

Immersive Virtual Reality Rehabilitation For Residual Dizziness And Balance Impairment In BPPV: A Randomized Controlled Trial

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DOI: [https://doi.org/10.63001/tbs.2026.v21.i04.S.I\(4\).pp515-520](https://doi.org/10.63001/tbs.2026.v21.i04.S.I(4).pp515-520)

KEYWORDS: Benign paroxysmal positional vertigo; Residual dizziness; Virtual reality; Vestibular rehabilitation; Dizziness Handicap Inventory; Berg Balance Scale; Balance impairment.

Received: 20/09 /2026

Accepted :07/10/2026

Published: 17/10/2026

ABSTRACT

Background: Benign paroxysmal positional vertigo (BPPV) is commonly treated successfully with canalith repositioning maneuvers; however, some individuals continue to experience residual dizziness and balance impairment after resolution of positional vertigo. Vestibular rehabilitation may help address these persistent functional symptoms, and immersive virtual reality (VR) provides an interactive environment for balance and movement-based training.

Objective: To compare the effects of immersive VR-based vestibular rehabilitation and conventional vestibular rehabilitation on residual dizziness and functional balance in individuals with BPPV following successful canalith repositioning.

Methods: A randomized controlled study was conducted on 30 adults with residual dizziness and/or balance impairment following successful treatment of BPPV. Participants were randomly allocated into two groups of 15 each. Group A received immersive VR-based vestibular rehabilitation using a PlayStation VR2 system with Synth Riders, while Group B received conventional vestibular rehabilitation. Both groups received 12 supervised sessions over 4 weeks, with three sessions per week. Dizziness-related disability was assessed using the Dizziness Handicap Inventory (DHI), and functional balance was assessed using the Berg Balance Scale (BBS). Assessments were performed before and after the intervention.

Results: Both groups demonstrated significant improvement following the intervention. In Group A, DHI scores decreased from 41.07 ± 7.10 to 24.27 ± 7.28 , with a mean reduction of 16.80 ± 2.65 points ($p < 0.001$). In Group B, DHI scores decreased from 44.13 ± 5.83 to 32.07 ± 6.94 , with a mean reduction of 12.07 ± 4.40 points ($p < 0.001$). The between-group difference in DHI change was 4.73 points ($p = 0.001$). BBS scores improved by 5.53 ± 1.60 points in Group A and 3.67 ± 1.80 points in Group B ($p < 0.001$ for both groups), with a between-group difference of 1.87 points ($p = 0.006$).

Conclusion: Both immersive VR-based and conventional vestibular rehabilitation were associated with significant improvements in dizziness-related disability and functional balance following successful BPPV treatment. The immersive VR group demonstrated greater improvement in both DHI and BBS scores. Immersive VR-based vestibular rehabilitation may therefore be a useful approach for managing residual symptoms following successful canalith repositioning.

INTRODUCTION

Benign paroxysmal positional vertigo (BPPV) is one of the most common peripheral vestibular disorders. It produces brief episodes of vertigo, usually triggered by changes in head position. The condition most often occurs when displaced otoconia enter a semicircular canal, with the posterior canal being the most frequently involved.^{1,2,3}

Canalith repositioning procedures (CRPs), including the Epley maneuver for posterior-canal BPPV, are the main treatment for the mechanical cause of positional vertigo. Current clinical guidelines recommend appropriate repositioning followed by reassessment to confirm resolution of the positional symptoms.¹

Although repositioning is usually effective, some patients continue to report dizziness, light-headedness, spatial disorientation or a feeling of unsteadiness after the positional vertigo has settled. This is commonly referred to as residual dizziness. Studies have shown that residual symptoms may persist for days or weeks after apparently successful treatment.^{4,5,6}

Residual dizziness matters clinically because patients may remain hesitant or unsteady during walking, turning, bending or other everyday activities even though the original positional vertigo has resolved. A systematic review and meta-analysis has reported that residual dizziness

occurs in a substantial proportion of patients after successful repositioning.^{7,18}

Vestibular rehabilitation can be used to address these remaining problems. It is an exercise-based approach that promotes vestibular compensation and improves the use of vestibular, visual and somatosensory information during movement and balance activities. Depending on the patient's presentation, treatment may include gaze stabilization, habituation, balance training and functional movement practice.^{8,19}

For patients who remain symptomatic after BPPV treatment, rehabilitation has a different role from canalith repositioning. Repositioning addresses displaced otoconia, whereas rehabilitation focuses on the functional consequences that may remain after the positional vertigo has resolved. These may include dizziness-related disability, reduced balance confidence and difficulty maintaining postural stability during movement.^{4,8}

The Dizziness Handicap Inventory (DHI) is a widely used patient-reported measure of the functional, physical and emotional effects of dizziness. The Berg Balance Scale (BBS) is a 14-item performance-based measure used to assess functional balance. Using both measures provides information about the patient's perceived disability as well as observed balance performance.^{14,15,16}

Virtual reality (VR) has become increasingly accessible in rehabilitation. An immersive VR system can provide an interactive environment in which visual and movement demands can be adjusted while the therapist maintains control over the task. This may allow repeated practice of weight shifting, head and trunk movements, visual-motor interaction and dynamic postural control.^{9,10,11,12}

Research on VR-based vestibular rehabilitation is growing, but the evidence remains heterogeneous. Previous studies have included different vestibular diagnoses, treatment protocols and outcome measures. Meta-analytic evidence suggests potential benefits of VR-based rehabilitation, while also emphasizing the need for better standardized trials.^{9,10,13,20} Importantly, relatively little research has focused specifically on people who have successfully undergone BPPV repositioning but continue to experience residual dizziness and balance impairment. This clinical subgroup may benefit from a rehabilitation programme that provides controlled, progressive sensory and balance challenges.^{7,9,20}

The present study therefore compares immersive VR-based vestibular rehabilitation with conventional vestibular rehabilitation in adults with residual dizziness and balance impairment following successful canalith repositioning. DHI was selected as the primary outcome and BBS as the secondary outcome to capture changes in dizziness-related disability and functional balance.

NEED OF THE STUDY

Successful canalith repositioning does not always mean that the patient feels completely normal. Residual dizziness and unsteadiness may continue even after the positional component of BPPV has resolved, and these symptoms can affect confidence and everyday mobility.^{4,5,7}

Conventional vestibular rehabilitation is commonly used to address persistent balance and vestibular symptoms. However, immersive VR offers a different way of delivering repetitive, interactive and progressively challenging tasks. It can combine visual-motor interaction with postural and movement challenges within a controlled environment.^{8,9,10}

Evidence supporting VR-based vestibular rehabilitation is encouraging, but studies have varied in diagnosis, treatment dose and outcome measures. There is therefore a need for a focused comparison in patients with residual symptoms specifically after successful BPPV treatment.^{9,10,13,20}

The present study addresses this gap by comparing immersive VR-based rehabilitation with conventional vestibular rehabilitation using DHI and BBS. The study is also intended to demonstrate a practical model for teaching research methodology in physiotherapy.

AIM AND OBJECTIVES

Aim

To compare the effects of immersive virtual reality-based vestibular rehabilitation and conventional vestibular rehabilitation on residual dizziness and functional balance in individuals with BPPV following successful canalith repositioning.

Objectives

- To determine the effect of immersive VR-based vestibular rehabilitation on dizziness-related disability measured using the Dizziness Handicap Inventory.
- To determine the effect of immersive VR-based vestibular rehabilitation on functional balance measured using the Berg Balance Scale.
- To compare the pre-to-post changes in DHI and BBS scores between the immersive VR and conventional rehabilitation groups.

HYPOTHESIS

Null hypothesis (H_0): There will be no statistically significant difference between the two groups in the change in DHI or BBS scores following the intervention.

Alternative hypothesis (H_1): There will be a statistically significant difference between the two groups in the change in DHI or BBS scores following the intervention.

MATERIALS AND METHODOLOGY

Study Design

This study was designed as a randomized controlled trial comparing immersive VR-based vestibular rehabilitation with conventional vestibular rehabilitation in adults with residual dizziness and balance impairment following successful canalith repositioning for BPPV.

Study Setting

The study was conducted in a physiotherapy/rehabilitation setting equipped for supervised vestibular and balance training.

Study Population

Participants were adults with clinically diagnosed BPPV who had undergone successful canalith repositioning and continued to report residual dizziness, unsteadiness and/or balance impairment.

Clinical sequence: BPPV → successful canalith repositioning → resolution of positional vertigo → persistent residual dizziness/balance impairment → vestibular rehabilitation.

Sample Size

A total of 30 participants were included and equally allocated to two groups:

- Group A (n = 15): Immersive VR-based vestibular rehabilitation
- Group B (n = 15): Conventional vestibular rehabilitation

Sampling and Group Allocation

Participants who met the eligibility criteria were recruited using convenience sampling. After baseline assessment, they were randomly allocated to Group A or Group B, with 15 participants in each group.

Inclusion Criteria

- Age ≥ 18 years.
- Clinical diagnosis of BPPV.
- Successful canalith repositioning with resolution of positional vertigo.
- Persistent residual dizziness, unsteadiness or balance impairment after repositioning.
- Ability to stand and participate in supervised balance activities.
- Ability to understand and follow instructions.
- Provided informed consent.

Exclusion Criteria

- Active untreated BPPV.
- Known central neurological disorder affecting balance.
- Severe visual impairment preventing participation in VR activities.
- Severe musculoskeletal problems limiting standing or walking.
- Significant cognitive impairment affecting instructions.
- Unstable medical condition contraindicating exercise or balance training.
- Previous significant adverse reaction to VR, such as severe motion sickness or persistent VR-induced dizziness.

Materials and Equipment

- PlayStation VR2 immersive virtual reality system
- Synth Riders VR application
- Open space for safe standing activities
- Stable support/hand support when required
- Dizziness Handicap Inventory (DHI)
- Berg Balance Scale (BBS)

PlayStation VR2 with Synth Riders was used as the immersive VR component of the programme. The application provided standardized visual-motor and movement-based activities during supervised standing exercises; it was used as a delivery platform rather than being treated as a stand-alone validated vestibular rehabilitation programme.

Outcome Measures

Dizziness Handicap Inventory (DHI)

The DHI is a 25-item questionnaire covering physical, functional and emotional effects of dizziness. Each item is scored as Yes = 4, Sometimes = 2 and No = 0. Total scores range from 0 to 100, with higher

scores indicating greater dizziness-related disability. DHI was the primary outcome measure.¹⁴

Berg Balance Scale (BBS)

The BBS contains 14 functional balance tasks. Each item is scored from 0 to 4, giving a maximum score of 56. Higher scores indicate better functional balance. BBS was the secondary outcome measure.^{15,16,17}

Intervention Protocol

Both groups received supervised vestibular rehabilitation for 4 weeks, three sessions per week, for a total of 12 sessions. Each session lasted approximately 30–40 minutes.

Group A: Immersive VR-based vestibular rehabilitation

- Visual-motor interaction
- Weight shifting
- Head and trunk movements
- Dynamic postural control
- Multidirectional movement
- Visual and multisensory challenges

Participants were first familiarized with the VR equipment. Task difficulty was then progressed according to tolerance and performance. The therapist supervised the sessions throughout and modified or paused activities when required for safety.

Group B: Conventional vestibular rehabilitation

- Gaze stabilization exercises
- Eye-head coordination exercises
- Static and dynamic balance exercises
- Weight-shifting activities
- Habituation exercises when clinically indicated
- Functional balance activities

Exercises were progressed according to tolerance and functional performance.

Assessment Procedure

DHI and BBS were recorded before the intervention and again after completion of the 4-week programme.

Data Collection and Change Scores

Data recorded for each participant included age, sex, group, pre-intervention DHI, post-intervention DHI, pre-intervention BBS and post-intervention BBS. DHI change was calculated as Pre – Post, whereas BBS change was calculated as Post – Pre.

Statistical Analysis

Continuous variables were summarized using mean and standard deviation, and categorical variables using frequency and percentage. The Shapiro–Wilk test was used to assess normality. Because the relevant variables were approximately normally distributed, paired t-tests were used for within-group comparisons and independent-samples t-tests were used to compare change scores between groups. Statistical significance was set at $p < 0.05$.

Safety and Ethical Considerations

Participants were supervised throughout the balance and VR sessions. Dizziness, nausea, visual discomfort, disorientation, fatigue or loss of balance were monitored, and activities were modified or stopped when necessary. Participants were informed about the procedure, and confidentiality and informed consent were maintained.

RESULTS

Thirty participants were included in the analysis, with 15 participants in each group. All participants contributed pre- and post-intervention DHI and BBS scores.

Demographic Characteristics

The mean age was 59.00 ± 6.93 years in Group A and 57.93 ± 6.16 years in Group B. The difference was not statistically significant ($t = 0.824$, $p = 0.417$). Group A included 9 females (60.0%) and 6 males (40.0%), while Group B included 10 females (66.7%) and 5 males (33.3%). Sex distribution did not differ significantly between groups ($\chi^2 = 0.000$, $p = 1.000$).

Table 1. Demographic characteristics of participants

Characteristic	Group A: Immersive VR (n=15)	Group B: Conventional (n=15)	p-value
Age, years, mean $\pm$ SD	59.00 ± 6.93	57.93 ± 6.16	0.417
Female, n (%)	9 (60.0)	10 (66.7)	1.000
Male, n (%)	6 (40.0)	5 (33.3)	1.000

Baseline Outcome Measures

At baseline, mean DHI scores were 41.07 ± 7.10 in Group A and 44.13 ± 5.83 in Group B. Mean BBS scores were 44.13 ± 3.54 and 43.53 ± 2.42 ,

respectively. Baseline differences were not statistically significant for DHI ($p = 0.206$) or BBS ($p = 0.592$).

Table 2. Baseline outcome measures

Outcome	Group A: Immersive VR	Group B: Conventional	p-value
DHI, mean $\pm$ SD	41.07 ± 7.10	44.13 ± 5.83	0.206
BBS, mean $\pm$ SD	44.13 ± 3.54	43.53 ± 2.42	0.592

Normality Analysis

Shapiro–Wilk testing showed p-values >0.05 for the relevant pre-intervention, post-intervention and change-score variables in both groups. Parametric tests were therefore used for the main analyses.

Within-Group Analysis of DHI

DHI decreased from 41.07 ± 7.10 to 24.27 ± 7.28 in Group A, a mean reduction of 16.80 ± 2.65 points (paired $t = 24.543$, $p < 0.001$). Group B decreased from 44.13 ± 5.83 to 32.07 ± 6.94 , a mean reduction of 12.07 ± 4.40 points (paired $t = 10.624$, $p < 0.001$).

Table 3. Within-group comparison of DHI

Group	Pre-intervention	Post-intervention	Mean reduction	t-value	p-value
Group A –	41.07 ± 7.10	24.27 ± 7.28	16.80 ± 2.65	24.543	<0.001

Immersive VR					
Group B – Conventional	44.13 ± 5.83	32.07 ± 6.94	12.07 ± 4.40	10.624	<0.001

BBS increased from 44.13 ± 3.54 to 49.67 ± 4.40 in Group A, a mean improvement of 5.53 ± 1.60 points (paired $t = -13.414$, $p < 0.001$). Group B increased from 43.53 ± 2.42 to 47.20 ± 3.12, a mean improvement of 3.67 ± 1.80 points (paired $t = -7.892$, $p < 0.001$).

Within-Group Analysis of BBS

Table 4. Within-group comparison of BBS

Group	Pre-intervention	Post-intervention	Mean improvement	t-value	p-value
Group A – Immersive VR	44.13 ± 3.54	49.67 ± 4.40	5.53 ± 1.60	-13.414	<0.001
Group B – Conventional	43.53 ± 2.42	47.20 ± 3.12	3.67 ± 1.80	-7.892	<0.001

4.73 points (95% CI 2.02–7.45), which was statistically significant ($t = 3.569$, $p = 0.001$).

Between-Group Comparison of DHI Change

The mean reduction in DHI was 16.80 ± 2.65 points in Group A and 12.07 ± 4.40 points in Group B. The mean between-group difference was

Table 5. Between-group comparison of DHI change

Variable	Group A	Group B	Mean difference	95% CI	t-value	p-value
DHI change	16.80 ± 2.65	12.07 ± 4.40	4.73	2.02–7.45	3.569	0.001

(95% CI 0.59–3.14), with a statistically significant difference ($t = 3.004$, $p = 0.006$).

Between-Group Comparison of BBS Change

Mean BBS improvement was 5.53 ± 1.60 points in Group A and 3.67 ± 1.80 points in Group B. The between-group difference was 1.87 points

Table 6. Between-group comparison of BBS change

Variable	Group A	Group B	Mean difference	95% CI	t-value	p-value
BBS change	5.53 ± 1.60	3.67 ± 1.80	1.87	0.59–3.14	3.004	0.006

Summary of Result

Both groups improved significantly in DHI and BBS after four weeks. The mean reduction in DHI and mean improvement in BBS were larger in the immersive VR group, and the between-group differences were statistically significant.

Figures

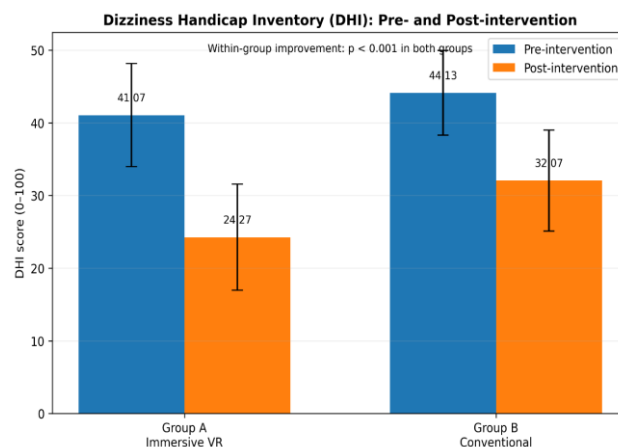
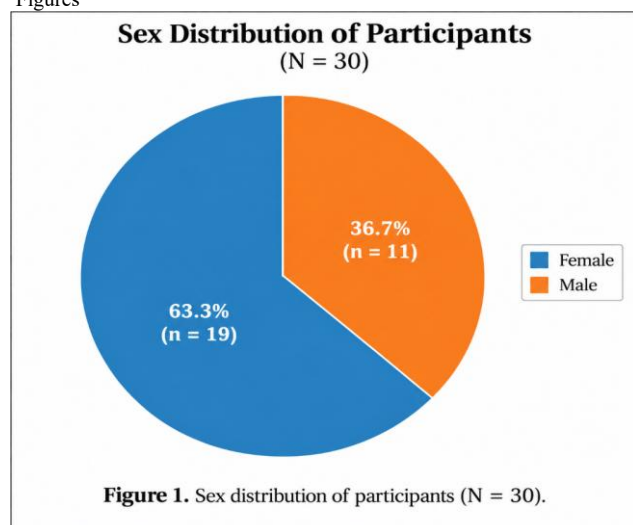


Figure 2. DHI scores before and after the intervention.

Figure 1. Sex distribution of participants (N = 30).

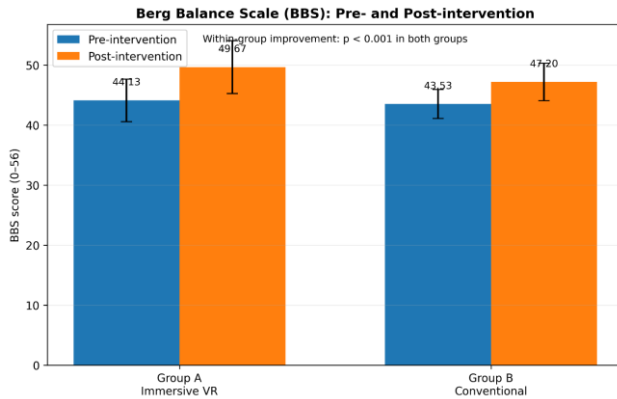


Figure 3. BBS scores before and after the intervention.

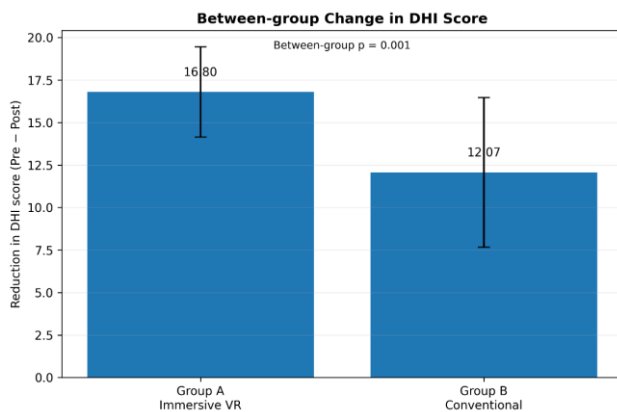


Figure 4. Between-group comparison of mean change in DHI.

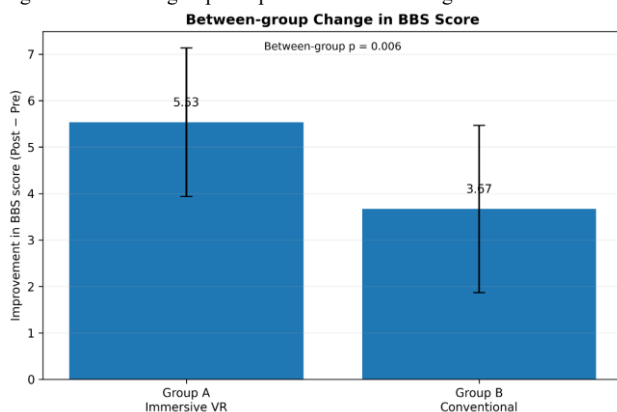


Figure 5. Between-group comparison of mean change in BBS.

DISCUSSION

This randomized controlled study compared immersive VR-based vestibular rehabilitation with conventional vestibular rehabilitation in adults who continued to experience dizziness and balance impairment after successful canalith repositioning for BPPV. Both groups improved significantly in DHI and BBS after four weeks, while the immersive VR group showed larger mean changes in both outcomes.

DHI decreased by 16.80 ± 2.65 points in the immersive VR group and by 12.07 ± 4.40 points in the conventional group. The between-group difference was 4.73 points ($p = 0.001$). This suggests that both

approaches were associated with reduced dizziness-related disability, with a larger change observed in the VR group within this study sample. Residual dizziness after successful repositioning is well described in the literature and may persist even when positional vertigo has resolved.^{4,5,7} BBS also improved in both groups. The immersive VR group improved by 5.53 ± 1.60 points compared with 3.67 ± 1.80 points in the conventional group, giving a between-group difference of 1.87 points ($p = 0.006$). Repeated weight shifting, head and trunk movement, visual-motor interaction and dynamic postural tasks may have contributed to the observed balance improvements.

The findings are broadly in line with previous work suggesting that VR can be incorporated into vestibular and balance rehabilitation. Systematic reviews and meta-analyses have reported potential benefits of VR, although the literature remains heterogeneous and the certainty of evidence is not consistently high.^{9,10,13,20}

The present study examined patients after successful BPPV repositioning rather than patients with untreated active BPPV. This distinction is clinically important: canalith repositioning addresses the mechanical cause of positional vertigo, whereas rehabilitation is directed at the dizziness, balance and adaptation problems that may remain afterward.^{1,4,7}

Overall, the results support the feasibility of using immersive VR as a rehabilitation approach for residual symptoms after BPPV treatment.

CONCLUSION

Both immersive VR-based vestibular rehabilitation and conventional vestibular rehabilitation were associated with significant improvements in dizziness-related disability and functional balance after successful canalith repositioning for BPPV. Larger mean improvements were observed in the immersive VR group for both DHI and BBS. These findings suggest that immersive VR may be a useful option for rehabilitation of residual symptoms after BPPV treatment.

STUDY LIMITATIONS

- The sample size was small (30 participants).
- The intervention lasted only four weeks, with no long-term follow-up.

- Only DHI and BBS were used as outcome measures.

FUTURE RECOMMENDATIONS

- Conduct larger randomized controlled trials with longer follow-up.
- Use standardized VR protocols with clearly described progression criteria.
- Examine adherence, treatment satisfaction and cost-effectiveness.
- Compare different VR-based vestibular rehabilitation approaches.

SUMMARY

This randomized controlled study compared immersive VR-based vestibular rehabilitation with conventional vestibular rehabilitation in 30 adults with residual dizziness and balance impairment after successful canalith repositioning for BPPV. Participants were allocated equally to two groups and received 12 supervised sessions over four weeks. DHI and BBS were assessed before and after treatment. Both groups showed significant improvement in dizziness-related disability and functional balance. The immersive VR group showed larger mean changes in both DHI and BBS, with statistically significant between-group differences.

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