in trunk control, balance, and gait. During previous studies, the participants did not have paraplegic backgrounds and were representatives of stroke patients [13]. In our study, improvements in trunk control were observed after training pelvic proprioceptive neuromuscular facilitation because the amount of force-field support provided by the trunk and pelvis directly affects how the center of pressure and pelvis move. This enables individuals with musculoskeletal and sensorimotor impairments, such as spinal cord injuries, to focus on higher-level rehabilitation goals set by their therapists [20]. The development of pelvic control can be attributed to the insertion of trunk musculature on the pelvis, as it provides a support base for the core musculature [13]. Core muscles, such as the transverse abdominis, internal abdominal oblique, quadratus lumborum, rectus abdominis, and pyramidalis, include both pelvis and trunk musculature and are essential for the preservation of spinal and pelvic strength, which in turn will help to transfer energy from the large to the small body segments in the course of activities of daily living (ADLs) [9]. The improved trunk performance, as determined by TCT, was evidence of the advantages of pelvic stabilization training. In the sitting position, the pelvis functions biomechanically as a portion of the lower trunk, maintaining dynamic stability while performing lateral and forward weight shifts. When an individual needs to perform seated lateral flexion and rotation of the trunk motions, the lower trunk and pelvis must have more dynamic stability [21]. The capacity to regulate how the trunk moves over the pelvis and lower limbs is a requirement for core stability to stabilize the spine. Core stability was thought to boost strength and allow for the best force output and control of lower-limb motions. [22]. Moreover, the selective contraction of the muscles in the lower trunk and proximal hip has decreased the excessive co-contraction and stiffness of the muscles in the lower limbs that are most affected, possibly reversing the usual movement patterns [23].

Gait training and balance are crucial areas for functional motions, and the core serves as the anatomical foundation for the mobility of distal components [24]. The other significant elements for gait performance are increased trunk portion propulsion and lateral pelvic expulsion within the stance phase, which are trained by pelvic PNF [25]. Enhanced pelvic stability is another phenomenon that can result in better gait speed, cadence, stance control, and limb advancement. Core strength is a fundamental part of this complicated process. For balance and gait, a multifaceted interaction between the central, peripheral, motor, and sensory structures is required. All these can be achieved with an increase in core strength. In a recent study, the effect of core strengthening combined with conventional physiotherapy was observed among people with paraplegia, and significant improvements were recorded in the study [14]. In our study, clinical and significant improvements in core strengthening with pelvic PNF were appreciated, which further helped enhance trunk control, balance, and gait in individuals with paraplegia. It could have been improved by simultaneously recruiting more muscle cells and correspondingly more physical impulses [24, 25].

These findings imply that if self-reported ratings indicate recovery and function, then improvements in such scores are only likely to be seen if the participants have undergone regular physiotherapeutic intervention in the given period. Recovery and improvement in trunk control, balance, and gait were demonstrated by outcome measures, such as the Trunk Control Test for SCI, Spinal Cord Injuries Functional Ambulatory Inventory (SCI-FAI), Walking Index for Spinal Cord Injury (WISCI), and Berg Balance Scale (BBS), through self-reported subjective index scores. Reduced trunk and pelvic control affect balance and gait during sitting, standing, and conducting ADLs, which raises the possibility of developing secondary problems and a lack of functional independence. The use of pelvic PNF combined with core strengthening for people with paraplegia is conceivable, and more extensive prospective studies should be conducted to confirm their effectiveness and advantages [16]. This investigation led us to conclude that pelvic PNF combined with core strengthening might effectively enhance trunk control, balance, and gait in people with paraplegia.

The functional integrity of trunk and pelvic control that has been compromised by spinal cord injury must be continuously monitored, and follow-up care must include patient education. Although this study has many strengths, there are certain limitations. First, SCI instances, including both traumatic and non-traumatic events, were considered. Therefore, our results cannot be generalized to a single domain. Second, we performed a short-term follow-up. The patient's early participation in the physiotherapy intervention helped to prevent the worsening of signs and symptoms and secondary complications. The early participation of spinal cord injury patients yielded higher chances of recovery. This study also suggests that if the intervention is followed for four weeks, five days a week, the patients will gain early recovery. There is a need to implement interventions for people with paraplegia to enhance trunk control, balance, and gait.

This experimental study has some limitations. First, there was no comparison with the control group owing to the smaller number of participants with paraplegia. Second, it was a single-centered study. Third, there are unavoidable errors in human observation. Fourth, the specific neurological level of injury patients was not considered due to the low prevalence rate. Fifth, the long-term effects of pelvic PNF and core strengthening were not determined.

CONCLUSION

The findings suggest that pelvic PNF and core strengthening synergistically impact patients' trunk control, balance, and gait. An improved core offers a solid foundation for movements of the trunk and lower limbs. Since no special equipment is needed, the administration is simple. We, therefore, reject the null hypothesis that core strengthening and pelvic proprioceptive neuromuscular facilitation have no discernible impact on paraplegics' trunk control, balance, and gait. The alternative hypothesis has, therefore, been confirmed to be appropriate.

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The first author planned the evaluations and assessments, examined the data, and created the manuscript. The second author participated in the research planning, while the first and second authors revised the manuscript.

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