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Effectiveness of Perturbation-Based Balance Training Versus Pilates Exercises on Balance in Patients with Stroke: A Randomised Comparative Study

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Abstract

Background: Stroke is defined as a clinical syndrome characterized by an acute loss of focal brain function with symptoms lasting more than twenty four hours or leading to death, and which is thought to be due to inadequate blood supply to a part of the brain or spontaneous haemorrhage into a part of the brain or over the surface of the brain. Imbalance is one of the clinical feature seen in post stroke patient's results either due to muscle imbalance or by damage to the higher centre which controls the balance (area number 9 and area of sensory integration 3, 1, 2). The therapeutic approach of strengthening the weak muscle groups and retraining the higher centres by neuroplasticity will improve balance in chronic stroke patients has been advocated.

Objective: To compare the effect of perturbation based balance training with Pilates exercise to improve balance among chronic stroke patients.

Methods: A comparative study was conducted on individuals with balance impairment among chronic stroke patients. Participants were selected based on inclusion and exclusion criteria and were randomly assigned into two groups. Group A received Perturbation based balance training while group B received Pilates exercise for a total of 8 weeks.

Results: Twenty stroke patients were randomly assigned to a Perturbation-Based Balance Training (PBBT) group (Group A) or a Pilate's exercise group (Group B). After 8 weeks of intervention, both groups showed significant pre- to post-test improvements in Berg Balance Scale scores (Group A: 37.80 ± 4.52 to 43.80 ± 4.18; Group B: 36.90 ± 4.37 to 39.80 ± 4.31) and Timed Up and Go Test performance (Group A: 15.46 ± 2.34 s to 12.74 ± 2.01 s; Group B: 17.21 ± 2.68 s to 15.85 ± 2.43 s). However, the PBBT group demonstrated greater gains than the Pilates group, suggesting that Perturbation-Based Balance Training is more effective in improving balance and functional mobility in patients with stroke.

Conclusion: Both interventions were effective in improving balance and reducing risk of fall in chronic stroke patients.. However, PBBT was more effective than Pilate's exercises.

Key Words: Stroke, Perturbation-based balance training (PBBT), Pilates exercise, Balance, Neuroplasticity.

Introduction

Stroke is defined as a clinical syndrome characterised by an acute loss of focal brain function with symptoms lasting more than twenty four hours or leading to death, and which is thought to be due to inadequate blood supply to a part of the brain or spontaneous hemorrhage into a part of the brain or over the surface of the brain. The rapid onset of focal neurological deficit, resulting from diseases of the cerebral vasculature and its contents [2].

The incidence of stroke is more in low and middle income countries. The significant decline in stroke incidence in high income countries coincided with a significant increase in treatments and decline in prevalence of casual risk factors. The significant increase in stroke incidence in low and middle income countries coincided with increasing exposure of the population to raised blood pressure, smoking, sedentary lifestyle as well as an increasing average age. Stroke is the most common neurological disorder under the age of 85 years. Throughout the world, about 5.7 million people die after a stroke each year. Stroke therefore contributes about 10% of all deaths around the world, making it the second most common cause of death after ischaemic heart disease. Among the 5.7 million deaths 5 million deaths are from low and middle income countries [1].

Balance problem is common in stroke cases, loss of body balance is either due to incoordination between the muscle groups or due to damage to the area responsible for balance. Balance problem is most commonly seen in patients with ACA, MCA and subcortical stroke. Other clinical features include sudden weakness or numbness of the face, arm and leg especially on one side of the body, difficulty in speaking or understanding the speech, sudden loss of vision in one or both eyes, loss of coordination, dizziness, hyperhidrosis and drooling of saliva. There are cortical, subcortical, brainstem and cerebellar lesions for stroke [3]. The physiotherapy treatment for stroke is to promote recovery of motor function, prevent secondary complications like contractures, pressure sores and chest infections, to reduce the dependency in activities of daily living and enhance quality of life. The therapeutic techniques in the acute stage of stroke are positioning to prevent contractures, to reduce risk of bed sores and to promote circulation. The positions promoted are supine lying, side lying and sitting with support. Chest physiotherapy should be given to eliminate chest infection. Passive movements are given gently to maintain the muscle properties. Reduce spasticity by stretching, prolonged positioning, splinting or orthosis. To reduce flaccidity facilitation techniques such as quick stretching and supporting devices like slings can be used. For sensory deficits sensory stimulation and mirror therapy are useful. For balance and coordination static and dynamic balance exercises, Frenkel's exercises, Pilates exercise and perturbation based balance training are beneficial. Patient and family education is important to make them do home exercise properly and modify lifestyle by controlling blood pressure, blood sugar, smoking, alcoholism and promote physical activities [1].

PBBT is a form of training that aims to improve reactive balance control after unexpected external perturbations. In a safe and controlled environment, participants are repeatedly exposed to destabilizing perturbations during various activities of daily living. Many different training setups can be utilized, from fairly simple lean and release perturbations requiring only a safety harness, to advanced systems that can provide a wide variety of perturbations types and intensities during various tasks [4]. Pilates is a targeted training of the patient's core muscles, which can improve the control of the abdomen, back, pelvis and buttocks muscles, strengthen muscle strength and maintain the stability of the body, thus improving patient's imbalance. Although both the PBBT and Pilates exercises show positive results in individuals with imbalance in chronic type of stroke. This study is to compare the effectiveness of PBBT and Pilates exercises, to find which is more effective. PBBT provided task specific activities and Pilates provided strengthening exercises. PBBT shows greater result than Pilates in individuals with imbalance among chronic stroke patients [25].

Methods

Ethical approval for this study was obtained from the Institutional Ethics Committee of Revathi Institute of Physiotherapy before the commencement of the study. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment. Ethical Clearance No. IEC-(RIPT/DT/21/0523)

Study design and participants

A comparative study was conducted on 20 individuals with balance impairment among chronic stroke patients. Participants were selected based on inclusion and exclusion criteria and were randomly assigned into two groups through lottery method. Group A received Perturbation based balance training while group B received Pilates exercise for a total of 8 weeks.

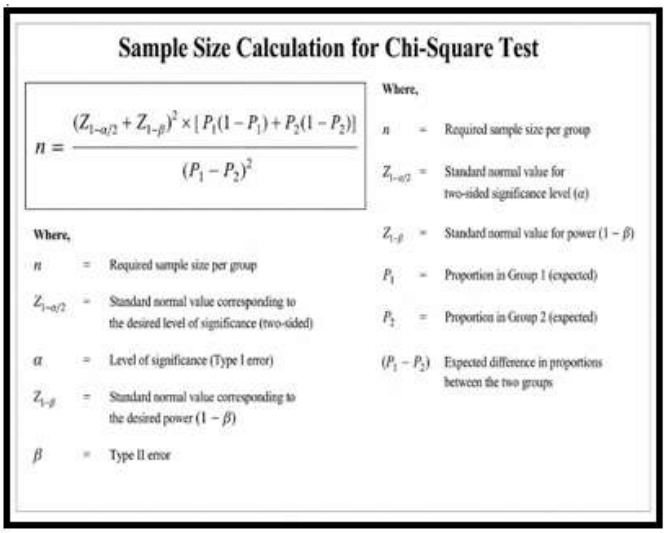


Fig 1. chi square test for sample size calculation

Inclusion and exclusion criteria

Participants of both gender/age 40-65 years, Post stroke up to 3 months to 2 years,Medically stable withPOMA score 19-24 and MMSE score 25-30, Patient able to stand independently for 15-20 minutes and able to follow verbal commands, MRC grading above 3 are included in the study. Individuals with history of recurrent stroke, Visual and auditory impairment, Severe spasticity, Other neurological conditions,

Cardiovascular impairment, Osteoporosis are excluded from the study.

Intervention

Participants allocated to Group A received Perturbation-Based Balance Training (PBBT) for 20–25 minutes per session, three sessions per week for a total duration of 8 weeks, with a 5-minute rest interval between exercises. During static perturbation training, 12–15 perturbations were applied in each position. The intervention progressed from static perturbations on firm surfaces (normal stance, close-feet stance, and walk stance) to static perturbations on soft surfaces (mattress) using the same standing positions. The therapist delivered sudden and unpredictable pushes in forward, backward, and lateral directions while guarding the patient at the trunk and pelvis, requiring the participant to regain balance through appropriate stepping and postural reactions. The dynamic phase included Swiss ball exercises (sitting balance, arm lifting, and leg lifting while sitting on the Swiss ball), balance board exercises (standing on the balance board and perturbations on the balance board), perturbations during walking, and perturbations while reaching for objects. Throughout the intervention, the therapist ensured patient safety by providing close supervision and guarding while delivering controlled, unexpected perturbations to improve reactive balance, postural stability, motor control, and functional balance responses.

Participants in Group B received Pilates exercises for 20–25 minutes per session, three sessions per week for 8 weeks, with a 5-minute rest interval between exercises. The programme was progressively divided into three phases. Day 1 emphasized core activation and static balance through breathing control with seated posture alignment, pelvic tilts, pelvic bridging, heel slides, close-feet standing, and single-leg stretch. These exercises focused on diaphragmatic breathing, core muscle activation, pelvic control, trunk stability, and postural alignment while being supervised by the therapist. Day 2 focused on dynamic balance and core stability using bridging with arm movement, side-lying leg lifts, modified hundred, spine twist, and single-leg stance, while Day 3 consisted of advanced balance exercises including side kick lying, modified hundred, roll-up (full/partial), side plank, squat with arm rise, and walking heel-to-toe with coordinated arm movement. All exercises were performed with therapist supervision using the prescribed repetitions, sets, and holding times, progressing from basic core stabilization to functional balance

activities to improve trunk control, postural stability, coordination, and balance in patients with chronic stroke.

Outcome measures

Berg balance scale and timed and go test are used to assess the level of balance among stroke patients. Outcome measures were assessed before and after completion of the intervention program.

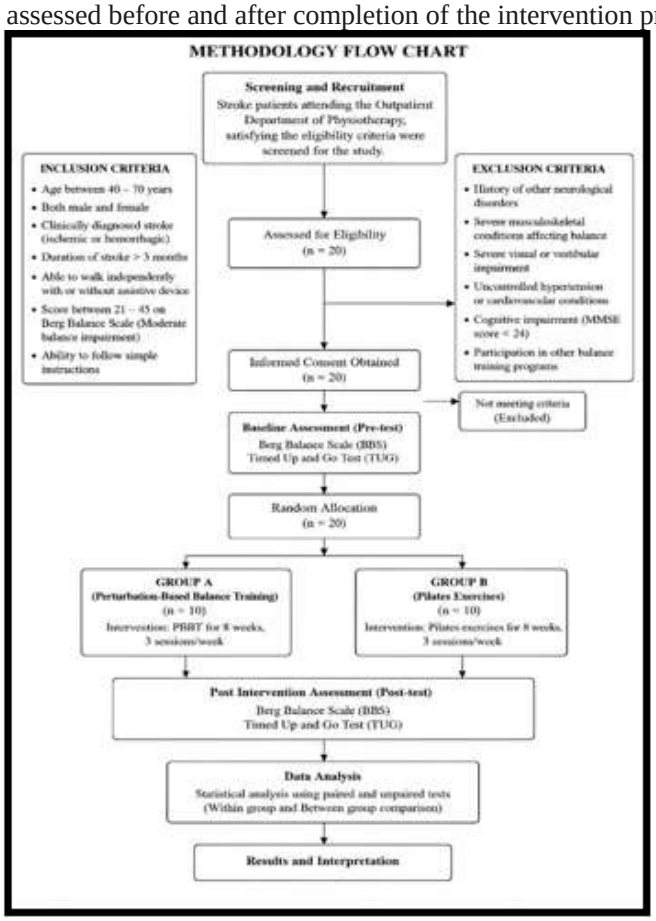


Fig 2. Methodology flow chart

Statistical analysis

Data were analyzed using statistical package for social science version 24,with a significance level of p value less than 0.05 and a 95% confidence interval set for all analysis. The Shapiro Wilk test was used to determine the normality of the data. In this study, Shapiro Wilk test showed that the data was normally distributed on the dependent values at P >0.05.

Results

A total of 20 participants with chronic stroke completed the study and were included in the final analysis. Participants were randomly allocated into two equal groups (n = 10 each). Group A received Perturbation-Based Balance Training (PBBT), whereas Group B received Pilates exercises. Both groups completed the 8-week intervention

Berg Balance Scale (BBS)

Within-group analysis demonstrated significant improvements in Berg Balance Scale scores following the intervention in both groups (p = 0.001). Group A improved from a mean score of 39.70 ± 4.98 at baseline to 43.80 ± 4.18 after the intervention, whereas Group B improved from 38.10 ± 4.33 to 39.80 ± 4.31. The improvement was greater in the PBBT group than in the Pilates group.

Between-group comparison showed no significant difference in baseline BBS scores (t = 0.766, df = 18, p = 0.454), indicating that both groups were comparable before the intervention. However, post-intervention BBS scores differed significantly between the groups (t = 2.10, df = 18, p = 0.001), with

Group A demonstrating significantly higher scores than Group B, suggesting superior improvement following

Perturbation-Based Balance Training.

Timed Up and Go (TUG) Test

Within-group analysis demonstrated significant improvements in Timed Up and Go test performance in both groups following the intervention (p = 0.001). The mean TUG score in Group A improved from 17.94 ± 1.58 seconds to 12.74 ± 2.01 seconds, while Group B improved from 16.88 ± 1.96 seconds to 15.85 ± 2.43 seconds. The reduction in TUG completion time was greater in the PBBT group, indicating better improvement in functional mobility.

Between-group comparison revealed no significant difference in baseline TUG scores (t = 1.31, df = 18, p = 0.205). However, a statistically significant difference was observed between the groups after the intervention (t = 3.84, df = 18, p = 0.001), with Group A demonstrating significantly lower TUG completion times than Group B. These findings indicate that Perturbation-Based Balance Training was more effective than Pilates exercises in improving functional mobility and dynamic balance among patients with chronic stroke.

Table 1: Mean value, standard deviation, t value and p value of berg balance scale for assessing balance between pre test and post test values within group A and group B

GROUPS	PRE TEST		POST TEST		t - TEST	SIGN IFICANCE
	MEAN	S.D	MEAN	S.D		
GROUP- A	39.70	4.98	43.80	4.18	4.95	.001**
GROUP- B	38.10	4.33	39.80	4.31	-2.84	.001**

(**- P ≤ 0.05 - Significant).

Graph 1: Graphical representation between pre test and post test values of berg balance scale for assessing balance within group A and group B

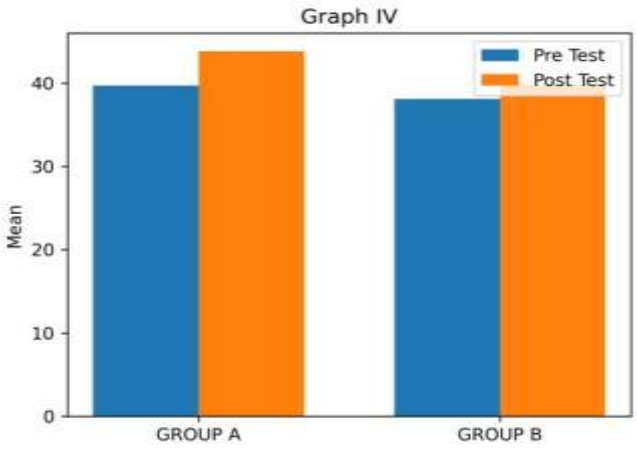


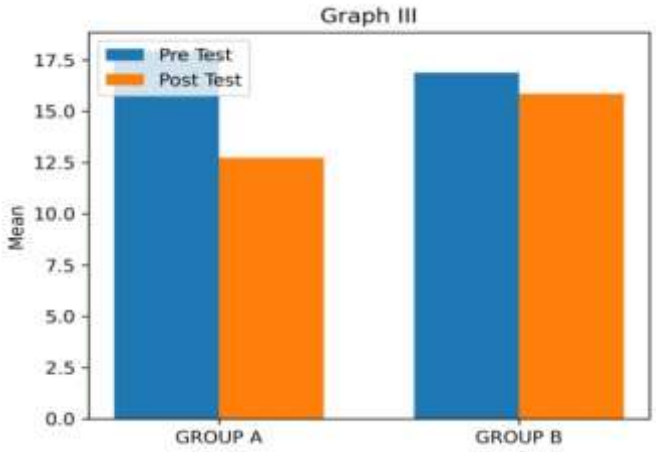
Table 2: Mean value, standard deviation, t value and p value between pre test and post test values of TUG test for assessing balance within group A and group B

GROUPS	PRE TEST		POST TEST		t - TEST	SIGNIFICANCE
	MEAN	S.D	MEAN	S.D		
GROUP- A	17.94	1.58	12.74	2.01	4.95	.001**
GROUP- B	16.88	1.96	15.85	2.43	-3.25	.001**

(**- P ≤ 0.05 - Significant).

Within-group analysis of the Timed Up and Go test revealed a significant improvement in Group A, with a calculated paired t value of 4.95, which exceeded the table t value of 3.250 at the 0.005 level. Group B showed a calculated paired t value of −3.25, which was less than the table t value of 3.250, indicating no statistically significant improvement. However, comparison of pre-test and post-test scores within both Group A and Group B demonstrated significant differences in both the Timed Up and Go Test and Berg Balance Scale scores at $P \leq 0.05$.

Graph 2 : Graphical representation between pre test and post test values of TUG test for assessing balance within group A and group B



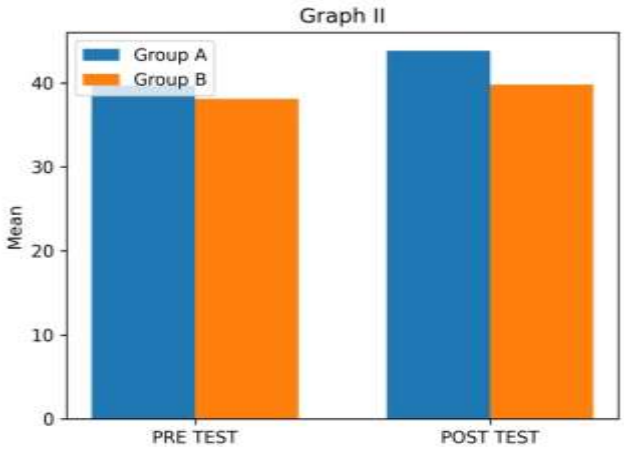
Between group comparison using the Berg Balance Scale showed a calculated paired t value of 2.10, which was less than the table t value of 2.878 at the 0.005 level, indicating no statistically significant difference between PBBT and Pilates exercises in improving balance among stroke patients. Nevertheless, comparison of the post-test mean scores revealed that Group A achieved a higher Berg Balance Scale score (43.80 ± 4.18) than Group B (39.80 ± 4.31) at $P \leq 0.05$, indicating greater clinical improvement with PBBT. Therefore, the null hypothesis was rejected. Overall, both PBBT and Pilates exercises demonstrated improvement in balance within their respective groups.

Table 3: Mean value, Standard Deviation, t-test, degree of freedom and p-value between pre test and post test values of berg balance scale for assessing balance among Group A & Group B

TEST	GROUP - A		GROUP - B		t - TEST	df	SIGNIFICANCE
	MEAN	S.D	MEAN	S.D			
PRE TEST	39.70	4.98	38.10	4.33	.766	18	.454 *
POST TEST	43.80	4.18	39.80	4.31	2.10	18	.001**

(*- P > 0.05 - Not Significant) & (**- P ≤0.05 - Significant).

Graph 3: Graphical representation of pre test and post test values of berg balance scale for assessing balance in group A and group B



Between-group comparison of the Timed Up and Go test demonstrated a calculated paired t value of 3.84, which was greater than the table t value of 2.878 at the 0.005 level, indicating a statistically significant difference between the two interventions. The post-test mean TUG score was lower in Group A (12.74 ± 2.01) than in Group B (15.85 ± 2.43) at $P \leq 0.05$, demonstrating that PBBT was more effective than Pilates exercises in improving functional mobility and dynamic balance among stroke patients. Based on these findings, the null hypothesis was rejected, and it can be concluded that although both interventions improved balance and mobility, Perturbation-Based Balance Training produced superior outcomes compared with Pilates exercises.

Graph 4: Graphical representation of pre test and post test values of TUG test for assessing balance in group A and group

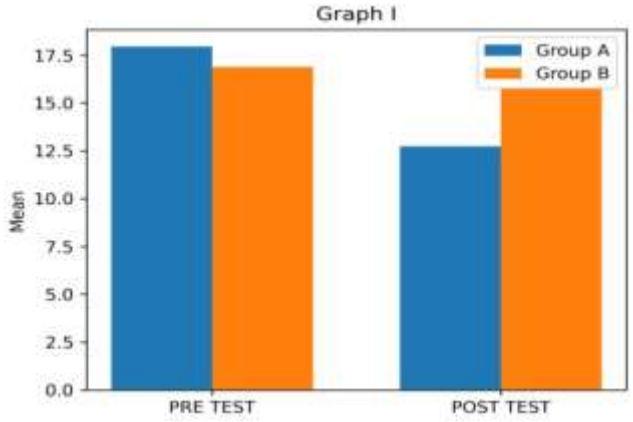


Table 4: Mean value, standard deviation, t- test, degree of freedom and p value between pre test and post test scores of TUG test for assessing balance among group A and group B

TEST	GROUP - A		GROUP - B		t - TEST	df	SIGNIFICANCE
	MEAN	S.D	MEAN	S.D			
PRE TEST	17.94	1.58	16.88	1.96	1.31	18	.20 * 5
POST TEST	12.74	2.01	15.85	2.43	3.84	18	.001**

(*- P > 0.05 - Not Significant) & (**- P ≤ 0.05 - Significant).

Discussion

The present study compared the effectiveness of Perturbation-Based Balance Training (PBBT) and Pilates exercises in improving balance among patients with stroke. Both interventions resulted in significant improvements in balance following an 8-week training program conducted three times per week. However, participants who received PBBT demonstrated greater improvements in Berg Balance Scale and Timed Up

and Go test scores compared to those who performed Pilates exercises, indicating that PBBT was more effective in enhancing balance and functional mobility.

The superior effectiveness of PBBT may be attributed to its ability to improve reactive postural control, sensory integration, proprioceptive feedback, and motor learning through repeated exposure to unexpected balance disturbances. While Pilates exercises enhanced core strength, flexibility, trunk stability, and neuromuscular coordination, they primarily involved slow and predictable movements that provided limited reactive balance challenges. Therefore, although both interventions are beneficial in stroke rehabilitation, PBBT appears to be a more effective approach for improving balance and reducing the risk of falls in patients with stroke.

The findings of this comparative study indicate that both Perturbation-Based Balance Training (PBBT) and Pilates exercises are effective interventions for improving balance and functional mobility in individuals with chronic stroke following an 8-week rehabilitation program. However, participants who underwent PBBT demonstrated greater improvements in Berg Balance Scale and Timed Up and Go test outcomes than those who received Pilates exercises. These findings suggest that PBBT may offer additional benefits in enhancing postural stability and dynamic balance in individuals with chronic stroke.

Incorporating task-specific perturbation training into stroke rehabilitation programs may improve functional recovery and reduce the risk of falls. Nevertheless, the findings should be interpreted with caution due to the small sample size and single-center study design. Future randomized controlled trials with larger sample sizes, multicenter participation, long-term follow-up, and assessment of fall-related outcomes are warranted to confirm these findings and establish the long-term effectiveness of PBBT in stroke rehabilitation.

Conclusion

This study was conducted to compare the effectiveness of Perturbation based balance training and Pilates exercise for improving balance among patients with stroke. 20 stroke patients were included in the study and were randomly divided into 2 groups. The group A was treated with Perturbation based balance training and group B was treated with Pilates exercise for 8 weeks. Balance was assessed using Berg balance scale and Timed up and go test before and after the intervention.

From the result it was concluded that there is significant difference between PBBT and Pilates exercise in the improvement of balance among stroke patients and the group A treated with PBBT shows greater improvement than group B treated with Pilates exercise. Hence the null hypothesis is rejected.

Limitations and Recommendations

The present study had certain limitations. The sample size was relatively small, which may limit the generalizability of the findings. Psychological factors that could influence balance performance and rehabilitation outcomes were not considered. In addition, the study was conducted over a short duration, making it difficult to evaluate the long-term effects of the interventions. Furthermore, the study did not include direct measurement of fall rates, which could have provided additional evidence regarding the effectiveness of the interventions in preventing falls.

Based on these limitations, future studies should include a larger sample size and participants from different age groups to improve the applicability of the findings. Long-term studies are recommended to evaluate the sustained effects of Perturbation-Based Balance Training and Pilates exercises. Future research should also incorporate clinical assessment tools that are more sensitive to reactive balance than the Berg Balance Scale. Additionally, the development of cost-effective and easily accessible perturbation devices may help improve the implementation of Perturbation-Based Balance Training in routine clinical practice.

Conflict of interest

Some individuals are not willing for the study, also the patients matching inclusion and exclusion criteria were limited in the study region.

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Authors contribution

Muhammed Musharaf A. T. , Conceptualization, Methodology, Participant recruitment, Data collection, Formal analysis, Manuscript drafting.
Dr. Athira M: Supervision, Methodology validation, Critical revision of the manuscript, Final approval of the manuscript.
Dr. P. Bright Alwin Victor: Research guidance, Manuscript review, Administrative support, Final approval of the manuscript.

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