INFORMATION BRIEF (RAPID REVIEW)

Virtual Reality Based Assessment and Rehabilitation for Vertigo and Balance Disorder

Malaysian Health Technology Assessment Section (MaHTAS)
Medical Development Division
Ministry of Health Malaysia
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Rapid Review

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TITLE: Virtual Reality Based Assessment and Rehabilitation for Vertigo and Balance Disorder.

PURPOSE

To provide evidence on the effectiveness and safety of [redacted] system or use of virtual reality in assessment and rehabilitation of patient with vertigo and balance disorder. This report has been prepared as per request from the Director of Medical Practice Division, Ministry of Health, following inquiry and proposal to introduce this service in health clinic, as this procedure is not listed in the 13th Schedule of the Private Healthcare Facilities and Services (Private Hospital and Other Private Hospital Facilities) Regulation (2013)

BACKGROUND

Vertigo is a symptom of vestibular balance disorders, typically characterized by a spinning sensation. The causes of vertigo can be categorized into peripheral, involving the labyrinth or vestibular nerve, and central, involving the brainstem. It affects 7.4% of individuals over their lifetime, with 80% experiencing work interruptions. This debilitating symptom increases healthcare utilization and reduces patient productivity, making peripheral vestibular disorders a significant societal cost. Most vertigo-related expenses stem from unnecessary diagnostic procedures and ineffective treatments.[1]

The primary approach to managing vestibular disorders involves vestibular rehabilitation and symptomatic medication. Vestibular rehabilitation leverages neuroplasticity mechanisms, including adaptation, habituation, and substitution. These mechanisms enhance both static and dynamic postural stability and improve visuovestibular interactions in situations with conflicting sensory information.[1] Vestibular rehabilitation can improve symptoms of both unilateral and bilateral peripheral vestibular hypofunction.[2] However, factors such as the incorrect performance of exercises and the need for active effort and interest from patients can influence the effectiveness of rehabilitation.[1] Additionally, conventional vestibular rehabilitation requires frequent in-person appointments, which are time-consuming and resource-intensive.[2] In this context, virtual reality presents an interesting solution to address these challenges

Virtual reality (VR) refers to an advanced human-computer interface that allows users to enter and interact with a highly realistic computer-generated environment, primarily through the delivery of optical illusions that provide visual information. Over the past decades, the use of VR has become more common in healthcare for both diagnosis and treatment.[3] VR was introduced as an alternative to traditional, monotonous physical therapy, which can be mundane and challenging for patient motivation. Additionally, VR through telerehabilitation offers remote therapy for patients who have difficulty accessing tertiary clinics. It provides a controlled environment within an augmented setting while influencing and tracking patients' kinematic responses.[3]

Technical Features

[redacted] is a chain of specialty vertigo clinics providing evaluation and treatment for vertigo and balance disorders. At [redacted], a detailed history of the patient is taken, followed by a comprehensive evaluation. The clinic has adopted a three-pronged strategy: 1) collaborating with ENT specialists and neurologists across India to set up Vertigo and Balance Disorder clinics, 2) utilizing a diagnostic equipment suite developed and manufactured indigenously by [redacted] Pvt Ltd, and 3) providing accurate and real-time diagnosis and support to doctors via a panel of vertigo specialists including ENT specialists, neurologists, and psychiatrists through the [redacted] using cloud technology. The technologies provided by [redacted] include Advanced Videonystagmography (VNG), Subjective Visual Vertical (SVV), Craniocorpography, Computerized Dynamic Visual Acuity, Electronystagmography, Computerized Stabilometry, and Virtual Reality-based Vestibular Rehabilitation.[4]

1. Advanced Videonystagmography (VNG)

[redacted]™ Videonystagmography (VNG) is a method for evaluating the vestibular and oculomotor systems, used to observe, measure, and analyze eye movements during various oculomotor and vestibular tests. [redacted]™ VNG assesses peripheral and central vestibular functions through the following protocols: spontaneous nystagmus with and without optic fixation, gaze-evoked nystagmus, fixed and random saccades, and smooth tracking at varying frequencies. The [redacted]™ VNG features a user-friendly binocular goggle design that requires no adjustment for focus or mirror settings. It is lightweight, with a direct USB connection to a laptop or desktop computer. Additionally, it includes an easy-fit magnetic cover for both occluded and unoccluded measurements and a built-in fixation light to simplify testing. The system operates with an advanced eye-tracking algorithm that eliminates errors caused by blinking.[4]

Figure 1: Advanced Videonystagmography[4]

Figure 2: Binocular google design.[4]

2. Subjective Visual Vertical (SVV).

   Subjective Visual Vertical (SVV) is a diagnostic tool used to evaluate the otolith system, responsible for the perception of verticality. Static and dynamic SVV assessments are crucial for evaluating chronic dizziness, diagnosing otolithic disorders, distinguishing between peripheral and central vestibular disorders, determining the affected side in acute peripheral vestibular insults, diagnosing compensated vestibular disorders, and evaluating the effectiveness of rehabilitation in vertigo patients. [redacted]™ SVV utilizes tubular vision goggles equipped with 9-axis gyroscopes for accurate measurements. It offers real-time data analysis and is fully integrated and computerized, allowing for both static and dynamic SVV assessments.[4]

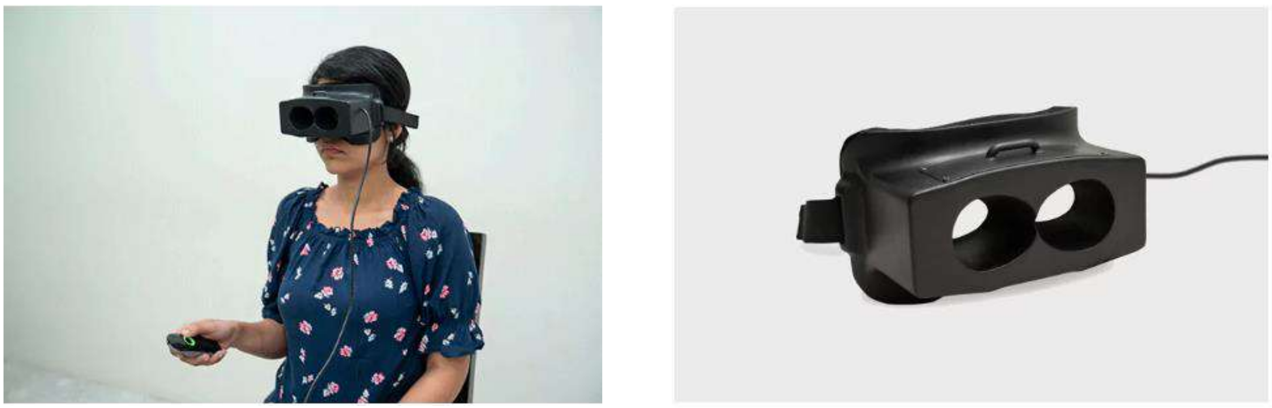

Figure 3: [redacted] Subjective Visual Vertical[4]

3. Craniocorpography

   [redacted]m™ Craniocorpography (CCG) is a neuro-otological assessment used to evaluate the vestibulospinal reflex, crucial for maintaining balance during gait testing. Its protocols include tests such as the Romberg Test, Tandem walking, and Unterberger's/Fukuda Test. Fully integrated and computerized, [redacted]™ CCG provides real-time data analysis.[4]

Figure 4: [redacted] Craniocorpography[4]

4. <u>Dynamic Visual Acuity</u>

[redacted]™ Dynamic Visual Acuity (DVA) is used to screen the vestibulo-ocular reflex (VOR). It detects vestibulotoxicity, identifies bilateral peripheral vestibulopathy, serves as a rehabilitation tool, and assesses the outcomes of rehabilitation. Dynamic visual acuity evaluates the VOR's ability to stabilize the image on the fovea of the retina during head movement. A defective VOR can cause image slippage, resulting in blurred vision or oscillopsia. [redacted]™ DVA is computerized and equipped with motion sensors for precise recording of head velocity and angulation.[4]

Figure 5: Neuroequilibrium Computerized Dynamic Visual Acuity[4]

5. <u>Electronystagmography (ENG).</u>

Electronystagmography (ENG) is a diagnostic test used to assess patients experiencing vertigo, dizziness, and balance issues. This study of eye movements provides insights into brain function and the balance system. Electronystagmography measures eye movements under various conditions and tests by detecting changes in the cornea-retinal potential. Surface electrodes placed near the patient's eyes capture these potential changes. Electronystagmography findings must be interpreted alongside the patient's medical history and other neuro-otological tests to determine the underlying cause of vertigo or dizziness. However, since its introduction, ENG has been largely replaced by the less invasive method known as Videonystagmography (VNG).[4]

6.

Figure 6: Electronystagmography[4]

Computerized Stabilometry.

[redacted]m™ Stabilometry provides an objective assessment of the postural control system, focusing on its steady-state behavior. It is also an effective tool for evaluating the outcomes of vestibular rehabilitation. This assessment includes tests such as the sensory integration of balance (mCTSIB), limits of stability (LOS), and rhythmic weight shift (RWS).[4]

Figure 7: [redacted]m™ Computerized Stabilometry[4]

7. Virtual Reality Based Vestibular Rehabilitation.

[redacted]™ Vestibular Rehabilitation Therapy utilizes advanced virtual reality-based exercise protocols aimed at enhancing gaze stabilization, sensory reorganization, desensitization, and the development of compensatory pathways. This therapy is given to patients experiencing symptoms such as dizziness, blurred vision during head movement, imbalance while walking, frequent falls, and sensations of spinning. VR-based vestibular rehabilitation is noted for its interactive and engaging nature. Gamification of exercises improves patient compliance and allows for quantifying improvements based on scores. Head movements are easily tracked in VR, enhancing therapy effectiveness.[4]

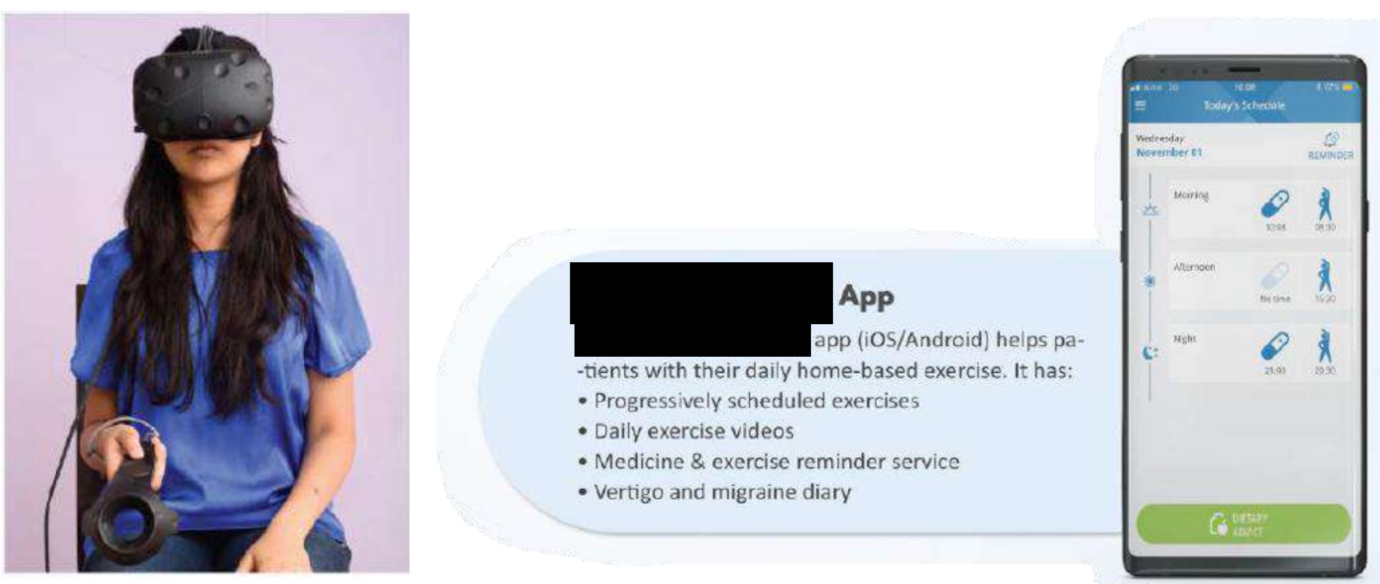

Figure 8: [redacted]™ Virtual Reality Vestibular Rehabilitation Therapy[4]

EVIDENCE SUMMARY

A total of 828 titles were retrieved from scientific databases including Medline, EBM Reviews (Health Technology Assessment, Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials, NHS Economic Evaluation Database via OVID) using search terms such as *imbalance disorder*, *vertigo*, *dizziness*, *vestibular diseases*, *videonystagmography*, *vestibular function test*, *subjective visual vertical*, *craniocorpography*, *dynamic visual acuity*, *electronystagmography*, *computerized stabilometry*, *vestibular rehabilitation therapy*, *virtual reality*, and *NeuroEquilibrium*. Searches were limited to English language and studies involving human adults published within the last 15 years (since 2009). The last search was conducted on April 22, 2024. Articles studying virtual reality in neurological disorders such as Parkinson's disease, stroke, brain injury, and spinal cord injury were excluded from this review. After removing duplicates and screening titles and abstracts, seven articles were included in this review: two systematic reviews, two randomized controlled trials, two validation studies, and one pre- and post-study.

EFFECTIVENESS

Among the seven articles retrieved, none specifically mention [redacted]™ in evaluating the efficacy or accuracy of virtual reality in diagnosing and treating vertigo and balance disorders. Of these articles, five focused on Vestibular Rehabilitation Therapy, one on Dynamic Visual Acuity, and one on Subjective Visual Vertical. No articles were found that assessed virtual reality in Videonystagmography, Craniocorpography, or Computerized Stabilometry.

(i) <u>Vestibular Rehab Therapy.</u>

Heffernan et al. (2021) conducted a systematic review and meta-analysis to evaluate the benefits of virtual reality (VR) and augmented reality (AR) interventions for symptoms of vestibular dysfunction (dizziness, vertigo, imbalance, or others) in patients with peripheral vestibular disorders (PVD) within three months of treatment. The review also aimed to assess long-term (>3 months) benefits, changes in patient quality of life post-intervention, and determine adverse events associated with VR and AR use. The analysis included five randomized controlled trials published from 2011 to 2019, involving 107 control group and 97 intervention group participants. Participants, 53% female, ranged in average age from 42 to 77 years and suffered from chronic PVD. These trials compared VR or AR vestibular rehabilitation interventions against drugs, dietary changes, home exercises, or standard vestibular rehabilitation. Regarding the effects of VR or AR on patient Dizziness Handicap Inventory (DHI) scores within 0-3 months post-intervention, all studies favored VR over control with a combined standardized mean difference (SMD) of -1.13 (95% CI -1.74, -0.52; Z=3.66, p=0.0003). Subgroup analyses based on PVD diagnoses indicated that VR interventions were favorable compared to controls for unilateral vestibular hypofunction (UVH) disorders (neuronitis, acoustic neuroma, post-polio syndrome, perilymphatic fistula, and Ramsay Hunt syndrome) with an SMD of -1.29 (95% CI -2.79 to 0.21), Meniere's disease

(MD) with an SMD of -1.13 (95% CI -1.77 to -0.49), and a group of PVDs with unspecified laterality (labyrinthine disorders, benign paroxysmal positional vertigo, labyrinthine disorders and benign paroxysmal positional vertigo, motion sickness/endolymphatic hydrops, perilymphatic vestibular nerve sheath tumors, and migraine-associated dizziness) with an SMD of -0.82 (95% CI -1.40 to -0.24). VR interventions also significantly improved scores on the Activities-specific Balance Confidence (ABC) scale more than standard vestibular rehabilitation alone one week post-treatment (p=0.0036). Regarding long-term effects, one study reported higher ABC scores at 12 months for the VR intervention compared to standard vestibular rehabilitation alone (p=0.0022). [5]

Xie et al. (2021) conducted a systematic review to evaluate the efficacy of virtual reality-based vestibular rehabilitation in patients with vertigo. The review included six randomized controlled trials and four additional prospective studies, involving 241 patients diagnosed with various pathologies such as vestibular hypofunction and Meniere's disease. Different virtual reality interventions were utilized across the studies, ranging from 3D virtual reality head-mounted devices with gaming exercises to immersive projected environments. Comparator groups varied from supervised vestibular rehabilitation to independent Cawthorne-Cooksey exercises. Outcomes measured included validated questionnaires, objective clinical tests, and balance or reflex measurements. Overall, virtual reality-based vestibular rehabilitation therapy demonstrated significant post-treatment improvements in otoneurological outcomes, ipsilesional vestibulo-ocular reflex (VOR) gain, and self-reported performance measures. One study reported significant post-treatment improvements in Dizziness Handicap Inventory (DHI) scores and dizziness analogue scale (ADS) scores with virtual reality vestibular rehabilitation. However, there were no statistically significant differences between groups in DHI scores, ADS scores, or stability limit areas when compared to controls. Another study noted that the virtual reality vestibular rehabilitation group showed significantly greater improvements in Subjective Visual Vertical (SVV) scores, Virtual Reality Comprehensive Efficacy Scale for Symptoms (VRCESS) scores, and Beck Anxiety and Depression Scale scores. Additionally, one study mentioned that after one year, patients undergoing virtual reality vestibular rehabilitation therapy achieved better otoneurological scores than those undergoing vestibular therapy alone. Xie et al. concluded in their review that virtual reality-based vestibular rehabilitation therapy shows potential clinical benefits compared to conventional vestibular rehabilitation. However, they highlighted significant heterogeneity and limitations in terms of population selection, intervention design, comparators, and evidence-based clinical outcomes, suggesting the need for future studies to address these limitations.[2]

Stankiewicz et al. (2020) conducted a randomized controlled trial to assess effectiveness of virtual reality (VR) vestibular rehabilitation in 20 patients suffering from vertigo due to peripheral vestibular dysfunction. The study included 9 women and 11 men aged 29 to 66 years, randomly assigned to either Group 1 (virtual reality) or Group 2 (conventional standard therapy). Virtual reality in the study utilized Google Cardboard-based technology. Outcomes were measured using the Vertigo Symptom Scale – Short Form (VSS-SF) and the Visual Analog Scale (VAS). Results indicated significant differences in patient satisfaction with therapy (p=0.015), with those undergoing VR therapy (M=8.70±1.49) reporting higher satisfaction compared to those receiving conventional therapy (M=6.40±2.27). Both groups showed a significant reduction in VSS-SF scores from initial to final measurements (p<0.001). However, there was no significant difference in the statistical trend of VSS-SF scores between the two therapy groups.[6]

Another RCTs has been conducted by Meldrum et al (2015) in Dublin, Ireland, comparing the effectiveness of virtual reality-based balance exercises to conventional balance exercise in patients with unilateral peripheral vestibular loss (UVL). The study recruited 71 patients experiencing dizziness/vertigo, as well as gait and balance impairment. Participants were randomly assigned to receive 6 weeks of either conventional balance exercises (n=36) or virtual reality-based exercises (n=35) using an off-the-shelf virtual reality gaming system based on Wii Fit Plus with a rocker board or home exercises. Both groups showed improvements in scores post-intervention, but there were no significant differences between groups in gait speed (mean difference, -0.03 m/s; 95% CI, -0.09 to 0.02 m/s), Sensory Organization Test (SOT) scores (mean difference, 0.82%; 95% CI, -5.00% to 6.63%), or any of the other secondary outcomes (p>0.05). The virtual reality-based group reported significantly higher enjoyment (p=0.001), less difficulty (p=0.009), and less tiredness after balance exercises (p=0.03). At 6 months, there were no significant between-group differences in physical outcomes. The authors concluded from this trial that virtual reality-based balance exercises were not superior to conventional balance exercises during vestibular rehabilitation but may offer a more enjoyable alternative.[7]

Basoglu et al., (2022) in a pre and post study conducted in Istanbul, Turkey, investigated the effects of virtual reality (VR)-based vestibular rehabilitation therapy in patients diagnosed with peripheral vestibular hypofunction (PVH). This study included 25 patients aged between 18 and 60 years with PVH. The VR-based vestibular rehabilitation program utilized a Sony PlayStation 4 VR Head Mounted Display. Outcomes were measured using the Dizziness Handicap Inventory (DHI), Sensory Organization Test (SOT), Adaptation test (ADT), Limits of Stability (LOS), Rhythmic Weight Shift (RWS), and Cybersickness Survey. Results indicated significant improvements post-VR-based vestibular rehabilitation therapy. Average DHI scores for patients were 54.60 before VR therapy, 19.20 immediately after therapy, and 16.84 at the 8-week follow-up ($p < 0.001$). Mean SOT composite scores also improved, measuring 58.08 before VR therapy, 77.16 post-therapy, and 76.40 at the 8-week follow-up ($p < 0.000$).[8]

In Clinical Practice Guideline produced in 2016 by The American Physical Therapy Association Neurological Section entitled Vestibular Rehabilitation for Peripheral Vestibular Hypofunction: An Evidence-Based Clinical Practice Guideline, it is moderately recommended for clinicians to provided individualized and targeted exercise technique to achieve specific goals to address identified impairments and functional limitations. This action statement includes virtual reality vestibular rehabilitation in the supporting evidence. [9]

(ii) <u>Dynamic Visual Acuity.</u>

One validation study was done by Holford et al (2021) to compare dynamic visual acuity (DVA) scores, perceived balance, and perceived dizziness when using traditional versus virtual reality (VR) environments for DVA testing among healthy individuals. In this study, 26 healthy adults were recruited within School of Kinesiology and Recreation at Illinois State University. The DVA instrument (The American Institute of Balance®, Largo, FL, USA) was implemented in VR and traditional clinical (TC) environments as indirect measure of vestibular function. The study found no significant differences in DVA results, balance, or dizziness ratings between the traditional clinical protocol and the VR variant. The authors concluded that DVA testing conducted in VR demonstrated clinical utility across all measures. Testing in VR produced effects on vestibular function comparable to those observed with traditional clinical testing. However, the study was conducted in healthy subjects and further validation is needed in patients with vestibular disorders.[10]

(iii) Subject Visual Vertical.

Mueller et al. conducted a validation study in 2020 to establish normative data for Virtual Subjective Visual Vertical (Virtual SVV) in healthy subjects and to compare it with traditional Subjective Visual Vertical (SVV) assessments in a clinical setting. The study, conducted at Northwestern University, Chicago, USA, recruited 43 healthy subjects aged between 21 and 56 years from April 2017 to August 2018. The results indicated that the Virtual SVV data obtained in this study were consistent with previously published normative SVV data by Clarke et al. However, the normative Virtual SVV data showed only weak correlations with ocular vestibular-evoked myogenic potentials (oVEMPs) including c-VEMP, AC-elicited, and BC-elicited responses. This study suggest that Virtual SVV may represent an attractive alternative to traditional SVV assessments in clinical settings.[11]

SAFETY

In a systematic review and meta-analyses by Heffernan et al in 2021, it is reported that most common side effects were nausea, oculomotor and disorientation symptoms. This is reported using validated simulator sickness questionnaire. However, there was a significant reduction in the symptoms associated with VR interventions over time. ($p<0.001$). In terms of treatment adherence, three out of the five RCTs indicated 100% adherence, with an overall adherence rate of 98.4% over a 4 to 6-week study period.[5] In the RCT conducted by Meldrum et al, a total of 3 study related adverse event was reported. One case of low back pain that attributed to the Wii Fit Plus with another two cases of neck pain and severe nausea were considered related to the gaze stabilization exercises.[7]

While several virtual reality technologies for vestibular rehabilitation have received approval from the U.S. Food and Drug Administration (FDA) namely; [redacted], [redacted],[12] however as of the time this article is written, [redacted] has not obtained certification or approval from either the U.S FDA or The Central Drugs Standard Control Organization (CDSCO), India.

COST

From the systematic search, no economic evaluations were found that studied the cost-effectiveness of the [redacted] system or the usage of virtual reality for vertigo and balance disorders. The cost of the product varies depending on the individual VR system itself. Common VR systems reported for healthcare use include [redacted] and [redacted],[3] costing approximately [redacted] for a standalone device depending on storage, displays and capacity. In addition to hardware costs, considerations should include expenses for software, exercise protocols, maintenance, and upgrades.

In regards to virtual reality vestibular telerehabilitation, it could possibly generate cost saving compared to conventional vestibular rehabilitation therapy if factors such physical therapist hours and travelling expenses by the patient taken into considerations. However, the evidence is deficient and further study is needed to establish this.[13]

CONCLUSION

There is currently no evidence retrieved demonstrating the effectiveness and safety of [redacted] equipment in diagnosing and treating vertigo and balance disorders. Regarding virtual-reality based vestibular rehabilitation, evidence is showing its efficacy in improving otoneurological scores such DHI, ABC, ADS. VSS. SOT and VOR gain in patient with vertigo and balance disorder, although it has not proven superior to conventional vestibular rehabilitation. There is limited evidence validating virtual reality used in assessment of dynamic visual acuity and subjective visual vertical. There is no evidence retrieved on usage of virtual reality in other assessment tools such as videonystagmography, craniocorpography, and computerized stabilometry. Regarding safety, the most common side effects from the use of virtual reality technologies are cybersickness, which manifests as nausea, oculomotor stress, and disorientation symptoms. However, these symptoms are generally well tolerated and tend to reduce over time. There is no evidence on the cost effectiveness of using virtual technologies in diagnosing and treating vertigo and balance disorders.

REFERENCE

1. Bergeron M, Lortie CL, Guitton MJ. Use of virtual reality tools for vestibular disorders rehabilitation: a comprehensive analysis. Advances in medicine. 2015;2015(1):916735.
2. Xie M, Zhou K, Patro N, et al, Archibald J. Virtual reality for vestibular rehabilitation: a systematic review. Otology & Neurotology. 2021 Aug 1;42(7):967-77.
3. Bateni H, Carruthers J, Mohan R,et al. Use of virtual reality in physical therapy as an intervention and diagnostic tool. Rehabilitation Research and Practice. 2024;2024(1):1122286.
4. Neuroequilibrium. Neuroequilibrium – Vertigo and Balance Disorders Clinics. Neuroequilibrium. Available from: https://www.neuroequilibrium.in/. Accessed 2024 June 14.
5. Heffernan A, Abdelmalek M, Nunez DA. Virtual and augmented reality in the vestibular rehabilitation of peripheral vestibular disorders: systematic review and meta-analysis. Scientific Reports. 2021 Sep 8;11(1):17843.
6. Stankiewicz T, Gujski M, Niedzielski A, et al. Virtual reality vestibular rehabilitation in 20 patients with vertigo due to peripheral vestibular dysfunction. Medical science monitor: international medical journal of experimental and clinical research. 2021;27:e930182-1.
7. Meldrum D, Herdman S, Vance R, et al. Effectiveness of conventional versus virtual reality–based balance exercises in vestibular rehabilitation for unilateral peripheral vestibular loss: results of a randomized controlled trial. Archives of physical medicine and rehabilitation. 2015 Jul 1;96(7):1319-28.
8. Başoğlu Y, Şerbetçioğlu MB, Çelik İ, et al. Effectiveness of virtual reality-based vestibular rehabilitation in patients with peripheral vestibular hypofunction. Turkish journal of medical sciences. 2022;52(6):1970-83.
9. Hall CD, Herdman SJ, Whitney SL, et al. Vestibular rehabilitation for peripheral vestibular hypofunction: an evidence-based clinical practice guideline: from the American Physical

Therapy Association Neurology Section. Journal of Neurologic Physical Therapy. 2016 Apr 1;40(2):124-55.

10. Holford KC, Jagodinsky AE, Saripalle R, et al. Leveraging virtual reality for vestibular testing: Clinical outcomes from tests of dynamic visual acuity. Journal of Vestibular Research. 2022 Jan 1;32(1):15-20.
11. Mueller AL, Liebmann LB, Petrak MR, et al. Evaluation of the utricular function with the virtual–subject visual vertical system: comparison with ocular vestibular-evoked myogenic potentials. Acta Oto-Laryngologica. 2020 May 3;140(5):366-72.
12. Center for Devices and Radiological Health. Augmented reality and virtual reality in medical devices, U.S. Food and Drug Administration. Available at: https://www.fda.gov/medical-devices/digital-health-center-excellence/augmented-reality-and-virtual-reality-medical-devices. Accessed 2024 June 24.
13. Lloréns R, Noé E, Colomer C, et al. Effectiveness, usability, and cost-benefit of a virtual reality–based telerehabilitation program for balance recovery after stroke: A randomized controlled trial. Archives of physical medicine and rehabilitation. 2015 Mar 1;96(3):418-25.

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