Case Report
Vestibular Rehabilitation Decreases Fall Risk and Improves Gaze Stability for an Older Individual with Unilateral Vestibular Hypofunction

Erin Horning, DPT;[1] Sharon L. Gorman, PT, MS, GCS[2]

[1] Kaiser Permanente, Sacramento, CA
[2] Samuel Merritt College, Oakland, CA

This case was presented as a poster at the 4th World Congress of the International Society of Physical and Rehabilitation Medicine, Seoul, South Korea on June 13, 2007.

ABSTRACT

Background and Purpose: Partial or total unilateral vestibular loss is the third most common cause of peripheral vestibular dysfunction. Dysfunction of one or both of the vestibular mechanisms can manifest physically as abnormalities of posture, balance, and/or visual acuity. This case report describes physical therapy examination and individualized intervention with vestibular rehabilitation for a patient with unilateral vestibular hypofunction. **Case Description**: The patient was an 80-year-old male with electronystamographically confirmed unilateral vestibular loss of 98.3%. He demonstrated altered balance and gaze stability classifying him as having an increased risk for falling. **Outcomes:** After 5 weeks of individualized vestibular rehabilitation, the patient significantly decreased his fall risk from 11 to 20 of 24 on the Dynamic Gait Index. His gaze stability also improved from a 4 to 1 line disparity with dynamic visual acuity testing. The patient also had a decrease in perceived disability on the Dizziness Handicap Inventory from 30/100 at evaluation to 12/100 at discharge. **Conclusion:** Individualized vestibular rehabilitation decreased fall risk and improved gaze stability for a patient with significant unilateral vestibular hypofunction.

Key Words: vestibular rehabilitation, gaze stabilization, vestibular hypofunction, geriatric physical therapy

INTRODUCTION

Falls are considered one of the leading contributing factors for morbidity and mortality in aging adults. Over one-third of adults over age 65 experiences at least one fall each year.[1] Visual detection capacities and reactive responses tend to become less efficient as age increases; potentially altering efficacy of dynamic balance.[2] Clinically, advanced age has been associated with decreased quality of performance on balance testing.[3] It is important that in-depth examination and evaluation of balance addressing each contributory system be completed during physical therapy evaluation of any patient with history of falling, and of individuals of advanced age regardless of fall history.

Dynamic postural control evolves from interactions between the visual, somatosensory, and vestibular systems.[4] Through visual images the brain is alerted to changes in terrain, environment, and surroundings.[5] Concurrently, sensory receptors in soft tissue, joints, and muscle throughout the body send pertinent information through the spinal cord to the cerebellum and somatosensory cortex to alert the brain to body position and movement. The vestibular system augments the information from the other systems by sensing movement of the head and maintaining stability of visual images on the retina to maintain postural control.[6]

Falls are often multifactorial, but vestibular dysfunction is an important risk factor by itself. The vestibular system functions in stabilizing gaze and in postural control, both of which contribute to balance.[6] By detecting movement of the head relative to gravity, the vestibular system sends pertinent information to maintain upright posture and balance. Symptoms of vestibular loss may include dizziness, vertigo, oscillopsia, nausea, nystagmus, vomiting, and disequilibrium.[7] Dizziness is the most common reason for adults over age 75 to see a physician; 70% will experience symptoms for more than 2 weeks.[6] Dysfunction of one or both of the vestibular mechanisms can manifest physically as abnormalities of posture, balance, and visual acuity or a combination of these problems.

According to *The Guide to Physical Therapist Practice*, physical therapists examine, evaluate, and provide risk reduction and primary prevention interventions for individuals with loss of balance and history of falling.[8] Vestibular rehabilitation, dating back to the 1940s, was largely based on anecdotal evidence.[4] Recent research has led to refinement of interventions that appear effective for a variety of vestibular disorders.[4]

Address all correspondence to: Sharon L. Gorman, Department of Physical Therapy, Samuel Merritt College, 450 30th Street, Suite 3734, Oakland, CA 94609 Ph: 510-869-6511 x4720, Fax: 510-869-6282 (sgorman@samuelmerritt.edu).

Currently, vestibular rehabilitation has become one of the most evidence-based modalities offered by physical therapists.[9] The popularity of vestibular research may be due to its success in decreasing the incidence of falls and the trend toward fall prevention demonstrated in many studies. Herdman et al[10] suggest that vestibular rehabilitation alone could reduce fall risk in patients with vestibular impairment. Horak et al[11] found that vestibular exercises resulted in improved postural stability when compared to placebo. Shepard and Telian[12] conclude that a customized vestibular exercise program leads to decreased dizziness and asymmetry with balance testing, providing additional evidence of the efficacy of vestibular rehabilitation. Both Szuturm et al[13] and Cowand[14] suggest that vestibular rehabilitation results in greatest improvements with a supervised versus an unsupervised home exercise program.

This case report describes the examination, evaluation, and development of a plan of care for an aging adult with unilateral vestibular loss. This patient was referred to physical therapy for balance improvement and was treated using a home program coupled with intermittent visits to PT for advancement of his vestibular rehabilitation exercises.

CASE DESCRIPTION

The patient, BR, was an 80-year-old retired male who reported spells of dizziness lasting several minutes and occurring intermittently during the day. He reported his dizziness as a feeling of being off-balance that occurred when walking or standing, which was exacerbated in busy environments or with decreased lighting. These symptoms had caused him to discontinue his hobbies of playing golf and tennis. He had fallen once in the previous month when ascending a flight of stairs. He also experienced occasional ringing in his right ear and hearing loss in both ears. His past medical history was significant for heart palpitations, laser vision correction, and seasonal allergies. Prior to symptom onset, he had been ill for approximately 3 weeks and was prescribed a non-neurotoxic antibiotic treatment. BR was not taking any medications at the time of his physical therapy evaluation and continued without medication during treatment.

MEDICAL EXAMINATION

Prior to presenting to the physical therapy department for evaluation, BR was examined by a Clinical Audiologist. Electronystagmography (ENG) is a procedure in which quantitative assessment is made of the vestibular system through electrodes around the patients' eyes.[15] ENG testing consists of ocular mobility testing, bithermal caloric testing, and positional testing.[15] The series of tests aims to determine the function of the peripheral vestibular system of each ear.

BR's ENG assessment was within normal limits for saccades, optokinetics, tracking, sitting, and supine positions as well as Dix-Hallpike maneuver. However, caloric tests were abnormal, revealing right unilateral dysfunction of 98.3%. Although he showed severe dysfunction, ice water caloric testing indicated he had some residual vestibular function. Caloric testing is considered the gold standard in identifying peripheral unilateral vestibular hypofunction.[6] The results suggested vestibular deficit arising from a peripheral disorder.

PHYSICAL THERAPY EXAMINATION

The PT examination included examination of body structure and function, activity limitation, and participation limitation (Table 1). BR was a tall, athletic male with head-forward posture who walked with decreased knee extension on his right in mid-to-terminal stance. Range of motion assessment was unremarkable, except limitation of bilateral ankle dorsiflexion to neutral. According to the American Academy of Orthopaedic Surgeons[9] the mean dorsiflexion range of motion at the ankle is 20°, other studies have reported age and gender adjusted means ranging between 8.5° to 13.1°.[16,17] A study by Kemoun et al[7] suggested that ankle dorsiflexion was a factor related to fall prediction. Proprioception (finger-nose and heel-shin) and coordination (rapid alternating movement) testing, as described by Umphred,[18] were unimpaired. During balance testing, BR demonstrated positive sharpened/tandem Rhomberg with eyes open and arms at his side. He could independently achieve the testing position but was unable to hold the position without a corrective step for more than 8 seconds. Rhomberg testing is considered positive or abnormal if the patient demonstrates excessive sway, loss of balance, or stepping when attempting to maintain the test position during a 30-second period.[18]

BR scored 11 out of 24 on the Dynamic Gait Index (DGI), which categorized him as having increased fall risk; scores less than 20 indicate an increased risk for falling.[5] According to Furman and Cass,[20] the vestibulospinal manifestations of unilateral peripheral vestibular loss may include disequilibrium and postural instability that includes leaning and veering of gait to the side of the lesion. BR demonstrated veering toward the

Table 1. Comprehensive PT Examination Schema

Test/Measure	Body Function/Structure	Activity Limitations	Participation Limitations
Sharpened Rhomberg	X		
Dynamic Gait Index	X	X	
Self-reported Activity Restrictions			X
Dizziness Handicap Inventory			X
Dynamic Visual Acuity	X		

right during the gait assessment portion of the DGI. The DGI was developed by Shumway-Cook and Wollacott[5] as a tool to assess balance with functional activities such as walking, stepping over obstacles, and walking with visual challenges. Scores on the DGI have correlated well (r = 0.78) with scores on the Berg Balance Scale, which suggests that the DGI is a valid test in identifying increased fall risk as a result of altered balance.[21] Shumway-Cook et al[22] reported the reliability of the DGI as excellent with 0.96 inter-rater reliability and 0.98 test-retest reliability.

BR scored 30 out of 100 on the Dizziness Handicap Inventory (DHI), with 0 indicating lack of perceived disability and 100 being marked perception of disability.[23] The DHI is scored in subsections dealing with emotional, functional, and physical disability. BR scored 12 out of 36 in the functional subsection, 12 out of 28 in physical subsection, and 6 out of 36 in the emotional subsection. Test-retest reliability of the DHI was high (r = .97, $p < .0001$) in a study conducted by Jacobson[23] amongst 14 patients with unspecified vestibular disorders.

BR demonstrated minimal oculomotor and vestibulo-ocular abnormality, both of which are tested to rule in or rule out cerebellar pathology. The oculomotor circuit participates in control of saccadic eye movements.[24] Saccades are rapid eye movements made in order to bring a target into the center of the line of sight and are used voluntarily and reflexively.[25] BR demonstrated mild catch-up saccades with testing. However, Desmond[25] cautions the practitioner to avoid over interpreting abnormal results with oculomotor testing. Because BR's ENG assessment for saccades was deemed normal, his mild finding on clinical testing during his PT examination was not included as an objective finding conclusive of impairment.

The vestibulo-ocular reflexes (VOR) work to keep the eyes fixed when the head moves.[25] The VOR is assessed clinically through dynamic visual acuity testing or active headshake while focusing on an object. Using either form of VOR assessment, the clinician observes eye movement quality and relies on subjective report of ability to focus on the object from the patient. Dynamic visual acuity (DVA) is defined as the number of lines on the visual acuity chart that become illegible with head movement when compared to static testing.[25] Normal disparity in dynamic and static visual acuity is considered a 1 line discrepancy.[25] BR had abnormal disparity in static versus dynamic visual acuity when reading 10 feet from the Snellen chart. He was able to read the 5-foot line statically and the 9-foot line dynamically, indicating a 4-line discrepancy. The underlying pathology of unilateral vestibular loss results in decreased gain of the VOR. Foster et al[26] found that decreased gain of the VOR leads to impairment in dynamic visual acuity.

PHYSICAL THERAPY DIAGNOSIS AND PLAN OF CARE

BR's diagnostic test results of decreased ankle dorsiflexion range of motion, abnormal balance, and abnormal VOR findings led to physical therapy diagnosis of decreased ability to participate in functional and leisure activities due to limitations in static and dynamic balance during ambulation and transitional activities, secondary to impaired dynamic visual acuity related to vestibular hypofunction right greater than left.

The goals for physical therapy were (1) to improve gaze stabilization as evidenced by a change from 4 to 2 line discrepancy on Dynamic Visual Acuity testing within 6 weeks and (2) to improve quality and safety of ambulation, as evidenced by a change in Dynamic Gait Index (DGI) score from 11 to 20 within 6 weeks.

Intervention

The initial intervention (a single session) included instruction in gaze stabilization exercises to enhance vestibular adaptation (Figure 1). Herdman et al[27] studied patients with unilateral vestibular loss who performed vestibular exercises and showed significant improvement in dynamic visual acuity as compared to placebo exercise. BR's exercise regimen consisted of exercises as described by Herdman.[28,34] To begin the exercise, BR was seated, and held a business card at arm's length so that printed words on the card were legible and in focus. BR was instructed to move his head from left to right at a self-selected speed, keeping the printed material in focus, while holding the card still, for one-minute period, 3 times per day. The frequency and duration of the home exercise program was determined based on evaluation and on previous research,[28,34] which suggests vestibular adaptation requires more than a few seconds of active practice each day.

Hu and Woollacott[29] reported improved balance as a result of exercises aiming to optimize the interaction of visual, vestibular, and somatosensory systems in individuals aged 65 to 90 years old. This evidence was considered in designing balance training activities for BR's home exercise. In order to focus on his somatosensory and vestibular components by removing visual input he was instructed to stand in a corner with wide base of support by placing his feet together with arms at his side and eyes closed, with the goal of remaining steady for 30 seconds at least 3 times per day. He was further instructed to open his eyes and shake his head from left to right, and then and up and down for an additional 30 seconds for each movement direction, 3 times per day. The combination of head shakes, removing visual input by closing his eyes, and standing with a narrow base of support provided practice and integration across the three systems which contribute to balance and postural control.

Eight days after initial evaluation, BR returned to the clinic for follow-up. He reported one new episode of disequilibrium that occurred when he got up in the middle of the night without the lights on. Overall, he reported feeling as though his tolerance for walking had improved. BR demonstrated improved static standing with Rhomberg testing, eyes closed evidenced by the ability to hold the position longer prior to taking a protective step. Upon reassessment, his VOR showed no change. When he demonstrated his vestibular exercises, the therapist noted that he was sitting much further than an arm's length from his target. On further questioning, BR

1a. Look straight ahead.

1b. Turn head 45º to right.

1c. Turn head 45º to left.

Figure 1. Gaze stabilization exercise (x1 viewing).

admitted that he was not able to maintain visual focus on the printed text at the distance he demonstrated. The therapist provided additional feedback, reinforcing the importance of maintaining his visual focus on the print throughout the exercise. Additional practice resulted in more accurate performance of the exercise. BR's home program was progressed to include standing with narrow base of support, with arms now crossed over his chest for all 3 conditions described previously (Table 2). His vestibular exercise was not progressed and continuation of his initial gaze stabilization exercises (Figure 1) was assigned.

Twenty days after initial evaluation BR presented with negative Rhomberg in both the eyes open and eyes closed conditions. However, with sharpened Rhomberg testing he was only able to maintain test position for 15 seconds before taking a protective step. He was instructed to use sharpened Romberg position with eyes opened as a progression of his balance exercise for his home program. BR demonstrated decreased path deviation when walking with his head turned to his right, a test item on the DGI he had previously had difficulty with. His gaze stabilization exercises were further progressed after 3 weeks; a busy background of checkerboard and striped print was placed behind the business card to increase the demand on the oculomotor control system or by adapting foot position in standing from wide base of support to narrower base of support to challenge postural control. He was instructed as described earlier (Figure 2, Table 2). As stated by Herdman,[4,31] exercises targeting gaze stabilization improvement may help improve postural stability.

During this session he was asked to carry out his entire vestibular program supervised to assure appropriate mechanics. Given his history of improper demonstration of exercises, he demonstrated while receiving active verbal feedback and was able to correctly perform his home program by the end of this treatment session.

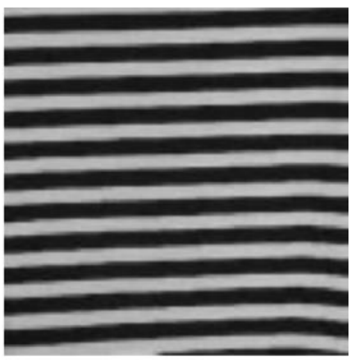
After 4 clinic sessions over a 5-week period, BR was reassessed. See Table 3 for a summary of outcomes. He reported that he had resumed golfing and playing tennis. His only complaint was decreased endurance with activity. Re-test of his Dynamic Gait Index (DGI) resulted in a total score of 20 out of 24, meeting the physical therapy goal and taking him out of range for increased fall risk. Dynamic visual acuity reassessment revealed 1 line discrepancy, surpassing the physical therapy goal of 2 line discrepancy improvement. Although not addressed in his physical therapy goals, BR also had decreased perception of dizziness handicap evaluated through the Dizziness Handicap Inventory. Total DHI score dropped from 30 to 12 out of 100, demonstrating a decreased perception of handicap. From evaluation his perception of emotional burden based on his condition dropped from a score of 6 to 0 while both physical and functional domains dropped from 12 at evaluation to 6 at discharge. Finally, BR demonstrated negative Rhomberg with both test positions, further solidifying that his balance had also improved since initial evaluation.

Discussion

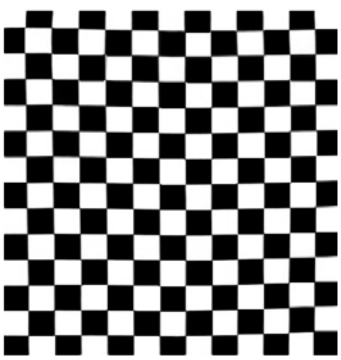
Two studies[3,11] have shown the success of vestibular rehabilitation over 6 or more weeks of individualized treatment. Other studies suggest that vestibular rehabilitation is most effective when supervised rather than through assignment of a home program.[13,14] BR demonstrated improvement in balance and gaze stability and significantly decreased his risk for falling after 4 physical therapy sessions over a 5-week period, coupled with an home program of vestibular exercises that were

Table 2. Summary of Home Vestibular Exercise Program and Progression

Physical Therapy Session	VOR exercises	Balance exercises
First (day 1)	Horizontal headshakes (see Figure 1)	Head shakes wide BOS eyes open
Second (day 9)	Horizontal headshakes	Head shakes narrow BOS eyes open
Third (day 20)	Horizontal headshakes distracting background (see Figure 2)	Head shakes sharpened Rhomberg position eyes open
VOR = vestibulocular reflex, BOS = base of support		



2a. horizontal lines



2b. checkerboard pattern

Figure 2. Examples of distracting backgrounds for advancement of gaze stabilization exercise.

sequentially advanced to place greater demand on vestibular and postural control systems. The outcomes reported in this case are consistent with those reported in previous studies.

As a case report there are limitations that should be mentioned. A single physical therapist examined, provided intervention, and re-examined BR; this creates a potential for bias in reporting outcomes. Because a case report documents the effects of therapy on a single patient, results may not be generalizable to larger populations of patients/clients encountered in physical therapy practice. While BR demonstrated fall risk on initial examination, his problems were primarily due to his diagnosis of unilateral vestibular hypofunction. Many elders who are at risk for falling do not have a vestibular disorder and would demonstrate other varied risk factors related to their fall risk which were not addressed in this case report. Also, BR presented to physical therapy with a confirmed diagnosis of unilateral vestibular hypofunction assessed via ENG testing. Many patients/clients who present to PT with balance deficits may not have had specific vestibular testing such as ENG assessment to clarify and quantify the integrity of the vestibular system at the time of initial physical therapy examination. The therapist would need to use a focused and systematic examination process to differentiate peripheral vestibular hypofunction from a central vestibular, cerebellar, or cervicogenic impairment, and potentially referral by the PT for ENG testing.

The tests, measures, and interventions used for BR are easily adaptable to most physical therapy settings, allowing many therapists one example of a vestibular rehabilitation program that could be adapted to suit the patients/clients frequently seen in their clinics. The tests and measures used to monitor BR's progress are simple to administer, are not excessively time consuming to perform, and can be used at reassessment to measure change over time with intervention. They do not require costly or bulky pieces of equipment and have been shown to be both reliable and valid, allowing multiple therapists to follow a patient/client over the course of therapy. Additionally, the compliment of tests and measures used to assess BR covered body functions/structures, activity limitations, and participation limitations described in the *International Classification of Functioning, Disability, and Health* Model of Functioning and Disability[31,32] adopted by the World Health Organization (Table 1). By focusing examination of BR's deficits from this variety of viewpoints, a more complete picture of how BR's intervention changed his ability to function and enabled him to return to his normal activities was available to both BR and his therapist.[34] It also allowed the

Table 3. Outcomes After 4 sessions of Vestibular Rehabilitation

Test/Measure	Initial Examination	Final Examination
Dynamic Gait Index (24 is maximum score)	11 / 24 (high fall risk)	20 / 24 (low fall risk)
Dynamic Visual Acuity (2 line disparity is normal)	4 line disparity	1 line disparity
Dizziness Handicap Inventory (lower score indicates less handicap)	30 / 100	12 / 100
Sharpened Rhomberg (sway or step before 30 seconds indicates altered balance)	8 seconds	32 seconds
Self-reported activity restrictions	Not golfing or playing tennis	Resumed golf and tennis

PT to see changes at all levels of BR's abilities throughout the course of physical therapy treatment.

Interventions were home-based, allowing for decreased frequency of PT visits. Weekly PT sessions were effective in assessing, correcting, and advancing BR's exercise regimen to ensure continued challenge and correct performance of the home-based program. The exercise regimen is easily adaptable to accommodate many patients/clients and their specific safety, home, and individual requirements.

This case report provides a model of a home-based vestibular rehabilitation program supported by periodic clinical follow-up. This program of vestibular rehabilitation was effective in decreasing fall risk and increasing gaze stability in an older patient with unilateral vestibular hypofunction. A similar strategy might be effective in home-care and other out-patient settings, for older adults with balance impairment and history of falls related to vestibular dysfunction or to impairments in sensory integration of visual, vestibular, and somatosensory systems.

ACKNOWLEDGEMENTS

To Shari Johnson, PT and Jeanine Perry, PT, Clinical Instructors at Kaiser Permanente. Without Shari's clinical standards and expertise, this report would not have been possible. Jeanine's constant fostering and encouragement also contributed to the successful completion of this case report.

REFERENCES

1. Sattin RW. Falls among older persons: a public health perspective. *Ann Rev Public Health*. 1992;13:489-508.
2. Silsupadol P, Siu KC, Shumway-Cook A, Woolacott MH. Training of balance under single and dual task conditions in older adults with balance impairment. *Phys Ther.* 2006;86:269-281.
3. Kammerlind AS, Odkvist LM, Skargren EI. Effects of home training and additional physical therapy on recovery after acute unilateral vestibular loss-a randomized study. *Clin Rehab*. 2005;19:54-62.
4. Herdman SJ. Advances in the treatment of vestibular disorders. *Phys Ther*. 1997;77:602-618.
5. Gill-Body KM, Beninato M, Krebs DE. Relationship among balance impairments, functional performance, and disability in people with peripheral vestibular hypofunction. *Phys Ther*. 2000;80:748-759.
6. Schubert MC, Minor LB. Vestibulo-ocular physiology underlying vestibular hypofunction. *Phys Ther*. 2004;84:373-386.
7. Kemoun G, Thoumie P, Boisson D, Guieu JD. Ankle dorsiflexion delay can predict falls in the elderly. *J Rehabil Med*. 2002;34:278-283.
8. *Guide to Physical Therapist Practice*. 2nd ed. Alexandria, Va: American Physical Therapy Association; 2003.
9. Norkin CC, White DJ. Measurement of Joint Motion, a Guide to Goniometry. 3rd ed. Philadelphia, Pa: FA Davis Company; 2003:260.
10. Herdman SJ, Schubert MC, Tusa RJ. Strategies for balance rehabilitation: fall risk and treatment. *Ann NY Acad Sci*. 2001;942:394-412.
11. Horak FB, Jones-Rycewicz C, Black FO, Shumway-Cook A. Effects of vestibular rehabilitation on dizziness and imbalance. *J Otolaryngol Head Neck Surg*. 1992;106:175-180.
12. Shepard NT, Telian SA. Programmatic vestibular rehabilitation. *J Otolaryngol Head Neck Surg*. 1995;112:173.
13. Szuturm T, Ireland DJ, Lessing-Turner M. Comparison of different exercise programs in the rehabilitation of patients with chronic peripheral vestibular dysfunction. *J Vestib Rest*. 1994;4:461-479.
14. Coward JL. Efficacy of vestibular rehabilitation. *Otolaryngol Head Neck Surg*. 1998;118:49-54.
15. Ford-Smith CD. The individualized treatment of a patient with benign paroxysmal positional vertigo. *Phys Ther*. 1997;77:848-856.
16. Vandervoort AA, Chesworth BM, Cunningham DA, Peterson DH, Rechnitzer PA, Koval JJ. Age and sex effects on the mobility of the human ankle. *J Gerontol.* 1992;476:M17.
17. Mecagni C, Smith JP, Roberts KE, O'Sullivan SB. Balance and ankle range of motion in community-dwelling women aged

64-87 years: a correlational study. *Phys Ther.* 2000;80:1004-1010.
18. Umphred D. *Neurological Rehabilitaiton*. 4th ed. St. Louis, Miss: Mosby, Inc; 2001:626, 724.
19. Franchignoni F, Tesion L, Martino MT, Ricupero C. Reliability of four simple, quantitative tests of balance and mobility in healthy elderly females. *Aging (Milano)*. 1998;10:26-31.
20. Furman JM, Cass SP. *Vestibular Disorders: A Case Study Approach*. 2nd ed. New York, NY: Oxford University Press; 2003:12.
21. Whitney SL, Walsh MK, Pieffer MD, Furman J. Concurrent validity of the Berg Balance Scale and the Dynamic Gait Index in people with vestibular dysfunction (Abstract). *Neurol Rep*. 1997;21(5):167-168.
22. Shumway-Cook A, Gruber W, Baldwin M, Liao S. The effect of multidimensional exercise on balance, mobility, and fall risk in community living older adults. *Phys Ther*. 1997;77:46-57.
23. Jacobson GP, Newman CW, Hunter L, Balzer GK. Balance function test correlates of the dizziness handicap inventory. *J Am Acad Audiol*. 1991;2:253-260.
24. Kandel ER, Schwartz JH, Jessell TM. *Principles of Neural Science*. New York, NY: MacGraw-Hill; 2000:861,808.
25. Desmond A. *Vestibular Function: Evaluation and Treatment*. New York, NY: Thieme; 2004:90.
26. Foster CA, Demer JL, Morrow MJ, Baloh RW. Deficits of gaze stability in multiple axes following unilateral vestibular lesions. *Exp Brain Res*. 1997;116:501-509.
27. Herdman SJ, Schubert MC, Das VE, Tusa RJ. Recovery of dynamic visual acuity in unilateral vestibular hypofunction. *Arch Otolaryngol Head Neck Surg*. 2003;129:819-824.
28. Herdman SJ. Assessment and treatment of balance disorders in the vestibular deficient patient. In: Balance Proceedings of the APTA Forum, Nashville, Tenn, June 13-15, 1989. Alexandria, VA: American Physical Therapy Association; 1990:87-94.
29. Hu MH, Woollacott MH. Mutlisensory training of standing balance in older adults: 1. postural stability and one-leg stance. *J Gerontol*. 1994;49:52-61.
30. Herdman SJ. Advances in the treatment of vestibular disorders. *Phys Ther*. 1997;77:602-618.
31. Steiner WA, Ryser L, Huber E, et al. Use of the ICF model as a clinical problem-solving tool in physical therapy and rehabilitation medicine. *Phys Ther.* 2002;82:1098-1107.
32. Jette AM. Toward a common language for function, disability, and health. *Phys Ther.* 2006;86:726-734.
33. Schere MJ, McAnaney D, Sax C. Opportunity is possibility; performance is action: measuring participation. *Disabil Rehab*. 2006;28:1467-1471.
34. Herdman SJ, Whitney SL. Treatment of vestibular hypofunction. In: Herdman SJ, ed. *Vestibular Rehabiliation*. 2nd ed. Philadelphia, Pa: F.A. Davis; 2000:387-423.