Effectiveness of Vestibular Stimulation Exercises Versus Trunk Control Training Exercises on Trunk Control, Balance and Gait in Subjects with Sub-Acute Stroke

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Abstract

Background: Stroke is a leading cause of long-term disability, resulting in impaired trunk control, balance, and gait. Although vestibular stimulation exercises and trunk control training are commonly used in stroke rehabilitation, evidence comparing their effectiveness in subjects with sub-acute stroke remains limited.

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Aim: To compare the effectiveness of vestibular stimulation exercises and trunk control training exercises on trunk control, balance, and gait in subjects with sub-acute stroke.

Methodology: A randomized controlled trial was conducted on 30 subjects with sub-acute stroke, randomly allocated into Group A (n = 15) and Group B (n = 15). Group A received vestibular stimulation exercises with conventional physiotherapy, while Group B received trunk control training exercises with conventional physiotherapy, three sessions per week for six weeks. Outcome measures included the Functional Reach Test (FRT), Timed Up and Go (TUG) Test, and Functional Ambulation Profile (FAP). Data were analyzed using paired and unpaired t-tests ($p < 0.05$).

Results: Both groups showed significant improvements after six weeks. In Group A, FRT improved from 6.42 ± 1.16 to 12.20 ± 1.54 inches, TUG decreased from 23.03 ± 2.35 to 13.67 ± 1.51 seconds, and FAP improved from 3.07 ± 0.70 to 4.47 ± 0.63 (all $p < 0.001$). In Group B, FRT improved from 6.20 ± 0.77 to 8.07 ± 0.83 inches ($p < 0.001$), TUG decreased from 24.36 ± 5.55 to 20.07 ± 5.05 seconds ($p = 0.035$), and FAP improved from 3.27 ± 0.70 to 3.93 ± 0.70 ($p = 0.014$). Between-group analysis favoured Group A for FRT (12.20 ± 1.55 vs. 8.07 ± 0.83), TUG (13.67 ± 1.51 vs. 20.07 ± 5.05 seconds), and FAP (4.46 ± 0.64 vs. 3.93 ± 0.70) ($p < 0.05$).

Conclusion: Both interventions significantly improved trunk control, balance, and gait in subjects with sub-acute stroke; however, vestibular stimulation exercises produced significantly greater improvements than trunk control training exercises.

Keywords: Sub-acute stroke, vestibular stimulation exercises, trunk control training, Functional Reach Test, Timed Up and Go Test, Functional Ambulation Profile, balance, gait.

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Introduction

Stroke is defined as an abrupt neurological deficit caused by impaired perfusion through the blood vessels to the brain [1]. It is a leading cause of long-term disability and frequently results in significant motor deficits, How to cite this article including impaired trunk control, balance dysfunction, and abnormal gait patterns [2]. Trunk control impairment is one of the earliest and most disabling consequences of stroke. Trunk muscles responsible for core stability are bilaterally innervated, and damage to the corticospinal tract disrupts their coordinated function, contributing to poor postural alignment, reduced balance control, and inefficient gait patterns [3,4].

A compensatory activation pattern emerges due to trunk muscle weakness, which limits postural transitions and mobility [5]. Trunk control ability in the early phase is a crucial predictor of recovery in future functional domains, and rehabilitation aimed at improving trunk control from the acute phase is essential to enhance functional outcomes [6]. Therefore, trunk stability and mobility are related to trunk muscle coordination, and achieving stability is a fundamental goal of movement [7]. Trunk control is the focus of rehabilitation exercises in stroke patients because improving trunk function is vital to enhance balance and gait [8].

Early rehabilitation targeting trunk function has been shown to accelerate recovery in stroke survivors, especially during the sub-acute phase when neuroplasticity is at its peak [9]. Commonly administered strategies to improve trunk balance include Swiss ball training, rocker board training, task-specific training, and vestibular training. The vestibular system plays a vital

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role in maintaining upright posture and coordinating head and eye movements, particularly during dynamic tasks [10].

Studies suggest that targeted vestibular stimulation can enhance neuroplasticity by promoting the reorganization of vestibulospinal pathways, thereby contributing to improved balance and spatial orientation in hemiparetic patients [11,12]. Exercises involving vestibular input, such as balance tasks on unstable surfaces, gaze stabilization techniques, and head movement training, have been shown to positively influence trunk stability, dynamic balance, and functional gait performance in individuals with stroke [2,13]. In a comparative analysis, trunk control training and vestibular stimulation exercises have both demonstrated efficacy in improving gait and balance parameters in stroke survivors. However, the targeted application of vestibular-based training may provide added benefit in the early stages of rehabilitation, where sensory reintegration and postural alignment are critical [14].

Therefore, the present study was undertaken to compare the effectiveness of vestibular stimulation exercises and trunk control training exercises on trunk control, balance, and gait in individuals with sub-acute stroke.

Materials and Methods

Study design and study setting

A randomized controlled trial was conducted to evaluate the effects of vestibular stimulation exercises compared with trunk control training exercises in individuals with sub-acute stroke. The study was conducted from October 2025 to March 2026 at the college of physiotherapy ,Sri Venkateswara Institute of medical sciences (SVIMS),Tirupati, Andhra Pradesh, India. Trunk

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control, balance, and gait were considered the primary outcomes. Treatment effects were evaluated using within-group and between-group comparisons with p-values to assess the magnitude of the intervention effects.

Sample size

A total of 30 eligible participants with sub-acute stroke who met the predefined inclusion and exclusion criteria were recruited and completed the study. All 30 participants completed the required assessments and intervention protocol and were included in the final analysis. Participants were randomly allocated into two equal groups of 15 subjects each.

Sampling technique

The study was conducted following approval from the Institutional Ethics Committee. Written informed consent was obtained from all participants before enrolment. Participants were recruited using a simple random sampling technique . Individuals diagnosed with sub-acute stroke were screened according to the predefined inclusion and exclusion criteria. After eligibility was confirmed, written informed consent was obtained. Eligible participants were then randomly allocated into two groups using a simple lottery method . Group A received vestibular stimulation exercises with conventional physiotherapy, while Group B received trunk control training exercises with conventional physiotherapy.

Inclusion criteria

Participants aged between 30 and 50 years of either gender with a clinical diagnosis of sub-acute stroke (onset between two weeks and three months), ability to understand and follow simple commands, ability to sit independently for at least 30 seconds, and willingness to participate in the study were included.

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Exclusion criteria

Individuals were excluded if they had a history of previous stroke, severe cognitive impairment, vestibular disorders unrelated to stroke, severe musculoskeletal conditions affecting the lower limbs or trunk, uncontrolled medical conditions (hypertension, diabetes mellitus), visual or auditory impairments that could interfere with exercise participation, or pregnancy.

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Chicago, USA). Descriptive statistics were used to summarize demographic and clinical characteristics and are presented as mean ± standard deviation (SD) for continuous variables . Within-group comparisons between pre- and post-intervention measurements were performed using paired-samples t-tests, while betweengroup comparisons were performed using independent-samples (unpaired) t-tests. A two-tailed p-value of < 0.05 was considered statistically significant.

Procedure

A total of 30 participants were recruited and allocated into two groups. Group A (Experimental Group) received vestibular stimulation exercises combined with conventional physiotherapy, while Group B (Experimental Group) received trunk control training exercises combined with conventional physiotherapy. Both groups received their respective interventions according to the prescribed treatment protocol for three sessions per week over a period of six weeks. Following completion of the intervention period, all outcome measures were reassessed using the same assessment tools.

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Outcome measures

Functional Reach Test (FRT)

The Functional Reach Test is a valid and reliable clinical measure used to assess dynamic balance and postural control. Participants stand next to a wall with the arm raised to 90° of shoulder flexion and reach forward as far as possible without moving the feet. The distance reached (in inches) is recorded. Greater reach distance indicates better dynamic balance [15].

Timed Up and Go (TUG) Test

The Timed Up and Go Test is a simple, reliable, and widely used clinical assessment tool for evaluating functional mobility, balance, gait performance, and fall risk. The participant is instructed to rise from a standard chair, walk a distance of 3 meters at a comfortable pace, turn around, walk back to the chair, and sit down. The total time taken is recorded in seconds. Lower completion times indicate better functional mobility [16].

Functional Ambulation Profile (FAP)

The Functional Ambulation Profile is a standardized scale used to assess the level of ambulatory independence. It grades walking ability from non-functional ambulation (grade 0) to independent ambulation on all surfaces (grade 5). Higher scores indicate greater functional ambulation independence [17].

Physiotherapy intervention

Both groups underwent a six-week progressive physiotherapy intervention, with sessions lasting approximately 45 minutes (including warm-up and cool-down). Group A received vestibular stimulation exercises that included gaze stabilization exercises (VOR × 1 and VOR × 2), imaginary target exercises, active sitting on a Swiss ball, anterior-posterior and lateral pelvic tilting on a Swiss ball, and anteriorposterior and medial-lateral rocking on a rocker board, along

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with reaching activities. Group B received structured trunk control training exercises performed in lying and sitting positions, including pelvic bridging, trunk rotation, knee rolling, single-leg drops, side-lying clamshells, four-point kneeling balance, bilateral leg cycling, static sitting balance, weight shifting in sitting, and reaching tasks in sitting. Both groups also received conventional physiotherapy.

Results

A total of 30 participants with sub-acute stroke were included in the study. The groups were comparable at baseline with no significant differences in age, gender, or NIHSS scores (Table 1). The mean age was 46.4 ± 3.7 years in Group A and 41.8 ± 9.5 years in Group B ($p = 0.10$). Gender distribution and NIHSS scores were also similar between groups.

TABLE 1: Demographic and Baseline Characteristics of the Study Participants (N = 30)

Variables	Group A (n = 15) Mean ± SD	Group B (n = 15) Mean ± SD	p-value
Age (years)	46.4 ± 3.7	41.8 ± 9.5	0.10
Gender (Male:Female)	9:6	8:7	0.71 ($\chi^2 = 0.136$)
NIHSS	8.46 ± 3.02	6.8 ± 2.83	0.13

NIHSS: National Institutes of Health Stroke Scale; SD: Standard Deviation.

Within-group analysis showed significant improvements in both groups following the intervention (Table 2). In Group A (vestibular stimulation), the mean FRT score increased from 6.42 ± 1.16 to 12.2 ± 1.54 inches (mean difference = 5.78; $p < 0.001$), the mean TUG time decreased from 23.03 ± 2.35 to 13.67 ± 1.51 seconds (mean difference = 9.36; $p < 0.001$), and the mean FAP score increased from 3.07 ± 0.70 to 4.47 ± 0.63 (mean difference = 1.40; $p < 0.001$). In Group B (trunk control training), the mean FRT score increased from 6.20 ± 0.77 to 8.07 ± 0.83 inches (mean difference = 1.87; $p < 0.001$), the mean TUG time decreased from

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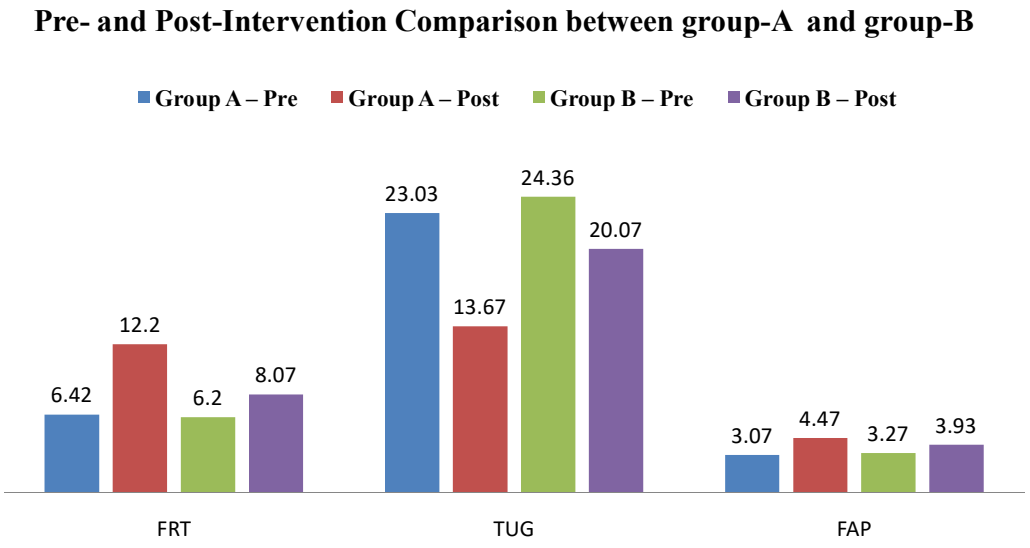
24.36 ± 5.55 to 20.07 ± 5.05 seconds (mean difference = 4.29; p = 0.035), and the mean FAP score increased from 3.27 ± 0.70 to 3.93 ± 0.70 (mean difference = 0.66; p = 0.014).

TABLE 2: Within-Group Pre- and Post-Intervention Comparison of Outcome Measures in Group A and Group B

Outcome Measures	Group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	Mean Diff.	t-value	p-value
FRT (inches)	Group A	6.42 ± 1.16	12.2 ± 1.54	5.78	29.94	< 0.001
	Group B	6.20 ± 0.77	8.07 ± 0.83	1.87	7.82	< 0.001
TUG (seconds)	Group A	23.03 ± 2.35	13.67 ± 1.51	9.36	27.06	< 0.001
	Group B	24.36 ± 5.55	20.07 ± 5.05	4.29	2.34	0.035
FAP	Group A	3.07 ± 0.70	4.47 ± 0.63	1.40	10.69	< 0.001
	Group B	3.27 ± 0.70	3.93 ± 0.70	0.66	2.79	0.014

Group A: Vestibular stimulation exercises; Group B: Trunk control training exercises; FRT:Functional Reach Test; TUG: Timed Up and Go Test; FAP: Functional Ambulation Profile;

GRAPH-1 Within-Group Pre- and Post-Intervention Comparison of Outcome Measures in Group A and Group B



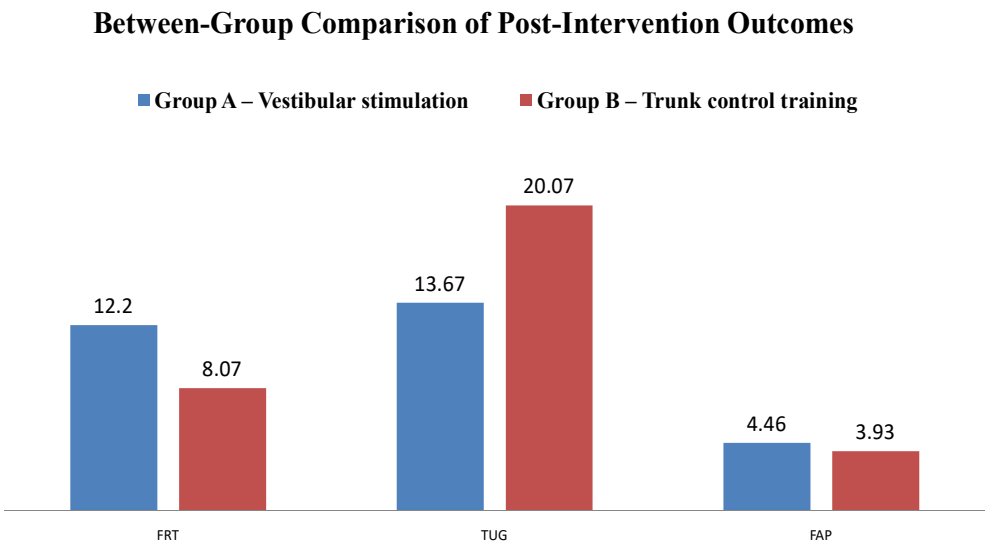
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Between-group comparison of post-intervention scores demonstrated statistically significant differences favoring Group A for all outcome measures (Table 3). Group A showed a significantly higher FRT score (12.2 ± 1.55 vs. 8.07 ± 0.83; $p < 0.001$), lower TUG time (13.67 ± 1.51 vs. 20.07 ± 5.05 seconds; $p < 0.001$), and higher FAP score (4.46 ± 0.64 vs. 3.93 ± 0.70; $p = 0.035$) compared with Group B.

TABLE 3: Between-Group Comparison of Post-Intervention Outcome Measures

Outcome Measures	Group A (Mean ± SD)	Group B (Mean ± SD)	t-value	p-value
FRT (inches)	12.2 ± 1.55	8.07 ± 0.83	9.14	< 0.001
TUG (seconds)	13.67 ± 1.51	20.07 ± 5.05	4.72	< 0.001
FAP	4.46 ± 0.64	3.93 ± 0.70	2.22	0.035

GRAPH-2 : Between-Group Comparison of Post-Intervention Outcome Measures



Discussion

The present comparative study evaluated the effectiveness of vestibular stimulation exercises in comparison with trunk control training exercises in individuals with sub-acute stroke. The

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findings demonstrated statistically significant improvements in trunk control, balance, and gait in both groups; however, greater improvements were observed in the vestibular stimulation group across all outcome measures. These findings support the role of vestibular-oriented physiotherapy interventions in the conservative management of sub-acute stroke.

The superior improvement in Functional Reach Test scores observed in the vestibular stimulation group may be attributed to enhanced vestibular input, improved sensory integration, and better postural control. Vestibular stimulation activates the vestibulospinal pathways, facilitating postural muscle activation and improving the body's ability to maintain the centre of gravity within the base of support during reaching activities [10,13]. These findings are consistent with previous studies reporting that vestibular stimulation improved balance and gait in hemiparetic patients [14,18].

Significant improvement in Timed Up and Go Test performance was also greater in the vestibular stimulation group. The superior improvement may be explained by the role of the vestibular system in maintaining upright posture, coordinating head and trunk movements, and stabilizing gaze during walking. Vestibular stimulation improves vestibulo-ocular and vestibulospinal reflexes, thereby enhancing balance reactions, postural orientation, and gait efficiency [12,18].

Greater improvement in Functional Ambulation Profile scores following vestibular stimulation exercises may be explained by enhanced vestibular input, improved gaze stability, better head and trunk coordination, and improved postural control during locomotion. The vestibular system plays a crucial role in maintaining dynamic equilibrium during walking by integrating visual, vestibular, and proprioceptive information [12,18]. These findings are supported by Meng et al.,

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who reported improvements in balance, gait, and functional mobility following vestibular rehabilitation in patients with stroke, particularly within the first six months after stroke [18].

The significant improvements observed in the trunk control training group indicate that trunk control exercises are also effective in improving balance and functional mobility after stroke. Trunk control is considered the foundation for coordinated limb movement, sitting balance, standing balance, and gait. Strengthening the trunk muscles improves proximal stability, enhances weight transfer, and facilitates efficient movement of the upper and lower extremities during functional activities [19,20]. Although trunk control training improved all outcome measures, the improvements were smaller than those observed in the vestibular stimulation group. This difference may be explained by the fact that vestibular stimulation directly targets the sensory system responsible for postural orientation and balance [12].

Overall, the findings of the present study suggest that both conventional physiotherapy combined with vestibular stimulation and conventional physiotherapy combined with trunk control training produced improvements in clinical and functional outcomes. However, the integrated vestibular approach produced superior improvements in dynamic balance, functional mobility, and gait, indicating that addressing vestibular sensory integration in addition to general exercise may enhance rehabilitation outcomes.

Limitations

This study has several limitations. First, the relatively small sample size of 30 participants may limit the generalizability of the findings. Second, the intervention period was limited to six weeks, and no follow-up assessment was conducted to evaluate the long-term effects of the interventions. Third, participant and therapist blinding was not feasible because of the nature of

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the interventions. Finally, the findings may not be generalizable to individuals with acute or chronic stroke, as the study included only participants with sub-acute stroke. Future studies should include larger sample sizes, longer follow-up periods, and blinded outcome assessors to further establish the effectiveness of vestibular stimulation and trunk control training exercises in stroke rehabilitation.

Conclusion

The findings of the present study indicate that both vestibular stimulation exercises and trunk control training exercises, when combined with conventional physiotherapy, were associated with improvements in clinical and functional outcomes in individuals with sub-acute stroke. However, vestibular stimulation exercises demonstrated statistically significant greater between-group improvements in dynamic balance (FRT), functional mobility (TUG), and gait performance (FAP) compared with trunk control training exercises. Therefore, the findings support the potential benefit of vestibular stimulation exercises, particularly for improving trunk control, balance, and gait, while its effects on other clinical outcomes should be interpreted with consideration of the observed between-group statistical results

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