Original Article

A Retrospective Study on the Association of Age and Sex with the Effectiveness of Canalith Repositioning and Home-Based Rehabilitation in Benign Paroxysmal Positional Vertigo Patients

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ABSTRACT

Objectives: To investigate the association between sex, age, and the effectiveness of the canalith repositioning procedure (CRP) combined with home-based vestibular rehabilitation in patients with benign paroxysmal positional vertigo (BPPV), and to examine their influence on dizziness-related quality of life as measured by the Dizziness Handicap Inventory (DHI).

Study design: Retrospective observational study

Setting: The Outpatient Departments of Otolaryngology and Physical Therapy, Trang Hospital, Trang Province, Thailand

Subjects: Seventy-eight adults with benign paroxysmal positional vertigo (BPPV) treated with canalith repositioning and home-based vestibular rehabilitation.

Methods: In this retrospective observational study, 78 patients who underwent CRP and home-based vestibular exercises between October 2023 and February 2024 were analyzed. Patients were divided into two age groups (18-59 years and ≥ 60 years) and compared by sex. Treatment outcomes were measured based on symptom resolution and changes in DHI scores before and after treatment. Group comparisons were performed using chi-square tests, t-tests, and correlation analyses, with statistical significance set at $p < 0.05$.

Results: The overall resolution rate was 97.4%. There were no significant differences by age or sex. Age correlated positively with DHI pre- and post-scores ($r = 0.83$ and 0.73, $p < 0.01$), and post-treatment DHI was higher in females than males ($p = 0.02$).

Conclusions: This study highlights that while CRP combined with home-based vestibular rehabilitation is effective for BPPV treatment, older adults and females experience greater dizziness-related handicaps. These findings emphasize the need for age- and sex-specific considerations in rehabilitation programs, particularly regarding realistic outcome expectations for older adults and enhanced support for females who may experience greater residual handicap.

Keywords: benign paroxysmal positional vertigo, canalith repositioning procedure, vestibular rehabilitation, age factors, sex factors

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Introduction

Benign paroxysmal positional vertigo (BPPV) is the most prevalent vestibular disorder. The annual incidence of BPPV across all ages is reported to be 171.5 per 100,000, with a significantly lower incidence in children, at 9.5 per 100,000, highlighting its rarity in younger populations.[1] BPPV occurs when calcium carbonate crystals (otoconia) become dislodged from the utricle and migrate into the semicircular canals, causing abnormal endolymph movement and inappropriate vestibular stimulation during head movements, resulting in characteristic rotatory vertigo and nystagmus.[2] These symptoms can severely impact patients' quality of life, leading to anxiety, fear, and activity avoidance.[3]

The primary treatment for BPPV is the canalith repositioning procedure (CRP), which involves a series of head maneuvers to reposition the otoconia.[2] CRP works by guiding displaced otoconia out of the affected semicircular canal back to the utricle through specific sequential head and body position changes, utilizing gravity to facilitate crystal repositioning. Common techniques include the Epley maneuver for posterior canal BPPV and the Gufoni or barbecue roll maneuver for horizontal canal BPPV.[2] Alongside CRP, vestibular rehabilitation (VR) plays a critical role in long-term management by promoting vestibular system adaptation and compensatory mechanisms, potentially reducing recurrence rates and improving quality of life.[4, 5] VR facilitates central nervous system adaptation to peripheral vestibular dysfunction through neuroplasticity mechanisms.

CRP combined with VR is highly effective for treating BPPV.[6-8] However, recurrence remains a concern. Studies have reported a 37.0% recurrence rate, with 28.0% of cases recurring in the same ear, and 56.0% of recurrences occurring within the first year.[9] Female sex and a history of prior BPPV are associated with an increased risk of recurrence,[9] emphasizing the need to consider demographic factors in long-term manage-

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ment. Despite the effectiveness of CRP and VR, not all patients achieve full symptom resolution.[10] Sex, age, comorbidities, and disease duration are key factors influencing treatment outcomes.[11, 12] While some studies have reported no significant association between age or sex and resolution rates.[13, 14] Batuecas et al.[10] reported higher rates of persistent dizziness in patients over 70 years old, highlighting the need for further investigation into how these factors affect BPPV outcomes. Thailand has a growing elderly population, and BPPV is increasingly prevalent among older adults. However, studies on the effectiveness of CRP and home-based vestibular rehabilitation in Thai populations remain limited. Therefore, this study aimed to examine the association between age, sex, and the effectiveness of CRP combined with home-based vestibular rehabilitation in improving the quality of life among patients with BPPV. We hypothesized that age and sex may influence the post-treatment outcomes of patients undergoing CRP and home-based vestibular rehabilitation.

This study aims to investigate the association between sex, age, and the effectiveness of BPPV treatment with CRP combined with VR in Thai patients, with the goal of providing insights for the development of tailored treatment guidelines.

Methods

Study design and setting

This retrospective analytical study was conducted at the Outpatient Departments of Otolaryngology and Physical Therapy, Trang Hospital, Trang Province, Thailand, using data collected between October 2023 and February 2024. The study received approval from the Ethics Committee of Trang Hospital on April 10, 2024 (Project ID: 012/04/2567).

This report followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guideline.

Participants

Patients were selected using purposive sampling based on the following inclusion criteria: (1) aged ≥ 18 years; (2) diagnosed with BPPV (ICD-10: H81.10); (3) treated with canalith CRP and home-based vestibular rehabilitation; and (4) complete follow-up data available. Exclusion criteria included a history of central nervous system disorders, inner ear conditions, or cervical spine limitations.

BPPV diagnosis was established by qualified ENT specialists using standardized diagnostic criteria including positive Dix-Hallpike test for posterior canal BPPV and supine roll test for horizontal canal BPPV. Diagnostic procedures were performed according to current clinical practice guidelines with inter-examiner reliability established. No missing data were encountered as complete follow-up data availability was an inclusion criterion, ensuring 100.0% data completeness for all 78 participants.

Intervention and follow-up

All CRP and home-based vestibular rehabilitation instructions were delivered by trained physical therapists following the same protocol based on clinical practice guidelines. The intervention protocol comprised the following components:

1. Canalith repositioning procedure (CRP): This was performed by certified physiotherapists using the Epley maneuver for posterior canal BPPV and the Gufoni maneuver or barbecue roll for horizontal canal BPPV.

2. Vestibular rehabilitation (VR): The VR program was standardized and designed by certified physiotherapists, including: (1) gaze stabilization exercises (X1 and X2 viewing), (2) balance training (static and dynamic), (3) habituation exercises, and (4) functional mobility training. Programs were standardized across all patients with intensity modifications based on individual tolerance. Patients were instructed to complete these exercises for 15-20 minutes daily, at least five days per week.

3. The intervention combined both hospital-based CRP with supervised VR training AND daily home-based VR exercises. Home-based Vestibular Rehabilitation: Customized exercise manuals were provided to patients and their caregivers. Weekly telephone follow-ups were conducted by physiotherapy assistants to assess patient progress and ensure adherence to the prescribed rehabilitation program. Additionally, patients attended weekly follow-up consultations at the dizziness clinic for further assessment and necessary adjustments to their treatment regimen.

Patients were discharged upon meeting the following criteria: (1) normalization of Dix-Hallpike and supine roll test results; (2) resolution of vertigo symptoms; and (3) the ability to resume normal daily activities. Most patients required 1-3 treatment sessions prior to discharge.

Outcome measurement

The primary outcome measures were the resolution rate, defined as the resolution of symptoms within three treatment sessions, and the Dizziness Handicap Inventory (DHI) scores, which were assessed both pre- and post-treatment. DHI was assessed only twice: (1) at baseline before any intervention, and (2) at discharge when resolution criteria were met. DHI was not assessed at intermediate weekly visits. DHI assessments were conducted at baseline (pre-treatment) and at discharge (post-treatment), with an average interval of 2.10 (SD = 0.80) weeks between assessments. For patients achieving early resolution (n = 8), post-treatment DHI was assessed at their discharge visit. The Thai version of the DHI, which has been validated for reliability and validity, was used in this study.[15] The DHI is a widely accepted tool for evaluating the impact of dizziness on patients' quality of life, with scores ranging from 0 to 100, where higher scores indicate greater impairment.

Sample size calculation

As this was a retrospective observational study, all patients diagnosed with BPPV between October 2023 and February 2024 who met the inclusion criteria were included. No a priori sample size calculation was performed. This

approach is acceptable for exploratory studies, as it reflects real-world data and helps minimize selection bias.

Data collection

Retrospective data were extracted from outpatient medical records, including demographic details, treatment specifics, and pre- and post-treatment DHI scores. The validated Thai version of the DHI, comprising 25 items across physical, emotional, and functional domains, was used, with higher scores reflecting greater impairment in quality of life.

Statistical analysis

Descriptive statistics summarized demographic data (frequencies, percentages, means, standard deviations). Chi-square and independent t-tests were used for group comparisons, and point-biserial correlation assessed associations between age, sex, and DHI scores. Multiple linear regression was performed to control for potential confounding factors. Subgroup analyses by age and sex were conducted; however, interaction terms (e.g., age × sex) were not included due to limited sample size in some subgroups, which may reduce model stability. Effect sizes (Cramér's V, Cohen's d) and 95% confidence intervals were reported. No a priori sample size calculation was performed; all eligible patients during the study period were included. A sensitivity analysis using an age cutoff of 65 years confirmed the robustness of findings. No missing data were present due to inclusion criteria requiring complete follow-up. Statistical significance was set at $p < 0.05$.

Results

A total of 85 patients were initially screened for eligibility. Seven patients were excluded due to incomplete follow-up data (missing final DHI assessment, n = 5; incomplete medical records, n = 2), resulting in 78 patients included in final analysis (Figure 1). All included participants completed the intervention protocol and follow-up assessments, yielding 100.0% completion rate among eligible participants.

A total of 78 patients (17 males, 21.8%; 61 females, 78.2%) were included (Table 1). The mean age was similar between males (64.1 (SD = 6.4) years) and females (63.7 (SD = 11.8) years; $p = 0.86$) (Table 2). Most patients (61.5%) were aged ≥ 60 years. The posterior canal was most affected (100% in males, 98.4% in females), with no significant differences by sex ($p = 0.28$) or age ($p = 0.20$) (Tables 1 and 2). A trend towards right-sided BPPV was observed in older adults ($p = 0.05$) (Table 2).

Primary outcome: resolution rate

The overall BPPV resolution rate within three CRP sessions was 97.4% (76/78; 95%CI: 93.9-100.0%). There were no statistically significant differences between age groups (94.7% in ≥ 60 vs. 100.0% in < 60 years, $p = 0.25$) or sexes (88.2% in males vs. 100.0% in females, $p = 0.39$) (Table 1, Supplementary Table S5).

Secondary outcomes: DHI scores and quality of life

Pre- and Post-treatment DHI Scores

Older adults had significantly higher DHI scores than younger patients at baseline (53.8 (SD = 6.5) vs. 36.7 (SD = 4.2), $p < 0.01$) and post-treatment (6.29 (SD = 3.4) vs. 0.3 (SD = 1.1), $p < 0.01$), reflecting greater perceived dizziness and residual symptoms (Table 2). Females also had higher post-treatment DHI scores than males (4.6 (SD = 3.9) vs. 2.00 (SD = 3.7), $p = 0.02$). These differences remained statistically significant after adjusting for covariates (Table S1), with adjusted mean DHI scores of 4.6 in females and 1.9 in males ($p < 0.01$), and 2.4 in patients with successful resolution vs. 4.1 in unresolved cases ($p = 0.02$).

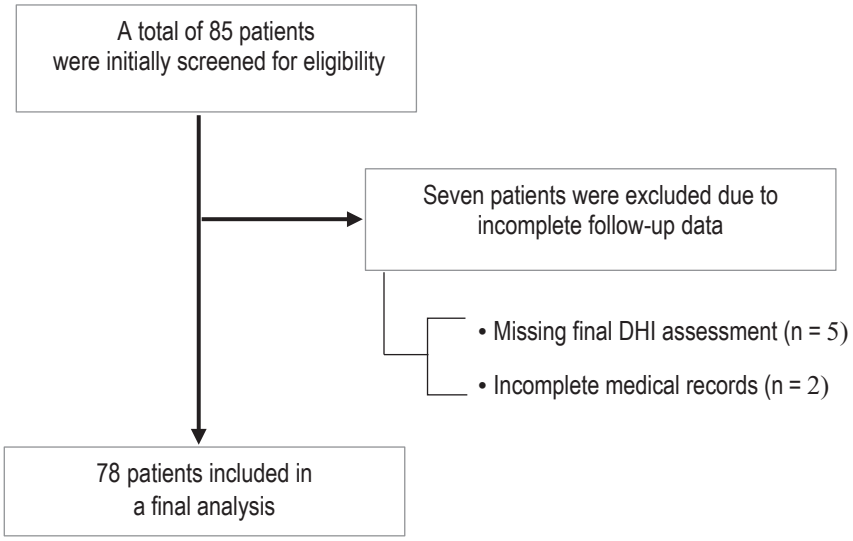

Figure 1. Flow of participants through the study. The diagram illustrates the number of patients who were screened for eligibility, the number of patients excluded with specific reasons for exclusion, and the final number of patients included in the analysis.

Table 1. Baseline characteristics and resolution rate stratified by age group (n = 78)

Variable	Younger group (n = 30)	Older group (n = 48)	χ^2 / t	*p*-value
Demographics				
Age[1]	52.3 (5.9)	70.9 (5.9)	t = –13.2	< 0.01**
Sex[2]			χ^2 = 0.75	0.39
Male	5 (16.7)	12 (25.0)		
Female	25 (83.3)	36 (75.0)		
Clinical characteristics				
BPPV location[2]			χ^2 = 1.62	0.20
Posterior canal	29 (96.7)	48 (100.0)		
Horizontal canal	1 (3.3)	0 (0.0)		
Affected side[2]			χ^2 = 3.76	0.05
Right side	12 (40.0)	30 (62.5)		
Left side	18 (60.0%)	18 (37.5)		
CRP treatment[2]			χ^2 = 1.62	0.20
Epley plus VR	29 (96.7)	48 (100.0)		
Gufoni/Barbecue plus VR	1 (3.3)	0 (0.0)		
Primary outcome			χ^2 = 1.28	0.25
Resolution rate (n/N)	30/30 (100.0)	46/48 (95.83)		
95%CI[a]	88.6-100.0	86.0-98.8		

[1]Mean (SD), [2]Number (%)

p-values calculated using independent t test for continuous variables and chi-square test for categorical variables. [a]95%CI = 95% confidence interval calculated using Wilson Score Interval.

Statistical significance: $p < 0.05$; $p < 0.01$; BPPV, benign paroxysmal positional vertigo; CRP, canalith repositioning procedure; VR, vestibular rehabilitation

Table 2. Comparison of age, dizziness handicap inventory (DHI) pre and post scores, and correlations by age group and gender

BPPV (n = 78)	Age group		*p*-value	Gender		*p*-value
	Younger group (n = 30)	Older group (n = 48)		Male (n = 17)	Female (n = 61)	
Age (mean (SD))	52.3 (5.9)	70.9 (5.9)	-	64.1 (6.4)	63.7(11.8)	0.86
DHI-pre	36.7 (4.2)	53.8 (6.5)	< 0.01**	46.7 (7.1)	47.4 (10.8)	0.76
95%CI	(35.2, 38.2)	(52.0, 55.6)		(43.4, 50.1)	(44.7, 50.1)	
DHI-post	0.3 (1.1)	6.3 (3.4)	< 0.01**	2.0 (3.7)	4.6 (3.9)	0.02*
95%CI	(-0.0, 0.7)	(5.3, 7.2)		(0.2, 3.8)	(3.6, 5.5)	

[a]Independent t test *p-value significant at the 0.01 level (2-tailed) **p-value significant at the 0.01 level (2-tailed) †95%CI calculated using standard error of the mean (SEM); CI may extend below 0 in groups with very low mean DHI post-treatment scores. Since DHI scores range from 0–100, negative lower bounds reflect statistical estimation rather than actual values; BPPV, benign paroxysmal positional vertigo; CRP, canalith repositioning procedure; VR, vestibular rehabilitation

Effect sizes and clinical significance

The mean DHI improvement (ΔDHI) exceeded the MCID threshold of 18 points in all subgroups except for males ≥ 60 years (ΔDHI = 14.3) (Table S3, Figure S1). The largest improvements were observed in females < 60 years (ΔDHI = 24.1, 95%CI: 18.1, 30.0). Cohen's d calculations indicated large effect sizes for age-related differences in DHI scores both pre-treatment (d = 2.96) and post-treatment (d = 1.00), as well as a moderate effect for the post-treatment sex difference (d = 0.65), supporting the clinical relevance of these findings.

Correlations

Age showed strong positive correlations with DHI scores both pre-treatment (r = 0.83) and post-treatment (r = 0.73) (p < 0.01) (Table 3). A weak but statistically significant negative correlation was found between sex (female = 1) and post-treatment DHI score (r = –0.27, p = 0.02). Multiple linear regression confirmed that sex and resolution status were significant independent predictors of post-treatment DHI, while age was not a significant predictor in the model (p = 0.10) (Table S2).

Discussion

This study investigated the association between sex, age, and the effectiveness of vestibular rehabilitation in BPPV patients. Our results showed that although sex and age did not significantly influence BPPV resolution rates with CRP combined with home-based vestibular rehabilitation,

Table 3. Correlations between age, sex, and dizziness handicap inventory (DHI) scores before and after treatment

Variable	*r*	*p*-value
Age vs. DHI-pre-treatment	0.83	< 0.01**
Age vs. DHI-post-treatment	0.73	< 0.01**
Sex vs. DHI-pre-treatment	-0.03	0.81
Sex vs. DHI-post-treatment	-0.27	0.02*

r = correlation coefficient; [b]point biserial correlation (used for continuous vs. dichotomous variables with equal variance); [c]Spearman's rank correlation (used for ordinal/non-normally distributed data) *p-value < 0.05 = significant; **p-value < 0.01 = highly significant (2-tailed)

significant differences were observed in the quality of life, as measured by DHI scores.

Our study aligns with previous research showing that age is a key factor in BPPV prevalence, with older adults being more susceptible. The mean onset age is around 54 years, and older individuals often face prolonged symptoms and higher rates of comorbidities, like cerebrovascular and cardiovascular diseases.[16, 17] In our study, older adults had significantly higher pre- and post-treatment DHI scores, reflecting a greater dizziness-related burden, likely due to age-related vestibular degeneration and reduced neuroplasticity. These findings suggest that older patients may benefit from tailored vestibular rehabilitation programs.[18-20]

Sex significantly influences BPPV prevalence and impact. In line with prior studies,[16,21] our study found a higher prevalence in females, with a female-to-male ratio of about 2:1. Although resolution rates did not differ by sex, females had higher post-treatment DHI scores, suggesting that hormonal, psychosocial, and physiological factors may affect their quality of life.[22] These findings highlight the need for tailored vestibular rehabilitation programs that address both physical and psychosocial factors, especially for female patients.

The overall resolution rate of 97.4% aligns with previous studies demonstrating the efficacy of CRP combined with vestibular rehabilitation.[19,23] The mechanical nature of CRP, which repositions otoconia, explains the consistent resolution rates across age and sex groups. However, some patients, particularly older adults, experienced persistent dizziness, underscoring the importance of combining CRP with home-based rehabilitation to facilitate neural adaptation.[24]

Our findings agree with Bruintjes et al.,[13] who reported no significant impact of age or sex on resolution rates. In contrast, Batuecas-Caletrio et al.[10] found lower resolution rates among older patients, likely due to the absence of vestibular rehabilitation in their protocol. These variations suggest that cultural and lifestyle factors specific to the Thai population may influence recovery and warrant further investigation. In particular, beliefs about aging, strong family support, and balance-intensive occupations may affect adherence and perceived handicap. Moreover, psychological factors such as anxiety, emotional distress, and fear of falling may influence symptom perception and rehabilitation adherence, particularly among older adults and females. Addressing these factors may enhance treatment outcomes and reduce recurrence.[3,16]

Recent studies support the integration of CRP with vestibular rehabilitation, with reports of improved balance and gait in patients receiving individualized rehabilitation alongside CRP,[19] and enhanced dynamic balance in elderly patients with chronic BPPV.[23] A key finding of our study is that, while BPPV resolution rates are high, older adults and females experience greater dizziness-related handicaps, emphasizing the need to address quality of life alongside symptom resolution.

Clinical implications

Healthcare providers should emphasize quality of life assessments in older and female BPPV patients, extend follow-ups, and provide targeted education to enhance rehabilitation adherence. Routine DHI screening for all BPPV patients, with heightened attention to older adults and females experiencing greater residual handicap. Providers should counsel patients about potential demographic differences in recovery patterns while maintaining optimism about treatment effectiveness.

Limitations

Study design limitations: Selection bias due to single-center design may overestimate treatment effectiveness. Information bias from medical record review was minimized through standardized protocols. Short follow-up period limits assessment of long-term outcomes. The study's retrospective design, single-center scope, and short follow-up are key limitations. Furthermore, adherence to the home-based rehabilitation program was not formally monitored, which may represent a limitation as differential adherence could influence outcomes.

Generalizability: These findings may be most applicable to Southeast Asian healthcare settings with comparable patient demographics, healthcare infrastructure, and cultural contexts. Generalizability to other populations requires validation. Future research should use prospective, multi-center studies with extended follow-up to assess long-term outcomes and explore factors like comorbidities and socioeconomic status.

Future research directions

Given our retrospective design limitations, prospective randomized controlled trials should be conducted to: (1) compare CRP combined with home-based VR versus CRP alone, (2) investigate optimal rehabilitation protocols for different demographic groups, and (3) assess long-term outcomes including recurrence rates.

Conclusions

CRP combined with home-based vestibular rehabilitation is effective for BPPV across sex and age groups. However, older adults and females experience greater dizziness-related handicap, indicating the need for tailored treatment programs that address both physical and psychosocial factors.

Conflict of interest declaration

The authors declare no conflicts of interest.

Generative AI declaration

The authors confirm that no large language models (LLMs) or artificial intelligence (AI) tools were used in the creation of this manuscript, including the writing, editing, or preparation of figures and tables, except for using Grammarly for basic grammar and spell-checking. All content was critically reviewed and edited by the authors.

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Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author (Tidaporn Tairattanasuwan) on reasonable request.

Author contributions

Watcharin Tayati: conceptualization, methodology, investigation, data curation, software, writing-original draft,

Tidaporn Tairattanasuwan: supervision, software, validation, writing-review & editing.

References

1. Choi HG, Kim G, Kim BJ, Hong SK, Kim HJ, Lee HJ. How rare is benign paroxysmal positional vertigo in children? A review of 20 cases and their epidemiology. Int J Pediatr Otorhinolaryngol [Internet]. 2020 [cited 2025 Mar 11];132:110008. Available from: https://pubmed.ncbi.nlm.nih.gov/32240880/
2. Bhattacharyya N, Gubbels SP, Schwartz SR, Edlow JA, El-Kashlan H, Fife T, et al. Clinical practice guideline: benign paroxysmal positional vertigo (update). Otolaryngol Head Neck Surg [Internet]. 2017 [cited 2025 Mar 11];156(3 Suppl):S1–47. Available from: https://pubmed.ncbi.nlm.nih.gov/28248609/
3. Weidt S, Bruehl AB, Straumann D, Hegemann SC, Krautstrunk G, Rufer M. Health-related quality of life and emotional distress in patients with dizziness: a cross-sectional approach to disentangle their relationship. BMC Health Serv Res [Internet]. 2014 [cited 2025 Mar 11];14:317. https://pubmed.ncbi.nlm.nih.gov/25052136/
4. Whitney SL, Alghwiri AA, Alghadir A. Physical therapy for persons with vestibular disorders. Curr Opin Neurol [Internet]. 2015 [cited 2025 Mar 11];28(1):61-8. Available from: https://pubmed.ncbi.nlm.nih.gov/25514252/
5. Hoseinabadi R, Pourbakht A, Yazdani N, Kouhi A, Kamali M, Abdollahi FZ, et al. The effects of the vestibular rehabilitation on the benign paroxysmal positional vertigo recurrence rate in patients with otolith dysfunction. J Audiol Otol [Internet]. 2018 [cited 2025 Mar 11];22(4):204–8. Available from: https://pubmed.ncbi.nlm.nih.gov/30016856/
6. Zou TM, Chen JM, Zhou XW, Chen DP, Liu QL, Liu Z, et al. [The curative effect of manual reduction combined with vestibular rehabilitation exercise in the treatment of benign paroxysmal positional vertigo]. Lin Chung Er Bi Yan Hou Tou Jing Wai Ke Za Zhi [Internet]. 2019 [cited 2025 Mar 11];33(11):1044–8. in Chinese. Available from: https://pubmed.ncbi.nlm.nih.gov/31914291/
7. Bressi F, Vella P, Casale M, Moffa A, Sabatino L, Lopez MA, et al. Vestibular rehabilitation in benign paroxysmal positional vertigo: reality or fiction? Int J Immunopathol Pharmacol [Internet]. 2017 [cited 2025 Mar 11];30(2):113–22. Available from: https://pubmed.ncbi.nlm.nih.gov/28485653/
8. Li D, Cheng D, Yang W, Chen T, Zhang D, Ren J, et al. Current therapies in patients with posterior semicircular canal BPPV: a systematic review and network meta-analysis. Otol Neurotol [Internet]. 2022 [cited 2025 Mar 11];43(4):421–8. Available from: https://pubmed.ncbi.nlm.nih.gov/34999620/
9. Luryi AL, Lawrence J, Bojrab DI, LaRouere M, Babu S, Zappia J, et al. Recurrence in benign paroxysmal positional vertigo: a large, single-institution study. Otol Neurotol [Internet]. 2018 [cited 2025 Mar 11];39(5):622–7. Available from: https://pubmed.ncbi.nlm.nih.gov/29649052/
10. Batuecas-Caletrio A, Trinidad-Ruiz G, Zschaeck C, del Pozo de Dios JC, de Toro Gil L, Martin-Sanchez V, et al. Benign paroxysmal positional vertigo in the elderly. Gerontology [Internet]. 2013 [cited 2025 Mar 11];59(5):408–12. Available from: https://pubmed.ncbi.nlm.nih.gov/29649052/
11. Babac S, Djeric D, Petrovic-Lazic M, Arsovic N, Mikic A. Why do treatment failure and recurrences of benign paroxysmal positional vertigo occur? Otol Neurotol [Internet]. 2014 [cited 2025 Mar 11];35(6):1105–10. Available from: https://pubmed.ncbi.nlm.nih.gov/24853239/
12. De Stefano A, Dispenza F, Suarez H, Perez-Fernandez N, Manrique-Huarte R, Ban JH, et al. A multicenter observational study on the role of comorbidities in the recurrent episodes of benign paroxysmal positional vertigo. Auris Nasus Larynx [Internet]. 2014 [cited 2025 Mar 11];41(1):31–6. Available from: https://pubmed.ncbi.nlm.nih.gov/23932347/
13. Bruintjes TD, Companjen J, van der Zaag-Loonen HJ, van Benthem PP. A randomised sham-controlled trial to assess the long-term effect of the Epley manoeuvre for treatment of posterior canal benign paroxysmal positional vertigo. Clin Otolaryngol [Internet]. 2014 [cited 2025 Mar 11];39(1):39–44. Available from: https://pubmed.ncbi.nlm.nih.gov/24438128/
14. 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. Laryngoscope [Internet]. 2005 [cited 2025 Mar 11];115(9):1667–71. Available from: https://pubmed.ncbi.nlm.nih.gov/16148714/
15. Emasithi A, Pakdee S, Isaradisaikul SK, Uthaikhup S. Translation and validation of the Dizziness Handicap Inventory into Thai language. Otol Neurotol [Internet]. 2022 [cited 2025 Mar 11];43(2):e252–8. Available from: https://pubmed.ncbi.nlm.nih.gov/34711779/
16. Salvinelli F, Trivelli M, Casale M, Firrisi L, Di Peco V, D'Ascanio L, et al. Treatment of benign positional vertigo in the elderly: a randomized trial. Laryngoscope [Internet]. 2004 [cited 2025 Mar 11];114(5):827–31. Available from: https://pubmed.ncbi.nlm.nih.gov/15126738/

17. Lawson J, Johnson I, Bamiou DE, Newton JL. Benign paroxysmal positional vertigo: clinical characteristics of dizzy patients referred to a Falls and Syncope Unit. QJM [Internet]. 2005 [cited 2025 Mar 11];98(5):357–64. Available from: https://pubmed.ncbi.nlm.nih.gov/15820968/
18. Kitahara T, Shiozaki T, Hosoi H. Frailty of the vestibular system in the super-aging society. J Int Adv Otol [Internet]. 2024 [cited 2025 Mar 11];20(1):76–80. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC10895879/
19. Se To PL, Singh DKA, Whitney SL. Effects of customized vestibular rehabilitation plus canalith repositioning maneuver on gait and balance in adults with benign paroxysmal positional vertigo: a randomized controlled trial. J Vestib Res [Internet]. 2021 [cited 2025 Mar 11];32(1):79–86. Available from: https://pubmed.ncbi.nlm.nih.gov/34151874/
20. Deems DA, Deems RO, O'Malley BW Jr. Managing challenges in an aging vestibular system: rehabilitation strategies normalize balance function in a cohort of patients up to 99 years. Ear Nose Throat J [Internet]. 2019 [cited 2025 Mar 11];98(1):37–43. Available from: https://pubmed.ncbi.nlm.nih.gov/30834792/
21. Caldas MA, Ganança CF, Ganança FF, Ganança MM, Caovilla HH. Clinical features of benign paroxysmal positional vertigo. Braz J Otorhinolaryngol [Internet]. 2009 [cited 2025 Mar 11];75(4):502–6. Available from: https://pubmed.ncbi.nlm.nih.gov/19784417/
22. De Moraes CG, Liebmann JM, Levin LA. Detection and measurement of clinically meaningful visual field progression in clinical trials for glaucoma. Prog Retin Eye Res [Internet]. 2017 [cited 2025 Mar 11];56:107–47. Available from: https://pubmed.ncbi.nlm.nih.gov/27773767/
23. Ribeiro KMOB, de 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. Disabil Rehabil [Internet]. 2017 [cited 2025 Mar 11];39(12):1198–206. Available from: https://pubmed.ncbi.nlm.nih.gov/27340939/
24. Lacour M, Bernard-Demanze L. Interaction between vestibular compensation mechanisms and vestibular rehabilitation therapy: 10 recommendations for optimal functional recovery. Front Neurol [Internet]. 2015 [cited 2025 Mar 11];5:285. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC4285093/

Table S1: Estimated marginal means of post-treatment dizziness handicap inventory (DHI-Post) adjusted by covariates

Covariates	Adjusted mean DHI-post	Std. error	95% CI lower	95% CI upper	*p*-value
Sex					
• Female	4.59	0.20	4.20	4.97	< 0.01
• Male	1.90	0.37	1.17	2.64	
CRP Resolution					
• Resolved	2.36	0.29	1.79	2.92	0.02
• Not resolved	4.12	0.40	3.32	4.93	

Covariates appearing in the model are evaluated at the following value: Age = 63.76 years, CRP dy[9y]; :BPPV, paroxysmal positional vertigo

Table S2: Multiple linear regression coefficients predicting post-treatment DHI (DHI-post)

Variable	B (Unstandardized)	Std. Error	95% CI Lower	95% CI Upper	*p*-value
(Constant)	4.95	0.72	3.52	6.37	< 0.01
Age	-0.2	0.01	-0.04	0.00	0.10
Sex (Female)	2.52	0.55	1.43	3.60	< 0.01
Resolution (Yes)	-1.83	0.54	-2.90	-0.77	0.01

Dependent variable, DHI-post; sex coded as female = 1, male = 0; resolution coded as Yes = 1, No = 0
B, indicates unstandardized regression coefficients

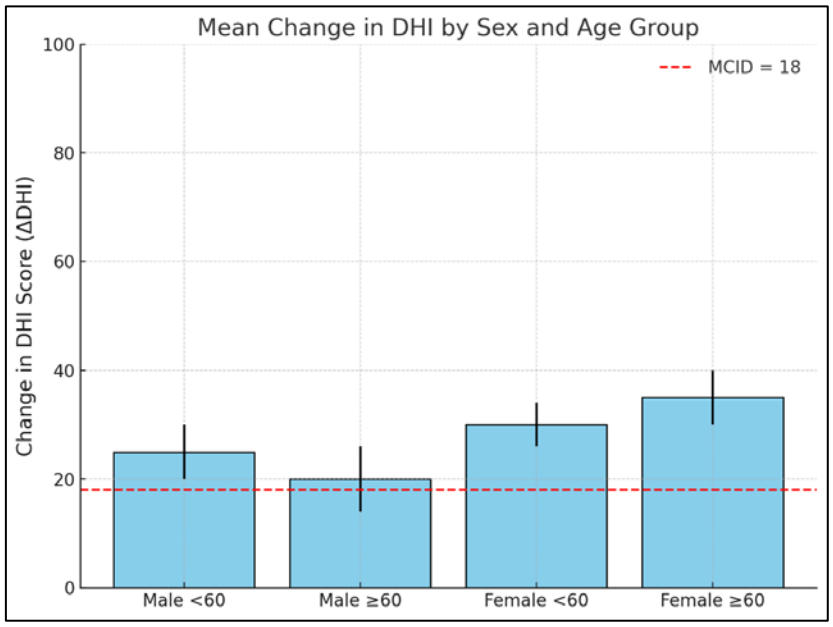
Table S3. Descriptive statistics and 95% confidence intervals of DHI improvement (**Δ**DHI) across age and sex

Group	N	Mean **Δ**DHI (SD)	95% CI
Male ≥ 60	10	14.30 (13.21)	(7.24, 21.36)
Female ≥ 60	18	20.83 (14.31)	(15.05, 26.60)
Male < 60	14	18.86 (16.41)	(10.06, 27.66)
Female < 60	36	24.06 (18.65)	(18.13, 29.99)

ΔDHI, difference in Dizziness Handicap Inventory scores between pre- and post-intervention;
SD, standard deviation. Higher scores indicate greater perceived improvement.

Supplementary Figure S1. Mean change in dizziness handicap inventory (ΔDHI) scores stratified by sex and age group

This figure illustrates mean change in DHI scores across four age/gender subgroups. Error bars show the spread one standard deviation above and one standard deviation below the mean. The dashed red line marks the threshold of 18 points for clinically meaningful improvement.



Error bars indicate ±1 SD from the mean.
MCID, Minimally Clinically Important Difference for DHI, defined as 18 points; ΔDHI, Difference in DHI score between pre- and post-treatment;

Supplementary Table S5. Absolute risk (AR), absolute risk reduction (ARR), and relative risk (RR) for resolution of benign paroxysmal positional vertigo (BPPV) by age and gender subgroups

Subgroup	Total (n)	Resolved (n)	AR (%)	ARR (%)	RR	95% CI for RR
Age < 60 years	40	40	100.00	—	Reference	—
Age ≥ 60 years	38	36	94.70	5.30	0.95	0.90–1.00
Male	17	15	88.20	11.80	0.88	0.82–1.00
Female	61	61	100.00	0.00	1.00	—

Age < 60 years and female group served as reference groups, respectively. 95% confidence intervals (CI) calculated using the Katz method. All patients received canalith repositioning procedure (CRP) combined with home-based vestibular rehabilitation.