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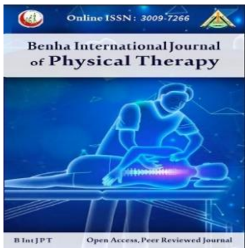

Original research

Effect of vestibular rehabilitation on balance and gait after stroke: A narrative review

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Abstract:
Background: Stroke is the third leading cause of mortality and long-term disability worldwide, often resulting in impairments in balance, gait, and spatial orientation. These functional limitations are frequently associated with both central and peripheral vestibular dysfunction following stroke. Vestibular rehabilitation therapy (VRT) is one of therapeutic approaches, neglected in neuro rehabilitation. (VRT) aimed to improve balance and gait after stroke. stroke patients always have balance problems and high risk of falling. **Purpose:** This review aims to summarize how stroke affects the vestibular system from peripheral to central and to evaluate the role and effectiveness of (VRT) in improving balance and gait among stroke patients. **Methods:** A narrative literature review was conducted by searching PubMed, the Cochrane Library, and Scopus databases for articles published between 2010 and 2024. The inclusion criteria focused on studies examining vestibular dysfunction in stroke and the application of VRT as a therapeutic intervention. **Results:** Vestibular dysfunction was found to occur in strokes involving both anterior and posterior circulation, affecting various components of the vestibular system. Evidence supports the effectiveness of vestibular rehabilitation in reducing dizziness, improving gait performance, enhancing postural control, and minimizing fall risk in stroke survivors. VRT facilitates recovery through mechanisms such as vestibular adaptation, sensory substitution, and central compensation. **Conclusion:** Vestibular rehabilitation is a valuable but often overlooked component of post-stroke neurorehabilitation. Integrating VRT into standard balance training protocols may significantly enhance functional recovery by addressing vestibular-related deficits. Its inclusion should be considered essential for improving overall mobility and independence in stroke patients.

Keywords: Balance training, cowthrone exercises, falling, gaze stabilization, stroke,vestibular rehabilitation exercise .

Introduction

A stroke occurs when blood supply to brain tissue is disrupted, leading to ischemia due to insufficient oxygen delivery or haemorrhage, where blood accumulates within the brain. Both mechanisms can result in focal or global tissue necrosis and cell death, causing significant neurological impairments[1].

Typical symptoms of stroke are unilateral weakness, facial dropping, interrupted speech and loss of sensation. less patient may present with vertigo visual problem and cognitive problem[2].

Stroke survivors often struggle with postural control and balance due to factors such as abnormal body alignment, asymmetrical posture, and

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difficulties in weight shifting[3]. Restoring balance following a stroke is crucial, as it is influenced by multiple factors, including muscle weakness, restricted joint movement, altered muscle tone, impaired motor coordination, and deficits in sensory organization[4].

The body's balance is achieved through inputs from main primary systems: the somatosensory/proprioceptive system, the vestibular system in inner ear, and the visual system. The Central Nervous System processes feedback output from these systems to achieve body orientation and generates stabilizing forces by activating specific muscles as needed.

Under normal conditions, healthy individuals depend approximately 70% on somatosensory input, 20% on vestibular input, and 10% on visual input when standing on a stable surface. But, shifting to unstable surface, the depend shifts to 60% vestibular input, 30% visual input, and 10% somatosensory input. Let me know if you'd like further refinements[5].

vestibular dysfunction is common after stroke and can significantly contribute to balance and gait impairments. Individuals with stroke often demonstrate abnormal coordination of trunk and pelvic segments during head movements, that can compromise postural stability. Impaired head and trunk control affect visual processing and spatial orientation, further disrupting balance[6].

Anatomy and function of vestibular system

the peripheral vestibular system is situated within the inner ear, specifically inside the labyrinth, which consists of both bony and membranous components. Within these structures, specialized hair cells act as motion receptors, contributing to vestibular function. The labyrinth is positioned adjacent to the air-filled middle ear on one side and the temporal bone on the other, while it lies posterior to the cochlea[7].

Bony Labyrinth: component of bony labyrinth are three semicircular canal and cochlea and vestibule, which serves as a connecting chamber. It is filled with peri lymphatic fluid; whose chemical composition closely mirrors that of cerebrospinal fluid due to its high sodium-to-potassium ratio. This fluid interacts with cerebrospinal fluid through the cochlear aqueduct, meaning changes in spinal fluid pressure (e.g., from lumbar punctures) can influence inner ear function.[8.]

Membranous Labyrinth: Suspended within the bony labyrinth by peri lymphatic fluid and connective tissue, the membranous labyrinth houses five sensory organs: three membranous semicircular canals and two otolith organs. Notably, each semicircular canal expands at one end to form an ampulla, which plays a vital role in vestibular function.

Hair Cells Hair: found in ampulla and otolith organ responsible to convert head motion to neural firing.

The Vestibular Nerve:

Vestibular nerve Fibers originate from Scarpa's (vestibular) ganglion which has peripheral processes innervate hair cells in semicircular canal and central processes projected to vestibular nuclei in the brain stem and cerebellum. vestibular nerve transmit signal through the internal auditory canal reaching to pons and cerebellum. the vestibular nerve serves a link between labyrinth and the brain stem[9].

Vascular supply

Peripheral vestibular system is supplied by labyrinthine artery. Its origin varies, typically branching from the anterior inferior cerebellar artery (AICA) or occasionally directly from the basilar artery. Once inside the inner ear, it splits into common cochlear artery and anterior vestibular artery. The anterior vestibular artery supplies ampulla of lateral and anterior semicircular canals, utricle and vestibular nerve. The common cochlear artery, in divided into the main cochlear artery and vestibulocochlear artery. The cochlear artery supplies cochlea and ampulla of the posterior semicircular canal[10].

Central Processing of Vestibular system

Vestibular signals from primary afferents primarily targets two areas: the vestibular nuclear complex in brain stem and the cerebellum. The vestibular nuclear complex is considered the primary processor, facilitating rapid connections between incoming vestibular signals and motor output neurons.

Meanwhile, the cerebellum serves as the adaptive processor, continuously monitoring vestibular function and adjusting central processing when needed. In both areas, vestibular nuclear complex and cerebellum, vestibular input is combined with somatosensory and visual input to ensure coordinated sensory processing[7].

Vestibular Nucleus complex: composed of four nuclei (superior, medial, lateral, and descending). This extensive structure is located in pons and medulla. Within this complex, vestibular sensory input is processed alongside other sensory information, including proprioceptive, visual, and efferent signals. The extensive network linking the vestibular nuclei to the cerebellum, ocular motor nuclei, and brainstem reticular formation systems ensures precise timing and orientation for Vestibule-ocular reflex and vestibulospinal reflex (VSR) outputs, which influence the extraocular and skeletal muscles[7].

Thalamus

The thalamus acts as a central relay station for all sensory information. It receives input from the bilateral vestibular nuclei and transmits it to the vestibular cortex. Specifically, the ventral posterior nucleus of the thalamus sends signals through the posterior limb of the internal capsule to reach the cortex. A stroke affecting the thalamus can result in impaired perception of visual verticality, balance disturbances, and unsteady gait[11].

Cerebral Cortex

There is no single, well-defined vestibular cortex; rather, it consists of several interconnected regions, including parts of the posterior parietal lobe, multiple areas within the temporal lobe, and the posterior insular region. Damage to the posterior insula has been associated with tilting of the subjective visual vertical. Moreover, stimulation of one side of the vestibular system leads to activation of the vestibular cortex on the same side (ipsilateral activation)[12].

Vascular Supply

The vertebrobasilar arterial system is essential for supplying blood to both the peripheral and central components of the vestibular system. The posterior-inferior cerebellar arteries (PICAs), which originate from the vertebral arteries, are crucial for the central vestibular network. They supply the lower cerebellar hemispheres and the dorsolateral medulla, including the lower regions of the vestibular nuclei.

The basilar artery, which runs along the pons, supports central vestibular areas through three sets of branches: perforating branches that supply the medial pons, short circumferential branches that target the anterolateral pons, and long circumferential branches that supply the dorsolateral pons.

The anterior-inferior cerebellar artery (AICA), arising from the basilar artery, plays a significant role in peripheral vestibular blood supply via the labyrinthine artery. It also supplies the ventrolateral cerebellum and the lateral tegmentum of the lower two-thirds of the pons.

Strokes within these vascular territories can result in vestibular syndromes: PICA strokes (commonly causing lateral medullary syndrome) typically lead to central vestibular symptoms due to involvement of the vestibular nuclei in the medulla and pons, along with the inferior cerebellum. AICA strokes cause a mixed picture of peripheral and cerebellar symptoms, as this artery supplies both the inner ear structures and parts of the cerebellum[7].

Cerebellum

plays a critical role in vestibular function, receiving input from the vestibular nuclear complex and contributing significant feedback itself. While vestibular reflexes can occur without the cerebellum, they lose calibration and effectiveness in its absence.

The cerebellar flocculus plays a crucial role in fine-tuning the vestibule-ocular reflex (VOR), ensuring that eye movements remain stable and appropriately aligned during head motion. Its function involves adjusting VOR gain—the ratio of eye movement velocity to head movement velocity—allowing the reflex to adapt to alterations in the visual or vestibular systems. When the flocculus is damaged, experimental models lose their ability to modify VOR gain effectively, leading to difficulties in compensating for situations where either an increase or decrease in gain is required)[12].

Function of vestibular system

The vestibular system plays a key role in perceiving body position and movement. It integrates multiple sources of motion-related input, including signals from the inner ear (vestibular), body position (proprioception), visual cues, and intended motor actions. These inputs are processed within the vestibular nuclear complex, which generates motor commands to coordinate both eye and body movements[13].

To maintain accuracy, the cerebellum continuously monitors and fine-tunes vestibular activity. The system's output is reflected in three primary reflexes: The vestibule-ocular reflex (VOR) stabilizes vision by producing eye movements that compensate for head motion. The vestibule colic reflex (VCR) activates neck muscles to stabilize the head. The vestibulospinal reflex (VSR) triggers postural adjustments to maintain balance and prevent falls. Together, these reflexes ensure stability and coordination during daily movements and activities[14].

Aim of this narrative review: is to explore the pathophysiology and clinical implications of vestibular dysfunction following stroke, and to highlight the role and effectiveness of vestibular rehabilitation exercises in improving balance and gait in post-stroke patients.

Significance of study: Vestibular dysfunction is a frequently overlooked consequence of stroke that can significantly impair balance, mobility, and quality of life. By summarizing current knowledge about the vestibular system, its vascular supply, and the impact of rehabilitation, this review can guide clinicians in identifying and managing vestibular issues more effectively, ultimately enhancing patient outcomes and reducing fall risk. activities[14].

Methods:

This narrative review aims to explore vestibular dysfunction and rehabilitation following stroke. A non-systematic literature search was conducted using electronic databases including PubMed, Cochrane library, and scoups. The following keywords were used in various combinations: "vestibular rehabilitation," "stroke," "gaze stabilization," and "balance training."

Articles published in English from [e.g., 2010 to 2024] were reviewed. Studies were selected based on their relevance to post-stroke vestibular dysfunction and rehabilitation strategies. Emphasis was placed on clinical trials, review articles, and relevant case studies that addressed mechanisms of dysfunction and therapeutic interventions. The findings were synthesized narratively to highlight mechanism of injury, therapeutic approaches, and clinical implications.

Articles will be eligible for inclusion if they meet the following criteria:

Inclusion criteria:

Studies published from 2010 to2024.

Studies explain how stroke affect the vestibular system and different exercise of vestibular system.

Studies examine the effect of vestibular system on balance and gait after stroke.

Narrative review, randomized controlled trial, systematic review.

Exclusion criteria:

Non -English studies.

Case report, editorial and animal studies.

Studies explain vestibular dysfunction rather than stroke.

Review findings:

Pathophysiology of vestibular dysfunction in stroke:

The vestibular pathways start from the eighth cranial nerve and the vestibular nuclei, then travel through ascending Fibers to various cortical and subcortical regions. These pathways are essential for maintaining balance and controlling posture[5].

Vestibular dysfunction in stroke patients may arise from lesions affecting either the anterior or posterior circulation. While some studies suggest that isolated vertigo and dizziness are indicative of posterior circulation strokes, others indicate that these symptoms can also be linked to anterior circulation involvement [15].

Central vestibulopathy can manifest through a range of symptoms, such as vertigo, nausea, abnormal eye movements (nystagmus), difficulty with coordination (ataxia), balance disturbances (disequilibrium), visual impairments, impaired ocular control, and sensory deficits. These symptoms arise due to dysfunction in central vestibular pathways rather than the inner ear [16].

Summary of pathophysiology:

Stage	Structure / Pathway	Blood Supply	Function	Symptoms When affected
1	Otolithic organs (utricle & saccule)	Labyrinthine artery (branch of AICA)	Detect linear acceleration and head position relative to gravity	Vertigo, imbalance, sensation of tilting or falling
2	Vestibular nerve (superior & inferior branches)	Labyrinthine artery	Transmit sensory signals from otoliths to brainstem	Acute vertigo, nausea, unsteadiness, possible hearing loss

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3	Vestibular nuclei (brainstem – pons & medulla)	PICA & AICA	Central processing and integration of vestibular input	Central vertigo, gaze instability, nystagmus, ataxia
4	Cerebellum (esp. flocculo-nodular lobe)	PICA, AICA, and SCA	Fine-tuning of balance and coordination	Truncal ataxia, disequilibrium, difficulty walking
5	Thalamus (VPL & posterior nuclei)	Thalamo-geniculate artery (from PCA)	Relay vestibular information to the cortex	General dizziness, disorientation
6	Vestibular cortex (posterior insula, parietal operculum)	Middle cerebral artery (MCA)	Conscious perception of balance, motion, and spatial orientation	Perceptual dizziness, spatial disorientation, visual-vestibular mismatch

diagnosis and assessment:

Diagnosis

History taking

History of fall

Neurological examination

Physical examination

Observation and general assessment: posture and balance at rest, gait assessment and spontaneous nystagmus.

Oculomotor examination: smooth pursuit, saccades, head impulse test and dynamic visual acuity test

Balance assessment and gait assessment

Other tests: subjective visual vertical, head shaking nystagmus and hyperventilation induced nystagmus

Imaging

MRI and CT scan to detect the location of stroke

Management and rehabilitation

Vestibular rehabilitation therapy (VRT) is a specialized exercise-based intervention aimed at enhancing balance, gait control, and somatosensory integration, while also stabilizing gaze. Beyond its role in stroke recovery, VRT effectively improves dynamic balance in stroke survivors by optimizing vestibular system function, aiding in postural stability and reducing dizziness-related impairments[17].

Mechanism of vestibular rehabilitation

Vestibular rehabilitation mechanisms after lesion and dysfunction depends on vestibular adaptation and vestibular substitution. Vestibular adaptation exercises are analogous to described by Cawthorne for patient of persistent unsteadiness[18]. Vestibular adaptation means recalibrating the gain of the vestibule-ocular reflex (VOR) or vestibulospinal reflex to enhance stability and compensation after vestibular dysfunction. This mechanism relies on neuroplasticity, allowing the brain to adjust its response to altered sensory input.

In contrast, vestibular substitution involves engaging alternative sensory or motor strategies to compensate for lost vestibular function. This may include increased reliance on visual and proprioceptive feedback to maintain balance and spatial orientation[19].

A patient who initially experiences a severe vestibular crisis, followed by ongoing disequilibrium or motion-induced vertigo that persists or recurs, is likely uncompensated. This remains true even if standard vestibular testing does not reveal identifiable abnormalities, indicating that compensation mechanisms have not effectively adjusted to the dysfunction[20].

Vestibular rehabilitation therapy (VRT) aims to enhance gaze stability, improve postural control, reduce vertigo symptoms, and boost daily functional activities. The principles guiding VRT align with these goals, ensuring targeted interventions that support recovery and adaptation[21].

Types of vestibular rehabilitation exercise

Gaze stabilization exercise

In this exercise, the patient focuses on a visual target while performing controlled head movements, first in the vertical direction (pitch) and then in the horizontal direction (yaw). The head speed is varied as per instructions, and the patient is required to maintain their gaze on the target without allowing it to blur[22].

Smooth pursuit exercise

In this exercise, the patient keeps their head stationary and focuses on a target positioned about 46 cm (18 inches) from their nose. The target is gradually moved within a 30° range in all directions—right, left, upward, and downward—while the patient tracks its movement[22].

Saccadic eye movement

In this exercise, two visual targets are positioned 46 cm (18 inches) from the patient's nose, one placed 15° to the left and the other 15° to the right. The patient is instructed to keep their head stationary while quickly shifting their gaze between the two targets. Vertical movements are then introduced, with the gaze alternating between targets placed 15° above and below the nose.

The therapist carefully observes for any undershoots (failing to fully reach the target) or overshoots (exceeding the target), as these may indicate impairments in oculomotor control[22].

Enhancing postural stability

Recovering postural stability tends to take longer than regaining gaze stability[23]. The key mechanisms driving postural recovery include substitution, where the patient increases reliance on visual and somatosensory cues to compensate for vestibular loss, and adaptation, where the vestibular system recalibrates its responses to improve balance control [24].

Patients with temporary vestibular deficits must focus on recovering normal postural strategies to restore balance naturally. In contrast, individuals with permanent vestibular deficits depend on compensatory strategies, such as increasing reliance on alternative sensory inputs like somatosensory cues and visual cues, to maintain stability and spatial orientation effectively[21].

Exercises for visual dependency:

for visually dependent patients, tailored exercises can be created to improve their balance by reducing or distorting visual input while ensuring strong somatosensory feedback (like going barefoot)[25].

Reducing Visual Dominance: Have the patient perform balance exercises in dim lighting or with translucent goggles that blur vision, encouraging reliance on other sensory inputs. Optokinetic Stimuli Exposure: Introduce moving patterns while performing postural tasks—striped wallpapers, rotating spiral discs, or digital simulations of swaying landscapes[25].

Head and Body Motion: Incorporate slow, controlled head movements while standing or walking in environments with conflicting visual cues. This enhances vestibular compensation. Environmental Distractors: Practice balance in spaces with moving crowds, shifting floor patterns (e.g., escalators or glass flooring), and unpredictable lighting variations to improve stability in real-world settings[25].

Exercises for somatosensory dependency

During vestibular recovery, patients with bilateral vestibular deficits often develop a heightened dependence on somatosensory input. In contrast to individuals with unilateral loss, those with bilateral impairment initially rely more on visual cues during the acute phase of recovery. As recovery progresses into the chronic phase, their dependence shifts predominantly toward somatosensory feedback, reflecting adaptive strategies essential for balance and spatial orientation [19].

Vestibular compensation in such cases does not rely solely on visual input. Instead, somatosensory cues play a leading role by supplying critical error signals necessary for the static recalibration of the vestibular nuclei. This phenomenon is termed somatosensory dependency, underscoring the importance of somatosensory feedback in the compensatory process[26].

To mitigate this dependency and promote more dynamic balance control, patients are encouraged to perform activities on unstable or compliant surfaces—such as foam pads, carpets, or tilt boards—which challenge and reduce somatosensory reliability. For example, catching a ball while standing on a carpet helps improve balance and adaptability[21].However, it's important to acknowledge that vestibular function, once lost, cannot be fully replaced by visual or somatosensory systems alone [20]

The key exercises for VRT based on the goals are described[21].

1. **Gaze fixation exercise**

Horizontal and vertical head turns: The patient rotates their head right to left (horizontally) while keeping their gaze fixed on a stationary target. This can also be performed while head move up and down.

• **Head-trunk turns:** The patient rotates their head and trunk together as a single unit (horizontally, maintaining gaze on their thumb. The arm moves in sync with the trunk.

• **Head turns while walking:** While walking in a straight line then walking in circle with different diameters, the patient rotates their head horizontally to the left and right while keeping their gaze fixed on a stationary target. This exercise can also be performed with vertical head turns.

2. **Exercises for enhancing eye movements:**

• **Saccade:** The patient fixes their head and moves only their eyes. two horizontally placed targets close together. While looking at one target, they quickly shift their gaze to the other without moving their head, repeating the movement multiple times.

• **Pursuit:** With the head neutral, the patient moves only their eyes. They extend one arm forward with the thumb as the focal point and move the arm side to side while keeping their gaze fixed on the thumb.

• **Saccade and vestibule-ocular reflex:** two horizontally placed targets, such as two extended arms with thumbs up. They look at one target, ensuring their head is aligned with it, then shift their gaze to the other target while turning their head slowly in the same direction. The movement is repeated in both directions' multiple times.

• **Imagery pursuit:** The patient looks directly at a target, ensuring their head is aligned with it, then closes their eyes and slowly turns their head away while mentally tracking the target. When they reopen their eyes, they check if their focus remained on the target. If necessary, they adjust their gaze and repeat in both directions, aiming for maximum accuracy.

3. Exercises for enhancing postural stability.

• **single limb stands:** The patient balances on one leg for 15 seconds then switching to the other leg.

• **Heel-to-toe stance:** Standing with feet in a heel-to-toe position and both arms extended, the patient maintains the posture for 15 seconds before switching the leading foot.

• **Sway back and forward:** Positioned behind a chair and in front of a wall for safety, the patient sway back and shift their center of gravity backward (toes lifted). They then bend forward and shift their weight forward (heels lifted). This sequence is repeated 10 times, as described by the authors.

• **March in place:** The patient lifts their knees alternately in a marching motion while maintaining balance.

4. Exercises for decreasing vertigo:

Diagonal arm reach: The patient starts by standing with one arm elevated overhead, focusing their gaze on the raised hand. They then bend diagonally, lowering the arm while keeping their eyes fixed on it until the hand reaches the opposite foot. This movement is repeated 10 times.

5-Exercises for activities of daily living

• **Gait with turns:** The patient practices walking while making sharp or wide turns to the right and left. This helps improve dynamic balance and coordination during directional changes.

• **Sit-to-stand transitions:** The patient moves from a seated position to standing, then returns to sitting. This exercise focuses on strengthening leg muscles and enhancing postural control**.**

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Factors Affecting Recovery of balance post stroke:

Medications

like vestibular suppressants, antidepressants, tranquilizers, and anticonvulsants don't negatively impact therapy outcomes, but their use tends to lengthen the overall recovery process[16].

Visual and somatosensory inputs are essential during recovery from unilateral vestibular loss. Preventing visuomotor activities or avoiding movements that provoke vertigo can delay progress[27].

The timing of treatment initiation was once considered crucial for faster results. However, evidence now suggests that there isn't a critical period for achieving significant functional improvement, regardless of the duration of symptoms[28].

Daily exercise duration

daily sessions of optokinetic stimulation (e.g., 30 seconds, ten times daily over 10 days) can effectively improve vestibule-ocular reflex (VOR) gain, which indicates that short, consistent stimulation can aid vestibular function recovery[28].

Lesion site

Patients with central or mixed lesions generally face extended therapy durations, but the ultimate outcomes are not influenced by the lesion location. However, individuals with mixed lesion sites often require longer therapy. Interestingly, those with purely central lesions tend to exhibit better therapy outcomes compared to patients with mixed lesions[2930,31].

Psychological factors such as anxiety, depression, or an overreliance on medications can interfere with the process of vestibular compensation, making recovery more challenging. Addressing these factors is essential to support effective therapy outcomes[21].

Effectiveness of vestibular rehabilitation after stroke:

((Abd Elwaged;2021,) (Correia ;2021), (Cui ;2024), (Dai;2013) and (Hyun Son ;2024))[32,33,6,34,35] all showed statistically significant improvements within both groups in balance and gait outcomes.(Bacli;2013) [16] found significant improvements within groups, but the difference between groups post-treatment was not statistically significant in balance and gait.(Chen ;1014) [36] found a statistically significant within the two group in turning speed toward the affected and unaffected side, improvement of walking speed in experimental group only and statistically significant between groups in speed, turning speed toward the affected side and unaffected side.

(Elhamrawy;2021)[37] reported statistically significant improvements in gait parameters (speed, cadence, non-paretic step length, and paretic step length) in the experimental group, while the control group showed no statistically significant changes.(Tramontano;2018)[38] found statistically significant between groups in gait parameters (Mitsutake;2017)[39] found a statistically significant improvement in the experimental group in the Dynamic Gait Index (DGI), but no statistically significant change in the Timed Up and Go test (TUG). The control group showed no significant changes in either outcome.

(Zeo ;2022) [30] reported statistically significant improvements between groups in both the Berg Balance Scale (BBS) and TUG.Saleem;2019)[31]found statistically significant between-group differences in the Mini-BESTest and a gait scale. (Hyun Son;2024) [35] also reported a statistically significant between-group difference in TUG. In contrast:(Hansson ;2020)[42] was the only study that showed no statistically significant in balance and gait within groups.

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Discussion

It is commonly believed among physiotherapists that vestibular dysfunction following stroke primarily results from lesions in the posterior circulation, given the close anatomical proximity of the vestibular nuclei and pathways to the brainstem and cerebellum. However, emerging evidence suggests that anterior circulation strokes can also lead to vestibular impairments. This may be due to cortical and subcortical involvement affecting multisensory integration necessary for balance control.

The main finding from the reviewed studies indicates a clear positive effect of vestibular rehabilitation therapy (VRT) on both balance and gait in post-stroke patients. This can be attributed to the fact that the vestibular system does not function in isolation; rather, it works in coordination with the visual and somatosensory systems to maintain postural stability. Thus, targeting the vestibular component through specific exercises (e.g., gaze stabilization, balance training) can significantly enhance overall functional outcomes in stroke rehabilitation.

The findings of this review indicate that vestibular rehabilitation (VR) can significantly improve balance and gait outcomes in post-stroke patients. Most of the included studies reported statistically significant improvements within and between groups following VR interventions, highlighting the efficacy of these exercises in addressing functional deficits caused by vestibular dysfunction.

Studies such as those by (Abd Elwaged ,2021)32;(Correia ,2021)33;(Cui ,2024)6;(Dai ,2013)34, and (Hyun Son ,2024)35 consistently showed improvements in both groups, suggesting that even conventional rehabilitation may have some benefits; however, the enhanced outcomes in experimental groups point to the added value of vestibular-specific training. This is further supported by (Elhamrawy ,2021)37, (Tramontano ,2018)38, and (Zeo ,2022)40, who reported superior improvements in experimental groups compared to controls, particularly in parameters such as gait speed, cadence, and balance scores.

(Chen ,2014) 36provided a more detailed view by showing improvements in directional turning speed and walking speed, indicating that VR may enhance motor coordination and spatial orientation—critical components of safe ambulation. Similarly, improvements in specific clinical measures like the DGI and Mini-BESTest, as seen in (Matsutake ,2017)39 and Saleem (2019), reinforce the functional gains VR can achieve in dynamic balance and postural stability.

However, not all findings were conclusive. (Bacli ,2013)16 and (Mitsutake ,2017) 39 showed within-group improvements without significant between-group differences, suggesting that certain protocols may be less effective or that individual variability influences responsiveness to VR. Furthermore, (Hansson ,2020)42 was the only study that reported no significant improvements, which may be due to factors such as small sample size, differences in intervention duration, or stroke severity.

These mixed findings highlight the importance of tailoring vestibular rehabilitation to patient-specific deficits and underline the need for standardized protocols. The general trend, however, supports the integration of VR into stroke rehabilitation programs to enhance balance, reduce fall risk, and improve overall mobility.

Clinical implications:

the evidence summarized in this review supports the integration of vestibular rehabilitation (VR) into routine physiotherapy programs for stroke patients, particularly those presenting with balance impairments or dizziness. Clinically, this suggests that:

Early identification and assessment of vestibular dysfunction post-stroke are essential, as these impairments can significantly contribute to poor balance and increased fall risk.

Incorporating VR exercises, such as gaze stabilization, habituation, and balance training, can lead to meaningful improvements in functional mobility, walking speed, and postural control.

Limitations

The review is narrative in nature and not systematic, which may introduce selection bias.

Variability in assessment tools and rehabilitation protocols across studies.

Conclusion

Vestibular rehabilitation is a valuable but often overlooked component of post-stroke neurorehabilitation. Integrating VRT into standard balance training protocols may significantly enhance functional recovery by addressing vestibular-related deficits. Its inclusion should be considered essential for improving overall mobility and independence in stroke patients.

DECLARATIONS

- **Consent to publish:** I certify that each author has given their consent to submit the work.
- **Competing interests:** None.
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