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Original Research Article

Effectiveness of vestibular rehabilitation among post-stroke pusher syndrome

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ABSTRACT

Background: Pusher syndrome is a post-stroke neurobehavioral disorder characterized by a distorted perception of upright posture and active pushing toward the hemiparetic side, leading to impaired balance, increased fall risk, and delayed rehabilitation.
Methods: This randomized clinical trial included 36 post-stroke patients diagnosed with pusher syndrome. Participants were randomly assigned to two groups for an 8-week intervention, conducted twice weekly with two sessions per day. Group A received vestibular rehabilitation therapy (VRT) focusing on gaze stabilization, dynamic balance, and proprioceptive training. Group B performed trunk and core stability exercises. Outcome measures included the scale for contraversive pushing (SCP) and postural assessment scale for stroke patients (PASS), assessed pre- and post-intervention.
Results: Both groups demonstrated significant improvement; however, group A showed a greater reduction in SCP scores (6.09±0.19 to 2.89±0.17, $p<0.001$) and a greater increase in PASS scores (11.6±1.1 to 25.8±1.0, $p<0.001$) compared to group B. Between-group analysis confirmed that VRT was significantly more effective in reducing contraversive pushing and improving postural control.
Conclusions: VRT is more effective than trunk stability exercises in improving postural alignment, reducing contraversive pushing, and enhancing functional independence in post-stroke pusher syndrome. Incorporating vestibular strategies into stroke rehabilitation may optimize recovery.

Keywords: Vestibular rehabilitation, Trunk stability, Postural balance, Stroke rehabilitation

INTRODUCTION

Stroke is one of the most significant health challenges worldwide, ranking among the leading causes of death and long-term disability in adults. It occurs when the blood supply to a part of the brain is either blocked by a clot (ischemic stroke) or interrupted due to bleeding (haemorrhagic stroke), which rapidly leads to loss of neurological function and potential brain tissue damage.[1] Without oxygen and essential nutrients, neurons in the affected region begin to die within minutes. Since different brain areas regulate specific motor, sensory, and cognitive functions, stroke can disrupt a wide range of abilities. Depending on the lesion's location and severity, individuals may present with hemiparesis, communication difficulties, visual problems, memory or thinking deficits, and other neurological impairments. Immediate recognition and intervention are vital for minimizing brain damage and improving the chances of recovery. Over recent decades, acute stroke care has advanced considerably with the introduction of thrombolytic drugs, endovascular procedures, and sophisticated imaging methods.[2]

Globally, stroke continues to be a major public health concern, accounting for around 10% of all deaths and contributing heavily to disability-adjusted life years (DALYs) lost.[3] This burden is especially high in low- and middle-income countries due to limited healthcare access and preventive strategies. Regions such as South Asia, Southeast Asia, and sub-Saharan Africa report higher incidence and mortality rates, partly because of rapid urbanization, poor management of hypertension, aging populations, and lack of awareness programs. In India, nearly 1.2 million people experience a stroke every year, with prevalence rates ranging between 0.84% and 1.2%. Urban populations show higher incidence due to risk factors such as sedentary lifestyle, obesity, smoking, and metabolic syndrome.[4] With the country's growing rates of diabetes and hypertension and insufficient preventive services in both rural and urban areas, the stroke burden is expected to rise further in the future.

The clinical features of stroke vary depending on the artery involved and the extent of brain damage. Occlusion of the middle cerebral artery (MCA) is the most frequent and usually results in significant weakness or sensory loss in the opposite face and upper limb. Left MCA strokes may lead to global aphasia, while right MCA strokes may cause spatial neglect and disorientation. Anterior cerebral artery (ACA) infarcts often affect the contralateral lower limb and may also produce urinary incontinence and behavioural changes such as apathy or impulsivity.[5] Posterior cerebral artery (PCA) strokes are commonly associated with visual field loss, visual agnosia, or cortical blindness in bilateral cases. Cerebellar strokes, often due to posterior inferior cerebellar artery (PICA) or superior cerebellar artery occlusion, can produce dizziness, imbalance, limb incoordination, and vertigo. Small vessel occlusions cause lacunar strokes, leading to presentations such as pure motor hemiparesis or ataxic hemiparesis. Involvement of the vertebrobasilar system is particularly life-threatening, as it can affect the brainstem and cause severe deficits, including locked-in syndrome.

A unique post-stroke condition is pusher syndrome (contraversive pushing), which differs from ordinary leaning caused by weakness. Patients with this condition actively push themselves toward the weaker side and resist being corrected to upright.[6] This occurs because they misjudge their body's orientation relative to gravity, perceiving themselves as vertical when tilted. Pusher syndrome is frequently linked to right hemisphere damage, particularly involving the posterolateral thalamus and nearby regions important for verticality perception.[7,8]

Its prevalence is estimated at 5-10% of all stroke survivors and is more common after moderate-to-severe strokes.[9] In India, about 5-8% of patients may experience it, although rural areas may underreport cases due to lack of neurorehabilitation expertise. Rehabilitation becomes more challenging in these patients because they need longer therapy durations and have higher fall risks.[10] Management focuses not only on muscle recovery but also on retraining perception of vertical orientation, often through visual, tactile, and task-specific training strategies.

The acute management of stroke differs according to subtype. For ischemic stroke, intravenous recombinant tissue plasminogen activator (rtPA) is highly effective if given within 4.5 hours of symptom onset.[11] In cases of large vessel occlusion, mechanical thrombectomy can be life-saving and shows the best outcomes if performed within 6-24 hours.[12] Haemorrhagic stroke treatment usually targets blood pressure control to prevent rebleeding, with agents like labetalol or nicardipine commonly prescribed.[13] Surgical options such as decompressive craniectomy may be considered in cases of severe hematoma or increased intracranial pressure.

Long-term management emphasizes secondary prevention and rehabilitation. Preventive strategies include strict control of hypertension, diabetes, and atrial fibrillation, in addition to adopting healthier lifestyles.[14] Antiplatelet therapy (aspirin, clopidogrel), anticoagulation in atrial fibrillation, and statins for cholesterol control are routinely used. Rehabilitation is central to recovery, with physiotherapy playing a major role in motor function restoration and reintegration into daily life. Evidence-based approaches such as repetitive task training, task-specific exercises, and constraint-induced movement therapy (CIMT) have proven effective in enhancing neuroplasticity.[15,16] Spasticity management may involve stretching, strengthening, neuromuscular electrical stimulation (NMES), and in some cases, botulinum toxin therapy.[17,18]

Gait and balance rehabilitation are crucial for independence. Robotic-assisted devices and electromechanical gait training have demonstrated significant improvements in walking ability and endurance.[18] Similarly, technologies like virtual reality (VR) offer engaging therapy environments that can enhance motivation and lead to better outcomes when combined with conventional physiotherapy.[17]

VRT is increasingly being recognized for its role in improving balance and reducing dizziness after stroke. VRT programs are tailored to include exercises for gaze stabilization, habituation, and balance retraining, thereby helping patients integrate sensory inputs more effectively.[19] Clinical trials show that VRT enhances postural stability, particularly in patients with vestibular dysfunction or subacute stroke. For those with pusher Syndrome, targeted visual and somatosensory feedback during VRT can help recalibrate their distorted vertical perception.[20-22]

Overall, stroke is a complex neurological condition requiring urgent care, preventive strategies, and structured rehabilitation. The presence of complications such as pusher syndrome makes recovery more challenging but not impossible, especially with modern techniques like vestibular rehabilitation and advanced physiotherapy methods. Advances in technology-assisted rehabilitation continue to improve outcomes, making individualized, early, and multidisciplinary care the cornerstone of stroke management.

METHODS

Study design

This study was designed as an experimental, randomized clinical trial.

Study setting and duration

The trial was conducted at Saveetha medical college and hospital, Thandalam, Chennai, between September 2024 and March 2025.

Inclusion criteria

Post-stroke survivors diagnosed with pusher syndrome. Scores greater than zero in all sections of the SCP.

Both male and female participants aged 35-72 years were included.

Exclusion criteria

Severe cognitive impairment, history of vestibular disorders, recent stroke or seizures and severe cardiac disease were excluded.

Sampling and randomization

A convenient sampling technique was used for recruitment. Sample size estimation was performed using G*Power software, with an alpha of 0.05, power of 0.80, and effect size of 0.7, resulting in a required sample size of 68. Of these, 32 patients did not meet the inclusion criteria, leaving 36 eligible participants.

Participants were randomly allocated into two groups (Group A and B, n=18 each) using a computer-generated randomization schedule. Allocation concealment was ensured by consecutively numbered, sealed, opaque envelopes.

Procedure

After obtaining written informed consent, baseline assessments were carried out by a blinded examiner. The same examiner performed post-intervention evaluations to minimize assessment bias.

Group A (Experimental group): Received VRT.

Group B (Control group): Received trunk stability exercises.

Both groups underwent interventions for 8 weeks, with two sessions per week. Each therapy day included two 45-minute sessions, conducted by licensed physiotherapists trained in respective protocols. Interventions progressively adapted based on patient tolerance and performance.

Intervention protocols

VRT (Group A): Gaze stabilization, smooth pursuit and saccadic eye movements, balance training on various surfaces, and coordinated head movement exercises.

Trunk stability exercises (Group B): Static and dynamic sitting, pelvic tilts, bridging, and trunk stabilization on unstable surfaces.

Outcome measures

Outcome assessments were conducted at baseline and after 8 weeks using: SCP and PASS.

Ethical approval

Ethical clearance was obtained from the institutional scientific review board (Approval No: ISRB-02/015/2024/ISRB/PGSR/SCPT).

Statistical analysis

Data were analyzed using paired t-tests for within-group comparisons and unpaired t-tests for between-group comparisons. P<0.05 considered statistically significant.

Table 1: Exercise protocol.

Weeks	Group A: VRT	Group B: trunk stability exercises
1	Gaze stabilization (VOR×1)	Seated trunk alignment awareness
	Seated balance with head turns	Pelvic tilts in sitting
	Eye tracking on fixed targets	Static seated balance
2	Gaze stabilization (VOR×1 and ×2)	Seated trunk rotations
	Standing with narrow base support	Reaching tasks from seated position
	Visual tracking + head motion	Dynamic balance on flat surface
3	Visual fixation with unstable surface	Sit-to-stand with trunk control
	Head turns with walking	Lateral weight shifts
	Tandem standing balance	Dynamic sitting on therapy ball
4	Dynamic head movements while walking	Seated bridging exercises
	Balance tasks with eyes closed	Trunk flexion/extension on therapy ball
	Obstacle walking with visual focus	Standing trunk exercises with support

Continued.

Weeks	Group A: VRT	Group B: trunk stability exercises
5	Balance on foam surface	Unilateral reaching in standing
	Gaze stabilization with dual tasks	Standing on unstable surfaces
	Walking with head turns in different directions	Trunk holds with resistance
6	Reactive balance training	Standing trunk rotation with resistance band
	Visual conflict exercises	Step-ups with core control
	Walking in busy environments (simulated)	Trunk lateral holds
7	Fast-paced head movement with postural correction	Dynamic trunk rotation with weight
	Tandem walking with visual tasks	Balance board activities
	Dual-task balance games	Seated perturbation training
8	Combined gaze, head, and body movement tasks	Complex trunk exercises in standing
	Full body coordination with visual cues	Stability on wobble boards
	Final balance testing simulation	Advanced core stabilization circuit

RESULTS

The study included 36 participants diagnosed with post-stroke pusher syndrome, who were randomly divided into two groups: Group A received VRT, and group B underwent trunk stability exercises. The outcomes were measured using the SCP and the PASS, both before and after the 8-week intervention. In Table 2 demographic details including type of stroke is mentioned.

In terms of SCP scores, group A showed a marked reduction from a pre-test mean of 6.09±0.19 to a post-test mean of 2.89±0.17, which was statistically significant (t=105.79, p<0.001). Group B also showed a significant but lesser reduction in SCP scores from 6.06±0.16 to 5.31±0.19 (t=45.00, p<0.001) (Table 3).

Unpaired t-test comparison of post-test SCP values between the groups confirmed a statistically significant difference in favor of group A (t=40.23, p<0.001), indicating greater improvement in reducing pushing behaviour through vestibular rehabilitation (Table 4).

For the PASS scores, group A exhibited significant improvements in postural control, with pre-test scores rising from approximately 11.6±1.1 to 25.8±1.0 (t=18.21, p<0.001). In contrast, group B improved from 11.5±1.7 to 13.2±1.0 (t=7.45, p<0.001) (Table 5).

Post-intervention comparison between groups showed a statistically significant difference in PASS scores, with group A scoring significantly higher (t=24.88, p=0.022) (Table 6), further confirming the superior effect of VRT on postural alignment and functional recovery. Overall, both groups benefited from their respective interventions; however, VRT produced significantly greater improvements in reducing contraversive pushing and enhancing balance, confirming its clinical utility in managing pusher syndrome.

Figure 1 about post mean values of Group A and group B obtained using contraversive pushing and Figure 2 about post-test of group A and group B obtained using PASS. Figure 3 represents the treatment of vestibular rehabilitation.

Table 2: Demographic details.

Variables	Group A (VRT), (n=18)	Group B (Trunk stability), (n=18)	Total, (n=36)
Age (in years)	35-72 (Mean±SD)	35-72 (Mean±SD)	35-72
Gender			
Male	10 (55.6%)	9 (50.0%)	19 (52.8%)
Female	8 (44.4%)	9 (50.0%)	17 (47.2%)
Type of stroke			
Ischemic	12 (66.7%)	13 (72.2%)	25 (69.4%)
Hemorrhagic	6 (33.3%)	5 (27.8%)	11 (30.6%)
Duration since stroke	<6 months: 9 (50.0%)	<6 months: 10 (55.6%)	19 (52.8%)
	>6 months: 9 (50.0%)	>6 months: 8 (44.4%)	17 (47.2%)

Table 3: Pre and post-test values of group A and B obtained using contraversive pushing scale.

Groups	Tests	Mean	SD	Paired test, t value	P value
Group A	Pre-test	6.09	0.19	105.79	<0.001
	Post-test	2.89	0.17		
Group B	Pre-test	6.06	0.16	45.00	<0.001
	Post-test	5.31	0.19		

Table 4: Post-test values of group A and B obtained using contraversive pushing.

Groups	Test	Mean	SD	Un paired test, t value	P value
Group A	Post-test	2.89	0.17	40.23	<0.001
Group B	Post-test	5.31	0.33		

Table 5: Pre and post-test values of group A and B obtained using PASS.

Groups	Test	Mean	SD	Paired test, t value	P value
Group A	Pre-test	~11.6	~1.1	18.21	<0.001
	Post-test	~25.8	~1.0		
Group B	Pre-test	~11.5	~1.7	7.45	<0.001
	Post-test	~13.2	~1.0		

Table 6: Post-test of group A and B obtained using PASS.

Groups	Test	Mean	SD	T value	P value
Group A	Post-test	25.8	2.3	24.88	<0.022
Group B	Post-test	13.2	1.0		

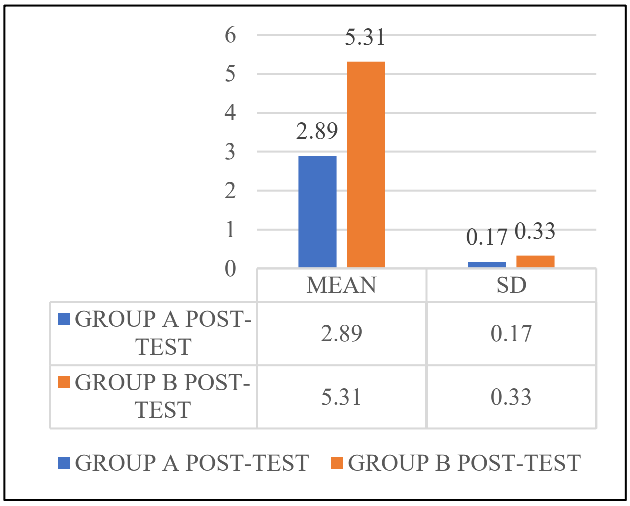

Figure 1: Post-test values of group A and B obtained using contraversive pushing.

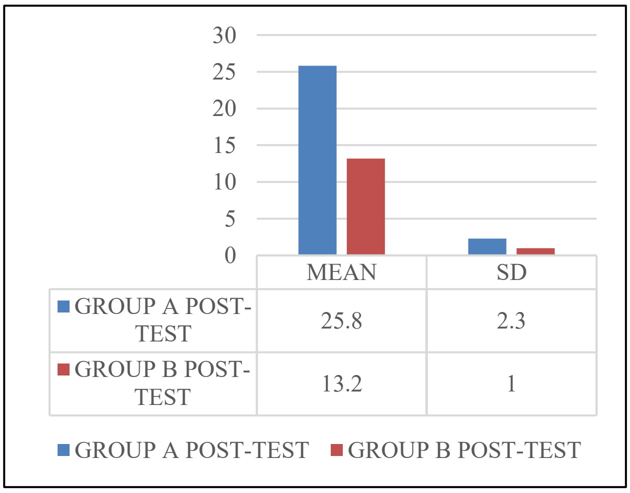

Figure 2: Post-test of group A and group B obtained using PASS.

Figure 3: Vestibular rehabilitation.

DISCUSSION

This study investigated the comparative effectiveness of VRT and trunk stability exercises in individuals with post-stroke pusher syndrome. The condition is marked by a disordered perception of verticality and postural alignment, resulting in patients actively pushing toward their paretic side. The study demonstrated that patients treated with VRT showed significantly greater improvement in postural balance and reduction in contraversive pushing behaviour compared to those receiving trunk-focused exercises. The findings provide further evidence supporting the hypothesis that sensory-perceptual interventions, particularly those targeting vestibular integration, are more effective than conventional physical approaches alone in the rehabilitation of pusher syndrome.

Pusher syndrome, also known as contraversive pushing, often follows a unilateral stroke, particularly those involving the right hemisphere, and is characterized by an altered sense of upright posture due to impaired processing in the posterolateral thalamus, parietal cortex, and adjacent vestibular-associated areas. These neural substrates are essential for integrating visual, vestibular, and somatosensory information to maintain postural control. Disruption in these areas leads to a mismatch between the subjective postural vertical (SPV) and the actual gravitational vertical, which drives the characteristic pushing behavior.[8] Unlike typical hemiparetic stroke patients who tend to fall toward the paretic side due to weakness, individuals with pusher syndrome push away from the unaffected side, exacerbating instability and prolonging rehabilitation.

Traditional rehabilitation for stroke patients often emphasizes motor re-education, trunk stability, and balance training. While these are vital components of post-stroke care, they may not sufficiently address the core perceptual and sensory deficits specific to pusher syndrome. Trunk stability exercises aim to improve core strength and proprioceptive control, which can enhance static and dynamic balance. However, they do not directly recalibrate distorted vertical perception. On the other hand, VRT, which incorporates gaze stabilization, head and body movements, and exercises that challenge the vestibulo-ocular and vestibulo-spinal systems, is uniquely positioned to correct perceptual mismatches and improve postural orientation.[23]

The results of this study align with previous research. Yoo et al conducted a randomized controlled trial in which VRT significantly improved gait performance and vestibulo-ocular reflex in post-stroke individuals, reinforcing the value of sensory-specific rehabilitation.[8] Similarly, Nestmann et al developed a Tilted Reality Device to help patients with Pusher syndrome recalibrate their vertical orientation using visual-vestibular cues, demonstrating that perceptual interventions can be clinically effective.[24] Baier and Karnath proposed that restoration of the SPV, rather than just motor correction, is crucial for recovery in pusher syndrome, highlighting the importance of targeting sensory systems.[25]

This study contributes to that body of evidence by demonstrating that structured VRT protocols can produce significant clinical improvements in postural control as measured by the SCP and the PASS.[26] The VRT group showed greater reduction in SCP scores and greater improvements in PASS scores than the trunk exercise group, indicating superior outcomes in both the behavioural and functional domains. These results can be attributed to the specific nature of VRT, which directly engages the neural networks responsible for spatial orientation and verticality perception.

From a neurophysiological standpoint, the efficacy of VRT is supported by evidence that vestibular stimulation activates cortical areas involved in spatial awareness, such as the parietal-insular vestibular cortex. Baier et al demonstrated through diffusion tensor imaging (DTI) that recovery of SPV perception post-stroke correlated with improved white matter integrity in vestibular-associated pathways.[27] The activation of these pathways during VRT likely contributes to neuroplastic changes that underpin functional recovery.

Additionally, sensory reweighting where the brain adjusts the relative contributions of visual, vestibular, and somatosensory inputs is a critical mechanism promoted through VRT. In patients with pusher syndrome, VRT may help recalibrate this integration by reinforcing vestibular input and reducing maladaptive dependence on somatosensory signals from the non-paretic side.[28]

Gaze stabilization exercises, balance training on unstable surfaces, and combined head-eye-body coordination tasks, all integral components of VRT, provide multisensory stimuli that facilitate central nervous system adaptation. As Langhorne et al noted, neurorehabilitation strategies that employ task-specific and sensory-rich environments yield better outcomes in functional recovery. The adaptability of VRT protocols allows for individualized therapy that can be scaled according to the patient's tolerance and progress, making it both effective and safe across various stages of stroke rehabilitation.[29]

An important clinical implication of this study is that VRT is a non-invasive, cost-effective intervention that requires minimal equipment and can be implemented in both inpatient and outpatient settings.[30] The results suggest that early integration of VRT into stroke rehabilitation programs, especially for patients with clear signs of Pusher Syndrome, can expedite recovery and reduce the duration of hospitalization. Furthermore, as Baccini et al observed, SCP scores are predictive of long-term functional independence, and early improvement in pushing behavior correlates with better overall outcomes. Hence, the inclusion of VRT could have far-reaching effects beyond postural control, potentially influencing discharge planning, caregiver burden, and community reintegration.[31]

Limitations

First, the relatively small sample size (n=36) limits the generalizability of the findings to the broader post-stroke population. Second, the study was conducted in a single tertiary care hospital, which may restrict external validity. Third, the intervention period was limited to eight weeks, and long-term follow-up was not performed to determine whether the observed improvements were sustained over time.

Additionally, the use of convenient sampling and the exclusion of patients with severe cognitive or cardiac conditions may have introduced selection bias. Finally, although outcome assessors were blinded, patient awareness of the intervention type could have influenced performance, potentially leading to bias in results.

CONCLUSION

VRT is significantly more effective than trunk stability exercises alone in improving postural alignment and reducing contraversive pushing in post-stroke Pusher syndrome. Incorporating targeted vestibular exercises into rehabilitation programs may therefore enhance balance recovery and functional independence in this population.

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