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Effectiveness of Neurodevelopmental Therapy on Pelvic Alignment, Trunk Control, and Gait Parameters in Chronic Stroke Individuals: A Randomized Controlled Trial

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ABSTRACT

Background: Stroke is a common neurological disorder that is exclusively due to vascular causes and is characterized by the quick onset of localized disturbance of brain function that results in death and disability. The pelvis is considered the key structure connecting the torso and the lower extremities. Hemiparesis results in pelvic instability, hence poor trunk and gait performance.

Methods: The study followed a single-blinded randomized controlled trial in which 28 patients, 10 males and 18 females, diagnosed with stroke were enrolled. Participants were randomly distributed into two groups. In which Group A was administered with both Neurodevelopmental and conventional therapy, and Group B received conventional therapy. Participants received the intervention 5 days each week for 4 weeks. Pelvic disparity was measured with a palpation meter, trunk control with the trunk impairment scale, and Gait parameters such as Cadence, Stride length, and Gait velocity were assessed before and after the treatment period.

Results: Showed that between the group and within the group, there was a statistically significant difference (P <0.05) in trunk control, pelvic disparity, and cadence among the experimental and the control group.

Conclusion: This study emphasizes the role of pelvic alignment, which has been relatively unexplored in prior research, despite its crucial contribution to gait and postural stability. Hence, addressing the pelvic alignment in stroke rehabilitation could enhance overall functional recovery, suggesting a broader scope for integrating pelvic control in future therapeutic approaches.

Keywords: stroke rehabilitation, hemiparesis, pelvic asymmetry, postural control, trunk control, gait impairment.

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INTRODUCTION

Stroke is a severe worldwide health condition that causes a person's physical and mental health to deteriorate overall, leading to social isolation. Common issues that stroke victims face include weakness, balance issues, postural adjustment issues, and spasticity, which can become obstacles in social situations [1]. Stroke is a significant issue in Asia because of its impact on declining quality of life and its higher average death rate compared to Europe, America, and Australia. With the majority residing in emerging nations, Asia accommodates a significant portion of the world's population. In lower-middle-income countries, strokes accounted for 87% of stroke-related mortality and 70% of stroke incidence [2].

Patients who have had a chronic stroke frequently have poor balance control, which impairs their capacity to walk on their own and perform daily tasks. Limited movement and deficiencies in motor control are the most well-known disabilities. The primary cause of impaired balance and gait in chronic stroke patients is spasticity [3].

Common stroke symptoms include stiffness, exhaustion, and loss of balance on the affected side, as well as gait impairment that makes it challenging to maintain postural alignment. Paralysis is among the most common issues that arise after a stroke. When a stroke occurs, paralysis usually affects the opposite side of the brain. The entire side of the body, the face, the upper or lower limb, or even one leg may be impacted [4].

Common deficits following a stroke include fatigue, loss of balance, and stiffness on the affected side. Gait impairments that make it difficult to maintain postural alignment. The pelvic region is thought to be the key location during both static and dynamic postural shifts, enabling the body to adjust weight variations and maintain momentum [5].

The biomechanics of human movement also heavily depend on trunk performance, which is intimately linked to lower limb function, balance, and gait [6]. A delay in trunk muscle activity affects the patient's capability to ambulate, postural stability while sitting, and sense of position. Trunk biomechanics and function are closely linked to balance and to trunk muscle activity, which affects gait. Poor posture results from weak trunk muscles, which can lead to functional disorders and dependence. Quality of life is significantly affected, and a decline in core muscle strength increases the risk of falling onto the affected side [7]. Altered weight distribution to the most involved distal extremity during locomotion in stroke patients may be explained by altered pelvic alignment resulting from poor trunk-pelvis coordination or decreased pelvic muscle control. Trunk muscle control at the pelvis is thought to be the primary contributor to post-stroke function, walking, and balance [8].

Motor relearning-based functional training exercises were modified and advanced in accordance with the patient's capacity. To promote neurodevelopment, the Bobath concept was chosen. It inhibits spasticity and promotes normal movement patterns by focusing on neuromuscular control, balance, and coordination. The Bobath method helps retrain the brain's motor pathways by activating the appropriate muscle groups through tactile stimulation and hands-on guidance [3].

Bobath's approach helps the individual develop motor control by engaging them in various activities and focusing on key areas [9]. The ultimate objective of the study is to identify the effectiveness of the Neurodevelopmental therapy on pelvic alignment, trunk control, and gait parameters in chronic stroke survivors.

METHODS

The study is designed as a single-blinded randomized controlled trial conducted from Justice K S Hegde Hospital, NITTE (Deemed to be University), Deralakatte, Mangaluru, Karnataka, India-575018. Ethical approval for this study received from the Institutional ethics committee of Nitte Institute of Physiotherapy, Mangalore, Karnataka, India on 19-01-2024 (Ref: NIPT/IEC/MIN//14/2023-2024) This study was prospectively registered with the clinical registry-India on 06/06/2025 with the registration number CTRI/2024/05/067887. 28 patients were included into the study by fulfilling the criteria, pre and post assessment were conducted. Before enrolment, participants received comprehensive information regarding the trial process, and written informed consent was obtained. Participants' autonomy was respected by allowing withdrawal from the study at any stage without requiring a reason. Patients diagnosed with stroke for the first time, either gender, aged 40 to 60 years, with chronic stroke. (Ischaemic stroke) ACA stroke, Brunnstrom stage of recovery greater than or equal to 2 in trunk and lower limbs, Spasticity less than 2 in Modified Ashworth Scale, MMSE score more than 23, No surgeries in the past year to trunk and lower limbs, Post stroke patients with impaired pelvic asymmetry, and Patients who were able to walk with or without walking aids. Patients with any other diagnosis of neurological/musculoskeletal apart from stroke, Fixed deformity of the spine and lower extremity, patients with convulsion episodes, Brainstem or cerebellar stroke, or cardiorespiratory issues.

STUDY POPULATION AND SAMPLING STRATEGY:

The sample size was calculated using the software G*Power version 3.1.9.7. Based on a significance level of 5% ($\alpha = 0.05$), statistical power of 80%, and a two-tailed independent t-test, the mean step length of the affected side was considered as 27.36 in the control group and 18.45 in Group B, with an assumed standard deviation of 8. The calculated effect size was 1.113. Accordingly, the required sample size was determined to be 14 participants per group, for a total of 28 participants.

Outcome measures: the study used the pelvic inclinometer, Trunk Impairment Scale, and gait parameters. A pelvic inclinometer that measures anterior and posterior tilt and identifies unequal pelvic height between the affected and uninvolved sides in stroke patients. The Trunk Impairment

Scale is a clinical outcome assessment used to evaluate trunk control in individuals with stroke. It focuses on static and dynamic sitting balance as well as coordination. It consists of 7 items with a total score of 23. Gait parameters involved in the study are cadence, stride length, and gait velocity. Cadence is the spatiotemporal component of gait assessment, in which the total number of steps per minute is measured in individuals with stroke. Stride length is a gait parameter; it is the distance covered by two consecutive steps of the same foot. Gait velocity is the speed at which an individual walks, measured in meters/sec.

After receiving the clearance from the scientific and institutional ethics committees, the study was initiated by recruiting chronic stroke patients with impaired Pelvic Alignment. Informed consent from the patient and the patient's party was obtained. The preliminary Data was entered in the data collection sheet. Selected Participants were randomly divided into two groups, Group A and Group B, using simple random sampling and assigned to each group via sequentially numbered, opaque, sealed envelopes.

Pre-intervention assessments were conducted for the experimental and control groups, in which pelvic asymmetry was measured with a pelvic inclinometer, trunk control was measured with the trunk impairment scale, and gait parameters such as cadence, stride length, and gait velocity were measured. Group A Received Neurodevelopmental therapy for 30 minutes along with conventional therapy for 30 minutes, for a total duration of one hour per session, 5 days a week, for a period of 4 weeks. Group B underwent conventional therapy for 30 minutes, 5 days for 4 weeks. To ensure baseline comparability and control for treatment duration as a confounding variable, both the control and experimental groups received 30 minutes of conventional therapy. This standardized intervention was implemented to ensure equal fundamental therapeutic exposure across groups. In addition, the experimental group received an additional 30 minutes of Neurodevelopmental Therapy (NDT) to evaluate its effectiveness specifically.

The inclusion of additional NDT time in the experimental group was intentional to assess NDT's therapeutic contribution beyond conventional therapy. Although the total treatment duration differed between groups, the additional intervention is the independent variable under investigation rather than a source of bias. Furthermore, since NDT was introduced as a novel intervention for participants in the experimental group, any observed improvements cannot be solely attributed to increased treatment time but rather to the specific effects of the NDT approach. This design allows for a clearer interpretation of the additive efficacy of NDT while maintaining internal validity.

After the intervention, a post-intervention evaluation was conducted in both groups for Pelvic alignment, Trunk control, and gait parameters. Pre- and post-evaluations are conducted by an assessor who has similar experience to the primary investigator, and the assessor is blinded to the study.

The Experimental Groups were neurodevelopmental therapy and conventional therapy. Trunk control: According to the functional limitation of the patient. weight transfer to the affected side with support on the extended arm (therapeutic handling is under the axilla, holding arm in abduction, lateral rotation, and elbow and fingers extended).

Pelvis alignment: Anterior Pelvis scooting, Posterior pelvis scooting.

The therapist and patient sit opposite each other. The patient's hand is supported on the therapist's shoulder to avoid any abnormal posture. The therapist's hand is placed on the patient's pelvis, which is lifted and brought forward and backward, scooting the pelvis to the side (bridging with rotation). The therapist's finger is placed on the lateral aspect of the pelvis. Therapeutic handling is performed on the lateral pelvis bilaterally. Reaching the shoulder forward, backward, left, and right sides, strengthening of the abdominal muscles, and training of the lumbar spine stabilizers

Gait training:

working for dorsiflexion of the affected foot while the patient steps forward with the sound leg. Single-leg stance facilitation: stepping backward with the affected leg; getting the heel to the ground improves walking forward.

Rotation of the pelvis while the patient walks produces external rotation of both legs, improving balance and walking patterns. Rotation of the pelvis backward (on the left side) facilitates external rotation of the leg with an everted foot. All of this exercise is performed in 3 sets of 10 repetitions. 30 minutes of NDT and 30 minutes of conventional therapy, including stretching, strengthening, AROM, PROM, and AAROM exercises, progressive resistive exercises, balance training, and gait training, performed in 2 sets of 10 repetitions for 30 minutes, 4 weeks, for the upper and lower limbs. In group B, treatment techniques included a range of motion exercises like passive range of motion, active range of motion, progressive resistive exercise strengthening, stretching exercise, postural stability training, and gait training 10 repetitions for 2 sets for 30 minutes for 4 weeks.

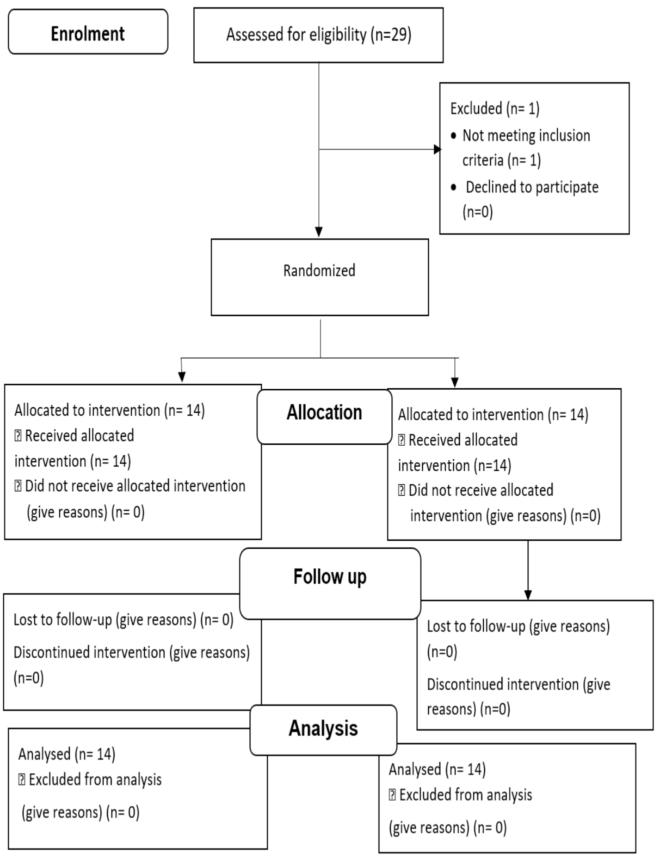


Figure 1: Participants flow chart

STATISTICAL ANALYSIS: Collected data were analyzed by using the Descriptive Statistics: frequency, percentage, mean, and S.D. The Independent "t" test was applied to compare age, duration of stroke, MMSE, trunk impairment scale, pelvic inclination, and the gait parameters: cadence, stride length as well as gait velocity; between the groups: Experimental and control, as well as according to gender and side affected. Paired "t" test was used for the pre to post-test comparison of trunk impairment scale, pelvic inclination (Inches), and gait parameters; irrespective of groups as well as within the groups. To compare the effectiveness (Difference between the pre- and post-measurements) in the trunk impairment scale, pelvic inclination, and the gait parameters, between the groups, the independent sample "t" test was used.

RESULTS

Age, sex distribution, stroke duration, trunk impairment scale scores, pelvic tilt, cadence, stride length, and gait velocity were among the baseline factors that showed no statistically significant differences between the experimental and control groups ($p > 0.05$ for all). This suggests that the groups were similar when the study began (Table 1)

Table 1: Baseline Characteristics with Variables

Characteristic		Control (Mean ±SD)	Experimental (Mean± SD)	P-value
Sex	Male	64.30%	64.30%	1.00
	Female	35.75%	35.70%	1.00
Age		50.58±18.60	51.85±6.56	0.635
Duration of Stroke		1.44±0.64	1.30±0.57	0.577
Trunk impairment scale		11.62±2.76	11.75±2.38	0.89
Pelvic Inclination (*)		0.42±0.09	0.049±0.14	0.15
Gait parameters	cadence	55.54±18.60	45.00±19.61	0.18
	Stride length	0.36±0.10	0.38±0.13	0.78
	Gait velocity	0.20±0.20	0.28±0.08	0.35

Comparisons Between and Within Groups. After the intervention, both groups showed notable improvements across most outcome measures (Table 2). Stride length ($p < 0.001$), pelvic tilt ($p = 0.041$), gait velocity ($p < 0.020$), and trunk impairment scale (from 11.75 ± 2.38 to 16.00 ± 2.26, $p < 0.001$) all improved more in the experimental group. To a lesser degree, the control group also showed notable improvements in these areas.

Table 2: Comparison of parameters within and between the groups

OUTCOME VARIABLES	WITHIN THE GROUP						BETWEEN THE GROUP				
	EXPERIMENTAL GROUP			CONTROL GROUP			EXPERIMENTAL GROUP		CONTROL GROUP		
	Pre-training	Post training	p- value	Pretraining	Post training	p-value	Pre-training	Post training	Pre training	Post training	p-value
Pelvic Inclination	0.49± 0.14	0.6± 0.13	0.041	0.42± 0.09	0.51± 0.10	0.043	0.42± 0.09	0.6± 0.13	0.42±0.09	0.51±0.10	0.043
Trunk impairment scale	11.75± 2.38	16.00± 2.26	<0.001	11.02± 2.76	13.54± 2.54	<0.001*	11.62± 2.76	16.00± 2.26	11.62±2.76	13.54±2.54	0.018
Cadence	45.00± 19.61	49.83± 20.06	<0.01	55.54± 18.60	68.38± 14.5	0.002	45.00± 9.61	49.83± 20.06	55.54±18.60	68.38±14.65	0.014
Stride length	0.38± 0.03	0.58± 0.03	<0.001	0.36± 0.14	0.52± 0.13	<0.03	0.38± 0.13	0.36± 0.14	0.36±0.14	0.52±0.13	0.045
Gait velocity	0.20± 0.20	0.29± 0.22	<0.020	0.26± 0.08	0.31± 0.10	0.028	0.26± 0.08	0.31± 0.10	0.26±0.08	0.31±0.10	0.044

Comparisons between the groups after the intervention showed that the experimental group had significantly greater improvements for: Scale of trunk impairment ($p = 0.018$), Inclination of the pelvis ($p = 0.043$), length of stride ($p = 0.045$), velocity of gait ($p = 0.044$).

Comparison of effectiveness in the trunk impairment scale, pelvic inclination, and gait parameters between the groups. The experimental group outperformed the control group by a substantial margin ($p < 0.001$) for trunk control. There was no significant difference in pelvic inclination changes across groups ($p = 0.611$). The experimental group's cadence dropped less than that of the controls, and this difference was statistically significant (p = 0.031). Figure 3: Stride length (p = 0.441) and gait velocity (p = 0.406) did not, however, differ significantly across the groups.

Table 3: Comparison of effectiveness in trunk impairment scale, pelvic inclination and gait parameters between the groups

EFFECTIVENESS (PRE-POST)		MEAN	SD	"T"	P VALUE
Trunk impairment scale	experimental	-4.25	0.97	-6.06	<0.001*
	control	-1.92	0.95		
Pelvic inclination	experimental	-0.12	0.17	-0.52	0.611
	control	-0.08	0.13		
Cadence	experimental	-4.83	1.95	2.30	0.031
	control	-12.85	11.90		
Stride length	experimental	-0.20	0.14	-0.79	0.441
	control	-0.08	0.15		
Gait velocity	experimental	-0.09	0.11	-0.85	0.406
	control	-0.06	0.08		

Figure 1: Pelvic Inclination pre and post in the experimental and control groups

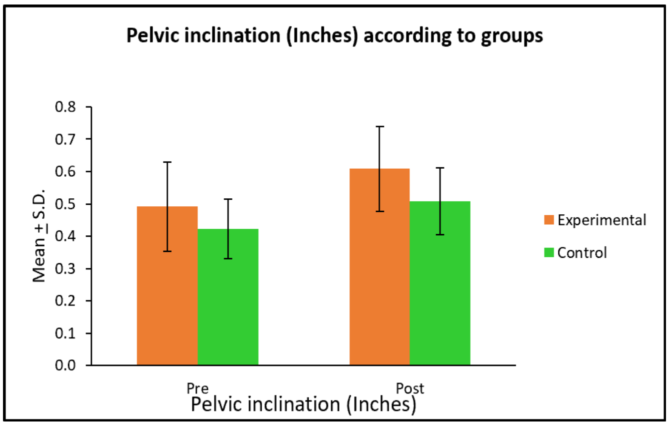


Figure 2: Trunk impairment pre and post in the experimental and control groups

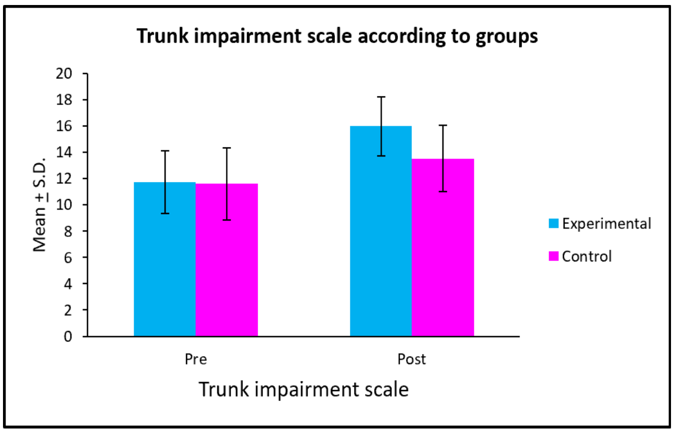


Figure 3: Cadence pre and post in the experimental and control groups

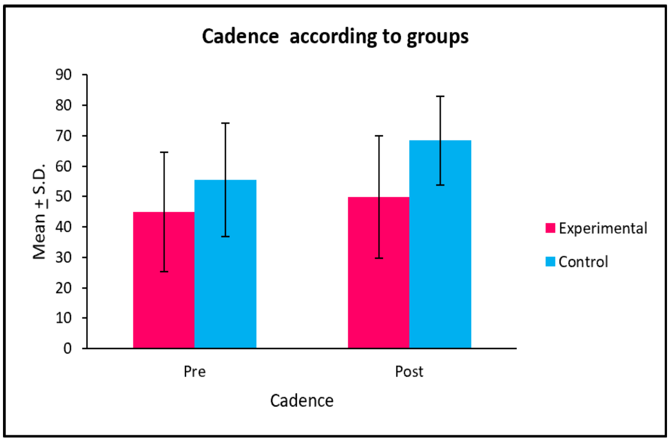


Figure 4: Stride length pre and post in the experimental and control groups

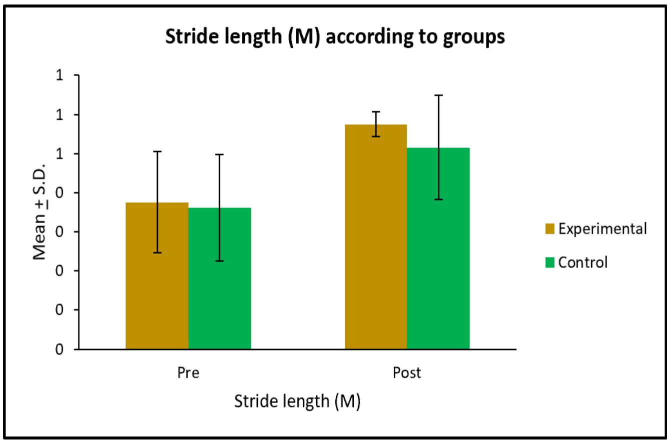
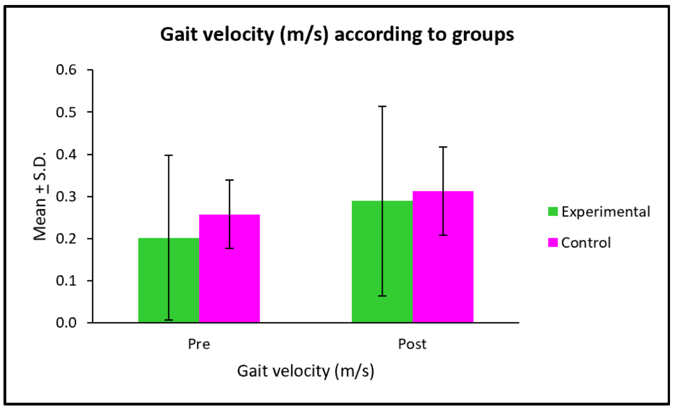


Figure 5: Gait velocity pre and post in the experimental and control groups



DISCUSSION

The study's primary goal is to determine the effects of Neurodevelopmental therapy on Pelvic alignment, Trunk control, and Gait characteristics, including cadence, stride length, and gait velocity, in individuals with chronic stroke.

In the study, we have included chronic stroke individuals with ages varying from 41 to 60 years, with a mean of 51.24 + 6.46 years. The distribution of participants is homogeneous, as indicated by the mean and standard deviation. The pelvic asymmetry, trunk control, and gait parameters were assessed during pre-intervention and post-intervention. After this, statistical analysis was conducted to assess disparities in pelvic inclination, TIS, and gait parameters between treatment and post-treatment within each group, as well as between groups.

The trunk muscle primarily connects the torso and the pelvis. Optimal core strength is necessary for the synchronized movement of the trunk and pelvis to carry out everyday activities. Poor selective movement of trunk flexion and rotation has been shown to affect pelvic stability while standing and contribute to restricted lower-limb motor recovery 10. We observed that neurodevelopmental therapy improved trunk control as measured by the TIS and improved pelvic alignment, as evidenced by a decrease in lateral pelvic tilt. As somatosensory cues provided at important proximal or distal control points helped promote symmetrical weight distribution between the buttocks and trunk muscle activation [11].

Patients with strokes have greater anterior and lateral pelvic tilt, which affects their stride length, step length, step breadth, and cadence, among other gait metrics [12]. Kilinc et al. in 2016 conducted a pilot randomized study in which the neurodevelopmental study showed improvements in trunk control, TUG, and gait parameters [13]. We observed that neurodevelopmental therapy significantly improved pelvic inclination and trunk control in individuals with chronic stroke, as well as gait components. Moreover, performing trunk exercises not only for the torso but also for the upper and lower limbs, equilibrium, and walking ability to attain superior functional quality. Reduced stance time in stroke patients was associated with impaired balance control during the stance phase on the paralyzed side [14].

Kaur et al. concluded that an uncontrolled pelvis can lead to a loss of balance when standing on the paretic leg, thereby decreasing weight-bearing ability and stance duration. This, in turn, seems to reduce the step and stride length of the nonparetic leg [12]. Substantial association between pelvic asymmetry and weight-bearing asymmetry, with the latter being more strongly associated with lateral tilt. For humans to carry out functional movements like walking and balance effectively and precisely, pelvic control is essential. However, patients may experience decreased gait speed, stability, and efficiency, or secondary issues such as falls, if pelvic control is not appropriately produced during movement as a result of neurological or musculoskeletal impairment [14]. In the present study, the strategies focused on improving pelvic alignment, which showed a statistically significant effect in both the experimental and control groups as a result of manual handling of the key area [12].

In ambulating stroke patients, asymmetric weight distribution between the feet may be explained by impaired lower-limb motor performance or poor dissociation between the upper body and pelvis [15].

Primary strategies employed in the NDT approach included facilitating the selective control of movements by reducing the fundamental movement patterns of the trunk, pelvis, and limbs. This is most likely held to a more noticeable increase in stride and step length [16].

In the present study, the experimental research group showed statistically significant changes in all assessed indicators before and after therapy. This supports the idea of E. Mikołajewska et al., who found that, in post-stroke gait rehabilitation, NDT-Bobath in conjunction with a traditional technique is more successful than a traditional strategy alone [17].

Exclusively involved the patients with ischemic stroke, particularly ACA stroke. To assess the progression of muscle strength, the dynamometer has been considered. Further studies with larger sample sizes, longer durations, and additional follow-up periods are recommended to explore the long-term effects of pelvic control on gait performance in individuals with chronic stroke.

CONCLUSION

The study demonstrates that Neurodevelopmental Therapy (NDT) significantly improves trunk control, pelvic alignment, and gait parameters, including stride length and cadence, in individuals with chronic stroke. Statistically significant differences were observed both within and between the groups, indicating the effectiveness of the intervention. The findings highlight the critical role of pelvic alignment in optimizing gait and postural stability, an aspect that has historically received limited emphasis in stroke rehabilitation. Therefore, incorporating strategies to enhance pelvic alignment should be considered an essential component of physiotherapy interventions aimed at improving functional movement patterns in stroke patients.

Abbreviations

ACA: Anterior Cerebral Artery
MMSE: Mini-Mental State Examination
NDT: Neurodevelopmental Therapy
AROM: Active Range of Motion Exercise PROM
Passive Range of Motion Exercise
AAROM: Active Assisted Range of Motion Exercise
TIS: Trunk Impairment Scale.

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