

REVIEW ARTICLE

Benign Paroxysmal Positional Vertigo, Vestibular Ageing and Falls in Older Adults: Mechanistic Pathways and Clinical Implications.

Hanan Ahmad^{1*}, Azliyana Azizan²

¹*Physiotherapy Unit, Department of Rehabilitation Medicine, Hospital Sultan Abdul Aziz Shah (HSAAS), Universiti Putra Malaysia (UPM), 43400 Serdang, Selangor, Malaysia.*

²*Centre of Physiotherapy, Faculty of Health Sciences, Universiti Teknologi MARA, Puncak Alam Campus, 42300 Bandar Puncak Alam, Selangor, Malaysia.*

Corresponding Author

Hanan Ahmad 

Physiotherapy Unit, Department of Rehabilitation Medicine, Hospital Sultan Abdul Aziz Shah (HSAAS), Universiti Putra Malaysia (UPM), 43400 Serdang, Selangor, Malaysia

Email: farhanah.ahmad@upm.edu.my

DOI: <https://doi.org/10.70672/tdm82x10>

Received: 29/04/2026. Revised: 21/08/2026. Accepted: 22/09/2026. Published online: 01/11/2026.

Abstract

This narrative review synthesises current evidence on the mechanistic pathways linking benign paroxysmal positional vertigo (BPPV), age-related vestibular decline, and fall risk among older adults. In the context of ageing, BPPV involves otoconia fragmentation and dislodgement, alongside altered endolymph dynamics, lead to impaired multisensory integration and reduced postural stability. Concurrently, vestibular ageing involves progressive degeneration of peripheral and central vestibular structures, leading to diminished gaze stabilisation, weakened vestibulo-spinal reflexes, and reduced adaptive capacity, thereby increasing vulnerability to falls. Four interrelated mechanistic pathways are identified through which BPPV contributes to falls in older adults: (1) episodic vertigo as a direct fall trigger, (2) chronic disequilibrium following BPPV episodes, (3) gait alterations and instability, and (4) cognitive and psychological mediators, including fear of falling and increased attentional demands. These mechanisms are further amplified by frailty and reduced physiological reserve in later life. The review underscores the importance of integrating fall risk profiling and frailty assessment into the clinical management of vestibular disorders in older adults. Comprehensive evaluation of dizziness severity, balance performance, and gait parameters is essential to improve diagnostic precision and guide targeted rehabilitation strategies. Management of BPPV in older adults requires interventions that balance mechanistic efficacy with geriatric safety, including modified canalith repositioning manoeuvres and individualised vestibular rehabilitation tailored to age-related vestibular decline. Addressing psychological sequelae, particularly fear of falling, is also critical, as maladaptive behaviours may exacerbate functional decline, reduce quality of life, and perpetuate fall risk in this population.

Keywords: *Benign paroxysmal positional vertigo, fall, older adults, vestibular ageing.*



This work is licensed under a [Creative Commons Attribution-Non-Commercial-ShareAlike 4.0 International License](https://creativecommons.org/licenses/by-nc-sa/4.0/).

Introduction

Benign paroxysmal positional vertigo (BPPV) is the most prevalent peripheral vestibular disorder in later life and a major, yet frequently under-recognised, contributor to falls among older adults [1][2][3]. BPPV is less commonly reported in children and younger adults and occurs predominantly among middle-aged and older adults. Clinical studies demonstrate that BPPV commonly affects individuals in middle age, with one clinical series reporting a mean age of 56.5 years and cases extending to 78 years [4]. Population-based data indicate a lifetime prevalence of approximately 2.4% in the general population, increasing to around 4.5% in individuals aged 75 years, with an annual incidence of about 0.6%. These figures demonstrate that BPPV is particularly prevalent in later life [4][5][6]. This age-related rise coincides with a period of heightened fall vulnerability, during which falls represent a leading cause of disability, institutionalisation, and mortality in geriatric populations [7]. The epidemiological impact of BPPV on falls is amplified by age-related sensory decline within the vestibular system. Ageing is characterised by progressive degeneration of otoconia, vestibular hair cells, and afferent pathways, resulting in reduced vestibulo-ocular and vestibulo-collic reflex gains and diminished central compensation [8][9]. In this context, otoconial fragmentation and displacement into the semicircular canals generate exaggerated and poorly compensated vestibular signals, leading to vertigo, postural instability, and spatial disorientation [1][8]. Notably, vestibular agnosia in some older adults results in atypical symptom presentation, such as vague unsteadiness without overt vertigo, contributing to underdiagnosis and persistent fall risk [3].

Beyond episodic vertigo, BPPV produces sustained impairments in postural control and gait. Older adults with BPPV demonstrate altered sensory orientation, impaired perception of verticality, increased postural sway, and reduced gait stability. Although these deficits improve following particle-repositioning manoeuvres,

complete normalisation is uncommon, particularly in the presence of frailty and recurrent symptoms [10] [11]. Residual dizziness and activity restriction further promote fear of falling, physical deconditioning, and accelerated frailty trajectories, reinforcing a self-perpetuating cycle of instability and falls [12][13]. While canalith repositioning procedures are highly effective in resolving positional vertigo, older adults frequently require repeated treatments and experience higher recurrence rates, reflecting the interaction between BPPV pathology and multisystem ageing [14] [15]. These observations underscore the need for a systems-based, multidisciplinary approach integrating timely BPPV identification, management of age-related comorbidities, and post-treatment rehabilitation to address residual imbalance. Collectively, BPPV and age-related vestibular decline jointly shape the epidemiology of falls by destabilising balance control at multiple levels, positioning BPPV as a critical and modifiable target in geriatric fall prevention strategies. This is also aligned with the International Classification of Functioning, Disability and Health (ICF) framework, with pathophysiological changes associated with vestibular ageing and impairments that lead to functional limitations and participation restrictions, including falls.

Literature search

Two authors independently conducted a structured literature search of the Scopus database on 12 December 2025 to identify relevant literature examining benign paroxysmal positional vertigo (BPPV) in the context of age-related vestibular decline and its association with fall-related outcomes among older adults. Scopus was selected as the primary database because of its extensive multidisciplinary coverage, strong indexing of peer-reviewed journals in medicine, rehabilitation, and allied health sciences, and comprehensive citation-tracking capabilities that support retrieval of both foundational and contemporary studies. Its broad inclusion of

international journals also supports a more globally representative evidence base, which is particularly relevant for geriatric and vestibular research.

The search strategy employed combinations of the following keywords: ("benign paroxysmal positional vertigo" OR BPPV) AND ("older adults" OR elderly OR ageing* OR geriatric) AND ("vestibular decline" OR "vestibular ageing*" OR "age-related vestibular loss" OR dizziness OR balance OR "postural control" OR gait) AND (falls OR "fall risk"). Articles were excluded if they were published in language other than English or if their primary focus was on paediatric populations or vestibular disorders not specific to BPPV. Articles were included if titles, abstracts, and full texts, where available, involved older adult populations, specifically focused on BPPV or addressed aspects of vestibular ageing in relation to fall risk, dizziness, balance and gait. No restrictions were applied regarding publication date or year, and no formal quality assessment was conducted, consistent with the narrative review design. The search identified 93 records. Following title and abstract screening, 54 records were excluded, leaving 39 full-text articles for eligibility assessment. Of these, 16 articles were excluded based on the predefined eligibility criteria, resulting in 23 articles included as the core evidence base for the narrative synthesis. An additional 48 references, identified outside the structured Scopus search through reference lists and other relevant sources, were incorporated as supporting background and contextual sources to inform the theoretical, mechanistic, diagnostic, rehabilitation, and clinical discussion. These additional sources were not considered part of the core search-derived synthesis. Thus, the manuscript contains 71 references in total, comprising 23 core articles identified through the structured Scopus search and 48 supporting references.

Age-related vestibular degeneration

Age-related vestibular degeneration reflects progressive structural and functional decline

across peripheral and central vestibular pathways, reducing the precision of vestibular signalling and impairing the integration of multisensory inputs essential for postural stability, thereby heightening susceptibility to instability and falls. Peripheral degeneration is marked by cumulative loss of vestibular hair cells, fragmentation and depletion of otoconia, and progressive neural atrophy. Hair cell loss in both semicircular canals and otolith organs reduces the accuracy of head-motion transduction and contributes to diminished sensitivity to rotational and linear accelerations [16][17]. Concurrent degeneration of otoconia, including numerical loss and morphological disruption, weakens utricular and saccular responsiveness to gravitational cues, further degrading spatial orientation [17][18]. Progressive neural decline, marked by a reduction in vestibular ganglion cells and primary afferent fibres, compounds these deficits by impairing transmission from the labyrinth to central vestibular nuclei [16]. Age-related vestibular decline proceeds unevenly across end organs: semicircular canal ageing manifests as reductions in vestibulo-ocular reflex gain, whereas otolith ageing is characterised more prominently by otoconial degeneration and hair cell loss [13]. Central vestibular ageing further amplifies peripheral decline by degrading multisensory integration, attenuating compensation mechanisms, and weakening sensory reweighting. Reduced central integration limits the ability to synthesise vestibular, visual, and proprioceptive cues, impairing the stability of internal spatial representations and increasing reliance on less reliable sensory channels [19][20]. This impairment becomes particularly consequential in environments with sensory conflict or diminished visual information. Ageing also reduces neural plasticity, dampening compensation following vestibular insults and decreasing the effectiveness of rehabilitation strategies [13][18]. Impaired sensory reweighting constraints the adaptive capacity of older adults to modulate reliance on vestibular, visual and somatosensory inputs in response to changing

environmental demands [19][20]. Together, these central deficits magnify the functional consequences of peripheral deterioration, producing a layered decline in balance control that contributes to instability, dizziness, and fall vulnerability in older adults.

Pathophysiology of BPPV in the context of ageing

The pathophysiology of BPPV in ageing emerges from interacting peripheral and central mechanisms that destabilise otoconial integrity, alter canal hydrodynamics, and reduce compensatory plasticity. Otoconia fragmentation and dislodgement represent the primary mechanisms through which ageing modifies BPPV risk. Declining calcium homeostasis, oestrogen deficiency, osteoporosis, and vitamin D insufficiency weaken otoconial mineralisation and accelerate microstructural degeneration, increasing the likelihood of particle detachment [1][21]. These metabolic and endocrine changes promote otoconial instability, facilitating debris migration into the semicircular canals or adhesion to the cupula [22][23]. Canalithiasis and cupulolithiasis subsequently disrupt normal mechanotransduction by imposing inappropriate gravitational forces on the cupula, producing exaggerated canal responses and positional vertigo [24].

Ageing further amplifies the biomechanical impact of displaced otoconia through altered endolymph dynamics. Degeneration of vestibular hair cells, ganglion cells, and afferent fibres reduces inhibitory modulation from otolith organs, heightening canal gain and sensitivity to particulate movement [17][25]. As a result, canalith-induced endolymph flow generates greater cupular deflection and more sustained nystagmus. These peripheral alterations coexist with central declines in neural plasticity and processing efficiency, limiting vestibular compensation and prolonging symptom persistence [19]. Age-modified symptom expression reflects the convergence of peripheral instability and central vulnerability. Older adults

experience prolonged vertigo episodes, increased postural sway, and delayed recovery due to impaired multisensory integration and a greater comorbidity burden [13][26][27][28]. Collectively, these mechanisms magnify fall risk and functional impairment, transforming BPPV into a more persistent and destabilising disorder.

Mechanism pathways and linking BPPV to falls in older adults

The linkage between BPPV and falls in older adults is mediated by interacting peripheral vestibular disturbances and age-related declines in central compensation. Reduced gaze stabilisation emerges as a critical interface, where age-related reductions in vestibulo-ocular reflex (VOR) gain impair visual fixation during head movement, while BPPV introduces episodic canal hyperexcitation due to displaced otoconia [23][29]. Superimposed recurrent canal-driven noise from BPPV further destabilises postural control, particularly under environmental or task-related challenges [30]. Frailty and co-existing vestibular hypofunction exacerbate deficits in reactive balance and gait adaptability [13][31]. At the integrative level, constraints in multisensory reweighting slow adaptive recalibration across vestibular, visual, and proprioceptive inputs, resulting in increased sway variability and prolonged stabilisation times [32][33][34].

Although visual dependence increases with vestibular loss, limited flexibility in sensory integration sustains instability and delays recovery from positional vertigo [35][36]. Furthermore, concomitant alterations in gait dynamics and cognitive–affective responses further compound instability [37][38]. Epidemiological evidence demonstrates increased fall incidence in individuals with BPPV, underscoring its clinical significance as a fall-related disorder [39][40]. Collectively, these interactions delineate four interrelated mechanistic pathways through which BPPV, superimposed on vestibular ageing, amplifies fall risk in older adults: episodic vertigo, chronic

disequilibrium, gait instability, and cognitive-psychological mediators, as shown in Figure 1.

Episodic vertigo as a direct fall trigger

Episodic vertigo functions as the most direct fall precipitant. Otoconial displacement in canalithiasis and cupulolithiasis provokes aberrant semicircular canal activation during even minor positional transitions, generating high-velocity ocular-vestibular conflict within milliseconds [23][29]. In addition, video head impulse testing demonstrates exaggerated VOR asymmetries and delayed corrective saccades during positional transitions in older adults [41][42]. These rapid perturbations impair spatial orientation, disrupt gaze stabilisation, and destabilise stance during routine tasks such as rising, bending, or rolling in bed. Epidemiological evidence linking BPPV with increased fracture incidence underscores the destabilising magnitude of these acute episodes [39][40]. The episodic, unpredictable nature of symptom onset further amplifies fall susceptibility, as older adults cannot reliably anticipate when head movements will trigger disabling vertigo.

Chronic disequilibrium in post-BPPV phase

Chronic disequilibrium represents a second mechanistic pathway. Despite successful canalith repositioning manoeuvres (CRM), a subset of individuals complains of residual dizziness marked by persistent imbalance, motion sensitivity, and impaired postural calibration [43]. Age-related reductions in central plasticity prolong compensatory timelines, producing a sustained period of functional vulnerability in which balance remains compromised despite symptom resolution on positional testing. These post-BPPV disequilibrium phases extend the temporal window of fall vulnerability well beyond the acute vertigo period, with longitudinal analyses demonstrating persistent functional vestibular symptoms and elevated fall rates months after treatment [44]. This persistent instability diminishes confidence, reduces

functional mobility, and promotes maladaptive avoidance behaviours.

Gait alterations and instability

Gait alterations constitute a third mechanistic pathway linking BPPV to falls, reflecting impaired vestibulo-spinal integration and aberrant sensory weighting. Concurrently, age-related impairment of vestibulo-spinal reflex (VSR) pathways amplifies instability through reduced speed, precision, and scaling of automatic postural responses, alongside compressed vestibular frequency responsiveness and altered muscle activation patterns [45][46]. Older adults with BPPV thus exhibit slower gait speed, greater mediolateral sway, reduced head-trunk coordination, and impaired tandem and turning performance; these kinematic patterns indicate destabilised dynamic balance [37]. These abnormalities increase step variability, reduce gait symmetry, and compromise turning control, all of which are strong predictors of falls in vestibular older adults. Sarcopenia and age-related reductions in lower-limb strength further exacerbate gait instability, particularly during rapid direction changes or tasks requiring reactive stepping [38]. When BPPV is superimposed on pre-existing vestibular hypofunction, postural instability intensifies, producing a cumulative destabilisation that extends across daily mobility tasks.

Cognitive and psychological mediators

Cognitive and psychological factors provide a fourth mechanistic pathway through which BPPV elevates fall risk. Fear of falling, commonly emerging after BPPV episodes, promotes maladaptive behavioural responses such as stiffened gait, reduced stride length, and avoidance of mobility-demanding activities [37]. These compensations degrade stability and promote deconditioning. Older adults with vestibular impairment rely disproportionately on cognitive resources to maintain balance, resulting in elevated dual-task costs, delayed compensatory reactions, reduced situational awareness, and

elevated fall susceptibility during everyday multitasking. These cognitive–affective dynamics interact synergistically with peripheral vestibular deficits, producing a multidimensional fall-risk profile that persists even after repositioning manoeuvres restore canal function.

Assessment and diagnostic considerations in older adults

Assessment and diagnosis of vestibular disorders in older adults requires adaptation to frailty, multisensory decline, and interactions between age-related vestibular degeneration and geriatric syndromes. Bedside positional testing remains central to identifying benign paroxysmal positional vertigo (BPPV); however, in frail individuals, procedural modification is often required. Although the Dix–Hallpike manoeuvre remains the diagnostic reference standard, cervical spine limitation and orthostatic vulnerability frequently necessitate side-lying variants or mechanical support to ensure safety without compromising diagnostic yield [13][47]. Complementary bedside assessments, such as the headshake test, provide rapid insight into vestibular asymmetry and have demonstrated predictive value for falls in older adults with multisensory dizziness [48].

Instrumental vestibular testing refines diagnostic precision by characterising frequency-specific vestibulo-ocular reflex (VOR) deficits associated with vestibular ageing. The video head impulse test (vHIT) detects high-frequency canal hypofunction, while rotatory chair testing evaluates mid-frequency dynamics and caloric testing identifies low-frequency and bilateral vestibular loss, all of which are closely linked to gait and balance impairment [49][31][50]. Vestibular evoked myogenic potentials (VEMPs) further delineate otolith pathway integrity and aid in identifying vestibular contributions to cognitive impairment [51]. Fall-risk profiling is an essential parallel component of vestibular assessment, as falls rarely arise from vestibular dysfunction alone. Comprehensive profiling integrates fall history, medication burden,

orthostatic responses, affective symptoms, reaction time, gait stability, and sensory integrity [52]. Frailty substantially modifies vestibular presentation; older adults with BPPV and frailty exhibit greater postural instability and higher fall incidence than non-frail peers [31]. Peripheral vestibular impairment is also over-represented among recurrent fallers, underscoring vestibular evaluation as a core element of geriatric fall-risk assessment [53].

Management strategies and fall-prevention implications

Management of BPPV in older adults requires interventions that balance mechanistic efficacy with geriatric safety while targeting both symptom resolution and fall-risk reduction. Age-related vestibular degeneration, frailty, cognitive slowing, and musculoskeletal limitations necessitate adapted clinical strategies that maintain therapeutic precision while ensuring feasibility and safety in ageing populations.

Canalith repositioning manoeuvres (CRMs) in older adults

CRMs are the first-line treatment for BPPV in older adults and demonstrate high short-term efficacy with rapid symptom resolution [54][55][56]. However, recurrence is more common in geriatric populations due to age-related otoconial degeneration, multisystem comorbidity, and reduced vestibular compensation, often requiring repeated interventions [55]. Standard CRMs may be constrained by cervical spine disease or limited mobility; therefore, modified approaches, including hybrid techniques and the rolling-over manoeuvre, provide effective and safer alternatives without compromising outcomes [57][58][59]. Patient education regarding positional triggers and structured follow-up is essential for recurrence prevention [55].

Vestibular rehabilitation tailored to age-related decline

Vestibular rehabilitation (VR) is a critical adjunct for older adults with residual dizziness, imbalance, or coexisting vestibular hypofunction. Individualised programs incorporating gaze stabilisation, balance reweighting, and habituation exercises consistently reduce dizziness severity and improve postural control and gait performance [51][60][61]. These interventions enhance vestibulo-ocular reflex function and adaptive postural responses while accommodating age-related sensory and cognitive decline [62].

Multidomain fall prevention

Fall prevention in vestibular older adults requires a multidomain strategy beyond vestibular-specific treatment. Multicomponent exercise programs combining strength and balance training are most effective for reducing falls and fractures [63][64]. Environmental hazard modification and systematic medication review further mitigate risk, while addressing fear of falling and activity avoidance is essential to sustain functional independence and rehabilitation adherence [65][66][67].

Innovative and mechanical adjuncts

Emerging technologies are expanding access to vestibular care. Telerehabilitation and virtual reality-based interventions demonstrate promising efficacy in improving balance and dizziness while overcoming mobility barriers [68][69][70]. Automated mechanical repositioning chairs offer a safe and effective alternative for patients unable to tolerate manual CRMs, with favourable recurrence profiles [71].

Conclusion

BPPV represents a clinically important and potentially modifiable contributor to falls in older adults. The findings of this review indicate that the consequences of BPPV in later life extend beyond transient positional vertigo because age-

related degeneration of vestibular hair cells, otoconia, and neural pathways concurrently reduces vestibular function, multisensory integration, sensory reweighting, and central compensatory capacity. This convergence of BPPV-related vestibular disturbance with age-related sensory decline creates a heightened vulnerability to postural instability and functional impairment. Four interconnected pathways-episodic vertigo, chronic disequilibrium, gait instability, and cognitive-psychological response-provide a mechanistic framework linking BPPV to increased fall risk. Concurrent gait alteration, frailty, sarcopenia, fear of falling, and activity restriction further reinforce a cycle of instability, reduced mobility, and functional decline. Accordingly, fall risk profiling should be systematically embedded within vestibular rehabilitation pathways and supported by objective assessment of dizziness severity, balance performance, and gait parameters. Psychological sequelae also warrant explicit attention, as chronic vestibular symptoms frequently precipitate fear of falling, anxiety, and activity restriction, reinforcing functional decline through behavioural avoidance and deconditioning.

From a practical perspective, the findings highlight the need for individualised, age-sensitive management strategies that integrate vestibular rehabilitation with multidomain fall prevention. Rehabilitation programmes should be tailored to age-related vestibular decline and frailty, with the dual aims of optimising postural control, gait stability, and gaze function while addressing psychological well-being to sustain participation in daily activities. Incorporating vestibular assessment into routine fall risk evaluation is therefore essential in geriatric practice, given that vestibular dysfunction remains a significant yet under-recognised contributor to falls in later life. Furthermore, from a theoretical perspective, this review advances understanding of vestibular ageing by situating BPPV within a systems-based framework linking pathophysiological changes to activity limitations

and participation restrictions. In alignment with the International Classification of Functioning, Disability and Health (ICF), the findings demonstrate how structural vestibular impairments interact with frailty, cognitive load, and environmental demands to generate falls as an emergent outcome. Refining theoretical models to account for these dynamic interactions will strengthen the foundation for future research and inform the development of integrated, mechanism-driven interventions targeting falls among vestibular older adults.

Acknowledgement

The authors would like to express their sincere gratitude to the Physiotherapy Unit, Department of Rehabilitation Medicine, Hospital Sultan Abdul Aziz Shah (HSAAS), Universiti Putra Malaysia (UPM), and the Centre of Physiotherapy, Faculty of Health Sciences, Universiti Teknologi MARA, Puncak Alam Campus, for their support and facilitation of this study.

Authors' contributions

HA handled conceptualisation, methodology, data curation, formal analysis, original drafting, review and editing, visualisations, and project administration. AA handled conceptualisation, methodology, data curation, formal analysis, review and editing, and validation. All authors contributed equally to the literature search, screening, and narrative synthesis. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

Conflicts of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article

Financial assistance

None.

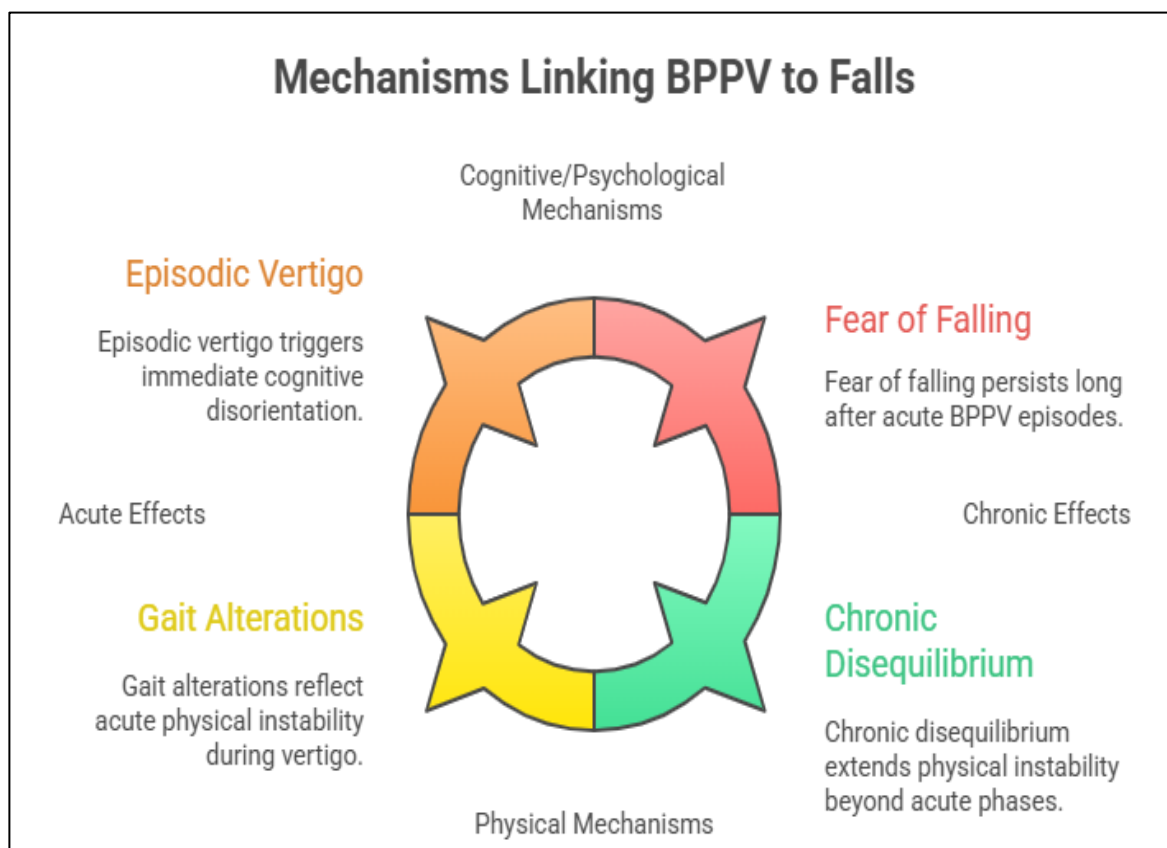


Figure 1. The schematic illustrates an integrated cyclical model in which acute vestibular disturbances and chronic sequelae interact to develop mechanistic pathways that elevate fall risk. Episodic vertigo represents the acute trigger, producing transient disorientation and immediate postural destabilisation during positional changes. This acute instability manifests biomechanically as gait alterations, including reduced speed, increased variability, and impaired turning, reflecting compromised dynamic balance. Persistent symptoms following BPPV episodes contribute to chronic disequilibrium, characterised by sustained deficits in postural control and sensory integration beyond the acute phase. Concurrently, cognitive and psychological mechanisms, particularly fear of falling, emerge and persist, reinforcing maladaptive movement patterns, increasing attentional demands, and heightening fall susceptibility in older adults with underlying age-related vestibular decline.

References

- [1] Parham K, Kuchel GA. A geriatric perspective on benign paroxysmal positional vertigo. *Journal of the American Geriatrics Society*. 2016 Feb;64(2):378-85. <https://doi.org/10.1111/jgs.13926>
- [2] Nuti D, Masini M, Mandala M. Benign paroxysmal positional vertigo and its variants. *Handbook of Clinical Neurology*. 2016 Jan 1; 137:241-56. <https://doi.org/10.1016/B978-0->

444-63437-5.00018-2

- [3] Li Y, Smith RM, Whitney SL, Seemungal BM, Ellmers TJ. We should be screening for benign paroxysmal positional vertigo (BPPV) in all older adults at risk of falling: A commentary on the world falls guidelines. *Age and ageing*. 2023 Nov 2;52(11):afad206. <https://doi.org/10.1093/ageing/afad206>
- [4] Patangay KK, Ansari R. Benign paroxysmal positional vertigo: our experience. *Indian Journal of Otolaryngology and Head & Neck Surgery*. 2016 Mar;68(1):39-41. <https://doi.org/10.1007/s12070-014-0818-z>
- [5] Fife TD. Benign paroxysmal positional vertigo. In *Seminars in Neurology* 2009 Nov (Vol. 29, No. 05, pp. 500-508). © Thieme Medical Publishers. <https://doi.org/10.1055/s-0029-1241041>
- [6] Lindell E, Finizia C, Davidsson H, Kollen L, Kern S, Skoog I, et al. Prevalence of benign paroxysmal positional vertigo in a population-based setting among 75-year-olds. *Journal of Vestibular Research*. 2024 Aug 29;34(4):195-204. <https://doi.org/10.3233/VES-240027>
- [7] Jumani K, Powell J. Benign paroxysmal positional vertigo: Management and its impact on falls. *Annals of Otology, Rhinology & Laryngology*. 2017 Aug;126(8):602-5. <https://doi.org/10.1177/0003489417718847>
- [8] Ishiyama G. Imbalance and vertigo: The aging human vestibular periphery. In *Seminars in Neurology* 2009 Nov (Vol. 29, No. 05, pp. 491-499). © Thieme Medical Publishers. <https://doi.org/10.1055/s-0029-1241039>
- [9] Iwasaki S, Yamasoba T. Dizziness and imbalance in the elderly: age-related decline in the vestibular system. *Aging and disease*. 2014 Feb 9;6(1):38. <https://doi.org/10.14336/AD.2014.0128>
- [10] Navarro PP, López SP, Alonso SM, Ayerve CN, San Eloy AB, De Dios JC, et al. Posturographic study in older patients with instability associated with benign paroxysmal positional vertigo: A prospective analysis. *Journal of Gerontology and Geriatrics*. 2023 Jul 20;71:166-74. <https://doi.org/10.36150/2499-6564-N620>
- [11] Pauwels S, Casters L, Meyns P, Lemkens N, Lemmens W, Meijer K, et al. Several components of postural control are affected by benign paroxysmal positional vertigo but improve after particle-repositioning maneuvers: A systematic review and meta-analysis. *Clinical Rehabilitation*. 2025 Jan;39(1):3-22. <https://doi.org/10.1177/02692155241292662>
- [12] Pauwels S, Lemkens N, Lemmens W, Meijer K, Bijmens W, Meyns P, et al. Physical

- activity and frailty are impaired in older adults with benign paroxysmal positional vertigo. *Journal of Clinical Medicine*. 2024 Dec 11;13(24):7542.
<https://doi.org/10.3390/jcm13247542>
- [13] Pauwels S, Lemkens N, Lemmens W, Meijer K, Meyns P, Berg RV, et al. The importance of frailty in older adults with benign paroxysmal positioning vertigo. *Journal of Neurologic Physical Therapy*. 2025 Apr 1;49(2):99-107.
<https://doi.org/10.1097/NPT.0000000000000495>
- [14] Laurent G, Vereeck L, Verbecque E, Herssens N, Casters L, Spildooren J. Effect of age on treatment outcomes in benign paroxysmal positional vertigo: A systematic review. *Journal of the American Geriatrics Society*. 2022 Jan;70(1):281-93.
<https://doi.org/10.1111/jgs.17485>
- [15] Ganança FF, Gazzola JM, Ganança CF, Caovilla HH, Ganança MM, Cruz OL. Elderly falls associated with benign paroxysmal positional vertigo. *Brazilian Journal of Otorhinolaryngology*. 2010 Jan 1;76(1):113-20. <https://doi.org/10.1590/s1808-86942010000100019>
- [16] Ji L, Zhai S. Aging and the peripheral vestibular system. *Journal of Otology*. 2018 Dec 1;13(4):138-40. <https://doi.org/10.1016/j.joto.2018.11.006>
- [17] Walther LE, Westhofen M. Presbyvertigo-aging of otoconia and vestibular sensory cells. *Journal of Vestibular Research*. 2008 Mar 1;17(2-3):89-92. <https://doi.org/10.3233/VES-2007-172-303>
- [18] Marioni G, Fermo S, Lionello M, Fasanaro E, Giacomelli L, Zanon S, et al. Vestibular rehabilitation in elderly patients with central vestibular dysfunction: A prospective, randomized pilot study. *Age*. 2013 Dec;35(6):2315-27. <https://doi.org/10.1007/s11357-012-9494-7>
- [19] Marchetti GF, Whitney SL. Older adults and balance dysfunction. *Neurologic Clinics*. 2005 Aug 1;23(3):785-805. <https://doi.org/10.1016/j.ncl.2005.01.009>
- [20] Wang J, Li Y, Yang GY, Jin K. Age-related dysfunction in balance: A comprehensive review of causes, consequences, and interventions. *Aging and disease*. 2024 Jan 24;16(2):714. <https://doi.org/10.14336/AD.2024.0124-1>
- [21] Kim SY, Koo JW. Why is benign paroxysmal positional vertigo (BPPV) more common in women. In *Sex/Gender-Specific Medicine in Clinical Areas* 2024 Jun 4 (pp. 461-466). Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-97-0130-8_29

- [22] Guerra J, Devesa J. Causes and treatment of idiopathic benign paroxysmal positional vertigo based on endocrinological and other metabolic factors. *Journal of Otology*. 2020 Dec 1;15(4):155-60. <https://doi.org/10.1016/j.joto.2020.04.001>
- [23] Yetiser S. Review of the pathology underlying benign paroxysmal positional vertigo. *Journal of International Medical Research*. 2020 Oct;48(4):0300060519892370. <https://doi.org/10.1177/0300060519892370>
- [24] Chen, L., Bradshaw, A., & Halmagyi, G. M. Benign paroxysmal positional vertigo. In *Clinical Neurophysiology*. 2014; (pp. 409–410). <https://doi.org/10.1016/B978-0-12-385157-4.00123-8>
- [25] Gacek RR. Pathology of benign paroxysmal positional vertigo revisited. *Annals of Otology, Rhinology & Laryngology*. 2003 Jul;112(7):574-82. <https://doi.org/10.1177/000348940311200702>
- [26] Zhou R, Wang H, Shan J, Li C, Han L. Clinical features of benign paroxysmal positional vertigo in the elderly. *Frontiers in Neurology*. 2025 Jun 16;16:1623914. <https://doi.org/10.3389/fneur.2025.1623914>
- [27] Balatsouras DG, Koukoutsis G, Fassolis A, Moukos A, Apris A. Benign paroxysmal positional vertigo in the elderly: Current insights. *Clinical Interventions in Aging*. 2018 Nov 5;2251-66. <https://doi.org/10.2147/CIA.S144134>
- [28] Karmali F, Whitman GT, Lewis RF. Bayesian optimal adaptation explains age-related human sensorimotor changes. *Journal of Neurophysiology*. 2018 Feb 1;119(2):509-20. <https://doi.org/10.1152/jn.00710.2017>
- [29] von Brevern M. Benign paroxysmal positional vertigo. In *Seminars in Neurology* 2013 Jul (Vol. 33, No. 03, pp. 204-211). Thieme Medical Publishers. <https://doi.org/10.1055/s-0033-1354590>
- [30] Cleworth TW, Allum JH, Luu MJ, Lea J, Westerberg BW, Carpenter MG. The effect of unilateral vestibular loss on standing balance during postural threat. *Otology & Neurotology*. 2020 Aug 1;41(7):e945-51. <https://doi.org/10.1097/MAO.0000000000002485>
- [31] Pauwels S, Lemkens N, Lemmens W, Meijer K, Meyns P, van de Berg R, et al. Co-existing vestibular hypofunction impairs postural control, but not frailty and well-being, in older adults with benign paroxysmal positional vertigo. *Journal of Clinical Medicine*. 2025 Apr 14;14(8):2666. <https://doi.org/10.3390/jcm14082666>

- [32] Allison LK, Kiemel T, Jeka JJ. Sensory-challenge balance exercises improve multisensory reweighting in fall-prone older adults. *Journal of Neurologic Physical Therapy*. 2018 Apr 1;42(2):84-93. <https://doi.org/10.1097/NPT.0000000000000214>
- [33] Jeka JJ, Allison LK, Kiemel T. The dynamics of visual reweighting in healthy and fall-prone older adults. *Journal of Motor Behavior*. 2010 Jul 1;42(4):197-208. <https://doi.org/10.1080/00222895.2010.481693>
- [34] Eikema DJ, Hatzitaki V, Konstantakos V, Papaxanthis C. Elderly adults delay proprioceptive reweighting during the anticipation of collision avoidance when standing. *Neuroscience*. 2013 Mar 27;234:22-30. <https://doi.org/10.1016/j.neuroscience.2012.12.053>
- [35] Block HJ, Sexton BM. Visuo-proprioceptive control of the hand in older adults. *Multisensory Research*. 2020 Jul 20;34(1):93-111. <https://doi.org/10.1163/22134808-bja10032>
- [36] Schneeberger LC, Lynn A, Scarcelli V, Seif A, Stevenson RA. Enhanced multisensory gain in older adults may be a by-product of inverse effectiveness: Evidence from a speeded response-time task. *Psychology and Aging*. 2024 Oct 7;39(7):770-780. <https://doi.org/10.1037/pag0000850>
- [37] Pauwels S, Casters L, Lemkens N, Lemmens W, Meijer K, Meyns P, et al. Gait and falls in benign paroxysmal positional vertigo: A systematic review and meta-analysis. *Journal of Neurologic Physical Therapy*. 2023 Jul 1;47(3):127-38. <https://doi.org/10.1097/NPT.0000000000000438>
- [38] Demircan SK, Öner F. The association of sarcopenia and body composition with benign positional paroxysmal vertigo in older adults. *The Laryngoscope*. 2025 Apr;135(4):1486-92. <https://doi.org/10.1002/lary.31995>
- [39] Liao WL, Chang TP, Chen HJ, Kao CH. Benign paroxysmal positional vertigo is associated with an increased risk of fracture: A population-based cohort study. *Journal of Orthopaedic & Sports Physical Therapy*. 2015 May;45(5):406-12. <https://doi.org/10.2519/jospt.2015.5707>
- [40] Abbott J, Tomassen S, Lane L, Bishop K, Thomas N. Assessment for benign paroxysmal positional vertigo in medical patients admitted with falls in a district general hospital. *Clinical Medicine*. 2016 Aug 1;16(4):335-8. <https://doi.org/10.7861/clinmedicine.16-4-335>
- [41] Abdulrahim R, Bhandary BS, Rajeshwary A, Goutham MK, Bhat V, Saldanha M. The role of video head impulse test (VHiT) in diagnosing benign paroxysmal positional vertigo

- (BPPV). Indian Journal of Otolaryngology and Head & Neck Surgery. 2022 Aug;74(Suppl 1):506-10. <https://doi.org/10.1007/s12070-020-02351-5>
- [42] Liu Y, Leng Y, Zhou R, Liu J, Wang H, Xia K, et al. Video head impulse test findings in patients with benign paroxysmal positional vertigo secondary to idiopathic sudden sensorineural hearing loss. Frontiers in Neurology. 2022 Jun 2;13:877777. <https://doi.org/10.3389/fneur.2022.877777>
- [43] Kim HA, Lee H. Autonomic dysfunction as a possible cause of residual dizziness after successful treatment in benign paroxysmal positional vertigo. Clinical Neurophysiology. 2014 Mar 1;125(3):608-14. <https://doi.org/10.1016/j.clinph.2013.08.008>
- [44] Acle-Cervera L, Carballo-Lahoz L, Esteban-Sánchez J, Álvarez-Morujó-de-Sande MG, Montilla-Ibáñez MA, Bécares-Martínez C, et al. Life after benign paroxysmal positional vertigo: One-year analysis of recurrence, headaches, neck pain, falls, and functional vestibular symptoms. European Archives of Oto-Rhino-Laryngology. 2025 Apr;282(4):1865-77. <https://doi.org/10.1007/s00405-024-09094-x>
- [45] Dalton BH, Blouin JS, Allen MD, Rice CL, Inglis JT. The altered vestibular-evoked myogenic and whole-body postural responses in old men during standing. Experimental Gerontology. 2014 Dec 1;60:120-8. <https://doi.org/10.1016/j.exger.2014.09.020>
- [46] Ha PL, Peters WB, McGeehan MA, Dalton BH. Age-related reduction in peak power and increased postural displacement variability are related to enhanced vestibular-evoked balance responses in females. Experimental Gerontology. 2022 Apr 1;160:111670. <https://doi.org/10.1016/j.exger.2021.111670>
- [47] Ribeiro KM, Freitas RV, Ferreira LM, Deshpande N, Guerra RO. Effects of balance vestibular rehabilitation therapy in elderly with benign paroxysmal positional vertigo: a randomized controlled trial. Disability and Rehabilitation. 2017 Jun 5;39(12):1198-206. <https://doi.org/10.1080/09638288.2016.1190870>
- [48] Ekvall Hansson E, Magnusson M. Vestibular asymmetry predicts falls among elderly patients with multi-sensory dizziness. BMC Geriatrics. 2013 Jul 22;13(1):77. <https://doi.org/10.1186/1471-2318-13-77>
- [49] Hong JP, Kim MB. Application of the Barany Society's presbyvestibulopathy criteria in older adults with chronic dizziness. Otolaryngology–Head and Neck Surgery. 2024 Feb;170(2):515-21. <https://doi.org/10.1002/ohn.551>
- [50] Agrawal Y, Van de Berg R, Wuyts F, Walther L, Magnusson M, Oh E, et al.

Presbivestibulopatía: criterios diagnósticos. Documento de consenso del Comité de Clasificación de la Bárány Society. Acta Otorrinolaringologica Espanola. 2022 Jan 1;73(1):42-50. <https://doi.org/10.1016/j.otorri.2021.05.002>

- [51] Bosmans J, Jorissen C, Gilles A, Mertens G, Engelborghs S, Cras P, et al. Vestibular function in older adults with cognitive impairment: a systematic review. Ear and Hearing. 2021 Sep 1;42(5):1119-26. <https://doi.org/10.1097/AUD.0000000000001040>
- [52] Jacobson GP, McCaslin DL, Grantham SL, Piker EG. Significant vestibular system impairment is common in a cohort of elderly patients referred for assessment of falls risk. Journal of the American Academy of Audiology. 2008 Nov;19(10):799-807. <https://doi.org/10.3766/jaaa.19.10.7>
- [53] Liston MB, Bamio DE, Martin F, Hopper A, Koohi N, Luxon L, et al. Peripheral vestibular dysfunction is prevalent in older adults experiencing multiple non-syncopal falls versus age-matched non-fallers: a pilot study. Age and ageing. 2014 Jan 1;43(1):38-43. <https://doi.org/10.1093/ageing/aft129>
- [54] White J, Savvides P, Cherian N, Oas J. Canalith repositioning for benign paroxysmal positional vertigo. Otology and Neurotology. 2005 Jul 1;26(4):704-10. <https://doi.org/10.1097/01.mao.0000178128.66482.7e>
- [55] Prokopakis E, Vlastos IM, Tsagournisakis M, Christodoulou P, Kawauchi H, Velegrakis G. Canalith repositioning procedures among 965 patients with benign paroxysmal positional vertigo. Audiology and Neurotology. 2013 Jan 1;18(2):83-8. <https://doi.org/10.1159/000343579>
- [56] Prokopakis EP, Chimona T, Tsagournisakis M, Christodoulou P, Hirsch BE, Lachanas VA, et al. Benign paroxysmal positional vertigo: 10-year experience in treating 592 patients with canalith repositioning procedure. The Laryngoscope. 2005 Sep;115(9):1667-71. <https://doi.org/10.1097/01.mlg.0000175062.36144.b9>
- [57] dos Santos Silva AL, Collange LA, de Sá Ferreira A. Hybrid maneuver for benign paroxysmal positional vertigo in individuals with limited neck mobility: Case series. Journal of Bodywork and Movement Therapies. 2024 Jan 1;37:386-91. <https://doi.org/10.1016/j.jbmt.2023.11.056>
- [58] Kader HA, Abdel Halim FN, Abdel Rahman TT. A comparative study on effectiveness of the rolling-over maneuver in rehabilitation of patients with posterior semicircular canal benign paroxysmal positional vertigo. The Egyptian Journal of Otolaryngology. 2014

- Apr;30(2):88-93. <https://doi.org/10.4103/1012-5574.133193>
- [59] Sugita-Kitajima A, Sato S, Mikami K, Mukaide M, Koizuka I. Does vertigo disappear only by rolling over? Rehabilitation for benign paroxysmal positional vertigo. *Acta Otolaryngologica*. 2010 Jan 1;130(1):84-8. <https://doi.org/10.3109/00016480902968086>
- [60] Alrwaily M, Whitney SL. Vestibular rehabilitation of older adults with dizziness. *Otolaryngologic Clinics of North America*. 2011 Apr 1;44(2):473-96. <https://doi.org/10.1016/j.otc.2011.01.015>
- [61] Alrwaily M, Whitney SL. Older adults with dizziness: rehabilitation strategies and novel interventions. *Dizziness and vertigo across the lifespan*. Elsevier Health Sciences. 2018:249. <https://doi.org/10.1016/B978-0-323-55136-6.00019-8>
- [62] Micarelli A, Viziano A, Micarelli B, Augimeri I, Alessandrini M. Vestibular rehabilitation in older adults with and without mild cognitive impairment: Effects of virtual reality using a head-mounted display. *Archives of Gerontology and Geriatrics*. 2019 Jul 1;83:246-56. <https://doi.org/10.1016/j.archger.2019.05.008>
- [63] Karinkanta S, Piirtola M, Sievänen H, Uusi-Rasi K, Kannus P. Physical therapy approaches to reduce fall and fracture risk among older adults. *Nature Reviews Endocrinology*. 2010 Jul;6(7):396-407. <https://doi.org/10.1038/nrendo.2010.70>
- [64] Markle-Reid M, Browne G, Gafni A, Roberts J, Weir R, Thabane L, et al. The effects and costs of a multifactorial and interdisciplinary team approach to falls prevention for older home care clients ‘at risk’ for falling: a randomized controlled trial. *Canadian Journal on Aging/La Revue canadienne du vieillissement*. 2010 Mar;29(1):139-61. <https://doi.org/10.1017/S0714980809990377>
- [65] Casteel C, Blalock SJ, Ferreri S, Roth MT, Demby KB. Implementation of a community pharmacy–Based falls prevention program. *The American Journal of Geriatric Pharmacotherapy*. 2011 Oct 1;9(5):310-9. <https://doi.org/10.1016/j.amjopharm.2011.08.002>
- [66] Charmant WM, Snoeker BA, van Hout HP, Geleijn E, van der Velde N, Veenhof C, et al. Strategies for implementation of a transmural fall-prevention care pathway for older adults with fall-related injuries at the emergency department. *BMC Emergency Medicine*. 2024 Oct 11;24(1):188. <https://doi.org/10.1186/s12873-024-01085-9>
- [67] Ong RH, Nurjono M, Oh HC, Lien CT, Jumala J, Teo RC, et al. Factors influencing the implementation of a fall prevention exercise program for community-dwelling older adults: a qualitative study guided by the PRECEDE-PROCEED Model. *Clinical Interventions in*

- Aging. 2024 Dec 31:857-71. <https://doi.org/10.2147/CIA.S454043>
- [68] Kapri P, Sharma N, Kaur S, Negi P, Kumar P, Singh G, et al. Digital rehabilitation for vestibular dysfunction: a systematic scoping review and meta-analysis on remote strategies for managing dizziness in older adults. *Revista Pesquisa em Fisioterapia*. 2025 Aug 25;15:e6155-. <https://doi.org/10.17267/2238-2704rpf.2025.e6155>
- [69] Kapri P, Sharma N, Kaur S, Negi P, Kumar P, Singh G, et al. Exploring the potential of telerehabilitation for advancing vestibular care: a systematically scoping review in managing dizziness in older adults. *Critical Reviews™ in Physical and Rehabilitation Medicine*. 2025;37(3). <https://doi.org/10.1615/CritRevPhysRehabilMed.2025057841>
- [70] van Vugt VA, van der Wouden JC, Essery R, Yardley L, Twisk JW, van der Horst HE, et al. Internet based vestibular rehabilitation with and without physiotherapy support for adults aged 50 and older with a chronic vestibular syndrome in general practice: Three-armed randomised controlled trial. *British Medical Journal*. 2019 Nov 5;367. <https://doi.org/10.1136/bmj.l5922>
- [71] Xia F, Zhu K, Ren Y, Wang N. Efficacy of the automated mechanical repositioning chair treatment for patients with benign paroxysmal positional vertigo. *The Journal of Laryngology & Otology*. 2025 Jan;139(1):34-9. <https://doi.org/10.1017/S002221512400118X>