Hearing, Balance and Communication, 2014; 12: 54–65

informa healthcare

REVIEW ARTICLE

Dizziness in the elderly

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Abstract

Dizziness is largely a problem in the elderly, being the most common reason patients over the age of 75 years seek medical attention. The term is used to describe many sensations, including vertigo, disequilibrium and light-headedness. There are different causes of dizziness in older people such as cardiovascular, neurological or locomotor disease, deterioration in sensory organs, vestibular dysfunction and adverse drug effects. Distinctions between the effects of aging and borderline pathology on instability and falls are not always clear-cut. The elderly's greater risk of balance disorders stems from a higher likelihood of impairments or diseases affecting the physiological subsystems underlying the complex skill of balancing. Diagnosing a specific cause of dizziness or vertigo in older people can be a challenge, since the symptom descriptions are often vague and examination findings overlap among potential causes. Once a differential diagnosis is formulated, it is not clear what tests – if any – will add clinical value. Intervention needs to be tailored to each patient to obtain the maximum effect, designing different exercises for individuals with different kinds of deficiency. Vestibular dysfunction in the elderly can be treated effectively with vestibular rehabilitation, which comprises both a 'generic' type and more specific protocols. Moreover, all the following interventions may have a role: exercises designed specifically to improve muscle function and to address sarcopenia, visual deficit treatment, pacemakers, vitamin D supplementation, gradual withdrawal of psychotropic medication, multifaceted podiatry and hip protectors, cognitive behavioural interventions, home safety assessment and modification interventions. In many cases, a multifactorial approach could be the best solution, as the elderly are frequently affected by multiple deficiencies. There is strong scientific evidence that rehabilitation has a significant role for multisensory dizziness, vestibular hypofunction and locomotor pathologies. More research is needed to evaluate the benefit of rehabilitation for neurological causes and benign positional paroxysmal vertigo.

Key words: *dizziness, rehabilitation, vestibular diseases, aged, postural balance, disability evaluation*

Introduction

Dizziness is often used as a non-specific term to describe many sensations, including vertigo, presyncope, disequilibrium and light-headedness (1). It is largely a problem in the elderly and is the most common reason why patients over 75 years of age seek medical attention. There are a number of different causes of dizziness in older people such as cardiovascular disease, deterioration in several sensory organs, benign positional paroxysmal vertigo and other vestibular dysfunctions, neurological and locomotor disease, and adverse drug effects. There is strong scientific evidence that rehabilitation has a significant role for multisensory dizziness, vestibular hypofunction and locomotor pathologies. The benefit of rehabilitation for neurological causes and benign positional paroxysmal vertigo has yet to be demonstrated.

Epidemiology

Despite dizziness being one of the most common symptom presentations in all medicine, epidemiological studies focusing on it are not conclusive for two main reasons. First, dizziness can only be measured by patient self-report and, among the wide range of manifestations reported, it is often unclear whether or not they can be correctly included in the definition. Secondly, selection criteria and methods can be very different among studies in the literature. Nevertheless, it seems reasonable to state that around 20–30% of people over 65 years of age experience dizziness in some form, and this number increases to 40–50% in the very old (85 + years) (2). Moreover, among a population of dizzy older primary care patients almost 60% experience a moderate or severe impact on everyday life due to dizziness (3).

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(Accepted 11 November 2013)

ISSN 2169-5717 print/ISSN 2169-5725 online © 2014 Informa Healthcare
DOI: 10.3109/21695717.2013.871793

In a population based study, Tinetti et al. observed some abnormality of gait in 15% of subjects over 60 years of age, and these disorders significantly increase the risk of falling (4). This risk varies greatly from well-functioning community dwelling subjects to frail institutionalized patients. Whereas no more than 10% of the fit elderly fell during the course of one year, at least 50% of institutionalized frail, elderly people are liable to falls (5) and people who have already had one fall are more likely to fall again (60–70%) in the subsequent year. Older adults have a five- to eight-fold increased risk for all-cause mortality during the first three months after hip fracture (6) and those who survive seldom regain their former level of mobility.

Falling is a problem strictly related to the fear of falling, each constituting a risk factor for the other. The fear of falling has prevalence rates that range from 20% to above 80% in community living older persons, depending on the methods and samples used (7). Benign paroxysmal positioning vertigo (BPPV) is the most common vestibular disorder and occurs at any age, but is much more common in the elderly and increases by 38% with each decade of life. The one-year prevalence of individuals with BPPV in a study was 3.4% in a population over 60 years of age and reached 10% in people over 80 years of age (8).

Finally, bilateral vestibular loss (BVL) of moderate to severe degree has a prevalence of 120/100,000 in the general population (9) and affects roughly 5% of unsteady people over 75 years of age (8).

Factors influencing balance, gait and falling risk in older people

Distinctions between the effects of aging and borderline pathology on instability and falls, are not always clear-cut (10). The elderly's greater risk of balance disorders stems from a higher likelihood of impairments or diseases affecting the physiological subsystems underlying the complex skill of balancing (11). A list of changes that can influence unsteadiness and risk of falling is given in Table I.

CNS, sensorium and musculoskeletal system: a physiological deterioration

Whether age-related balance impairments are due more to changes in the integration mechanisms of the central nervous system (CNS) or to sensory deficits or musculoskeletal factors has yet to be thoroughly established. Some studies seem to indicate that CNS factors are predominant, since central integration mechanisms important to postural reflexes tend to become slower with age (13). Older brains are weaker in processing capacity and dividing attention, so the appropriate allocation of central processing resources between concurrent tasks is disturbed. When older adults combine walking with performing a concurrent cognitive task, they are at greater risk of falling, while this risk is lower when they concurrently perform mobility or manual tasks (14).

Visual (15), hearing (16) and vestibular (8,17) functions physiologically deteriorate with age and many elderly people have accumulated multiple, often fairly minor, deficits in these sensory systems. This accumulation hinders older people from receiving compensatory information about body position and the environment, thus jeopardizing a person's confidence in maintaining a balanced position (10). Unfortunately, in many older adults, the normal effects of aging are associated with borderline disorders or the use of medication that can further increase their instability. These medical factors are listed in Table II.

Loss of muscle strength, slowing of muscle contraction, a smaller range of motion and flexibility, and an increased susceptibility to fatigue have been well documented changes associated with aging. All these factors might represent biomechanical limitations affecting the ability to execute the stabilizing actions required to maintain an upright stance. It should be noted, however, that normal age-related reduction in muscle strength does not typically affect balance in well-functioning older people.

Cardiovascular disease

In a recent survey (18) on elderly people consulting their family physician for persistent dizziness it was

Table I. Age related changes affecting falling risk. (adapted from Maki BE et al, 2003) (12).

Sensory system	Musculoskeletal systems	Nervous system
Lower visual acuity, contrast sensitivity, depth perception and adaptation to darkness	Lower muscle strength	Slower nerve conduction
Weakening vestibular function	Slower muscle contractions	Slowing and impairment of information processing
Weakening proprioception	Greater muscle fatigue	
Declining cutaneous sensitivity	More severe joint stiffness	
Declining hearing function	Reduced range of motion	

Table II. Medical risk factors for instability and falls (adapted from Maki BE et al, 2003) (12).

Sensory disorders	Neurological disorders	Disorders causing transient disturbances	Other conditions	Medication and drugs
Cataracts, macular degeneration, glaucoma	Parkinson's disease, peripheral neuropathies (diabetes, pernicious anaemia, nutritional), dementia, normal pressure hydrocephalus	Cardiac arrhythmia, transient ischaemia attack, ocular ischaemia, orthostatic or postprandial hypotension	Foot anomalies, musculoskeletal disorders	Antidepressants, benzodiazepines, alcohol
Bilateral or unilateral vestibular deficit, benign paroxysmal positioning vertigo			Acute illness, seizure, syncope, incontinence	

found that cardiovascular disease was the most common major cause (57%), followed by vestibular (14%) and psychiatric (10%) illness. In a quarter of all patients an adverse drug effect was considered to be a contributory cause of dizziness (23%). Furthermore, locomotor disease was a major cause in 4% and neurological pathologies (excluding cerebrovascular diseases) in 3% of cases. Cardiovascular dizziness should be suspected whenever patients: 1) describe dizziness as light-headedness; 2) have a history of cardiovascular disease; 3) have dizziness associated with syncope, pallor or a need to sit/lie down; and 4) find that prolonged standing causes symptoms. An overlap between dizziness, syncope and falls is frequently observed (19).

In a double-blind study on vertebrobasilar insufficiency (20), the authors recommended a vertebrobasilar radiological evaluation for all the patients complaining of isolated positional vertigo or dizziness of unexplained aetiology, and having at least three thrombotic stroke risk factors. In some studies on elderly populations stroke probably accounts for 3–7% among all causes of vertigo. (21).

Continuous phasic blood pressure monitoring with orthostatic blood pressure measurements, standardized carotid sinus massage and 70° head-up tilt test permit differentiation between the three most common hypotensive disorders, i.e. carotid sinus syndrome, postural hypotension and vasovagal syncope. According to Wu et al. (22), symptoms of dizziness provoked by orthostatic hypotension could be around 5.8% in elderly adults over 70 years of age.

Vestibular system

As reported earlier, BPPV is the most frequent type of peripheral vertigo in the elderly and is still an under-recognized entity. Elderly people with BPPV often do not report positional vertigo even on specific questioning. Instead they complain of dizziness, light-headedness or unsteadiness.

A unilateral vestibular loss (UVL) may cause different degrees of vertigo and disequilibrium depending on whether the lesion has developed suddenly or slowly (or whether vestibular function is fluctuating), on the degree of both vestibular weakness and vestibular compensation, and on comorbidity and psychological factors. In the general population about 20% of patients with a stable and complete UVL still may experience ataxia and oscillopsia. In elderly frail patients this percentage may reach 30–40%. Furthermore, asymmetric vestibular function is overrepresented in elderly persons with hip fractures and wrist fractures, suggesting that vestibular asymmetries may contribute to falls and fractures (23).

Elderly patients affected by Ménière's disease (MD) have clinical and vestibular features similar to young and middle-aged MD patients except for a higher incidence of oculomotor system alterations and a higher frequency of Tumarkin attacks (24,25).

BVL causes not vertigo, but unsteadiness of gait, particularly in the dark, and oscillopsia associated with head movements or when walking. This is due to the insufficiency of the vestibulo-ocular reflex at higher frequencies. As reported in a following section, diagnosis of BVL of mild entity is difficult both on a clinical and instrumental test basis and its prevalence is still not clear. Typically, these patients are unable to keep standing on a soft yielding surface, such as a mattress, with the eyes closed, without falling.

Anxiety, drugs, CNS and PNS pathology

Clinical evidence demonstrates a significant interaction between balance control and emotional and cognitive functioning. Maarsingh et al. demonstrated that anxiety and/or depressive disorder were present in 22% of older dizzy patients (26). Antidepressants modulate these complex pathophysiological interactions via mechanisms of action that have been little explored to date. The potential use of these drugs to treat dizziness in various patient populations, whether associated with anxiety or not, justifies a more careful investigation (27). Tranquillizers such as benzodiazepines inhibit the input from the vestibular labyrinth and further impair the central integration of sensory information. Benzodiazepines are GABA modulators that act centrally to potentiate GABA and suppress vestibular responses. Although benzodiazepines are useful for managing acute vertigo in surprisingly small doses, addiction, memory impairments and a higher risk of falls are known drawbacks associated with their use. In a recent report, Suzuki et al. (28) described two cases of fatal falls in older females, caused by antihistamine-induced drowsiness. For a long time, cerebral and cerebellar atrophy and subcortical white matter lesions have all been associated with imbalance in older people (11). Colledge et al. (29) confirmed that MRI white matter lesions in the midbrain were more common in dizzy than in non-dizzy subjects (22% vs. 4%, $p < 0.001$). Pathologically, these MRI images correspond to areas of myelin thinning and gliosis, and are often accompanied by lacunar infarctions and small vessel atherosclerotic disease. More recently, a study on a very large older population demonstrated that only periventricular white lesions are associated with impaired balance and reduced walking speed, although the speed difference between subjects with a small number of lesions and those with a large number of lesions is only about 20% (30).

Peripheral neuropathy can be a cause of unsteady gait, related to loss of position sensation from the feet. It is generally easily suspected in diabetic patients, while nutritional and vitamin deficiency forms are probably underestimated. Vitamin B12 deficiency is common in the population over 80 years of age (about 10%) and may be due to: decreased intake, malabsorption, pernicious anaemia, stomach and small bowel disorders, medication interaction or over-consumption. It is also defined as 'sensory ataxia' and, when associated with spinal cord disease, it is sometimes termed 'subacute combined degeneration'.

In addition to the risk of severe injury such as hip fractures, instability and falling can cause anxiety and restrict activity, leading to social withdrawal and a poorer quality of life, and often ultimately to a loss of independence and transfer to a nursing home. Over 40% of nursing home admissions are related to falls. Furthermore, the simple fear of falling may push older adults into a spiral of loss of confidence and physical frailty (31). Persons who simultaneously had balance, vision and hearing difficulty had an over eight-fold higher risk for fear of falling compared to persons who did not have any of these three sensory difficulties (32).

Clinical assessment of the dizzy patient

Diagnosing a specific cause of dizziness or vertigo in older people can be a challenge, since the symptom descriptions are often vague and examination findings overlap among potential causes (33). For example, elderly people with BPPV often do not report positional vertigo even on specific questioning. Instead they complain of unsteadiness or resulting falls. This might be due to unconscious limitation and avoidance of movements and positions that evoke vertigo. In a public, inner-city geriatric population, 9% were found to have unrecognized BPPV (34). Thus, the physician should suspect BPPV in elderly patients with unsteadiness, even in cases where other findings, such as multiple sensory deficit, polyneuropathy, Parkinsonism, apparently explain the symptomatology, and the diagnostic manoeuvre for BPPV should be performed. Moreover, BPPV is usually a self-limited condition with a mean spontaneous remission time of several weeks. Patients often present during an asymptomatic period, so that only a re-examination on an urgent basis when the symptoms reappear, permits clarification of the diagnosis.

Despite these difficulties, patient history is the first and most important aspect of the diagnostic process. When, after having obtained the patient's history there is no suspicion about the possible cause of the patient's dizziness, it is most likely that even after all the clinical and instrumental tests it will still not be possible to formulate a clear diagnosis (35).

Patient history should include some questions regarding impact of the dizziness on daily life, in order to identify a more individualized diagnostic and rehabilitative programme (3).

An examination of a patient's balance should begin with the patient standing in the Romberg position. It should be noted that performance in the Romberg test deteriorates with age, albeit with a considerable degree of individual variability. Vestibular, cerebellar and severe proprioceptive disorders prevent patients from maintaining this position, particularly with their eyes closed. Thus, the test is not specific and does not help to distinguish between UVL and BVL. On the other hand, sensitivity is high and can be further increased by having the patient stand on foam rubber, which disrupts proprioceptive inputs (36,37).

Patients are then asked to walk normally from one end of the room to the other and to turn around quickly. They should then try tandem walking; this can accentuate balance problems associated with CNS disorders and cerebellar lesions in particular. It should not be considered normal for elderly people to have trouble walking heel-to-toe.

Having the patient rise from a chair without using the arms and clinical testing of strength and joint mobility of the lower extremities are simple and useful tests, also.

Vestibulo-ocular function is then tested by bedside clinic examination which, in many cases, rules out vestibular pathologies. Besides the Dix-Hallpike manoeuvre for BPPV, two other useful bedside tests are the head impulse test (HIT), also named the head-thrust test of Halmagyi (38), and the dynamic visual acuity test (DVAT). The HIT consists of a rapid rotation of the patient's head, guided by the hands of the examiner. The patient should be instructed to stare at the nose of the examiner during the rotation. HIT identifies subsequent catch-up saccades after the head rotation, and measures the gain of the angular vestibulo-ocular reflex (VOR) as indirect sign of VOR deficit. However, covert saccades during head rotation occur more frequently with higher acceleration and may be missed by clinicians. The repetition of the test reduces the probability of false negatives and facilitates detection of a deficit.

During the DVAT, the patient is asked to oscillate the head back and forth at a speed of at least one cycle per second while reading a standard visual acuity chart. In normal persons, VOR limits retinal image instability during imposed head motion. In healthy subjects, visual acuity may decline by one or two lines on the optotype chart. A decline of more than two lines is considered abnormal (39), but severely affected BVL patients may show a decline of five or more lines (40). The combination of a bilateral positive HIT, a reduced DVAT and a positive Romberg test on rubber foam can identify patients with severe and moderate BVL. However, identification of mild BVL remains a challenge as laboratory tests, including caloric irrigation, rotational chair and video head impulse testing, show considerable overlap between patients and normal subjects (41).

In a recent study (42) the so-called 'triple test', i.e. spontaneous nystagmus, head-shaking nystagmus, and the head impulse test, demonstrated a high negative predictive value (NPV) in the diagnosis of unilateral vestibular weakness. In other words, 80.4% of patients with a negative triple test also had a normal response on caloric testing. In pronounced canal paresis ($\geq$50%), the triple test reached an NPV of 94.1%.

Nevertheless, video-oculography (VOG) and caloric stimulation still play a major role in evaluation of both peripheral and central vestibular disorders. A detailed description of the clinical and instrumental assessment of oculomotricity, spontaneous and evoked nystagmus, is beyond the aim of this paper. For a recent review on vestibular testing for rehabilitative purposes see Slattery et al. (43).

The evaluation may require further tests, whose selection depends on the clinical history and previous findings. Maarsingh et al. (44) combined empirical evidence with expert opinion, systematic review and practice guidelines for the development of a set of 21 diagnostic tests for evaluating dizziness in the elderly (Table III). Visual acuity can be measured with the standard Snellen visual acuity chart.

The characteristic stocking/glove distribution sensory loss of peripheral neuropathy is easily identified. B12 vitamin, haemoglobin and non-fasting blood glucose dosage, may confirm the diagnosis and the cause of the neuropathy.

Experienced neurologists may be able to establish a topographical diagnosis for a gait disorder based on the clinical observation of an individual's gait and their formal neurological examination (45).

Table III. List of diagnostic tests for evaluating dizziness in elderly patients in a primary care set. (adapted from Maarsingh et al, 2009), (44).

		Patient History		
Present dizzy symptoms	Medication	Alcohol intake	Medical history	
		Physical Examination		
Cardiovascular System	Locomotor System	Neurological System	Vestibular System	Remaining Tests
Pulse measurement	Orthopaedic screening of lower extremities	Tendon reflexes	Otoscopy	Visual acuity
Blood pressure	Tandem gait	Semmes-Weinstein Monofilament Test	Dix-Hallpike manoeuvre	
Orthostatic hypotension test				
Auscultation of the heart				
		Additional Tests		
Cardiovascular System	Laboratory Tests	Psychiatric Testing	Vestibular System	
Electrocardiogram	Haemoglobin	Patient Health Questionnaire	Audiometry	
ECG-monitoring	Non-fasting blood glucose			

Damage to the vestibular, somatosensory or visual systems typically produces subtle gait anomalies, such as a slight widening of the base, shortening of the stride, and slow, careful turns (46). Patients with proprioceptive or vestibular deterioration come to depend on their vision, so their signs and symptoms are much worse in the dark or when their eyes are closed, as the Romberg test can show. Patients with basal ganglia disorders, particularly those with Parkinson's disease, have a characteristic akinesia and rigidity, while cerebellar disorders produce wide-based, ataxic and highly compromised gait. Table IV lists the features of gait disorders in older people. Observational gait analysis is generally more widely used than instrumented methods. Observational methods are inexpensive, require little or no technology and several studies have reported a high correlation with biomechanical measures. On the other hand, instrumental gait assessments provide quantitative measures of gait kinematics, kinetics and electromyographic activity of muscle with a high degree of accuracy. However, they are expensive, time-intensive and require skilled analysis and interpretation (47). Thus, the role of these instrumental tests is still controversial.

Rotational chair testing (43) and, more recently, the Dynamic Visual Acuity Test (DVAT) (40) and the Gaze Stabilization Test (GST) provide information regarding higher frequency vestibulo-ocular reflex (VOR) function.

Finally, the cervical Vestibular Evoked Myogenic Potential (cVEMP) test and the Dynamic Subjective Visual Vertical (DSVV) test provide information regarding saccular and utricular function, respectively.

The combination of caloric, sinusoidal and step-velocity rotary chair (RC) testing revealed the strongest predictive capabilities for identifying peripheral vestibular injury. Furthermore, the combination of an abbreviated form of RC testing with caloric testing yielded nearly identical results to full caloric and rotational testing (48).

Computerized Dynamic Posturography (CDP) explores the interaction of the vestibular, visual and proprioceptive systems for posture control. The clinical utility of CDP is still debated. The different posturographic systems available for use in clinical practice test postural control as a whole, with the various sensory inputs interacting in physiological ways, or mimicking potential real-life challenges to upright balance – hence their strength and, at the same time, their weakness, since they lack specificity. CDP has certainly advanced our knowledge of how postural mechanisms work, and how posture is impaired in certain patient groups, but many authors have stressed that it is of little or no value in the clinical examination of individual patients (49).

Some of the most frequently used questionnaires to measure the impact of dizziness on quality of life and on activities of daily living in elderly people are: the Dizziness Handicap Inventory (DHI); the Disability Index; the VSS; the Vestibular Disorders Activities of Daily Living scale; and the Activities-Specific Confidence scale. Moreover, the DHI score has been demonstrated to be a useful tool for the prediction of BPPV. The correct diagnosis of BPPV is 16 times greater if the DHI score is greater than or equal to 50 (50). With regard to the scales, they are used in clinical practice to score various aspects of gait and balance in elderly people by means of simple bedside tests. A recent systematic review identified as many as 30 different functional balance assessment tools (51), which may be either generic or disease-specific, and may have different operational ranges. Widely accepted scales are: the Tinetti Gait Scale (TGS); the Gait Assessment and Intervention Tool (G.A.I.T); the Berg Balance Scale; the Dynamic Gait Index; the Get Up and Go; and the Functional Reach tests. The timed Get-Up-and-Go test is performed by observing the time it takes a person to rise from an armchair, walk three metres (10 feet), turn, walk back, and sit down again. The average healthy adult over 60 years of age can perform this task in less than 10 s (52). A Unified Balance Scale has been recently introduced as a single tool for 'bed-to-community' balance measurement, i.e. within the hospital as well as in the community setting (53) and regardless of the aetiology of the lesion causing the loss of balance. Unfortunately, there is a considerable individual variability in all such scales and no clear cut-offs for identifying a balance disorder (i.e. the need for rehabilitation treatment) have been established to date.

Table IV. Features of gait disorders in older people. (adapted from Baloh et al 2003). (46).

Category	Characteristic feature of gait
Sensory loss	"Cautious gait", slightly widened base, shortened stride, slow turns
Musculoskeletal deterioration	Difficulty rising, generally slow, limping, limited elevation of the feet, locking of the knees
Cerebellar lesion	"Ataxic gait", markedly widened base, trunk instability, overactive postural reflexes
Basal ganglia lesions	Difficulty starting, freezing, stiffness, lack of associated movements, turns en bloc
Frontal cortex and subcortical white matter lesions	"Apraxic gait", small shuffling steps, feet adhere to the floor, poor reflex control

Finally, with regard to falls, quick validated fall risk screening tools for older people are available for community, hospital, and nursing and residential care settings. These screening tests identify people at increased risk of falls who need detailed fall risk assessment and intervention (54).

Rationale, strategies and outcomes of rehabilitation

Figure 1 is a scheme of how sensorimotor integration is organized in the brain. Each of the primary sensory systems sends information to a first set of individual central processors that pass this information on to a common central processor, which produces signals that command eye movements and postural reflexes (55). The functioning of the system as a whole comes under adaptive control in much the same way as in other aspects of brain functioning and behaviour.

Understanding these adaptive mechanisms is important in clinical practice with regard to the rehabilitation of patients with lesions involving the different parts of the sensory system. There is mounting evidence that the brain of older persons is able to undergo plasticity changes, although there appear to be limits on how much the brain of the elderly can compensate. Most probably there is no difference in benefit of postural balance training according to age (56). The aim of this training is to stabilize the body' s centre of mass (57) (Figure 2). It is consequently important to understand the mechanisms behind a given patient's postural instability and so programme a targeted therapeutic plan to achieve the maximum effect.

In other words, following a balance training course, older subjects should learn what to expect from their actions, i.e. they should develop internal models that are critical for predictive motor control. Internal models are fundamental when controlling systems that have delays. It is reasonable to assume that much of the benefit of rehabilitative treatment may depend on internal models (58). At least two other cognitive processes are usefully influenced by a generic training, or simply by experience and motion learning of limits and sensory weighting (59). The first is related to learning what is safe and what is not, thus avoiding older subjects being either overly cautious, or excessively confident. These two extreme conditions might cause either an excessive avoidance of motion and independency, or an increasing risk of falls. The second process refers to the capacity of selection and favours one of several redundant senses over another. Typically, selection occurs between vision, vestibular and somatosensory inputs when a person is attempting to balance. For instance, diabetics with peripheral neuropathy and sensory/proprioceptive impairments in their feet rely heavily on visual afferents, becoming much less stable in the dark.

Functional imaging techniques have recently enabled the visualization of a hierarchic network for postural control in humans by means of functional imaging techniques. Growing evidence suggests that the so-called 'supraspinal locomotor regions' groups of neurons that are able to initiate or modulate spinal stepping in the cat in response to electrical or chemical stimulation, also exist in humans. The supraspinal network for locomotion is just beginning to be recognized as an important factor in the pathophysiology of common balance and gait disorders (60).

Prior to the 1990s therapists often used to treat all dizzy patients with the same protocol and only after that period was there an effort to advocate exercises customized to individual diagnoses or at least functional patterns. Rehabilitation programmes aim to retrain the brain to use residual sensory inputs to compensate for malfunctioning areas. This means that training to improve balance needs to be tailored

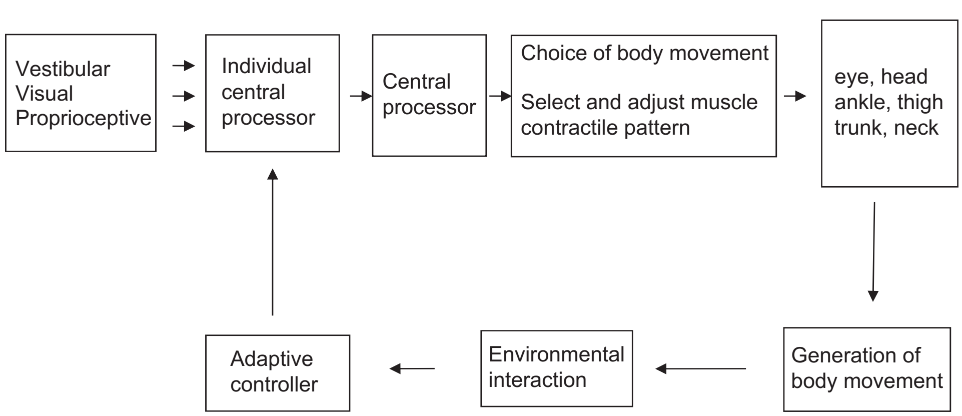

Figure 1. Block diagram showing how sensorimotor integration is organized in the brain (adapted from Baloh et al, 2001). (55).

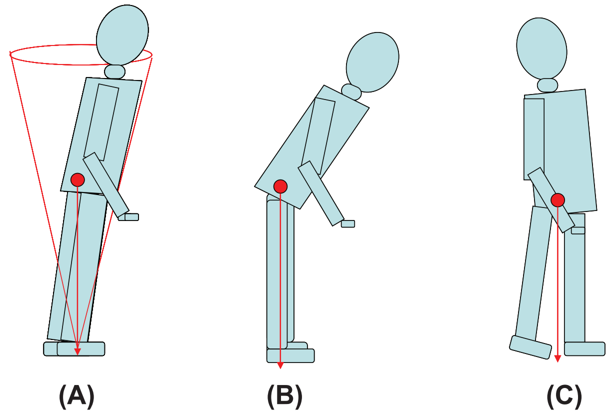

Figure 2. Normal and abnormal limits of stability. (A) A healthy man leaning his body's centre of mass (red dot) towards his forward limit of stability (represented as the area within the cone). (B) A woman with multisensory deficits attempts to lean forward without moving her body's centre of mass forward. (C) A woman with multisensory deficits attempts to lean backwards but immediately takes a step back to increase her base of support. The projection of the body's centre of mass over the base of support is schematically indicated with the arrow (modified from Horak et al 2006) (57).

to each patient to obtain the maximum effect, designing different exercises for individuals with different kinds of deficiency.

Patients with a prevalent dysfunction of the vestibular system can be treated effectively with vestibular rehabilitation (VR), which includes both a 'generic' type and more specific protocols. In generic VR, patients are provided with a series of tasks to perform that require them to use their eyes while their head is moving, and possibly when their body is also moving. On the other hand, specific protocols have been initially proposed by Cawthorne and Cooksey (61,62), followed by several others in subsequent decades (63). VR has been shown to promote significant improvements in several aspects of balance, including vestibulo-visual interaction during head movements, static and dynamic postural stability in conditions of conflicting sensory information, and diminished individual sensitivity to head movements (64).

Avocational activities can also be excellent for vestibular rehabilitation, provided that they involve using the eyes while the head and body are in motion. Older subjects should find one that is fun, safe, and somewhat stimulating. Dancing is, of course, an excellent vestibular rehabilitative activity. In recent years the force plate/virtual reality systems (i.e. Nintendo Wii Fi ®) are becoming universally available and more and more frequently used as a therapy for balance disorders in older subjects. In combination with the visual and auditory feedback that is unavailable with conventional exercises, other aspects such as balance challenges, an enriched sensory environment, enjoyment and the subsequent effect on adherence also require consideration (65). Interestingly, Clark et al. (66) recently showed that the Nintendo Wii board tracks the centre of pressure with a similar accuracy to a gold standard forceplate. Finally, simply walking around the block looking from side to side may be a useful activity.

Most studies on VR are carried out with patients suffering from BVL, although an increasing number of data is available regarding people with symptomatic UVL. A recent review (67) on the effectiveness of vestibular rehabilitation in this last subset of patients demonstrated moderate to strong evidence that VR is an effective management, and in the studies with a follow-up assessment (3–12 months) positive effects were maintained. McGibbon et al. (68) recommended practising the traditional Chinese martial art of Tai Chi, which produces significant benefits in elderly people, ameliorating their balance, fitness, strength and possibly also indirectly improving their self-confidence (69).

With regard to the outcome of rehabilitation in older patients with prevalent vestibular disorders, data are still not conclusive. In a recent study on BVL, roughly 80% of patients do not improve independently of age, gender, time-course of manifestation and severity: thus, the prognosis seems less favourable than assumed previously (70). These patients have a 'visual dependence' so they should avoid walking in the dark, or without corrective lenses if they have refraction disorders, especially in open spaces. Whenever possible, surgical treatment of a visual deficit is generally beneficial (71). Finally, they should be encouraged to use a walking stick and, since they cannot see clearly while walking, they should stop and hold the head still whenever they want to read a sign or see the face of someone passing.

Most studies on BPPV reveal, on the one hand, a low success rate in the treatment of this entity and a higher frequency of recurrences in elderly patients compared to the general population (72). In a recent Cochrane meta-analysis (73) it was concluded that although there is evidence that the Epley manoeuvre is an effective treatment for posterior canal BPPV (based on the results of controlled trials with relatively short follow-up), there is no good evidence that this treatment provides a long-term resolution of symptoms.

Although data are mixed, a few studies have indicated that use of vestibular rehabilitation may decrease recurrence rates for BPPV (72–74). On the other hand, it should be noted that in treated old patients the estimated recurrence rate of BPPV is 30–50% (72–75), and that natural resolution of untreated cases is probably around 20–30% (76).

Rehabilitation of gait and balance disorders in patients with normal vestibular function depends on the prevalent cause of the problem. Sarcopenia and other forms of lower limb muscular weakness may benefit from home-made or group exercise, Tai Chi, dancing or other vocational activities. Recently, Nubia et al. (77) measured the effects of aquatic lower limb muscle endurance training in community-dwelling healthy elderly people. After 40-min sessions twice a week for six weeks, participants showed a significant improvement in their static and dynamic balance.

In contrast, patients with cerebellar gait disorders generally gain little from rehabilitative treatments. Furthermore, because the cerebellum is the key centre for adapting postural reflexes, they are also unable to use their vision to improve their balance, and their walking may be severely impaired even when they can see clearly. Nevertheless, with adequate counselling these patients should be made aware of their limits and abilities, and given access and knowledge concerning walkers, canes, and related appliances.

A recent Cochrane review (78) provides the possible outcomes in the rate of falls and the risk of falling for a series of different treatments:

1. Group and home-based exercise programmes including Thai Chi, and home safety interventions, reduce rate of falls and risk of falling.
2. Multifactorial assessment and intervention programmes (i.e. pacemakers in people with carotid sinus hypersensitivity, podiatry in people with disabling foot pain, gradual withdrawal of psychotropic medication) reduce rate of falls but not risk of falling.
3. Overall, vitamin D supplementation does not appear to reduce falls but may be effective in people who have lower vitamin D levels before treatment.

In conclusion, a multifactorial approach could be the best solution for a number of elderly people, who generally suffer from multiple deficiencies (79).

Unfortunately, several studies have demonstrated that the results achieved can soon be lost if the elderly revert to their previous sedentary lifestyle and limited activity. One way to avoid this is to continue the postural training at home whenever feasible, possibly prescribing more straightforward exercises to help patients maintain a minimal but continuous practice routine (80).

Finally, it is important to bear in mind that elderly people who have fallen may have a degree of cognitive impairment that prevents them from properly appreciating the risk of falling again and the need to contain it. Sadly, it is impossible to eliminate all risks without interfering to an unacceptable degree with an elderly person's independence.

Measuring response to rehabilitation

Evaluating the outcome of balance and vestibular rehabilitation is more difficult than it sounds because of several possible biasing factors. First, it should be considered that most disorders have a tendency to improve on their own, so attributing the improvement to therapy could be incorrect in a number of cases. As an example, the natural resolution of untreated BPPV is still unclear: in two studies it varied from 20% to 38% (81,82) and up to 84% at three months follow-up in a third study (83). Secondly, psychological factors are important, but it is still difficult to separate them from other aspects. In this regard, it is a common clinical experience that whenever the fear of falling reduces, people increase their activity improving their steadiness and gait, independent of rehabilitation. Thirdly, a reliable method for measuring 'balance' does not exist, although we have many tests evaluating different things associated with balance.

Nevertheless, a subjective rating by means of questionnaires is commonly used. The questionnaires we have reported in a previous section can capture subtle aspects of improvement such as increased independence. Unfortunately, these measures are greatly handicapped by their intrinsic variability and the tendency for people to scale their responses according to what they think they should be doing rather than actual performance. Mobility oriented scales are also useful in evaluating the benefit obtained with different rehabilitative protocols. Finally, it should be noted that the easiest way to carry out this task is to ask patients to score their degree of instability (before and after treatment) on a 100-mm closed visual-analogue scale (VAS), ranging from no sensation of unsteadiness (0 mm) to the worst possible symptoms (100 mm). Unfortunately, individual variability partially limits the use of all these instruments in single patient evaluation, while the assessment of the benefit obtained in groups of patients can be sufficiently reliable (84).

Conclusion

Particle repositioning manoeuvre and VR are thought to improve long-term outcomes for BPPV (72–75). Nevertheless, natural resolution of untreated cases is probably around 20–30% (81–83) and recurrence is also high in treated patients (75). Thus, the real long-term effectiveness of particle repositioning manoeuvre and VR in the elderly is still questionable.

With regard to other causes of vertigo and dizziness, there is strong scientific evidence that rehabilitation has a significant role for multisensory dizziness, locomotor pathologies and unilateral vestibular hypofunction. More research and well designed trials are still required to evaluate the benefit of rehabilitation for neurological causes and bilateral vestibular hypofunction.

In general, protocols of vestibular and balance rehabilitation would enable better planning and managing of interventions to diminish dizziness symptoms, functional disability and body imbalance, and to prevent falls in this population.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

1. Luxon LM, Davies RA. Handbook of vestibular rehabilitation. London: Whurr Publisher Ltd., 1997.
2. Jonsson R, Sixt E, Landahl S, Rosenhall U. Prevalence of dizziness and vertigo in an urban elderly population. J Vestib Res. 2004;14:47–52.
3. Dros J, Maarsingh OR, Beem L, van der Horst HE, ter Riet G, Schellevis FG, et al. Impact of dizziness on everyday life in older primary care patients: a cross-sectional study. Health Qual Life Outcomes. 2011;9:44–55.
4. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. N Engl J Med. 1988;319:1701–7.
5. Tinetti ME, Speechley M. Prevention of falls among the elderly. N Engl J Med. 1989;320:1055–9.
6. Haentjens P, Magaziner J, Colón-Emeric CS, Vanderschueren D, Milisen K, Velkeniers B, et al. Meta-analysis: Excess Mortality After Hip Fracture Among Older Women and Men. Ann Intern Med. 2010;152:380–90.
7. Scheffer AC, Schuurmans MJ, van Dijk N, van der Hooft T, de Rooij SE. Fear of falling: measurement strategy, prevalence, risk factors and consequences among older persons. Age Ageing. 2008;37:19–24.
8. Ueneri A, Polat S. Vertigo, dizziness and imbalance in the elderly. J Laryngol Otol. 2008;122:466–9.
9. Natl Ctr for Health Statistics. National Health Interview Survey 2008. Hyattsville, Maryland: United States National Institute on Deafness and Other Communication Disorders and United States Public Health Service; 2008.
10. Horak FB, Shupert CL. Components of postural dyscontrol in the elderly: a review. Neurobiol Ageing. 1989;10:727–38.
11. Kerber KA, Enrietto JA, Jacobson KM, Baloh RW. Disequilibrium in older people: a prospective study. Neurology. 1998;51:574–80.
12. Maki BE, McIlroy WE, Fernie GR. Change-in-support reactions for balance recovery. IEEE Eng Med Biol Mag. 2003; 22:20–6.
13. Teasdale N, Stelmach GE, Bard C, Fleury M. Posture and elderly persons: deficit in the central integrative mechanisms. In: Wollacott M, Horak F, editors. Posture and Gait: Control Mechanisms. Portland, Oregon: University of Oregon; 1992. p. 203–7.
14. Lundin-Olsson L, Nyberg L, Gustafson Y. 'Stops walking when talking' as a predictor of falls in elderly people. Lancet. 1997;349:617.
15. Steinman BA, Allen SM. Self-reported vision impairment and its contribution to disability among older adults. J Aging Health. 2012;24:307–22.
16. Bovo R, Ciorba A, Martini A. Environmental and genetic factors in age related hearing impairment. Aging Clin Exp Res. 2011;23:3–10.
17. Tian JR, Shubayev I, Baloh RW, Demer JL. Impairments in the initial horizontal vestibulo-ocular reflex of older humans. Exp Brain Res. 2001;137:309–22.
18. Maarsingh O, Dros J, Schellevis F, van der Weert H, van der Windt D, der Riet G, et al. Causes of persistent dizziness in elderly patients in primary care. Ann Fam Med. 2010;8:196–205.
19. McIntosh SJ, Da Costa D, Kenny RA. Outcome of an integrated approach to the investigation of dizziness, falls and syncope in elderly patients referred to a 'syncope'. Age Ageing. 1993;22:53–8.
20. Moubayed SP, Saliba I. Vertebrobasilar insufficiency presenting as isolated positional vertigo or dizziness: a double-blind retrospective cohort study. Laryngoscope. 2009;119:2071–6.
21. Della-Morte D, Rundek T. Dizziness and vertigo. Front Neurol Neurosci. 2012;30:22–5.
22. Wu J, Yang Y, Lu F, Wu C, Chang C. Population based study on the prevalence and correlates of orthostatic hypotension/ hypertension and orthostatic dizziness. Hypertens Res. 2008;31:897–904.
23. Kristinsdottir EK, Jarnlo GB, Magnusson M. Asymmetric vestibular function in the elderly might be a significant contributor to hip fractures. Scand J Rehabil Med. 2000;32:56–60.
24. Mizukoshi K, Shojaku H, Aso S, Watanabe Y. Clinical study of elderly patients with Ménière's and related diseases. Auris Nasus Larynx. 2000;27:167–73.
25. Ballester M, Liard P, Vibert D, Häusler R. Ménière's Disease in the Elderly. Otol Neurotol. 2002;23:73–8.
26. Maarsingh OR, Dros J, van der Windt DA, ter Riet G, Schellevis FG, van Weert HC, et al. Diagnostic indicators of anxiety and depression in older dizzy patients in primary care. J Geriatr Psychiatr Neurol. 2011;24:98–107.
27. Ramos RT. Antidepressants and dizziness. J Psychopharmacol. 2006;20:708–13.
28. Suzuki H, Shigeta A, Fukunaga T. Accidental death of elderly persons under the influence of chlorpheniramine. Leg Med. (Tokyo). 2013;15:253–5.
29. Colledge N, Lewis S, Mead G, Sellar R, Wardlaw J, Wilson J. Magnetic resonance brain imaging in people with dizziness: a comparison with non-dizzy people. J Neurol Neurosurg Psychiatr. 2002;72:587–9.
30. Baszner H, Blahak C, Poggesi A, Pantoni L, Inzitari D, Chabriat H, Erkinjuntti T, Fazekas F, Ferro JM, Langhorne P, O'Brien J, Scheltens P, Visser MC, Wahlund LO, Waldemar G, Wallin A, Hennerici MG; LADIS Study Group. Association of gait and balance disorders with age related white matter changes. The LADIS Study. Neurology. 2008; 70:935–42.
31. Scheffer AC, Schuurmans MJ, van Dijk N, van der Hooft T, de Rooij SE. Fear of falling: measurment strategy, prevalence, risk factors and consequences among older persons. Age Ageing. 2008;37:19–24.
32. Viljanen A, Kulmala J, Rantakokko M, Koskenvuo M, Kaprio J, Rantanen TJ. Fear of falling and coexisting sensory difficulties as predictors of mobility decline in older females. Gerontol A Biol Sci Med Sci. 2012;67:1230–7.
33. Newman-Toker DE, Cannon LM, Stofferahn ME, Rothman RE, Hsieh YH, Zee DS. Imprecision in patient

reports of dizziness symptom quality: a cross-sectional study conducted in an acute care setting. Mayo Clin Proc. 2007;82:1329–40.
34. Oghalai JS, Manolidis S, Barth JL, Stewart MG, Jenkins HA. Unrecognized benign paroxysmal positional vertigo in elderly patients. Otolaryngol Head Neck Surg. 2000;122: 630–4.
35. Brandt T. Patient History. In: Brandt T, Dieterich M, Strupp M (editors). Vertigo and dizziness 2nd edn. London: Springer Verlag; 2013. p. 5–6.
36. Lanska DJ, Goetz CG. Romberg's sign: development, adoption, and adaptation in the 19th century. Neurology. 2000; 55:1201–6.
37. Shumway-Cook A, Horak FB. Assessing the influence of sensory interaction of balance. Suggestion from the field. Phys Ther. 1986;66:1548–50.
38. Weber KP, Aw ST, Todd MJ, McGarvie LA, Curthoys IS, Halmagyi GM. Head impulse test in unilateral vestibular loss: vestibulo-ocular reflex and catch-up saccades. Neurology. 2008;70:454–63.
39. Fife TD, Tusa RJ, Furman JM, Zee DS, Frohman E, Baloh RW, et al. Assessment: vestibular testing techniques in adults and children. Report of the Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology. Neurology. 2000;28;55:1431–41.
40. Demer JL, Honrubia V, Baloh RW. Dynamic visual acuity: a test for oscillopsia and vestibulo-ocular reflex function. Am J Otol. 1994;15:340–47.
41. Weber KP, Aw ST, Todd MJ, McGarvie LA, Curthoys IS, Halmagyi GM. Horizontal head impulse test detects gentamicin vestibulotoxicity. Neurology. 2009;72:1417–24.
42. Rohrmeier C, Richter O, Schneider M, Wirsching K, Fiedler I, Haubner F, et al. Triple test as predictive screen for unilateral weakness on caloric testing in routine practice. Otol Neurotol. 2013;34:297–303.
43. Slattery EL, Sinks BC, Goebel JA. Vestibular tests for rehabilitation: applications and interpretation. Neuro Rehabil. 2011;29:143–51.
44. Maarsingh OR, Dros J, van Weert HC, Schellevis FG, Bindels PJ, van der Horst HE. Development of a diagnostic protocol for dizziness in elderly patients in general practice: a Delphi procedure. BMC Famil Pract. 2009;10:12.
45. Nutt JG, Marsden CD, Thompson PD. Human walking and higher-level gait disorders, particularly in the elderly. Neurology. 1993;43:268–79.
46. Baloh RW. Normal and abnormal balance. In: Luxon L, Furman JM, Martini A, Stephens D, editors. Textbook of Audiological Medicine: Clinical Disorders of Hearing and Balance. London: Martin Dunitz; 2003. p. 773–9.
47. Simon SR. Quantification of human motion: gait analysis – benefits and limitations to its application to clinical problems. J Biomech. 2004;37:1869–80.
48. Ahmed MF, Goebel JA, Sinks BC. Caloric test versus rotational sinusoidal harmonic acceleration and step-velocity tests in patients with and without suspected peripheral vestibulopathy. Otol Neurotol. 2009;30:800–5.
49. Kerber KA, Fendrick AM. The Evidence Base for the Evaluation and Management of Dizziness. J Eval Clin Pract. 2010;16:186–91.
50. Saxena A, Prabhakar MC. Performance of DHI Score as a Predictor of Benign Paroxysmal Positional Vertigo in Geriatric Patients with Dizziness/Vertigo: A Cross-Sectional Study. PLoS ONE 2013.8:e58106.
51. Tyson SF, Connell LA. How to measure balance in clinical practice. A systematic review of the psychometrics and clinical utility of measures of balance activity for neurological conditions. Clin Rehabil. 2009;23:824–40.
52. Bohannon RW. Reference values for the timed up-and-go test: a descriptive meta-analysis. J Geriatr Phys Ther. 2006;29:64.
53. La Porta F, Franceschini M, Caselli S, Cavallini P, Susassi S, Tennant A. Unified Balance Scale: an activity-based, bed-to-community, and aetiology-independent measure of balance calibrated with Rasch analysis. J Rehabil Med. 2011;43: 435–44.
54. Close JC, Lord SR. Fall assessment in older people. Br Med J. 2011;14:343.
55. Baloh RW, Honrubia V. Clinical Neurophysiology of the Vestibular System. 3rd edn. New York: Oxford University Press; 2001. p. 19.
56. Whitney SL, Wrisley DM, Marchetti GF, Furman JM. The effect of age on vestibular rehabilitation outcomes. Laryngoscope. 2002;112:1785–90.
57. Horak FB. Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls? Age Ageing. 2006;35(Suppl 2):7–11.
58. 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;133:383–9.
59. Hain TC. Neurophysiology of vestibular rehabilitation. Neuro Rehabil. 2011;29:127–41.
60. Jahn K, Zwergal A. Imaging supraspinal locomotor control in balance disorders. Restor Neurol Neurosci. 2010;28:105–14.
61. Cawthorne T. Vestibular injuries. Proc R Soc Med. 1946; 39:270–2.
62. Cooksey FS. Rehabilitation in vestibular injuries. Proc R Soc Med. 1946;39:273–5.
63. Alrwaily M, Whitney SL Vestibular rehabilitation of older adults with dizziness. Otolaryngol Clin North Am. 2011;44: 473–96.
64. Hansson EE. Vestibular rehabilitation: for whom and how? A systematic review. Adv Physiother. 2007;9:106–16.
65. Young W, Ferguson S, Brault S, Craig C. Assessing and training standing balance in older adults: a novel approach using the 'Nintendo Wii' balance board. Gait Posture. 2011; 33:303–5.
66. 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;31:307–10.
67. Hillier SL, McDonnell M. Vestibular rehabilitation for unilateral peripheral vestibular dysfunction. Cochrane Database Syst Rev. 2011;16:CD005397.
68. McGibbon CA, Krebs DE, Parker SW, Scarborough DM, Wayne PM, Wolf SL. Tai Chi and vestibular rehabilitation improve vestibulopathic gait via different neuromuscular mechanisms: preliminary report. BMC Neurol. 2005;5: 1–12.
69. Li F, Harmer P, Fisher KJ, McAuley E. Tai Chi: improving functional balance and predicting subsequent falls in older persons. Med Sci Sports Exerc. 2004;36:2046–52.
70. Zingler VC, Weintz E, Jahn K, Mike A, Huppert D, Rettinger N, et al. Follow-up of vestibular function in bilateral vestibulopathy. J Neurol Neurosurg Psychiatr. 2008;79:284–8.
71. Cumming RG, Ivers R, Clemson L, Cullen J, Hayes MF, Tanzer M, et al. Improving vision to prevent falls in frail older people: a randomized trial. J Am Geriatr Soc. 2007; 55:175–81.
72. Batuecas-Caletrio A, Trinidad-Ruiz G, Zschaeck C, Del Pozo de Dios JC, de Toro Gil L, Martin-Sanchez V, et al. Benign Paroxysmal Positional Vertigo in the Elderly. Gerontology. 2013;15:408–12.
73. Hilton MP, Pinder DK. The Epley (canalith repositioning) manoeuvre for benign paroxysmal positional vertigo. Cochrane Database of Syst Rev. 2004, Issue 2. Art. No.: CD003162.

74. Angeli SI, Hawley R, Gomez O. Systematic approach to benign paroxysmal positional vertigo in the elderly. Otolaryngol Head Neck Surg. 2003;128:719–25.
75. Brandt T, Huppert T, Hüfner K, Zingler VC, Dieterich M, Strupp M. Long-term course and relapses of vestibular and balance disorders. Restor Neurol Neurosci. 2010;28: 69–82.
76. Pérez P, Franco V, Cuesta P, Aldama P, Alvarez MJ, Méndez JC. Recurrence of benign paroxysmal positional vertigo. Otol Neurotol. 2012;33:437–43.
77. Núbia CPA, Bastone AC, Alcântara MA, Gomes WF. Effectiveness of aquatic and non-aquatic lower limb muscles endurance training in the static and dynamic balance of elderly people. Rev Bras Fisioter, São Carlos. 2010;14: 229–36.
78. Gillespie LD, Robertson MC, Gillespie WJ, Sherrington C, Gates S, Clemson LM, Lamb SE. Interventions for preventing falls in older people living in the community. Cochrane Database Syst Rev. 2012;12;9:CD007146.
79. Aquaroni Ricci N, Aratani MC, Caovilla HH, Freitas Ganança F. Effects of conventional versus multimodal vestibular rehabilitation on functional capacity and balance control in older people with chronic dizziness from vestibular disorders: design of a randomized clinical trial. Trials. 2012;13:246.
80. Johansson M, Åkerlund D, Larsen HC, Andersson G. Randomized controlled trial of vestibular rehabilitation combined with cognitive-behavioural therapy for dizziness in older people. Otolaryngol Head Neck Surg. 2001;125: 151–6.
81. Lynn S, Pool A, Rose D, Brey R, Suman V. Randomized trial of the canalith repositioning procedure. Otolaryngol Head Neck Surg. 1995;113:712–20.
82. Froehling DA, Bowen JM, Mohr DN, Brey RH, Beatty CW, Wollan PC, Silverstein MD. The canalith repositioning procedure for the treatment of benign paroxysmal positional vertigo: a randomized controlled trial. Mayo Clin Proc. 2000; 75:695–700.
83. Asawavichianginda S, Isipradit P, Snidvongs K, Supiyaphun P. Canalith repositioning for benign paroxysmal positional vertigo: a randomized, controlled trial. Ear Nose Throat J. 2000;79:732–4, 736–7.
84. Hånsson EE, Mansson NO, Håkansson A. Effects of specific rehabilitation for dizziness among patients in primary health care: a randomized controlled trial. Clin Rehabil. 2004;18: 558–65.