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Do virtual reality tools in vestibular rehabilitation offer advantage beyond increased practice times? A narrative review

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Background: The successful implementation of vestibular rehabilitation is frequently hindered by low patient adherence due to provoked symptoms and repetitive exercises. Virtual reality is increasingly deployed as a digital health solution to overcome these barriers through gamification, yet the specific active ingredient driving its clinical efficacy remains unclear.
Objective: This review evaluates whether the therapeutic advantage of virtual reality in vestibular rehabilitation is driven by specific technological features or by the confounding effect of longer practice durations relative to traditional methods.
Methods: We conducted a narrative review of studies published between 2010 and 2025 using PubMed, Scopus, and Google Scholar. The analysis focused on trials comparing virtual reality tools to conventional rehabilitation.
Results: Although intervention protocols varied substantially, studies demonstrating better outcomes (e.g., Vestibulo-Ocular Reflex gain, Dizziness Handicap Inventory, Berg Balance Test) with virtual reality consistently involved greater practice exposure in the virtual reality group. Our analysis suggests that when training duration was matched between intervention arms, virtual reality demonstrated no clinical advantage over conventional rehabilitation with one recent trial reporting better outcomes for conventional rehabilitation.
Conclusion: Virtual reality appears to enhance engagement in vestibular rehabilitation; however, current evidence suggests that the observed benefits could be attributed to increased practice dosage rather than unique technological effects. Future studies should standardize protocols to determine the independent contribution of virtual reality to clinical outcomes.

KEYWORDS
adherence, gamification, implementation, practice duration, vestibular rehabilitation, virtual reality

1 Introduction

Virtual-reality technologies have been widely studied in recent years as a training tool in various rehabilitation fields, such as stroke, cancer, and cardiac rehabilitation (Chen J. et al., 2022; Chen Y. et al., 2022; Su et al., 2024). Numerous studies have also examined the effects of virtual reality in vestibular rehabilitation for a variety of conditions such as unilateral and bilateral vestibular hypofunction, and residual symptoms post Benign Paroxysmal Positional Vertigo (BPPV) (Hazzaa et al., 2023; Heffernan et al., 2021; Xie et al., 2021).

Vestibular rehabilitation consists of exercises that combine head movements with gaze stabilization and balance training (Hall et al., 2022). These exercises aim to help the vestibular system adapt, habituate, or compensate for deficits. Numerous studies have demonstrated that this form of rehabilitation is both effective and safe (Hall et al., 2022; McDonnell and Hillier, 2015; Porciuncula et al., 2012). While practicing vestibular rehabilitation, people may experience temporary dizziness and nausea (Hall et al., 2022; Whitney et al., 2016). The exercises should be performed for short durations (2–5 min of exercise per session) several times a day for total of 12–40 min per day (Hall et al., 2022). The combination of the need to practice many times and the symptoms resulting from practice reduce adherence to vestibular rehabilitation (Kalderon et al., 2024). The use of virtual reality in vestibular rehabilitation has been demonstrated to be more enjoyable than the use of conventional rehabilitation in several studies (Meldrum et al., 2015; Micarelli et al., 2019; Phillips et al., 2018). Thus, gamification and the increasing enjoyment that virtual reality offers may be able to provide at least a partial solution to the problem of insufficient adherence.

Virtual reality creates an interactive digital environment that simulates real or imaginary worlds (Bergeron et al., 2015; Levac et al., 2016). It is displayed on various screens and can include accessories like motion-sensitive remote controls (Bergeron et al., 2015; Levac et al., 2016). Virtual reality can be immersive (for example, using a head-mounted display), or non-immersive (for example, using Wii-Fit) (Garay-Sánchez et al., 2021; Omlor et al., 2022).

Integrating virtual reality into vestibular rehabilitation has the potential to optimize clinicians' time, enhance accessibility for patients and reduce costs for insurance providers (Xie et al., 2021). There is some evidence to suggest that the use of virtual reality improves clinical outcomes in vestibular rehabilitation when compared to conventional treatment methods (Hazzaa et al., 2023; Micarelli et al., 2019; Garcia et al., 2013; Van Vugt et al., 2019; Liu et al., 2025). Considering the potential of virtual reality, it is important to determine if rehabilitation using virtual reality is indeed more effective than conventional rehabilitation.

This review aims to analyze the existing research on virtual reality in vestibular rehabilitation and examine the factors that contribute to its success. The review will explore whether the advantage of virtual reality arises from external factors, such as increased practice time, or internal factors such as the type of virtual reality used. By addressing this question, this review seeks to contribute to a better understanding of the impact of virtual reality on the vestibular rehabilitation process and to provide recommendations for the effective implementation of this technology in clinical practice.

2 Methods

2.1 Methodology for literature searching

A thorough literature search was conducted between February and March 2025 to identify relevant interventional studies published between January 2010 and April 2025. The search utilized databases such as PubMed, Scopus, and Google Scholar. The search strategy was developed using a combination of free text keywords and Medical Subject Headings (MeSH) to ensure comprehensive coverage of the literature. The following string was applied: (vestibular OR 'vestibular rehabilitation' OR 'vestibular hypofunction') AND ('virtual reality' OR VR OR technology OR 'head-mounted display'). This approach allowed for the inclusion of studies that used either broad terms or specific clinical terminology. This string was adapted to the specific syntax requirements of each database. Additional sources were identified by manually screening the reference lists of pivotal articles to ensure a comprehensive review. For the Google Scholar search, the first 150 results were screened, sorted by relevance. A stopping rule was applied where the search was terminated after three consecutive pages of results yielded no further articles meeting the inclusion criteria.

2.2 Study selection and screening

After the initial search, duplicates were identified and manually removed to establish a unique set of records. Inclusion was limited to peer-reviewed, interventional studies published in English. To focus on recent literature, studies published between 2010 and 2025 were included. Study types such as opinion articles, editorials, and reviews without original data were excluded to maintain focus on clinical outcomes and practice dosage. The screening process involved a systematic two-stage review of titles and abstracts followed by a full-text assessment to ensure adherence to the inclusion and exclusion criteria, specifically focusing on the availability of detailed training protocols and dosage data.

2.3 Inclusion and exclusion criteria

Inclusion criteria: (1) Used virtual reality for vestibular rehabilitation; (2) Specified the type of virtual reality used; (3) Specified the total minutes per day spent exercising and/or the type and frequency of exercises per day; (4) Published in peer-reviewed journals; (5) Written in English.

Exclusion criterion: Opinion articles that did not incorporate original research.

The practice duration data presented in this review reflects the prescribed daily dose. In situations where the type of exercise was reported without a specific time (e.g., Brandt–Daroff exercise 5 times a day), an estimate of the exercise time was made based on the clinical practice guideline for vestibular rehabilitation for peripheral vestibular hypofunction (Hall et al., 2022), and authors' clinical experience. It is important to note that estimations were exclusively conducted for studies that provided a detailed description of the exercise types, ensuring the estimated dosage reflected the specific protocol reported. Studies that did not provide a clearly defined protocol- and therefore did not permit duration estimation-were excluded from the analysis, as noted above. To ensure consistency, standardized time-values were assigned to common protocols: for example, a single repetition of VOR (Vestibular Ocular Reflex) adaptation exercises was estimated at 1 min, and a complete cycle of Brandt-Daroff maneuvers (including rest) was estimated at 2 min. Additionally, for protocols where the practice duration increased progressively throughout the rehabilitation period, the average daily practice time was calculated and used for analysis to ensure a standardized comparison across studies.

2.4 Synthesis and extraction of data

To deliver a narrative summary of the existing evidence and highlight gaps in the research, the selected articles were analyzed and organized into thematic categories. These categories included the type of virtual reality employed and variations in practice durations.

3 Discussion

3.1 Effectiveness of virtual reality for vestibular rehabilitation

There has been a growing body of evidence in recent years supporting the feasibility and effectiveness of virtual reality as a method for vestibular rehabilitation. Studies consistently demonstrate that virtual reality-based vestibular rehabilitation is at least as effective as conventional methods, with some even showing significant advantages for virtual reality in clinical outcomes. In this section we will review the existing evidence, and in the following sections we will provide potential explanations for these findings.

In the following three studies, Wii-Fit was used as a virtual reality platform. For example, Meldrum et al. (Meldrum et al., 2015) conducted a study on individuals with unilateral peripheral vestibular loss. The study included 35 individuals in the experimental group, who received a walking program, eyes exercises and virtual reality-based balance exercise. The control group included 36 individuals, who received the same program, using conventional tools without the use of virtual reality. They found that virtual reality-based rehabilitation was as effective as conventional methods. Both groups showed significant improvement in the Sensory Organization Test (SOT) and gait speed. However, the virtual reality group reported significantly greater enjoyment, less difficulty, and reduced fatigue compared to the conventional group. Rosiak et al. (Rosiak et al., 2018) observed similar findings in a study with unilateral peripheral vestibular dysfunction. The study included 25 individuals in the experimental group, who received virtual reality rehabilitation and Cawthorne-Cooksey exercises and 25 individuals in the control group, who received static posturography and Cawthorne-Cooksey exercises. Both virtual reality and conventional groups showed significant improvements in VOR gain and static posturography measures. However, the virtual reality group reported greater improvements in subjective measures, such as the Vertigo Symptom Scale-short form (VSS-sf). Similarly, Phillips et al. (Phillips et al., 2018) reported significant improvements in balance scores, quality of life (SF-36), and reduced dizziness (Dizziness Handicap Inventory (DHI)). They examined 21 participants in the experimental group, who received Wii Fit exercises with balance games, and 19 in the control group, who received conventional rehabilitation. While there was no significant difference between virtual reality and conventional groups in mains outcome measures (DHI & SF-36), the virtual reality group also reported higher exercise enjoyment.

In a more recent study, Kelly et al. (Kelly et al., 2023) used an immersive virtual reality system to compare virtual reality and conventional rehabilitation individuals with chronic vestibular dysfunction. The experimental group (N = 15) received Contextual Sensory Integration (CSI) training *via* an immersive virtual reality in addition to a home exercise program of conventional vestibular rehabilitation. The control group (N = 15) received conventional rehabilitation with clinic appointments and a home exercise program. Both groups showed improvements in functional outcomes (e.g., Functional Gait Assessment, Timed-Up and Go, and The Four-Square Step Test) and self reported outcomes (Visual Vertigo Analog Scale, Activities-specific Balance Confidence (ABC) and DHI questionnaire).

However, a recent study indicates that conventional rehabilitation is superior to virtual reality-based rehabilitation. In a randomized controlled non-inferiority trial conducted by Le Perf et al. (Le Perf et al., 2025), virtual reality-based rehabilitation was compared with conventional vestibular rehabilitation in individuals with various vestibular disorders (acute or chronic, unilateral, bilateral, functional). The experimental group (N = 38) performed multisensory balance exercises using an immersive virtual reality system (HTC Vive® and Virtualis® software) alongside a multidisciplinary rehabilitation program. The control group (N = 38) performed the same rehabilitation program, except that multisensory balance exercises were delivered using traditional tools such as an optokinetic stimulator and a simulated environment synchronized to body movement. Both groups demonstrated improvements in postural control, as measured by computerized posturography, and reductions in the DHI questionnaire. However, the virtual reality program did not meet the predefined non-inferiority margin compared to conventional rehabilitation.

Other studies demonstrated clear advantages of virtual reality-based vestibular rehabilitation over conventional methods. All of these studies use immersive virtual reality. Yan et al. (Yan et al., 2024), for instance, found that among 124 patients with residual symptoms post benign paroxysmal positional vertigo (BPPV), the virtual reality group (N = 31) showed significantly greater reductions in DHI and Vertigo Symptom Index (VSI) scores compared to control groups that performed Cawthorne–Cooksey (N = 31) and Brandt–Daroff exercises (N = 31) and no intervention group (N = 31). Additionally, the virtual reality group demonstrated better balance (Berg Balance Test Scores) and reduced anxiety compared to the control groups. Micarelli et al. (Micarelli et al., 2017) demonstrated advantages for the virtual reality group in a study of individuals with UVH. The experimental group received home-based virtual reality gaming exercises and conventional vestibular rehabilitation with home exercise program. The control group (N = 24) received only conventional rehabilitation with home exercise program. They showed significant improvements in posturography parameters, DHI, and Activities-specific Balance Confidence (ABC) questionnaire. Furthermore, Viziano et al. (Viziano et al., 2019) studied individuals with unilateral vestibular hypofunction (UVH) over a 12-m onth follow-up. The study was conducted as a follow-up to that conducted by Micarelli et al. (2017). The virtual reality group achieved better results in VOR gain and static posturography measures. In another study, Micarelli et al. (Micarelli et al., 2019) investigated virtual reality-based vestibular rehabilitation among 47 patients with UVH, including

23 with mild cognitive impairment (MCI). The study included four groups: (Chen J. et al., 2022): Virtual reality + conventional vestibular rehabilitation, with older adults (N = 11); (Chen Y. et al., 2022); Virtual reality + conventional vestibular rehabilitation, with individuals with MCI (N = 12); (Su et al., 2024); Conventional vestibular rehabilitation with older adults (N = 12); (Hazzaa et al., 2023); Conventional vestibular rehabilitation with individuals with MCI (N = 12). They found better improvements in VOR gain and posturography measures, with particularly notable progress among participants with MCI.

3.2 Contributing factors to treatments

A key unresolved question is what underlies the success observed in the studies in which vestibular symptoms improved following the use of virtual reality.

3.3 Control groups

When assessing the effectiveness of virtual reality in vestibular rehabilitation, it is important to consider what kind of intervention the control group receives. The type of exercises they perform or whether they receive any at all can greatly impact the study results. A few studies used control groups that did not receive conventional vestibular rehabilitation, but rather a specific exercise program (e.g., only Brandt-Daroff exercise) or, in some cases, no exercise at all. For example, in the study by Yan et al. (Yan et al., 2024) there were three control groups: one included only Cawthorne-Cooksey exercises, one included only Brandt-Daroff exercises, and one did not include any intervention. Moreover, in Garcia et al.'s (Garcia et al., 2013) study, on individuals with Meniere's disease, the control group only received dietary advice and Betahistine pills without an exercise program. In both studies, it was found that the virtual reality group performed better than the control group (in postural stability parameters, DHI and Berg Balance Test). The control group either received a partial exercise program or no exercises at all, which does not meet the vestibular rehabilitation guidelines. As a result, these studies do not provide clear conclusions about the benefits of virtual reality compared to conventional exercises. On the other hand, in some studies the intervention duration was insufficient according to the recommendation of the clinical practice guidelines. For example, in the study by Rosiak et al. (2018), the duration of the intervention was only 2 weeks. They found no difference between the control and study groups, but the lack of difference may be due to the study being too short. Similarly, in Le Perf et al. (Le Perf et al., 2025) study that showed an advantage for conventional rehabilitation over virtual reality-based rehabilitation, the duration of the intervention was only 3 weeks, and the difference they found may be related to the short duration of the study.

3.4 Immersive vs. non-immersive Virtual reality?

In this review, virtual reality systems are operationally defined into two categories based on the level of sensory immersion. Immersive virtual reality refers to systems using a Head-Mounted Display (HMD) that isolates the user from the physical environment and provides a 360-degree field of view. Non-immersive virtual reality refers to screen-based systems (e.g., Nintendo Wii-Fit or desktop displays) where the user remains visually connected to the physical surroundings while interacting with a digital environment *via* motion sensors or remote controls.

Several previous studies (*cf.* Heffernan et al.[5], Hall et al.[7]) suggest that immersive virtual reality systems are more effective than conventional vestibular rehabilitation, whereas non-immersive virtual reality systems appear less effective and do not yield comparable results. Our review supports this pattern: most of the studies demonstrating advantages for virtual reality over conventional treatment employed immersive systems, while studies using non-immersive systems generally showed no such advantage. However, a recurring limitation across many studies is the lack of detailed reporting on intervention protocols—particularly with regard to daily practice time and frequency. This omission complicates the interpretation of results, as it remains unclear whether observed improvements stem from the immersive nature of the virtual reality system or simply from increased exposure and practice time. Indeed, in all studies where immersive virtual reality showed superiority, participants in the virtual reality group practiced for longer durations than those in the control group.

Furthermore, the study by Le Perf et al.[23] found that conventional rehabilitation outperformed immersive virtual reality despite equal practice time—further challenging the notion that the immersive platform alone accounts for the differences observed between studies reporting significant advantages for virtual reality and those that did not.

While most studies showing superior outcomes employ immersive virtual reality systems, it is difficult to isolate the effect of immersivity from other factors. Notably, the immersive virtual reality protocols in our review also involved higher practice doses and, in several cases, more intensive clinical supervision than the non-immersive groups This confounding element makes it difficult to disentangle the potential neuroplastic benefits of immersion from the effects of increased treatment dosage. However, beyond increased practice time, immersive virtual reality may offer specific physiological advantages by providing more potent stimuli for vestibular compensation. As noted by Warchoł et al. (Warchoł et al., 2024), immersive systems using an HMD can create a controlled 'visual-vestibular conflict' through artificial sensory simulation. This immersive environment allows manipulation of environmental perception to induce sensory mismatch, which has been shown to increase the sensory weight of the vestibular system, a key driver of neuroplasticity and VOR recalibration (Warchoł et al., 2024). This suggests that while dosage remains a primary factor, the immersive nature of virtual reality might provide a qualitative advantage by delivering specialized stimuli for vestibular adaptation that are difficult to replicate in traditional or screen-based settings.

3.5 Could practice time difference explain the advantage of Virtual reality?

Examining the existing evidence, practice time plays a significant role.

TABLE 1 A summary of articles reporting that VR-practice groups improve key outcomes more than conventional-practice groups.

Authors	Population	Intervention	Frequency of treatment	Source of dose-data	VR type	Setting & supervision	Time difference between group
(Yan et al., 2024)	124 patients diagnosed with benign paroxysmal positional vertigo (BPPV) with residual symptoms Four weeks of rehabilitation for all groups	**Experimental group:** VR-based rehabilitation combining Cawthorne–Cooksey and Brandt–Daroff exercises with immersive VR training system (N = 31)	**Experimental group:** 10–20 min per day of VR (1 session) + 20 min per day of Cawthorne-Cooksey exercises (2 sessions) + Brandt–Daroff: 5 repetitions ~10 min (5 sessions) Total: ≈ 35 min per day (3–7 session)	VR + Cawthorne-Cooksey - Reported Brandt–Daroff- Estimated	Immersive (Head-Mounted Display)	Supervised laboratory environment	The experimental group performed **15–25 min more** per day than the other groups
		Other groups 1. Cawthorne–Cooksey exercises (N = 31) 2. Brandt–Daroff exercise (N = 31) 3. No intervention (N = 31)	**Other groups** 1. Cawthorne–Cooksey: 20 min per day (2 sessions) 2. Brandt–Daroff: 5 repetitions ~ 10 min (5 sessions) 3. No intervention: o min				
(Viziano et al., 2019)	47 patients with unilateral vestibular hypofunction, 1 year after completing rehabilitation Four weeks of rehabilitation for both groups	**Experimental group:** Mixed-method rehabilitation combining conventional and head-mounted gaming tasks (N = 23)	**Experimental group:** 20 min per day of VR (1 session) + 35 min of conventional vestibular rehabilitation Total: ≈ 55 min per day	Calculated average from protocol - Reported	Immersive (Head-Mounted Display)	Mixed. Supervised twice a week by two physiotherapists (VR); unsupervised daily home exercises	The experimental group performed **20 min more** per day than the control group
		Control groups: Conventional vestibular rehabilitation only (N = 24)	**Control group:** 35 min of conventional vestibular rehabilitation (no mention of sessions number) Total: ≈ 35 min per day				
(Garcia et al., 2013)	44 patients definite Ménière's disease Six weeks of rehabilitation for both groups	**Experimental group:** VR in the Balance Rehabilitation Unit (BRU) + dietary recommendations and prescribed 48 mg/day of betahistine (N = 23)	**Experimental group:** 12.8 min per day of VR (2 sessions of 45 min per week) Total: ≈ 12.8 min per day	Calculated average from protocol - Reported	Immersive hybrid. Projected stimuli using a BRU™. Includes a goggles system (Head-Mounted Display) with virtual reality stimuli	Supervised laboratory environment	The experimental group performed **12.8 min more** per day than the control group
		Control groups: Dietary recommendations and prescribed 48 mg/day of betahistine (N = 21)	**Control group:** No vestibular rehabilitation performed Total: 0 = min per day				
(Micarelli et al., 2017)	47 patients with unilateral vestibular hypofunction (UVH), 24 in the control group and 23 in the experimental group Four weeks of rehabilitation for both groups	**Experimental group:** Combined conventional vestibular rehabilitation with a home-based Head-Mounted Device (HMD)-based gaming protocol (Track Speed Racing 3D) (N = 23)	**Experimental group:** 20 min per day of VR + 35 min per day of conventional vestibular rehabilitation Total: = 55 min per day	Reported explicitly	Immersive (Head-Mounted Display)	Mixed. Vestibular rehabilitation sessions (supervised) twice a week; daily home VR (unsupervised but monitored)	The experimental group performed **20 min more** per day than the control group
		Control groups: Conventional vestibular rehabilitation (N = 24)	**Control group:** 35 min per day of conventional vestibular rehabilitation Total: = 35 min per day				

(*Continued*)

TABLE 1 Continued

Authors	Population	Intervention	Frequency of treatment	Source of dose-data	VR type	Setting & supervision	Time difference between group
(Micarelli et al., 2019)	47 elderly patients with UVH, including 23 with Mild Cognitive Impairment (MCI) Four weeks of rehabilitation for both groups	**VR reality groups** 1. VR reality (HMD) + conventional Vestibular rehabilitation + older adults' group (N = 11) 2. VR (HMD) + conventional Vestibular rehabilitation MCI group (N = 12)	**Both VR groups** 20 min per day of VR + 35 min per day of conventional vestibular rehabilitation Total: = 55 min per day	Reported explicitly	Immersive (Head-Mounted Display)	Mixed. Vestibular rehabilitation sessions (supervised) twice a week; daily home VR (unsupervised but monitored)	The VR groups (1 & 2) performed **20 min more** per day than the control group
		Conventional Groups 3. Conventional Vestibular rehabilitation older adults' group (N = 12) 4. Conventional Vestibular rehabilitation MCI group (N = 12)	**Both conventional groups:** 35 min per day of conventional vestibular rehabilitation Total: = 35 min per day				

VR, virtual reality.
~ An estimate of the time spent per exercise, based on the vestibular rehabilitation guidelines (Hall et al., 2022) and authors' experience.
≈ A daily average of the minutes spent exercising based on the values reported in the original research papers.

It is possible that the longer practice duration contributed to the superior improvement observed in the virtual reality group compared to the conventional group in the reviewed studies. In studies where the virtual reality group had better outcomes than the conventional group in key outcome measures (e.g., VOR gain, DHI, postural stability), the former group also had longer practice times (see Table 1). For instance, Yan et al. (Yan et al., 2024) reported that participants in the virtual reality group practiced approximately 35 min per day, compared to only 10–20 min per day in control groups performing conventional exercises such as Cawthorne–Cooksey and Brandt–Daroff. Similarly, in Micarelli et al. (Micarelli et al., 2019; Micarelli et al., 2017), the experimental groups had an extra 20 min of daily virtual reality practice. This additional practice may have contributed to the better outcomes in these studies.

On the other hand, in studies where the virtual reality and conventional groups demonstrated similar improvements in key outcomes, the practice time was identical between the groups (see Table 2). For example, Phillips et al. (Phillips et al., 2018) reported no difference in practice duration, with both groups engaging in 60 min of daily practice. Kelly et al. (Kelly et al., 2023) also found no time differences between groups, with participants in both groups practicing for approximately 20 min per day. Further, in a study by Le Perf and co-authors (Le Perf et al., 2025), which concluded that conventional rehabilitation is more effective than virtual reality, both groups practiced a multidisciplinary rehabilitation program with multisensory balance exercises for the same number of minutes, approximately 130 min of practice per day.

In summary, the analyzed evidence reveals a consistent pattern. In the five studies where training duration was strictly matched between groups, no unique clinical advantage of virtual reality over conventional methods was found. In contrast, the five studies reporting superior outcomes with virtual reality all used a significantly higher practice dose in the virtual reality arm. Full details regarding these studies, including the specific virtual reality systems used, exact practice times, and the level of supervision, are provided in Tables 1 and 2. While differences in patient populations and virtual reality types across these trials require cautious interpretation, the consistent recurrence of this dose-response pattern across various settings points to practice volume as a potential key factor. This observed trend highlights the need for further research to isolate the independent effects of virtual reality technology from training dosage.

Figure 1 compares studies reporting greater improvement with virtual reality interventions to those showing no significant group differences. It highlights the differences in practice time between the groups in studies that found virtual reality to be superior to conventional therapy.

The longer practice duration in virtual reality-based rehabilitation may offer additional benefits beyond physical practice. Extended time with virtual reality systems can enhance user enjoyment and engagement, since the nature of virtual reality may provide gamification of treatments and a greater sense of connection to the therapy. However, it may be assumed that if a user has a negative experience with the virtual reality system, the additional practice time could potentially lead to reduced enjoyment and a weaker connection to the therapy, amplifying the negative aspects of their experience. Since most studies show significantly greater enjoyment in virtual reality-based rehabilitation than in conventional methods, it suggests that virtual reality makes the rehabilitation process more engaging.

TABLE 2 A summary of articles reporting that conventional groups perform similarly to VR groups in key outcomes.

Authors	Population	Intervention	Frequency of treatment	Source of dose-data	VR type	Setting & supervision	Time difference between group
(Meldrum et al., 2015)	71 adults with unilateral peripheral vestibular loss Six weeks of rehabilitation for both groups	**Experimental group:** Combined eye exercise vestibular rehabilitation + walking + VR-based balance training using Wii Fit Plus (N = 35)	**Experimental group:** 21.6 min of walking on average per day (gradually rising from 10 min to 30 min) + 21.6 min of eyes exercises on average per day (5 session per day, gradually rising from 10 min to 30 min) + 10.7 min (on average) VR-based balance exercises using Wii Fit Plus Total: ≈ 54 min per day	Calculated average from protocol - Reported	Non-Immersive (Nintendo Wii Fit Plus with Wii Balance Board)	Home-based exercises	No practice time difference between groups
		Control groups: Combined eye exercise vestibular rehabilitation + walking + balance training using foam balance mat (N = 36)	**Control group:** 21.6 min of walking, on average, per day (gradually rising from 10 min to 30 min) + 21.6 min of eyes exercises on average per day (5 session per day, gradually rising from 10 min to 30 min) + 10.7 min (on average) conventional balance exercises with foam balance mat Total: ≈ 54 min per day				
(Rosiak et al., 2018)	50 individuals with unilateral peripheral vestibular dysfunction Two weeks of rehabilitation for both groups	**Experimental group:** Hybrid VR system using a force plate and motion sensors, including gamified tasks. (N = 25)	**Experimental group:** 21.4 min on average per day of VR (5 session per week of 30 min) + ~10 min Cawthorne-Cooksey exercises at home (3 sessions per day) Total: ≈ 31.4 min per day	Calculated average from protocol - Reported	Hybrid VR (Includes a 55-inch screen, motion sensors, and a force platform)	Supervised laboratory environment	No practice time difference between groups
		Control groups: Static posturography with visual feedback tasks using a firm surface and visual target tracking. (N = 25)	**Control group:** 21.4 min on average per day of Static posturography (5 sessions per week of 30 min) + ~ 10 min Cawthorne-Cooksey exercises at home (3 sessions per day) Total: ≈ 31.4 min per day				
(Phillips et al., 2018)	40 individuals with chronic dizziness Sixteen weeks of rehabilitation for both groups	**Experimental group:** Wii Fit platform exercises with a tailored routine of nine balance games (N = 21)	**Experimental group:** 60 min of Wii Fit platform exercises per day (2 sessions per day) Total: = 60 min per day	Reported explicitly	Non-Immersive (Nintendo Wii Fit™ balance platform)	Mixed. Clinical & Home-based. Initial 1-h instructional session at a hospital clinic, followed by a home-based program	No practice time difference between groups
		Control groups: Conventional vestibular rehabilitation (N = 19)	**Control group:** 60 min of conventional vestibular rehabilitation per day (2 session per day) Total: = 60 min per day				

(*Continued*)

TABLE 2 Continued

Authors	Population	Intervention	Frequency of treatment	Source of dose-data	VR type	Setting & supervision	Time difference between group
(Kelly et al., 2023)	30 individuals with chronic vestibular dysfunction Eight weeks of rehabilitation for both groups	**Experimental group:** Contextual Sensory Integration (C.S.I.) training *via* an immersive VR-based HTC Vive (N = 15)	**Experimental group:** 4.2 min on average per day of VR (C.S.I) + 15 min per day of conventional vestibular rehabilitation (2 sessions per day) Total: ≈ 19.4 min per day	Calculated average from protocol - Reported	Immersive (Head-Mounted Display)	Mixed. Clinical & Home-based. Once per week in the clinic plus a daily home exercise program	No practice time difference between groups
		Control groups: Conventional vestibular rehabilitation (N = 15)	**Control group:** 4.2 min on average per day of conventional at clinic + 15 min per day of conventional vestibular rehabilitation (2 sessions per day) Total: ≈ 19.4 min per day				
[a](Le Perf et al., 2025)	76 adults with vestibular disorders (acute or chronic, unilateral, bilateral, functional) Eight weeks of rehabilitation for both groups	**Experimental group:** Multisensory balance exercises using HTC Vive® and Virtualis® software + vestibular physiotherapy + group balance circuits + physical activity (N = 38)	**Experimental group:** 42.9 min of VR-based multisensory balance exercises (2 sessions of 30 min per day, 5 days a week) + 42.9 min of group balance circuit (once a day of 60 min[a] 5 days a week) + 42.9–64.3 min of physical activity tailor-made to participant condition (2–3 session per day of 30 min, 5 days a week) Total: ≈ 128.7 min per day	Calculated average from protocol - Reported	Immersive (Head-Mounted Display)	Supervised. Exercises were provided by physiotherapists and specialists	No practice time difference between groups
		Control groups: Multisensory balance exercises using optokinetic stimulator and body-sway-coupled visual surround + vestibular physiotherapy + group balance circuits + physical activity (N = 38)	**Control group:** 42.9 min of conventional optokinetic exercises (2 sessions of 30 min per day, 5 days a week) + 42.9 min of group balance circuit (once a day of 60 min[a] 5 days a week) + 42.9–64.3 min of physical activity tailor-made to participant condition (2–3 session per day of 30 min, 5 days a week) Total: ≈ 128.7 min per day				

VR, virtual reality.
~ An estimate of the time spent per exercise, based on the vestibular rehabilitation guidelines (Hall et al., 2022) and authors' experience.
≈ A daily average of the minutes spent exercising based on the values reported in the original research papers.
[a]The conventional rehabilitation group showed better results than the virtual reality group.

3.6 Study limitations

Despite our structured search approach, some relevant studies may not have been identified, as this is not a systematic review, consequently, a formal risk-of-bias assessment of the included studies was not performed. This approach was adopted to prioritize a narrative synthesis of emerging trends and dose-response patterns across diverse clinical protocols, rather than providing a cumulative statistical effect size which would require standardized bias

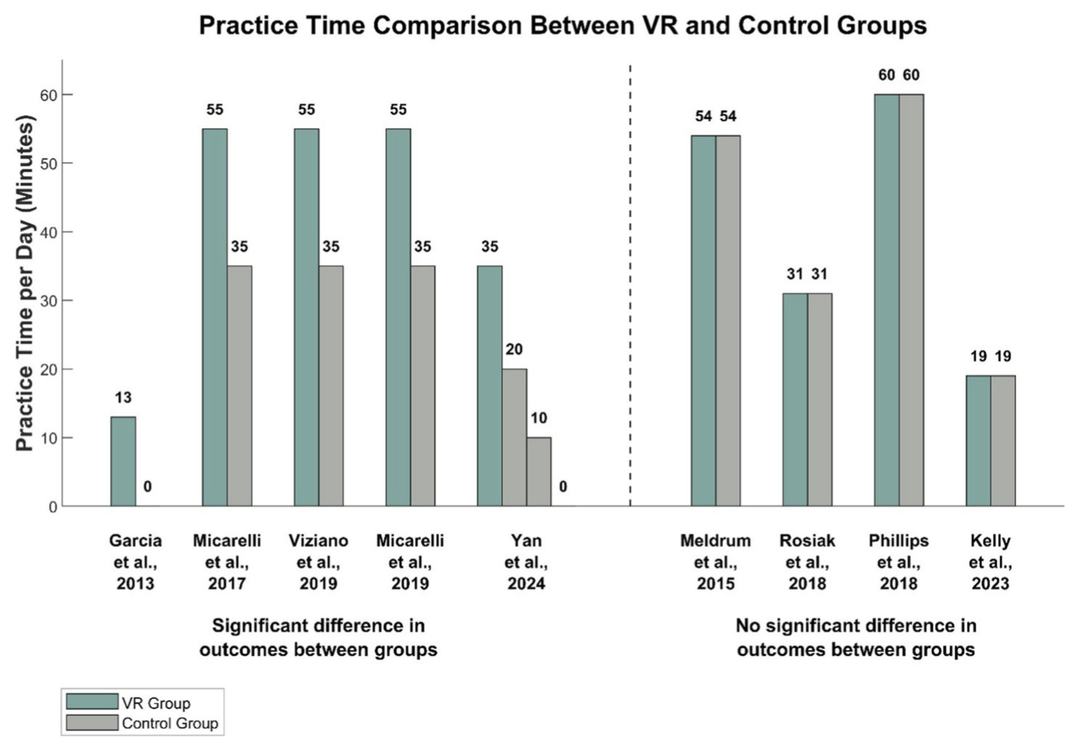

FIGURE 1
Comparison of prescribed daily practice time between virtual reality (VR) and control groups across studies. Values represent the average minutes per day as calculated from the specific research protocols reported in each study. Bars on the left represent studies that found significant clinical differences favoring virtual reality, while bars on the right represent studies with no significant between-group differences. For Yan et al. (2024), practice duration was estimated based on the exercise types specified in the protocol and clinical practice guidelines, whereas for all other studies, durations were derived directly from the reported intervention schedules. For protocols where practice duration increased progressively over the treatment period, the plotted value reflects the calculated average daily dose to allow for a standardized comparison.

grading. Additionally, publication bias remains, as studies with negative or null results on the efficacy of virtual reality may be underreported in literature. In addition, studies are characterized by considerable heterogeneity, particularly in intervention duration, type of virtual reality systems, and outcome measures, which may limit direct comparisons and affect interpretation. This variability, combined with the current scarcity of dose-matched trials, suggests that while our findings point to practice time as a key factor driving improvements in balance and symptom reduction, they should be viewed as an emerging pattern rather than a definitive conclusion. Furthermore, inconsistent reporting of training dosage and patient adherence makes it difficult to identify the unique contribution of virtual reality technology. Another limitation of this review is the reliance on estimated practice times for a study that did not explicitly report duration. To address potential bias, we conducted a sensitivity analysis by applying a ±25% range to the estimated values. Importantly, such estimation was required for only one study, where duration was inferred based on the type of exercise. In all other cases, practice time was calculated directly from data reported in the articles and supplementary materials (e.g., session frequency and duration). This strong reliance on reported values substantially reduces the risk of estimation bias, and the core findings remained unchanged across the tested sensitivity bounds.

4 Conclusion

Virtual reality presents a promising tool in vestibular rehabilitation, offering unique advantages such as gamification and better enjoyment. In spite of this, it is difficult to draw conclusions from the existing research regarding the effectiveness of virtual-reality-based rehabilitation compared to conventional rehabilitation. This is because the studies that show an advantage for the virtual reality group involve longer training time for this group.

There is a need for further research centered on standardization of the training protocol, which includes: (1) identical practice times and frequency for virtual reality groups and control groups; (2) the same type of up-to-date practice following the latest clinical practice guidelines; (3) a direct comparison between practicing with immersive vs. with non-immersive virtual reality. In this way, we would be able to conclude about benefits of virtual reality compared to conventional vestibular rehabilitation practice and differentiation between the effects of virtual reality as a whole vs. the effects of immersive qualities. Until such controlled trials are conducted, clinicians should view the added value of virtual reality with caution; while it is a promising tool for engagement, our findings suggest that training dosage may be the primary driver of recovery, a hypothesis that requires further empirical validation through strictly dose-matched studies.

Author contributions

AK: Conceptualization, Formal Analysis, Investigation, Methodology, Writing – original draft, Writing – review and editing. LK: Conceptualization, Methodology, Investigation, Writing – review and editing. SL-T: Conceptualization, Funding acquisition, Methodology, Project administration, Writing – review and editing. YG: Conceptualization, Funding acquisition, Methodology, Project administration, Writing – review and editing.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

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