Vestibular rehabilitation: advances in peripheral and central vestibular disorders

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Purpose of review
Rehabilitation for persons with vertigo and balance disorders is becoming commonplace and the literature is expanding rapidly. The present review highlights recent findings of both peripheral and central vestibular disorders and provides insight into evidence related to new rehabilitative interventions. Risk factors will be reviewed to create a better understanding of patient and clinical characteristics that may effect recovery among persons with vestibular disorders.

Recent findings
Clinical practice guidelines have recently been developed for peripheral vestibular hypofunction and updated for benign paroxysmal positional vertigo. Diagnoses such as persistent postural-perceptual dizziness (PPPD) and vestibular migraine are now defined, and there is growing literature supporting the effectiveness of vestibular rehabilitation as a treatment option. As technology advances, virtual reality and other technologies are being used more frequently to augment vestibular rehabilitation. Clinicians now have a better understanding of rehabilitation expectations and whom to refer based on evidence in order to improve functional outcomes for persons living with peripheral and central vestibular disorders.

Summary
An up-to-date understanding of the evidence related to vestibular rehabilitation can assist the practicing clinician in making better clinical decisions for their patient and hopefully result in optimal functional recovery.

Keywords
balance, dizziness, exercise, outcomes, rehabilitation, vestibular rehabilitation

INTRODUCTION

There have been exciting advances in vestibular rehabilitation over the last 2–3 years related to the treatment of vestibular hypofunction, benign paroxysmal positional vertigo (BPPV), persistent postural-perceptual dizziness (PPPD), vestibular migraine, multiple sclerosis (MS), and concussion. Technological advances in the use of virtual reality and optokinetic scenes are changing clinical methods utilized in the recovery of persons living with balance and vestibular disorders. Based on recent findings, clinicians now have better indicators of which patients will likely have positive or negative outcomes in vestibular rehabilitation.

PERIPHERAL VESTIBULAR HYPOFUNCTION

The American Physical Therapy Association published clinical practice guidelines for vestibular rehabilitation for patients with peripheral vestibular hypofunction in 2016 [1▪▪]. These guidelines outline the effectiveness of vestibular rehabilitation over no treatment or sham treatments in improving balance function, functional recovery, quality of life, and reducing fall risk in patients with acute, subacute, and chronic unilateral and bilateral peripheral vestibular hypofunction [1▪▪]. This is an exciting step for the field of vestibular rehabilitation, as it is the first clinical practice guideline in this population. A review by McDonnell and Hillier [2] determined that vestibular rehabilitation can improve subjective symptom report, perceived handicap, gait

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KEY POINTS

- Vestibular rehabilitation is safe and improves function in adults with peripheral vestibular disorders.
- New diagnostic criteria for both vestibular migraine and PPPD have been established and is anticipated to facilitate further research on the role and effectiveness of vestibular rehabilitation in these patient populations.
- There is advancing evidence for the proposed critical role of vestibular rehabilitation in lessening disability among patients with the diagnosis of PPPD.
- Persons with central vestibular disorders have improvements in balance, dizziness, and quality of life after vestibular rehabilitation.
- Persons postconcussion have dizziness and vestibulo-ocular deficits, which appear to be modifiable with vestibular rehabilitation.
- Comorbid psychologic factors can delay recovery and lead to suboptimal outcomes after either a peripheral or central vestibular disorder.

performance, balance, and activities of daily living for persons with peripheral vestibular disorders. They conclude that vestibular rehabilitation is safe, effective and can provide long-term benefits for patients with peripheral vestibular dysfunction [2]. Although there is not yet strong evidence to determine optimal dose and specific exercises for persons with peripheral vestibular hypofunction, there is compelling evidence for supervised, targeted exercise programs to address functional impairments and individual patient goals (Table 1) [1▪▪]. Targeted exercise may include gaze stabilization exercises to improve vestibulo-ocular reflex (VOR) gain, habituation to improve sensitivity to body movements, or optokinetic exercises to improve visual motion sensitivity [1▪▪]. There are strong recommendations against the use of saccadic and smooth pursuit exercises in isolation without head movement [1▪▪].

The International Consensus on the treatment of Meniere's disease suggests that vestibular rehabilitation should be offered as a treatment option for patients between vertigo crises [3]. Although a systematic review by van Esch *et al.* [4] found inconclusive evidence for a positive effect of vestibular rehabilitation in improving balance and quality of life in persons with Meniere's disease, it is a safe treatment option and may be effective, particularly in patients at risk for falls and with other comorbidities. They highlight the need for high quality, unbiased studies for the use of vestibular rehabilitation in patients with Meniere's disease.

The evidence-based guidelines for emerging therapies for the treatment of patients with vestibular schwannoma published by the Congress of Neurological Surgeons states that there is level three evidence supporting the use of vestibular rehabilitation prior to surgery to aid in postoperative recovery [5]. Improvements in postoperative mobility are seen, particularly when vestibular rehabilitation is combined with gentamicin ablation during the preoperative phase [5,6].

BENIGN PAROXYSMAL POSITIONAL VERTIGO

BPPV is the most commonly occurring vestibular disorder [7]. Updated clinical practice guidelines for BPPV published by the American Academy of Otolaryngology – Head and Neck Surgery Foundation reiterate that persons with BPPV should be diagnosed with the Dix-Hallpike and roll tests and treated by a trained healthcare provider with the appropriate canalith repositioning treatment (CRT) [8▪▪]. Evidence suggests that either the modified Epley maneuver or the Semont (Liberatory) maneuver are effective in treating posterior canal BPPV [8▪▪,9]. A recent meta-analysis evaluating the efficacy of the Semont maneuver concluded that it is superior to no treatment or sham maneuvers and has equal effectiveness

Table 1. Current treatment recommendations for persons with peripheral vestibular hypofunction from the Academy of Neurologic Physical Therapy

Treatment	Recommendation	Level of evidence
Saccadic exercises[a]	Strong recommendation against	I
Smooth pursuit exercises[a]	Strong recommendation against	I
Targeted exercises	Moderate recommendation	II
Supervised exercises	Moderate recommendation	II
Gaze stability exercise for 12–20 min/day[b]	Expert opinion	V

[a]Offered in isolation.
[b]Daily total of 12 min for acute peripheral vestibular hypofunction and daily total of 20 min for chronic peripheral vestibular hypofunction.
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to the modified Epley maneuver and Brandt-Daroff exercises [9]. It should be noted that Brandt–Daroff exercises are not as effective as the modified Epley or Semont maneuvers in patients with BPPV [10]. Li *et al.* [11] propose a modified Semont maneuver, where the patient is not required to turn their head and found it to be as effective as the modified Epley in a sample of patients with posterior canal BPPV in a randomized clinical trial. This maneuver may be particularly useful in patients with restricted cervical mobility. Post-CRT restrictions are no longer recommended due to insufficient evidence for the effectiveness of these restrictions in the treatment of BPPV [8▪▪]. Even with successful treatment, BPPV is thought to reoccur in up to 36% of patients [10]. Of note, females, persons with sleep disorders, and a history of inner ear dysfunction may be at a higher risk for reoccurrence of BPPV [12]. Vitamin D supplementation may decrease the chance of BPPV recurrence [13,14].

It is well documented that vestibular rehabilitation providers can perform the CRT and that the CRT is superior to general habituation such as Cawthorne–Cooksey and Brandt–Daroff exercises [2]. However, physician referral to generalized vestibular rehabilitation (habituation and/or balance treatments) is a treatment option for patients with BPPV and has demonstrated short and long-term effectiveness in this population [8▪▪,15]. Vestibular rehabilitation may be particularly effective for patients who do not recover after the initial CRT, if additional impairments are present, or for patients diagnosed with posttraumatic BPPV, as they are more likely to have a protracted recovery time and multicanal involvement [8▪▪,16]. Timely treatment of BPPV is important based on evidence of increased risk for fracture in patients with BPPV and decreased occurrence of falls when patients are treated with CRT [17,18]. Also, recent evidence suggests that vestibular rehabilitation in addition to the CRT improves dynamic balance in older adults [19,20]. Despite this, there is evidence that primary care practitioners underutilize the CRT and vestibular rehabilitation for patients with BPPV, outlining the need for physician awareness of the benefits of vestibular rehabilitation [21–23]. Please see 'Peripheral Vestibular Disorders' by López Escámez *et al.* (pp 165–173) in this issue of Current Opinion in Neurology for more information on BPPV.

PERSISTENT POSTURAL-PERCEPTUAL DIZZINESS

One of the most steadily advancing fields in vestibular rehabilitation has been the evolving differential diagnosis and increasing efficacy of treatment techniques for PPPD [24▪▪,25,26▪▪,27]. When properly recognized, PPPD is estimated to account for 15–20% of patients seen in tertiary practice [26▪▪]. The recent publication of the Barany Society's International Classification of Vestibular Disorders diagnostic criteria for PPPD [28▪] and the integration of the diagnosis into the most recent release of the WHO, International Classification of Diseases (ICD-11) [29▪] has helped to clarify the diagnostic criteria for PPPD. Pilot studies have demonstrated a 78% sustained (>1 year) reduction in dizziness utilizing combined antidepressant medications, cognitive behavioral therapy, and vestibular rehabilitation [30,31]. Development of models for both the putative mechanisms of PPPD [26▪▪,28▪] and the cognitive behavior components [32] are expanding patient/clinician understanding and allowing for more refined care. Neuroanatomical and neurophysiological understanding of PPPD is also evolving alongside of the behavioral advancements. Building on earlier functional magnetic resonance imaging (fMRI) studies which showed widespread changes in brain networks responsible for space-motion (parietoinsular vestibular cortex, visual cortex, and hippocampus) [33], a recent fMRI study examined fifteen patients with PPPD who were stimulated with a 'virtual reality rollercoaster'. The patients had different responses to the virtual scene in the insular and occipital regions compared with healthy controls that correlated with levels of perceived disability [34].

Sohsten *et al.* [35] completed the first investigation of posturography in patients with the recently established criteria for PPPD. Persons living with PPPD were found to have degraded efficiency (more overall elevated sway) and poorer performance consistent with theoretic constructs of high-risk postural control strategies and multimodal spatial integration issues compared with controls. This study calls into question established 'aphysiologic test performance criteria' [36,37] for patients fitting the criteria for PPPD. Wuehr *et al.* [38] found increased cocontractions of lower extremity musculature during static standing in patients with phobic postural vertigo compared with healthy controls and a normalization of body sway and muscle contraction with the addition of a cognitive task.

According to evidence, vestibular rehabilitation techniques that may be helpful for the treatment of patients with PPPD include education, threat reduction, integrated relaxation/mindfulness practice, graded habituation, balance retraining, and visual/optokinetic motion desensitization [26▪▪,32]. A website has been developed to better standardize education and offer patient support for those living with functional disorders, and a downloadable printed fact sheet about PPPD is available at: www.neurosymptoms.org/dizziness/453319731.

For effective treatment to advance, PPPD cannot just be a diagnosis of exclusion but requires adherence to clinical features, early diagnosis to minimize the development of chronic symptoms, and a multidisciplinary approach of which vestibular rehabilitation is one of the key modalities for success [24▪▪,25,26▪▪,27]. Future studies are needed to better define interdependence of various treatment interventions and most effective specific treatment strategies for persons living with PPPD.

VESTIBULAR MIGRAINE

Support is building for the adjunctive use of vestibular rehabilitation in the optimal management of vestibular migraine [39,40▪▪,41,42▪▪,43,44▪]. Vestibular migraine is a common cause of dizziness with a historical lack of consensus in treatment. A recent epidemiologic study utilizing the Centers for Disease Control's 2008 National Health Interview Survey (21 780 adults) data applied the 2012 diagnostic criteria for vestibular migraine [45] and found a prevalence rate of 2.7% in US adults [46▪], which is much higher than previously described and would place the prevalence of vestibular migraine above that of BPPV. Another retrospective survey found that vestibular rehabilitation was underutilized in the care of persons with vestibular migraine [47]. Previously, only a small number of uncontrolled retrospective studies supported the efficacy of vestibular rehabilitation in persons with vestibular migraine [42▪▪,48]. Vitkovic *et al.* [44▪] studied the effect of vestibular rehabilitation on outcomes in patients who had vestibular impairment with or without migraine. Both groups improved after vestibular rehabilitation, but the vestibular migraine group had less improvement in subjective outcomes [44▪]. Challenges identified when applying vestibular rehabilitation to persons with vestibular migraine include comorbid anxiety, premorbid motion sickness vulnerabilities, and the presence of behavioral traits that are associated with sensory sensitivity that may lead to complicating factors of hypervigilance and increased arousal [44▪]. A more recent study examined changes in headache in 39 patients with vestibular migraine treated with vestibular rehabilitation [43]. Vestibular rehabilitation contributed to improvements in self-reported headache, less disability, and reduced anxiety and depression [43].

Migraine interactions in the pathophysiology of mal de debarquement syndrome (MdDS) have been questioned in the literature. A recent study supports the effective management of MdDS as vestibular migraine, and patients who were treated with lifestyle adjustments and migraine prophylaxis medication outperformed those treated with vestibular rehabilitation [41]. There is weak data to support that vestibular rehabilitation is effective in the management of vestibular migraine as there are no current randomized trials to support its efficacy [40▪▪,42▪▪,48].

MULTIPLE SCLEROSIS

The role vestibular rehabilitation in central disorders has traditionally been limited to small, uncontrolled studies. Recently, there are a few randomized controlled studies with respect to efficacy of vestibular rehabilitation in persons living with MS [49▪▪,50,51]. Hebert *et al.* [49▪▪] studied the efficacy of vestibular rehabilitation for persons diagnosed with MS who were ambulatory and noted improvements in balance, dizziness, fatigue, and health-related quality of life, regardless of whether brainstem/cerebellar lesions were present. Vestibular rehabilitation consisted of standing on different surfaces, mobility-based balance, walking with or without head motions, saccades, smooth pursuits, and gaze fixation exercises. In another randomized controlled trial, Ozgen *et al.* [51] demonstrated the effectiveness of a customized vestibular rehabilitation program on balance, quality of life, and functional capacity in ambulatory persons living with MS. In this study, vestibular rehabilitation included gaze stabilization exercises, static and dynamic balance exercises, habituation, and ambulation exercises that were modified and advanced by varying posture, type and/or size of support, trunk/arm position, visual input, and target distances.

Computerized gaze stabilization and dynamic visual acuity tests have been utilized in people living with MS [50]. Patients with MS performed worse than controls, suggesting that the VOR may not function optimally in persons living with MS [50]. The authors propose that the dynamic visual acuity and gaze stabilization tests, which are nonphysiologic measures of the VOR, are likely affected by other impairments such as coordination, motor learning, and/or cognitive attention. There is growing evidence in support of vestibular rehabilitation with respect to persons living with MS.

CONCUSSION

There is emerging evidence that vestibular rehabilitation is helpful in persons with concussion. The vestibular ocular motor screening (VOMS) tool was developed to screen vestibular and/or ocular disorders in persons postconcussion [52–56]. Tests of smooth pursuits, the VOR in the vertical and horizontal planes, saccadic eye movements, visual motion sensitivity, and near point of convergence

(NPC) are included in the VOMS [54]. Symptom provocation is assessed via patient self-report of nausea, dizziness, fogginess, and headache following each eye or eye/head movement, and the mean NPC distance is measured in cm and recorded. Symptom scores of 2 or more on any VOMS component or NPC distance of 5 cm or more were shown to be able to differentiate persons who were concussed versus control participants [54]. Worse scores on the VOMS have been related to longer recovery times with rehabilitation [57].

Alsalaheen *et al.* [58] were one of the first groups to report that vestibular rehabilitation could improve functional recovery in persons with balance and dizziness complaints after concussion. Persons postconcussion were provided with balance and ocular exercises as part of their vestibular rehabilitation program. Others have suggested that vestibular rehabilitation is an appropriate intervention for persons with dizziness after concussion [52,59–61,62▪,63,64]. An intensive eye/head exercise program in persons at least 6 months post sport concussion has been studied [65]. Participants participated in a 5-day intensive program where they exercised three times per day for 9 min with 1.5-h breaks [65]. Although the participants had chronic concussive symptoms, there was a decrease in their postconcussion symptom severity and improvements in their physical and mental health [65]. Studies of persons with chronic symptoms postconcussion suggest that physical therapy interventions were helpful [66–69], but one report suggests that there were adverse events with increased activity levels, with an increase in symptoms in 30% of the sample studied [66]. However, evidence suggests that earlier mobilization rather than complete rest may be warranted for optimal recovery postconcussion [70–72].

Dizziness Handicap Inventory scores in persons immediately postconcussion have been associated with the Immediate Postconcussion Assessment and Cognitive Testing, which is a test of memory, attention span, problem solving and reaction time [73]. Balance scores and cognitive function have also been related at the start of care in persons postconcussion [73]. Buckley *et al.* [74] reported that student athletes after concussion have slower anticipatory postural control during the initiation of gait compared with nonconcussed athletes, suggesting that gait is affected in the acute stage of concussion.

Headache is the most common symptom after concussion and photophobia is frequently reported. Colored lenses can be used to relieve photophobia and were used in 85% of the sample in one study [75]. There are, however, concerns about whether avoidance of light as a symptom trigger is helpful for long-term recovery. Sensitivity to light, sound, and motion is common after a concussion [76,77]. Pavlou *et al.* [76,77] have developed two questionnaires related to dizziness and visually induced symptoms that have been validated in children. Techniques commonly used in vestibular rehabilitation may be effective in persons who experience balance and dizziness postconcussion.

TECHNOLOGY TO AUGMENT VESTIBULAR REHABILITATION

In a recent trial, a balance task augmented with vibrotactile and auditory feedback resulted in reduced sway amplitudes and improved balance control in patients with bilateral vestibular loss [78]. Home vibrotactile feedback improves balance in healthy older adults and in persons with vestibular disorder [79]. The home-based vibrotactile trainer is the size of a smart phone and can be utilized by older adults in the home with instruction. The use of noisy galvanic vestibular stimulation has also been associated with improvements in gait speed, gait variability, and postural stability in small samples of patients with bilateral vestibular loss [80–82].

VIRTUAL REALITY

The use of a head mounted virtual reality device (HMD) is effective when combined with vestibular rehabilitation in a recent randomized trial among persons with unilateral vestibular hypofunction [83]. Postural control, VOR gain, dizziness, and balance confidence improved in the HMD group [83]. Use of virtual reality including eye/head exercises in persons with chronic mild disability associated with Meinere's disease showed improved postural control after 4 weeks of training [84].

Gait changes are seen in the acute phase after concussion [85]. The military recently piloted a virtual reality system where the participants performed dual tasks as part of their rehabilitation program in persons with concussion [86]. Investigators have suggested that dual tasking or the use of complex gait tasks are more promising to identify long-term sequalae of concussion [85]. The dual tasking during virtual reality exposure suggested by Robitaille *et al.* may optimally identify abnormalities of gait in the postacute phase [86]. Dual tasking during rehabilitation is commonly performed clinically to challenge the person and optimize gait performance.

FACTORS THAT AFFECT VESTIBULAR REHABILITATION OUTCOMES

The clinical practice guideline for peripheral vestibular hypofunction outlines several factors that

negatively affect outcomes in vestibular rehabilitation, including longer time from onset, long-term use of vestibular suppressant medications, and patient comorbidities such as migraine, peripheral neuropathy, and anxiety [1▪▪]. A recent study by MacDowell *et al.* [87] indicates that persons with vestibular disorders and comorbid anxiety and depression improve with vestibular rehabilitation. However, groups with negative affect did not achieve similar subjective and objective outcome measure scores as those with positive affect [87]. Ocular misalignments may also negatively affect recovery time after vestibular injury [88]. Catastrophizing, hyper-vigilance, higher levels of neuroticism, and lower levels of extraversion may adversely affect rehabilitation outcomes [24▪▪,89]. Research supports the use of psychological adjuncts to vestibular rehabilitation that may improve outcomes for patients with anxiety [1▪▪]. Walker *et al.* [90] found that physical therapists report using various cognitive-behavioral techniques with patients who have anxiety, such as greater emphasis on education and building trust, but outline the need for specialized psychological support and guidance when treating some patients with anxiety in vestibular rehabilitation. Additional research is needed to determine best treatment practices for persons with vestibular disorders and psychological morbidity.

CONCLUSION

Evidence is growing related to the positive effects of vestibular rehabilitation in persons living with dizziness and balance impairments. Other than increases in symptoms postexercise in persons with concussion, there is little in the literature to suggest that vestibular rehabilitation is harmful [1▪▪]. With greater knowledge of which factors negatively affect recovery, clinicians can better predict prognosis for their patients. There is support in the literature for the use of vestibular rehabilitation for persons living with peripheral and central vestibular disorders. Patients with gait and/or balance impairment, dizziness, and certain psychologic profiles can improve after vestibular rehabilitation.

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Conflicts of interest

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