Lea J, Pothier D (eds): Vestibular Disorders. Adv Otorhinolaryngol. Basel, Karger, 2019, vol 82, pp 164–169
DOI: 10.1159/000490285

Advances in Vestibular Rehabilitation

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Abstract

Vestibular rehabilitation is an exercise-based program that has been in existence for over 70 years. A growing body of evidence supports the use of vestibular rehabilitation in patients with vestibular disorders, and evolving research has led to more efficacious interventions. Through central compensation, vestibular rehabilitation is able to improve symptoms of imbalance, falls, fear of falling, oscillopsia, dizziness, vertigo, motion sensitivity and secondary symptoms such as nausea and anxiety. Early intervention is advised for falls prevention and symptom management; however, symptomatic patients with chronic vestibular disorders may still demonstrate benefit from a course of vestibular rehabilitation. Recent advances in balance and gait training, gaze stability training, habituation training, use of virtual reality, biofeedback, and vestibular prostheses are discussed in this chapter in the context of unilateral and bilateral vestibular disorders.

Introduction

The use of exercises for the treatment of patients with vestibular symptoms dates back 70 years ago, when two practitioners, Sir Terence Cawthorne and Harold Cooksey, observed that patients with vestibular injuries tended to do better when they were given exercises designed to encourage eye and head movements in a graduated fashion [1, 2]. Since the late 1990s, there has been a significant increase in evidence regarding treatment techniques used for patients with vestibular pathologies, allowing interventions to become more refined and efficacious.

The physical presentation and functional limitations of patients with similar diagnoses can often be quite different. Although most vestibular rehabilitation therapy (VRT) exercise programs utilize eye and head movements, the types of exercise and their prescription is individualized and exercises are targeted to the deficits and symptoms of the patient, rather than being specific to a particular diagnosis. Symptom complaints may include imbalance (in static positions and in gait, especially associated with head movements), falls and fear of falling, oscillopsia, dizziness, anxiety, nausea, vertigo, and motion sensitivity (to body movements or motion in the environment).

A recent Cochrane review comprised 39 trials with more than 2,400 patients with unilateral vestibular dysfunction [3]. The authors reported that there is moderate to strong evidence that VRT is a safe, effective management for unilateral peripheral vestibular dysfunction. Not surprisingly for the specific diagnostic group of BPPV, the canalith repositioning maneuver was the optimal first line intervention compared to exercise-based VRT; although some studies suggested that the use of vestibular rehabilitation after repositioning maneuvers promoted greater balance and mobility skills [3]. After repositioning, some patients continue to have balance deficits up to 1–3 months post repositioning [4, 5].

A clinical practice guideline was also recently developed by international experts to optimize rehabilitation outcomes in patients with peripheral vestibular hypofunction. Based on strong evidence and a preponderance of benefit over harm, the guideline suggests that clinicians should offer vestibular physical therapy to persons with unilateral and bilateral vestibular hypofunction (BVH) with impairments and functional limitations related to the vestibular deficit [6]. This chapter will focus on recent advances in VRT for patients with unilateral and bilateral vestibular disorders.

Unilateral Vestibular Hypofunction

Patients presenting with unilateral hypofunction of the vestibular system are good candidates for VRT [3, 6]. Signals from the vestibular labyrinth provide accurate information to the brain regarding head movements. When there is an asymmetry of vestibular function in the acute phase, the brain interprets this asymmetrical information as though the head is moving and patients perceive a sensation of movement even at rest. As central compensation occurs, that constant sense of motion diminishes, however, the brain may perceive motion with head movements, causing dizziness and imbalance [7]. Furthermore, if there are deficits of the vestibulo-ocular reflex (VOR), patients experience visual blurring and a perception of dizziness with head motion. As a result, patients tend to avoid moving their head, which can delay the dynamic compensation process and lead to secondary issues such as fear of movement, anxiety, and neck stiffness. Vestibular rehabilitation aims to promote compensation and hence, many of the balance, gait, and gaze stability exercises incorporate head movements. Recovery from unilateral vestibular hypofunction is quite good and most patients return to normal activities.

Balance and Gait Training

Static balance training is an important aspect of VRT. The patient may be asked to maintain balance in a variety of situations, such as with eyes open or eyes closed on level ground and on compliant surfaces such as thick carpets or a foam pad. Exercises with the eyes closed decrease visual dependence on balance; whereas exercises on compliant surfaces alter somatosensory inputs required for balance and promote the use of visual and vestibular inputs to maintain balance. Once patients are able to master these balance conditions, the addition of head movements in all planes add perturbations to their balance and facilitate compensation [8]. External perturbations are also widely used to increase a patient's stability and generate strategies to maintain balance and avoid falls.

In an effort to minimize symptoms of dizziness and unsteadiness, patients tend to adopt en-bloc postures (head and trunk remain rigid together) when they are in motion. The addition of head movements is often incorporated during walking

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exercises. Head movements are encouraged in different planes to allow the brain to desensitize these movements and compensate for the asymmetrical vestibular function so that patients can learn to normalize their balance in gait [8].

Gaze Stabilization

Gaze stability exercises are used for VOR adaptation; these exercises are provided with the aim of increasing the VOR gain and stabilizing vision during active and passive head movements. This dynamic process is mediated through visual inputs (retinal slip) and relies on the occipital lobes, midbrain, and cerebellum to use the error information to recalibrate the VOR gain [9]. The first exercise many patients start with is referred to as "VOR × 1." Patients are asked to maintain gaze on a stationary target in front of them, while they move their head on the horizontal plane for 1–2 min, then in the vertical plane for 1–2 min, with the goal of keeping the target in focus [10]. Such exercises are usually given as part of the home exercise program, and patients are expected to complete them 3–5 times daily. The patient gradually increases the velocity of head movement to the level just before they lose focus of the target. As VOR function improves, patients are able to perform the movement with fewer symptoms at faster head velocities. The exercise is progressed to the use of more visually stimulating targets, such as checkerboards and eventually moving targets, where the target moves opposite to the head movement – often referred to as "VOR × 2" exercises. Speed, backgrounds, distance to the target, and stance vs. gait are all manipulated as part of the exercise program.

The VOR exercises have been shown to improve dynamic visual acuity [11, 12]. Proposed mechanisms include an increase in the VOR gain independent of peripheral vestibular recovery and an increase in the number of compensatory saccades during head rotations [11, 12]. Recent evidence suggests that the angular VOR can be selectively trained on the involved side in the laboratory. A trial is ongoing to determine if long-term adaptation can occur from training at a preset VOR gain [13].

Timing of Intervention

People with acute unilateral vestibular loss are often responsive to early VRT interventions [14]. Hall et al. [6] reported that early VRT intervention after vestibular loss reduced falls, improved activities of daily living, and demonstrated improvements in quality of life. Early exercise can also prevent complications such as fear of movement, anxiety, and falls. In cases where the vestibular loss is chronic and uncompensated, VRT is still indicated, however, the therapist must identify the maladaptive strategies or conditions that have prevented compensation and manage them. Some of the barriers to recovery that may need to be addressed include avoidance of certain movements, psychological factors (fear of falling, anxiety /depression), use of vestibular suppressants, medical comorbidities such as migraines, or visual, sensory or central pathologies [15]. If such issues are present, psychological support, education, and a multi-disciplinary approach may be beneficial.

Visually Induced Dizziness

After vestibular hypofunction, some patients tend to over-utilize visual information, and this can result in symptoms being provoked or made worse when confronted with disorienting visual stimuli or motion in the environment, such as in crowds, traffic, grocery stores, when watching movies or when visualizing complex patterns. Bittar and Lins recently looked at the characteristics of patients with persistent postural perceptual dizziness, a recent diagnosis that has been included in the International Classification of Disease 11. They found that 74% of patients with persistent postural perceptual dizziness complained of visually induced dizziness and a high percentage of these patients showed symptomatic benefit from medications such as selective serotonin reuptake inhibitors [16]. According to

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Bronstein et al. [17], relying primarily on vision after a vestibular disorder is a negative predictor of successful rehabilitation. Physical therapy interventions have been shown to reduce visually induced dizziness [18–21], however, exercises may need to be combined with medications to decrease sensitivity to provocative stimuli [15].

Habituation type exercises are generally preferred to decrease visual symptoms. The exercises are applied through graded, repetitive exposure to the movements or situations that provoke symptoms, with the goal of desensitizing the patient to that stimulus. This can involve training balance and the VOR with a variety of visual backgrounds, through the use of virtual reality or other immersive environments [18, 22, 23] or through use of optokinetic exercises such as disco balls, screen savers or with take home DVDs showing optokinetic stimulation [19, 20]. Developments in the gaming industry have resulted in low cost virtual reality systems like the Nintendo Wii Fit Plus, which also uses force plate technology to gather center of pressure information to provide visual feedback on the screen during balance games [24]. Meldrum et al. [25] utilized the Wii Fit in a recent randomized trial, but focused on balance exercises rather than on visual symptoms. The use of the Wii Fit and conventional balance exercises yielded functional improvements but there were no differences in outcomes. Patients did, however, report that they enjoyed the virtual training [25]. Given that it is an enjoyable activity that can be done at home, the Wii Fit or other newer low cost virtual reality devices on the market may be useful tools for decreasing the responsiveness to visual stimuli, however, further studies are needed to validate this effect.

Bilateral Vestibular Hypofunction

Bilateral vestibular loss is a challenging condition for patients, especially when the loss is complete. Symptoms of postural instability, oscillopsia, and falls are often more pronounced in this patient population [26]. Central compensation with BVH occurs through sensory reweighting [27]. With BVH, the goal is to: (1) augment vision and proprioception to compensate for the vestibular loss, (2) develop compensatory strategies in situations of imbalance, and (3) develop substitution strategies to assist with gaze stability. Vestibular rehabilitation assumes an important role in recovery/compensation of these three areas with the goal of enhanced patient safety and an increased independence.

Biofeedback Training

Patients with BVH often become unsteady in the dark or on uneven ground, therefore, the VRT exercises used often involve learning to stand and balance with eyes closed or on compliant surfaces. In balance situations, where vision and proprioceptive information are compromised (i.e., on a compliant surface with eyes closed), patients typically fall. A recent advance in VRT has come from the use of biofeedback devices that code for head and body orientation and provide auditory or vibrotactile feedback to enhance postural control [28–31]. With auditory biofeedback, patients are provided with sound coding related to their body sway. Dozza et al. [28] reported that the auditory biofeedback compensates for missing vestibular information; a patient with bilateral vestibular loss on a compliant surface with eyes closed benefits far more than a healthy individual. They noted a higher frequency of postural corrections in the BVH group [28]. Vibrotactile feedback studies have demonstrated that patients with BVH are capable of using orientationally correct vibrotactile cues on the head to stabilize posture in standing [29] or on the trunk to improve gait [30]. Further studies are needed to determine if there is any long-term training effect with these devices. Portable vibrotactile devices that can be used at home are currently being tested to determine if the devices can assist with fall reduction and improve postural stability.

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Gaze Stabilization

To manage complaints of oscillopsia, in addition to gaze stability exercises (as used with unilateral vestibular hypofunction), saccadic substitution exercises are used, where patients are trained to coordinate eye and head movements [10]. Studies confirm that performing saccadic eye movements has a positive effect on stabilizing gaze by way of improving dynamic visual acuity. This improvement, however, does not seem to be due to increases in the gain of the VOR, rather a proposed mechanism for this improvement may lie in the central programming of eye movements [11, 32].

A recent systematic review attempted to determine the effect of VRT on adults with BVH. They reported that there is moderate evidence that gaze and postural stability improve after VRT [33].

Vestibular Prosthesis

Despite its benefits, VRT does not lead to recovery of the vestibular system in patients with BVH and patients can still be left with significant impairments, especially in environments where visual or somatosensory cues are diminished or absent. BVH also leads to a considerable reduction in quality of life and increases risk of falls [34], thus supporting the need for future advances in VRT to mitigate these issues. Surgically implanted vestibular prosthesis prototypes are being used in select patients in centers around the world. These implants aim to detect motion and electrically stimulate the corresponding ampullary nerves to generate VOR responses. Preliminary results show that the stimulation can activate vestibular-ocular reflex pathways and generate smooth and controlled eye movements [35]. Future advances in this field, along with vestibular rehabilitation to train patients to use the inputs from these implants, will hopefully lead to improved function and less disability in patients living with BVH.

Conclusion

Vestibular rehabilitation techniques have evolved over the past few decades, and there is reliable research into the efficacy of vestibular exercises for peripheral vestibular dysfunction. Customized treatment programs focus on decreasing symptoms of dizziness, oscillopsia and postural instability, and addressing the patient's functional deficits. The aim of the exercises is to promote central compensation for the vestibular dysfunction. While patients with unilateral vestibular dysfunction tend to do quite well and can often return to all or most of their activities of daily living, patients with bilateral vestibular loss continue to have difficulties with balance. Future advances in the area of vestibular prostheses may prove beneficial for persons living with BVH.

References

1 Cawthorne T: The physiological basis for head exercises. J Chartered Soc Physiother 1944;3:106–107.

2 Cooksey FS: Rehabilitation in vestibular injuries. Proc R Soc Med 1946;39:273–278.

3 McDonnell MN, Hillier SL: Vestibular rehabilitation for unilateral peripheral vestibular dysfunction. Cochrane Database Syst Rev 2015;1.

4 Blatt PJ, Georgakakis GA, Herdman SJ, Clendaniel RA, Tusa RJ: The effect of canalith repositioning maneuver on resolving postural instability in patients with benign paroxysmal positional vertigo. Am J Otol 2000:21:356–363.

5 Giacomini PG, Alessandrini M, Magrini A: Long-term postural abnormalities in benign paroxysmal positional vertigo. ORL J Otorhinolaryngol Relat Spec 2002; 64:237–241.

6 Hall CD, Herdman SJ, Whitney SL, Cass SP, Clendaniel RA, Fife TD, Furman JM, Getchius TS, Goebel JA, Shepard NT, Woodhouse SN: Vestibular rehabilitation for peripheral vestibular hypofunction: an evidence-based clinical practice guideline: from the American physical therapy association neurology section. J Neurol Phys Ther 2016;40:124–155.

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DOI: 10.1159/000490285

7 Herdman SJ, Blatt P, Schubert MC, Tusa RJ: Falls in patients with vestibular deficits. Am J Otol 2000;21:847–851.
8 Klatt BN, Carender WJ, Lin CC, Alsubaie SF, Kinnaird CR, et al: A conceptual framework for the progression of balance exercises in persons with balance and vestibular disorders. Phys Med Rehabil Int 2015;2:1044.
9 Gretsty MA, Hess K, Leech J: Disorders of the vestibule-ocular reflex producing oscillopsia and mechanisms compensating for loss of labyrinthine function. Brain 1977;100:693–716.
10 Herdman SJ: Exercise strategies for vestibular disorders. Ear Nose Throat J 1989;68:961–964.
11 Schubert M, et al: Mechanism of dynamic visual acuity recovery with vestibular rehabilitation. Arch Phys Med Rehabil 2008;89:500–507.
12 Schubert MC, Migliaccio AA, Della Santina CC: Modification of compensatory saccades after aVOR gain recovery. J Vestib Res 2006;16:285–291.
13 Migliaccio AA, Schubert MC: Pilot study of a new rehabilitation tool: improved unilateral short-term adaptation of the human angular vestibulo-ocular reflex. Otol Neurotol 2014;35:310–316.
14 Vereeck L, et al: The effect of early customized vestibular rehabilitation on balance after acoustic neuroma resection. Clin Rehabil 2008;22:698–713.
15 Whitney SL, Alghadir AH, Anwer S: Recent evidence about the effectiveness of vestibular rehabilitation. Curr Treat Options Neurol 2016;18:13.
16 Bittar RS, Lins EM: Clinical characteristics of patients with persistent postural-perceptual dizziness. Braz J Otorhinolaryngol 2015;81:276–282.
17 Bronstein AM, Golding JF, Gresty MA: Vertigo and dizziness from environmental motion: visual vertigo, motion sickness, and drivers' disorientation. Semin Neurol 2013;33:219–230.
18 Pavlou M, Kanegaonkar RG, Swapp D, Bamiou DE, Slater M, Luxon LM: The effect of virtual reality on visual vertigo symptoms in patients with peripheral vestibular dysfunction: a pilot study. J Vestibular Res 2012;22:273–281.
19 Pavlou M, Bronstein AM, Davies RA: Randomized trial of supervised versus unsupervised optokinetic exercise in persons with peripheral vestibular disorders. Neurorehabil Neural Repair 2013;27:208–218.
20 Pavlou M: The use of optokinetic stimulation in vestibular rehabilitation. J Neurol Phys Ther 2010;34:105–110.
21 Szturm T, Ireland DJ, Lessing-Turner M: Comparison of different exercise programs in the rehabilitation of patients with chronic peripheral vestibular dysfunction. J Vestib Res 1994;4:461–479.
22 Gottshall KR, Sessoms PH, Bartlett JL: Vestibular physical therapy intervention: utilizing a computer assisted rehabilitation environment in lieu of traditional physical therapy. Conf Proc IEEE Eng Med Biol Soc 2012;2012:6141–6144.
23 Alahmari KA, Sparto PJ, Marchetti GF, Redfern MS, Furman JM, Whitney SL: Comparison of virtual reality based therapy with customized vestibular physical therapy for the treatment of vestibular disorders. IEEE Trans Neural Syst Rehabil Eng 2014;22:389–399.
24 Clark RA, Bryant AL, Pua Y, McCrory P, Bennell K, Hunt M: Validity and reliability of the Nintendo Wii Balance Board for assessment of standing balance. Gait Posture 2010;31:307–310.
25 Meldrum D, Herdman S, Vance R, Murray D, Malone K, Duffy D, Glennon A, McConn-Walsh R: Effectiveness of conventional versus virtual reality-based balance exercises in vestibular rehabilitation for unilateral peripheral vestibular loss: results of a randomized controlled trial. Arch Phys Med Rehabil 2015;96:1319–1328.
26 Brandt T: Bilateral vestibulopathy revisited. Eur J Med Res 1996;1:361–368.
27 Dieterich M, Bauermann T, Best C, Stoeter P, Schlindwein P: Evidence for cortical visual substitution of chronic bilateral vestibular failure (an fMRI study). Brain 2007;130:2108–2116.
28 Dozza M, Horak FB, Chiari L: Auditory biofeedback substitutes for loss of sensory information in maintaining stance. Exp Brain Res 2007;178:37–48.
29 Goebel JA, Sinks BC, Parker BE Jr, Richardson NT, Olowin AB, Cholewiak RW: Effectiveness of head-mounted vibrotactile stimulation in subjects with bilateral vestibular loss: a phase 1 clinical trial. Otol Neurotol 2009;30:210–216.
30 Wall C 3rd: Application of vibrotactile feedback of body motion to improve rehabilitation in individuals with imbalance. J Neurol Phys Ther 2010;34:98–104.
31 Hegeman J, Honegger F, Kupper M, Allum JH: The balance control of bilateral peripheral vestibular loss subjects and its improvement with auditory prosthetic feedback. J Vestib Res 2005;15:109–117.
32 Herdman SJ, Hall CD, Schubert MC, Das VE, Tusa RJ: Recovery of dynamic visual acuity in bilateral vestibular hypofunction. Arch Otolaryngol Head Neck Surg 2007;133:383–389.
33 Porciuncula F, Johnson CC, Glickman LB: The effect of vestibular rehabilitation on adults with bilateral vestibular hypofunction: a systematic review. J Vestib Res 2012;22:283–298.
34 Herdman SJ, Blatt P, Schubert MC, Tusa RJ: Falls in patients with vestibular deficits. Am J Otol 2000;21:847–851.
35 Guinand N, van de Berg R, Cavuscens S, Stokroos RJ, Ranieri M, Pelizzone M, Kingma H, Guyot JP, Perez-Fornos A: Vestibular implants: 8 years of experience with electrical stimulation of the vestibular nerve in 11 patients with bilateral vestibular loss. ORL J Otorhinolaryngol Relat Spec 2015;77:227–240.

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