Original Article

Comparative Effects of Perturbation-Based Balance Training and Whole-Body Vibration on Balance and Gait in Subacute Stroke Patients

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ABSTRACT

Objective: To explore the comparative effects of perturbation-based balance training (PBBT) and whole-body vibration (WBV) on balance and gait in patients during the subacute phase of stroke.

Methodology: This randomized clinical trial was conducted at DHQ Hospital, Sialkot and included twenty-eight participants with ischemic or hemorrhagic stroke who were between 12–20 weeks post stroke, aged 40–60 years, able to stand independently, walk 2 meters, and score >20/56 on Berg Balance Scale. The participants were selected through a non-probability convenience sampling technique. The study was carried out over a ten-month period, from April 2022 to January 2023, following ethical approval. Subjects were randomly allocated into two groups using computer-generated numbers (n=14 each). Group 1 received balance-oriented training with unidentified perturbations combined with conventional physical therapy, while Group 2 received whole-body vibration therapy with conventional physical therapy. The Berg Balance Scale (BBS) and Dynamic Gait Index (DGI) were used as outcome measures, assessed at baseline and after six weeks of intervention. The independent t-test and paired t-test were used to identify differences within and between groups, with a significance level set at $p < 0.05$.

Results: Significant differences were detected in the scores of the BBS and DGI between the two groups. The within-group analyses for both Group 1 and Group 2 indicated significant improvements, with more marked improvements in the perturbation-based balance training (PBBT) group. Baseline comparison of BBS and DGI showed mean differences of 0.83 and 0.50, respectively, with $p > 0.05$, indicating similarity at baseline. Post-intervention comparison for the BBS showed a mean score of 31.91±3.87 in the PBBT group and 26.58±3.98 in the WBV group. For the DGI, the mean score was 14.66±1.61 in the PBBT group and 12.41±1.92 in the WBV group.

Conclusion: The study concluded that while both interventions resulted in significant improvements in balance and gait, PBBT led to greater improvements than WBV.

KEYWORDS: Balance**,** Berg Balance Scale**,** Falls, Gait, Perturbation-based Balance Training, Rehabilitation, Stroke, Whole Body Vibration.

INTRODUCTION

Stroke, a condition caused by abnormal blood flow to the brain, is a major global health issue, ranking as the second leading cause of death and the third leading cause of disability worldwide.[1] It often leads to acquired disabilities such as hemiparesis that impairs balance, mobility, and the ability to perform daily activities. Balance problems are a common consequence of stroke and can increase the risk of falls, impacting autonomy and independence.[2,3] Reactive balancing is essential for fall prevention. Stroke patients have shown a reduction in their risk of falling due to improvements in reactive balance through Perturbation-Based Balance Training (PBBT) and Whole-Body Vibration (WBV) therapy.[4]

Various therapeutic methods, including neurofeedback training, rehabilitation robotics, visual-motor training, and action observation education, have been employed to improve postural control in stroke survivors.[4,8] Balance training programs typically involve exercises to enhance

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balance during stationary and purposeful movement, reducing the likelihood of falls and improving functional outcomes.[5] Whole-body vibration (WBV) therapy has emerged as a potential alternative to improve neuromuscular function and reduce fall risk by utilizing mechanical vibrations to trigger muscle reflexes and enhance muscle activation.[1,14]

Gait perturbation training, which involves exposing individuals to unpredictable disturbances during walking, is being explored as a strategy to prevent falls and improve stability after stroke.[15] The Berg Balance Scale (BBS) and the Timed Up and Go (TUG) test are commonly used assessment tools to evaluate balance and mobility in stroke patients. These assessments demonstrate good reliability and responsiveness in detecting changes in balance performance over time.[5,7]

Studies have highlighted the importance of considering factors such as initial BBS scores and the need for walking assistance when evaluating the impact of interventions for stroke patients with impaired activity, such as regulated WBV exercise.[6] Additionally, cognitive and emotional domains represent areas of high unmet needs among stroke survivors, with neurobehavioral disability encompassing behavioral dysregulation, emotional disorders, and inappropriate social behaviors.[8]

In conclusion, stroke presents significant challenges to individuals' physical, cognitive, and emotional well-being, affecting balance, mobility, and overall quality of life. Therapeutic interventions aimed at improving balance control and reducing fall risk play a crucial role in stroke rehabilitation. The Berg Balance Scale (BBS), Timed Up and Go (TUG), and Dynamic Gait Index (DGI) are useful tools for evaluating balance and supporting treatment planning in stroke survivors. Recent studies report that the DGI shows strong reliability in chronic stroke and that clinically meaningful change is estimated to be approximately 1–2 points. Ongoing research efforts are essential to deepen the understanding of stroke-related impairments and to develop more effective interventions that improve functional outcomes and quality of life for stroke survivors.

The study aims to determine which intervention is more effective in improving balance and gait in subacute stroke patients and to provide evidence-based recommendations for rehabilitation interventions. The findings may offer valuable insights to healthcare professionals in the management of patients with subacute stroke and contribute to enhancing the quality of care delivered.

METHODOLOGY

A randomized controlled trial (RCT) was conducted at District Headquarters (DHQ) Hospital, Sialkot, over a ten-month period, commencing in April 2022 after synopsis approval and concluding in January 2023. The study was approved by the Lahore Research and Ethical Committee of Riphah International University on April 4, 2022, with reference number REC/RCR & AHS/22/0229. Every participant gave written consent to the study, or their family members in the case of those who were incapable of giving consent. Using Epitool software, a final sample of 28 participants (14 per group) was determined after adjusting for potential attrition. Participants were recruited through a non-probability convenience sampling technique, and data collection was carried out at DHQ Hospital, Sialkot.

Eligible participants were male or female patients with ischemic stroke or hemorrhagic stroke, aged 40–60 years, 12–20 weeks post-stroke, able to stand independently, walk at least two meters, and achieve greater than 20 score on the Berg Balance Scale.[5] Exclusion criteria included other neurological disorders, severe balance impairment, orthopedic conditions, recent trauma, blindness, or lower-limb weight-bearing pain.[9]

Participants were randomly allocated into two groups using computer-generated numbers. Group 1 received perturbation-based balance training in combination with conventional physical therapy,

whereas Group 2 received whole-body vibration therapy with conventional physical therapy.[10]

Data collection was carried out using validated outcome measures. Balance was assessed with the Berg Balance Scale (BBS), a reliable and valid tool for evaluating balance and fall risk (test–retest reliability, r = 0.98). Walking balance during functional tasks was assessed using the Dynamic Gait Index (DGI), which has demonstrated strong reliability (r = 0.95).[11]

Participants who met the inclusion criteria were informed about the study, provided written consent, and were randomly allocated into groups using a computer-generated block randomization method, with allocation concealed in sealed envelopes. Group 1 received conventional physical therapy consisting of standard physical therapy aimed at improving joint mobility, muscle strength, balance, gait, and activities of daily living (ADLs). The intervention included passive, active-assistive, and active range of motion exercises; resistive strengthening exercises; and activities performed in different functional positions such as sitting and standing three times per week for six weeks (20–30 minutes per session), in addition to perturbation-based balance training (PBBT).[12] The PBBT program included 18 sessions of random, multidirectional platform translations tailored to individual abilities to safely challenge balance recovery. Group 2 received whole-body vibration (WBV) therapy in addition to conventional therapy, consisting of 18 supervised sessions over six weeks, with 10–15 minutes of vibration training per session (frequency: 20–30 Hz; amplitude: 2–3 mm), performed in a semi-flexed posture with the use of a buttock belt for safety.[13]

Compliance was closely monitored, and all sessions were supervised by a physical therapist who documented any difficulties or adverse effects. Post-intervention assessments were conducted at the end of 6 weeks using standardized outcome measures to evaluate treatment effectiveness in both groups. Data were analyzed using SPSS version 25. Descriptive statistics were applied to quantitative variables, while frequencies were reported for categorical data. The Shapiro–Wilk test was used to assess normality. Within-group comparisons were performed using paired t-tests, and between-group comparisons using independent t-tests, with the significance level set at $p < 0.05$.

RESULTS

Initially, thirty-four patients were screened for eligibility, of whom twenty-eight met the inclusion criteria and were enrolled in the study. Four participants (two from each group) discontinued participation and were excluded from the analysis. Thus, data from 24 participants who completed the study were analyzed, with 12 participants in each group. Baseline demographic and clinical characteristics are presented in Table 1. No statistically significant differences were observed between the two groups with respect to age, gender distribution, affected side, type of stroke, family history, or time since stroke, indicating baseline comparability (Table 1).

Table 1: Demographic and baseline characteristics of participants

Variables	Group 1 (n = 12)	Group 2 (n = 12)
Age (Years), Mean ± SD	47.92 ± 4.83	50.75 ± 4.20
Gender		
• Male (%)	4 (33.3%)	7 (58.3%)
• Female (%)	8 (66.7%)	5 (41.7%)
Side Affected		
• Right (%)	4 (33.3%)	6 (50.0%)
• Left (%)	8 (66.7%)	6 (50.0%)
Type of Stroke (%) Ischemic Hemorrhagic	 10 (83.3%) 2 (16.7%)	 8 (66.7%) 4 (33.3%)
Family History (%) Positive Negative	 5 (41.7%) 7 (58.3%)	 8 (66.7%) 4 (33.3%)
Time Since Stroke (weeks), Mean ± SD	7.63 ± 2.22	11.25 ± 3.91

SD = standard deviation, Group 1 = conventional physical therapy + perturbation based balanced training,
Group 2 = Conventional physical therapy + whole body vibration.

The mean age of patients in the perturbation-based balance training group (group 1) was 47.92 ± 4.83 years, whereas in the whole-body vibration group (group 2) it was 50.75 ± 4.20 years. Each group included 12 participants. Group 1 comprised 4 men (33.3%) and 8 women (66.7%), while Group 2 comprised 7 men (58.3%) and 5 women (41.7%) (Table 1). According to group allocation, 10 participants (83.3%) in Group 1 had ischemic stroke and 2 (16.7%) had hemorrhagic stroke, whereas Group 2 included 8 participants (66.7%) with ischemic stroke and 4 (33.3%) with hemorrhagic stroke (Table 1). Regarding family history, 5 participants (41.7%) in Group 1 reported a positive family history of stroke and 7 (58.3%) reported none; while in Group 2, 8 participants (66.7%) reported a positive family history and 4 (33.3%) reported none. The test of normality showed that the data were normally distributed, as the significance value was greater than 0.05 for all variables (Table 2).

Table 2: **Test of Normality (Shapiro–Wilk)**

	Shapiro-Wilk		
	Statistic	**df**	**Sig.**
Pre-Intervention Berg Balance Scale Score	0.978	24	0.852
Post-Intervention Berg Balance Scale Score	0.954	24	0.331
Pre-Intervention Dynamic Gait Index Score	0.874	24	0.306
Post-Intervention Dynamic Gait Index Score	0.953	24	0.307

Normality of the outcome variables was assessed using the Shapiro–Wilk test, which indicated that pre- and post-intervention Berg Balance Scale (BBS) and Dynamic Gait Index (DGI) scores were normally distributed ($P > 0.05$ for all variables; Table 2). Therefore, parametric tests were applied for subsequent analysis.

Within-group comparisons were performed using the paired t-test and revealed statistically significant improvements in balance and gait in both intervention groups following the 6-week training period (Table 3). In the perturbation-based balance training (PBBT) group, the mean BBS score increased from 15.0 ± 2.95 to 31.91 ± 3.87, and the mean DGI score increased from 8.83 ± 2.85 to 14.66 ± 1.61 ($P < 0.05$). Similarly, participants in the whole-body vibration (WBV) group demonstrated significant improvements, with the mean BBS score increasing from 15.83 ± 2.69 to 26.58 ± 3.98 and the mean DGI score increasing from 9.33 ± 2.70 to 12.41 ± 1.92 ($P < 0.05$).

Table 3: Within-group Pre–Post comparison of BBS and DGI scores

Variables	Groups	Baseline Mean ± SD	Post-Intervention Mean ± SD	Mean Difference	P-value
Berg Balance Scale (BBS)	Group 1 (PBBT)	15.0 ± 2.95	31.91 ± 3.87	16.91	<0.05
	Group 2 (WBV)	15.83 ± 2.69	26.58 ± 3.98	10.75	<0.05
Dynamic Gait Index (DGI)	Group 1 (PBBT)	8.83 ± 2.85	14.66 ± 1.61	5.83	<0.05
	Group 2 (WBV)	9.33 ± 2.70	12.41 ± 1.92	3.08	<0.05

A p-value < 0.05 indicates statistical significance.

PBBT = perturbation base balance training, WBV = whole body vibration, $P < 0.05$. Paired sample t-tests within both groups demonstrated significant improvements in BBS and DGI) post-intervention ($p < 0.05$).

Between-group comparisons were conducted using the independent t-test (Table 4). Baseline analysis showed no statistically significant differences between the two groups for BBS or DGI scores ($P > 0.05$), confirming baseline equivalence.

Table 4: Between-group comparison of BBS and DGI scores

Outcome	Time point	Group 1 (PBBT) Mean ± SD	Group 2 (WBV) Mean ± SD	Mean Difference (95% CI)	P-value
BBS	Baseline	15.0 ± 2.95	15.83 ± 2.69	0.83 (−3.22, 1.55)	0.47
DGI	Baseline	8.83 ± 2.85	9.33 ± 2.70	0.50 (−2.85, 1.85)	0.66
BBS	Post-intervention	31.91 ± 3.87	26.58 ± 3.98	5.33 (2.00, 8.66)	<0.05
DGI	Post-intervention	14.66 ± 1.61	12.41 ± 1.92	2.25 (0.74, 3.75)	<0.05

A p-value < 0.05 indicates statistical significance.

The independent sample t-test compared both groups, showing no significant baseline differences in Berg Balance Scale (BBS) and Dynamic Gait Index (DGI) ($p>0.05$). Group 1 received Perturbation-Based Balance Training (PBBT), while Group 2 received Whole-Body Vibration (WBV).

However, post-intervention analysis at the end of the sixth week showed significantly greater improvements in the PBBT group compared to the

WBV group, with mean differences of 5.33 (95% CI: 2.00–8.66; P < 0.05) for BBS and 2.25 (95% CI: 0.74–3.75; P < 0.05) for DGI, indicating superior efficacy of perturbation-based balance training. Both interventions improved balance and gait, but PBBT training resulted in significantly greater improvements (Table 4).

DISCUSSION

The current study aimed to evaluate and compare the effects of perturbation-based balance training (PBBT) and whole-body vibration (WBV) therapy on gait and balance in stroke patients. Both groups received conventional therapy in addition to either PBBT or WBV. The findings revealed statistically significant improvements in both groups, with the PBBT group demonstrating greater improvement in gait and balance compared to the WBV group. These findings suggest that PBBT may be a more effective intervention for enhancing balance in patients with sub-acute stroke.

Similarly, Molhemi et al. reported that PBBT outperformed conventional balance training (CBT) in improving reactive balance and reducing falls in individuals with multiple sclerosis, as measured by the Berg Balance Scale and other assessments.[14] PBBT has been shown to be at least as effective as conventional balance training in improving stability and decreasing fall risk. Our study demonstrated a statistically significant difference on the Berg Balance Scale. Although improvements were also observed in the whole-body vibration group, the greater gains in the PBBT group indicate that PBBT is more effective in enhancing balance, which in turn improves gait and walking ability in stroke patients.

Gerards et al. assessed PBBT for fall prevention in older adults and found it to be a feasible strategy involving treadmill-based systems and therapist-administered perturbations. These methods, incorporating oscillations and varying orientations, were considered particularly beneficial in clinical settings.[15]

Allin et al. demonstrated that perturbation-based balance training (PBBT) effectively improves postural stability and reduces fall risk in older adults through the use of controlled slip- and trip-specific perturbations.[16]

M. M. Rieger et al. conducted a study to appraise the impact of a four-week treadmill training on dynamic walking stability in daily life. Their findings provided insight into how perturbation-based treadmill training can enhance gait stability in everyday activities while reducing the risk of falls and related accidents. Perturbation-based training was found to enhance balance recovery techniques and reduce the risk of falls.[17]

The study by A. Bisla, T. Fahim, and, colleagues revealed that exercises involving synchronized movements across various joints markedly enhance postural stability. Manual perturbation exercises were shown to improve balance by fostering both reactive and anticipatory responses. Furthermore, the research demonstrated that training protocols designed to elicit whole-body reactions are effective in mitigating fall risks. Comparable enhancements were also noted in participants of a group who underwent six weeks of perturbation-based balance training.[18]

Research conducted by Y. Moon and Y. Bae suggested that PBBT improved gait ability in chronic stroke patients, with significant improvements observed in Dynamic Gait Index scores between pre- and post-intervention assessments. The growth of the mirror neuron system can be aided by repeated performance of an activity following repeated observation of the action, although even simple observation of an action is sufficient to stimulate a related region of the brain. The findings of our study are consistent with previous research, further demonstrating that recurrent PBBT training improves gait function in chronic stroke patients.[19]

Research by Vahid Esmaeili and colleagues indicates that high-intensity and unpredictable disruptions to gait are promising components of training programs aimed at improving balance capabilities and community engagement in

individuals with chronic stroke. Notably, secondary outcomes revealed a significant increase in balance confidence associated with this exercise approach. Our study corroborates these findings, showing substantial improvements in balance among stroke patients who adhered to this unpredictable perturbation regimen for approximately five to six weeks.[11]

This study supports the effectiveness of PBBT in improving balance recovery in individuals with subacute stroke. The findings revealed statistically significant improvements in both groups, with the PBBT group demonstrating greater gains in gait and balance. Specifically, both groups showed enhancements in areas such as fall thresholds, balance, and gait function (measured using the BBS assessment tool). However, the two groups varied statistically significantly, with greater improvements observed in the PBBT group. Our study supports the notion that PBBT has positive impacts on balance and gait. It demonstrated improved balance and gait performance in the participants who underwent PBBT. Perturbation-based training, which simulates real-life balance challenges, has proven effective in improving balance and walking in stroke patients. This approach likely enhances patients' ability to manage everyday balance demands. These results align with the systematic review by Coelho et al. (2022), which reported that PBBT improves postural control and gait in individuals with Parkinson's disease. Together, these findings suggest that PBBT may be a particularly effective intervention for enhancing balance and functional mobility in patients with sub-acute stroke, supporting its use across different neurological populations.[20]

CONCLUSION

Both perturbation-based balance training (PBBT) and whole-body vibration (WBV) are effective in improving balance and gait; however, PBBT appears to be more effective than WBV in enhancing these parameters in sub-acute stroke patients.

Limitations: Comparing perturbation-based balance training (PBBT) and whole-body vibration (WBV) is challenging due to differences in protocols and patient characteristics, which may affect their effectiveness. The study's specific patient selection along with the high cost and extensive time required for randomized controlled trials (RCTs) pose challenges for generalizability and timely completion of the study, while ensuring treatment compliance can influence the accuracy of the results.

Recommendations: Perturbation-based balance training (PBBT), combined with conventional therapy, is recommended to improve balance and gait in sub-acute stroke patients, with programs tailored to individual needs. Standardized assessment tools should be used to monitor progress, and future studies should explore long-term effects and include larger sample sizes for generalizability

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Rida Aziz: Conceived the study designed, carried out the data collection and statistical analysis and drafted the manuscripts.

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