

Vestibular Rehabilitation: An Overview

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ABSTRACT

The approach in management of dizziness and disequilibrium is multidisciplinary. However, the emphasis is on function. Management models based on pathology alone may not provide the desired outcome as patients with similar pathologies will present with significant differences in impairments and functional limitations. Because of these differences, patients with similar pathologies may not respond the same to a given treatment. Both pathology and impairment information is essential for effective treatment planning. This article gives an overview of vestibular rehabilitation emphasizing on management models utilising treatment plans customized to individual patient's impairments. It briefly describes the anatomy and physiology of the motion sensors and its connections, explains the physiological basis of recovery from vestibular dysfunction and emphasizes the importance of history taking and examination to delineate impairments that cause activity limitation and participatory restrictions. Machine-based assessment may be used to quantify impairments. Use of equipments for rehabilitation shows good outcome but may not always be cost effective. Physiotherapists dealing with balance disorders are proficient in making a functional diagnosis to improve patient's balance and mobility tasks for safe and effective function in their daily life.

Keywords: Dizziness, Disequilibrium, Vestibular rehabilitation, Balance disorders.

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INTRODUCTION

Balance is one of those 'ordinary' body functions we do not think about until its disruption. Sit in a violently spinning roller coaster ride for a few minutes, however, and then try to walk upright. You'll become acutely aware that your vestibular system, located in your inner ear has been upset. The dizziness and nausea you feel are symptoms that the roller coaster ride disrupted the normal functioning of the system that maintains proper balance.

Unlike all other primates, humans ordinarily walk upright. This upright posture makes 'particular demands on the vestibular apparatus' because humans balance a large body mass 'on very small areas of support'. Our obligatory bipedalism is, maintained by the distinctive arrangement of the semicircular canals in our vestibular system.¹

The vestibular system, which is a contributor to our balance system and our sense of spatial orientation, is the sensory system that provides the dominant input about

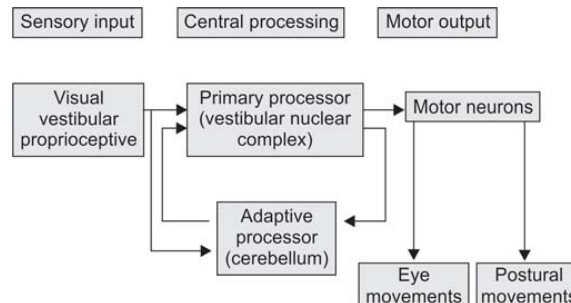


Fig. 1: Components of vestibular system

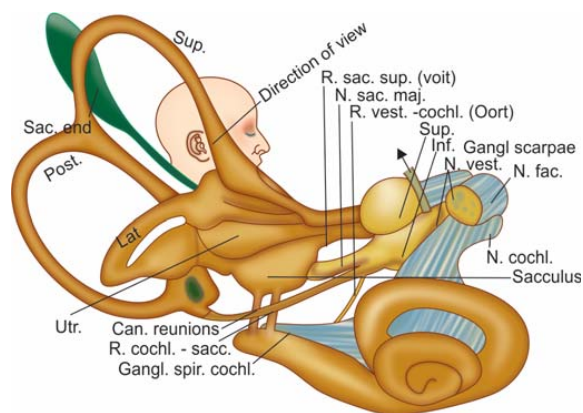


Fig. 2: Bony and membranous labyrinth

movement and equilibrioception. The vestibular sense provides information related to movement and head position and is important for development of balance, coordination, eye control, attention, being secure with movement and some aspects of language development.

The human vestibular system has three components: A peripheral sensory apparatus, a central processor and a mechanism for motor output (Fig. 1). The peripheral apparatus consists of a set of motion sensors that send information to the central nervous system—specifically, the vestibular nuclear complex and the cerebellum about angular head velocity (semicircular canals) and linear acceleration (Otoliths; Fig. 2). The central nervous system processes these signals and combines them with other sensory information to estimate head and body orientation. The output of the central vestibular system goes to the ocular muscles and the spinal cord to serve three important reflexes, the vestibulo-ocular reflex (VOR), the vestibulocollic reflex (VCR) and the vestibulospinal reflex (VSR). The VOR generates eye movements that enable clear vision while the

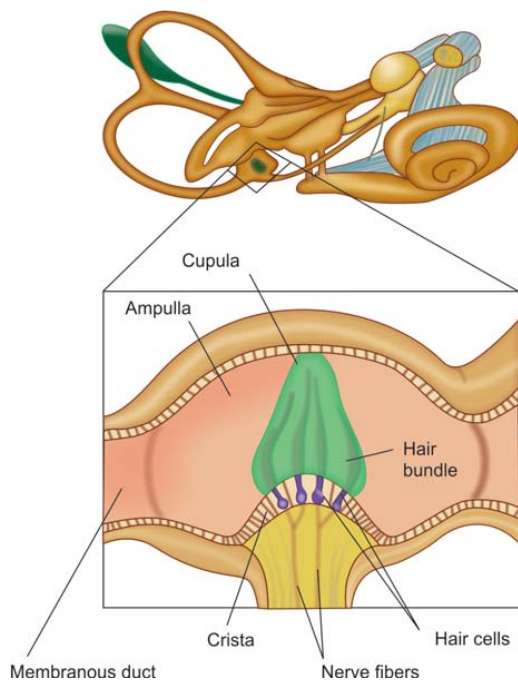
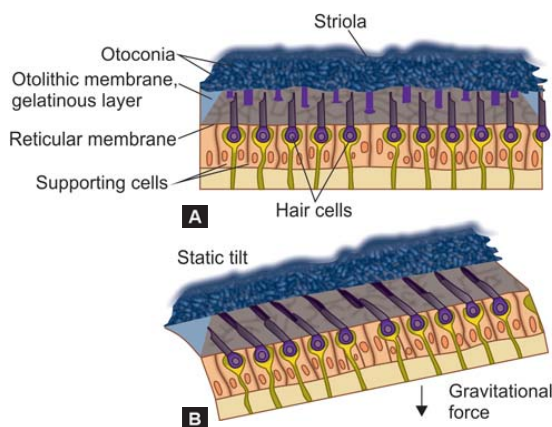


Fig. 3: Hair cells of ampulla



Figs 4A and B: Hair cells of otoliths

head is in motion. The VCR acts on the neck musculature to stabilize the head. The VSR generates compensatory body movements in order to maintain head and postural stability and thereby prevents falls. The performance of the VOR, VCR and VSR is monitored by the central nervous system, is readjusted as necessary by the cerebellum, and is supplemented by slower but more capable higher cortical processes.^{2,3} Physiotherapy treatment is directed toward retraining these reflexes and their connections to gain optimum function of the patient in his environment.

Hair cells present in ampulla and otolith organ, convert displacement due to head motion into neural firing. In the semicircular canals, the hair cells of ampulla rest on crista ampullaris (tuft of blood vessels, nerve fibers and supporting tissue). A gelatinous membrane called cupulae overlies each crista, which causes endolymphatic pressure differentials associated with head motion, to be coupled to hair cells (Fig. 3). The hair cells of saccule and utricle called the maculae, are located on the medial part of the saccule and floor of utricle (Figs 4A and B). Membranes of otolith are similar to cupulae, but as they contain calcium carbonate crystals called otoconia, they have more mass. The mass causes maculae to be sensitive to gravity. In contrast, the cupulae have same density as surrounding endolymph and are insensitive to gravity.^{2,3}

The labyrinthine artery, which is a branch of anterior inferior cerebellar artery, supplies the peripheral vestibular system (Fig. 5). Labyrinthine artery divides into anterior vestibular artery (AVA) and common cochlear artery. AVA supplies vestibular nerve, utricle and ampullae of lateral and anterior SCC. Common cochlear artery divides into main cochlear artery and vestibulocochlear artery that supplies part of cochlea, ampulla of posterior SCC and inferior part of saccule. It is important to note that the labyrinth has no collateral anastomosis and, therefore, is susceptible to ischemia. Only 15 seconds of selective blood flow cessation is needed to abolish auditory nerve excitability.⁴

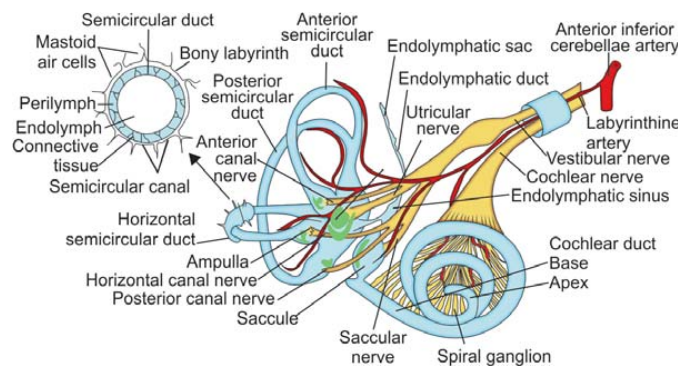
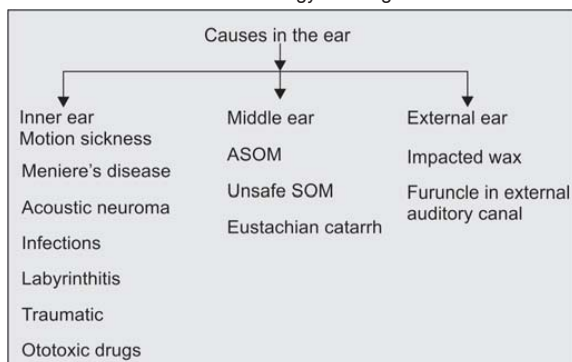


Fig. 5: Vascular supply of the vestibular apparatus

Box 1: Etiology of vertigo**Box 2: Systemic causes of vertigo**

- Cervical spondylosis:
 - Osteophytes reduce blood supply to labyrinth through compression of vertebral arteries
- Visual disorders like refractory errors and glaucoma
- Cardiovascular diseases
 - Hypertension/hypotension
 - Atherosclerosis
- Neurological diseases
 - Cerebellar tumors or abscess
 - Raised intracranial tension
 - Vertebrobasilar syndrome
 - Disseminated sclerosis
- Anemia
 - Diminished oxygen supply to labyrinth
- Metabolic disorders
 - Diabetes mellitus resulting in VIII cranial nerve neuritis
 - Hypoglycemia resulting in reduced nutrition to vital centers

VERTIGO

Vertigo is a distressing, illusionary sensation of turning linked to impaired perception of a stationary environment. It is an illusion of movement of self or environment resulting from sudden imbalance of tonic neural activity in the vestibular cortical pathway (Labyrinth, VIII nerve, thalamus and vestibular cortex). It is a mismatch between actual sensory inputs and expected pattern of sensory stimulation.

Vertigo is a symptom and not a disease. It often is accompanied by other symptoms, such as dizziness, disequilibrium, lightheadedness, rocking or swaying, motion sickness, nausea, vomiting, oscillopsia, floating, swimming, spinning. Vertigo indicates an imbalance in the vestibular system, which originates in: The inner ear, deep para-vertebral stretch receptors of the neck, Vestibular centers, cerebellum/upper cerebral pathways/cortex (Boxes 1 and 2).

History and Examination

History is the most important part of examination. The tempo, symptoms and circumstances of the complaint are the key items in the history. History should include a complete list of all of a patient's prescription as well as daily activities affected by dizziness (Box 3). The bedside clinical examination can distinguish peripheral from central vestibular problems, the extent of loss and how acute the problem may be (Boxes 4 to 7). Laboratory testing confirms

Box 3: Key questions in history

Questions to ask a patient with vestibular disorder	Current functional status
1. Do you experience spells of vertigo (a sense of spinning)? If yes, how long do these spells last?	1. Are you independent in self-care activities?
2. When was the last time the vertigo occurred?	2. Can you drive: • In the daytime? • In the nighttime?
3. Is the vertigo spontaneous, induced by motion induced by position changes?	3. Are you working? If yes, occupation: _____
4. Do you experience a sense of being off-balance (disequilibrium)? If yes, is the feeling of being off-balance constant, spontaneous, induced by motion, induced by position changes, worse with fatigue, worse in the dark, worse outside, worse on uneven surfaces?	4. Are you on medical disability?
5. Does the feeling of being off-balance occur when you are lying down sitting, standing or walking?	5. Can you perform all your normal parenting activities?
6. Do you stumble, stagger or side-step while walking?	6. Do you have difficulty: • Watching TV? • Reading? • Being in stores or malls? • Being in traffic? • Using a computer?
7. Do you drift to one side while you walk? If yes to which side do you drift?	7. Do you have difficulty walking up and down ramps, stairs, walking on grass?
8. At what time of day do you feel best? _____ worst? _____	
9. How many times per day do you experience symptoms?	
10. Do you have hearing problems?	
11. Do you have visual problems?	
12. Have you been in an accident (e.g. motor vehicle)?	
13. What medications do you take?	
14. Do you live alone?	
15. Do you have stairs in your home?	
16. Do you smoke? If yes, please indicate how much per day.	
17. Do you drink alcohol? If yes, please indicate how much.	

Box 4: Clinical examination of a dizzy patient

<i>Oculomotor examination (in room light)</i>	<i>Positional testing</i>
Nonvestibular: Extraocular movements, pursuit, saccades, VORc, diplopia	Hallpike: Dix test, side-lying test, roll test
Vestibular: Skew, spontaneous and gaze-evoked nystagmus, VOR to slow and rapid head thrusts, visual acuity test with head stationary and during gentle oscillations of the head	Motion sensitivity: Motion- and position-induced dizziness
With Frenzel lenses: Spontaneous and gaze-evoked nystagmus, head shaking-induced nystagmus, tragal pressure-induced nystagmus, hyperventilation-induced nystagmus and positional nystagmus	Sitting balance (active or passive, anterior-posterior and lateral): Weight shift, head righting, equilibrium reactions, upper and lower extremity, ability to recover trunk to vertical
Sensory examination: Superficial, deep, cortical sensations Superficial and deep reflexes Vision—visual acuity and field	Static balance (performed with eyes open and closed): Romberg test, sharpened Romberg test, single leg stance, stand on rail, force platform
Coordination tests: Optic ataxia/past pointing, rebound, diadochokinesia, heel to shin and postural fixation	Balance with altered sensory cues: Eyes open and closed, foam
Range of motion (active and passive): Upper and lower extremity, neck (rotation, extension, flexion, lateral flexion)	Dynamic balance (self-initiated movements): Standing reach (Duncan), functional (Gabell and Simons), Fukuda's stepping test
Strength (gross): Grip, upper extremity, lower extremity, trunk	Ambulation: Normal gait, tandem walk, walk while turning head, singleton to right and left, Dynamic Gait Index, Timed 'Up and Go'
Postural deviations: Scoliosis, kyphosis, lordosis	Functional Gait assessment: Obstacle course, double-task activities, stairs, ramps, grass and sand

Box 5: Motion sensitivity

Motion sensitivity quotient			
<i>Baseline symptoms</i>	<i>Intensity (A) (0-5)</i>	<i>Duration (B) in seconds</i>	<i>Score (A + B)</i>
1. Sitting to supine			
2. Supine to left side			
3. Supine to right side			
4. Supine to sitting			
5. Left Hallpike dix			
6. Return to sit from left Hallpike dix			
7. Right Hallpike dix			
8. Return to sit from right Hallpike dix			
9. Sitting head tipped to left knee			
10. Sitting, head up from left knee			
11. Sitting, head tipped to right knee			
12. Sitting, head up from right knee			
13. Sitting, turn head horizontally 5 times			
14. Sitting, move head vertically 5 times			
15. Standing, turn 180° to right			
16. Standing, turn 180° to left			
Duration: MSQ = Total score x (# of positions with symptoms)/20.48 5-10 secs = 1 point, MSQ 0-10 = Mild 11-30 secs = 2 points, 11-30 = Moderate >30 secs = 3 points >30 = Severe			

Box 6: The positive and negative affective scale (PANAS) for anxiety and depression

PANAS scale				
1	2	3	4	5
<i>Very slightly or not at all</i>	<i>A little</i>	<i>Moderately</i>	<i>Quite a bit</i>	<i>Extremely</i>
_____interested (P)	_____irritable (N)	_____jittery (N)	_____strong (P)	
_____nervous (N)	_____enthusiastic (P)	_____distressed (N)	_____alert (P)	
_____active (P)	_____excited (P)	_____ashamed (N)	_____afraid (N)	
_____upset (N)	_____inspired (P)	_____hostile (N)	_____guilty (N)	
_____determined (P)	_____proud (P)	_____scared (N)	_____attentive (P)	
P score (35.0 ± 6.4) if below 22 = Depression				
N score (18.1 ± 5.9) if above 29.9 = Anxiety				

Note: This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to it. Indicate to what extent you generally feel this way, that is, how you feel on the average. Use the following scale to record your answers.

Box 7: Clinical findings and pathology

Physical finding	Pathology
Spontaneous nystagmus present	Acute unilateral vestibular loss or brain stem/cerebellum abnormality
Skew eye deviation (vertical eye misalignment)	Disruption of peripheral or central utricle pathway
Decreased vestibular ocular reflex	Chronic vestibular hypofunction
Eye movements and vertigo elicited only during maneuvers	Usually, benign paroxysmal positional vertigo Rarely, central positional vertigo or nystagmus, perilymphatic fistula, hypermobile stapes, Ménière's disease, superior semicircular canal dehiscence
Visual tracking impaired	Brain stem abnormality
Imbalance while standing or walking	Any listed in table

the provisional diagnosis, quantifies the degree of loss and provides evidence of central compensation.

The components of the history and examination helpful in developing treatment goals are as follows:

1. List of patient's subjective complaints using patient questionnaires wherein the patient is presented with a written list of symptoms to check off.
2. Quantifying the intensity of specific symptoms using visual analog scale (VAS).
3. Impact of dizziness on functional activities using multidimensional dizziness inventory (Box 8).
4. The perceived disability caused by dizziness can be determined by the disability scale⁵ (Box 9).
5. History of falls should include description of any falls as well as 'near falls', the frequency of falls, last occurrence and any injuries associated with it.
6. The patient's confidence in balance can be obtained with the activities specific balance confidence scale developed by Powell and Myers which can either be self-administered or done through interview⁶ (Box 10)
7. Interference with daily activities like activities of daily living (ADLs), such as dressing, bathing, toilet activities, preparing meals, housekeeping, driving any problems at workplace should be noted.

Oculomotor and VOR Assessment

The oculomotor examination is one part of the overall assessment of the 'dizzy' patient and is an important part of physiotherapy evaluation.

1. **Spontaneous nystagmus in room light:** Spontaneous nystagmus occurs because of an imbalance in the tonic or resting firing rate of the vestibular neurons. In patients with unilateral peripheral vestibular hypofunction, spontaneous nystagmus will be observable in room light during the acute stage after onset of the lesion. Within a few days of onset, the patient should suppress the nystagmus with visual fixation. Patients in this acute stage often complain of having difficulty reading and watching television.⁷
2. **Smooth pursuit movements:** This is tested by asking the patient to track a moving object with the eyes while the head is stationary. Typically this test also assesses the motor function of cranial nerves III, IV and VI. Inability to perform downgaze is not a sign of vestibular deficits but can occur with other neurological problems (e.g. progressive supranuclear palsy). Patients with this problem may have difficulty seeing objects on the ground as they walk and with descending steps. During

Box 8: Dizziness handicap inventory*Dizziness handicap inventory*

Patient name _____ Date _____

Instructions: Please circle the correct response:

1. I have dizziness/unsteadiness: (1) 1 per month (2) >1 but <4 per month (3) more than one per week
 2. My dizziness/unsteadiness is: (1) mild (2) moderate (3) severe

Please read carefully: The purpose of the scale is to identify difficulties that you may be experiencing because of your dizziness/unsteadiness. Please check off 'Yes', 'Sometimes', or 'No' to each item. Answer each question as it pertains to your dizziness/unsteadiness only.

Yes Sometimes No

- _____ P1. Does looking up increase your problem?
 _____ E2. Because of your problem, do you feel frustrated?
 _____ F3. Because of your problem, do you restrict your travel for business or recreation?
 _____ P4. Does walking down the aisle of a supermarket increase your problem?
 _____ F5. Because of your problem, do you have difficulty getting into or out of bed?
 _____ F6. Does your problem significantly restrict your participation in social activities, such as going out to dinner, going to movies, dancing or to parties?
 _____ F7. Because of your problem, do you have difficulty in reading?
 _____ P8. Does performing more ambitious activities, like sports, dancing household chores, such as sweeping or putting dishes away increase your problem?
 _____ E9. Because of your problem, are you afraid to leave your home without someone accompanying you?
 _____ E10. Because of your problem, have you been embarrassed in front of others?
 _____ P11. Do quick movements of your head increase your problem?
 _____ F12. Because of your problem, do you avoid heights?
 _____ P13. Does turning over in bed increase your problem?
 _____ F14. Because of your problem, is it difficult for you to do strenuous house work or yard work?
 _____ E15. Because of your problem, are you afraid people may think you are intoxicated?
 _____ F16. Because of your problem, is it difficult for you to go for a walk by yourself?
 _____ P17. Does walking down a sidewalk increase your problem?
 _____ E18. Because of your problem, is it difficult for you to concentrate?
 _____ F19. Because of your problem, is it difficult for you to walk around your house in the dark?
 _____ E20. Because of your problem, are you afraid to stay home alone?
 _____ E21. Because of your problem, do you feel handicapped?
 _____ E22. Has your problem placed stress on your relationships with members of your family or friends?
 _____ E23. Because of your problem, are you depressed?
 _____ F24. Does your problem interfere with your job or household responsibilities?
 _____ P25. Does bending over increase your problem?

Examiner _____

Other _____

Comments: _____

Jacobson GP, Newman CW. The development of the dizziness handicap inventory. Arch Otolaryngol Head Neck Surg 1990;116:424-27.

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Box 9: Disability scale

For the following, please pick the one statement that best describes how you feel:

- | | |
|---|-----|
| _____ Negligible symptoms | (0) |
| _____ Bothersome symptoms | (1) |
| _____ Performs usual work duties but symptoms interfere with outside activities | (2) |
| _____ Symptoms disrupt performance of both usual work duties as well as outside duties | (3) |
| _____ Currently on medical leave or had to change jobs because of symptoms | (4) |
| _____ Unable to work for over 1 year or established permanent Disability with compensation payments | (5) |

Box 10: ABC scale for balance

The Activities-specific Balance Confidence (ABC) Scale*

For each of the following activities, please indicate your level of self-confidence by choosing a corresponding number from the following rating scale:

0% 10 20 30 40 50 60 70 80 90 100%
no confidence completely confident

How confident are you that you will not lose your balance or become unsteady when you...

1. ...walk around the house? ____%
2. ...walk up or downstairs? ____%
3. ...bend over and pick up a slipper from the front of a closet floor ____%
4. ...reach for a small can off a shelf at eye level? ____%
5. ...stand on your tip toes and reach for something above your head? ____%
6. ...stand on a chair and reach for something? ____%
7. ...sweep the floor? ____%
8. ...walk outside the house to a car parked in the driveway? ____%
9. ...get into or out of a car? ____%
10. ...walk across a parking lot to the mail? ____%
11. ...walk up or down a ramp? ____%
12. ...walk in a crowded mall where people rapidly walk past you? ____%
13. ...are bumped into by people as you walk through the mall? ____%
14. ...step onto or off an escalator while you are holding onto a railing?
15. ...step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing? ____%
16. ...walk outside on icy sidewalks? ____%

*Powell, LE and Myers AM. The ABC scale. J Gerontol Med Sci 1995;50(1):M28-34.

the test of smooth—pursuit eye movements, the presence of gaze evoked nystagmus and the quality of the eye movement should be noted. Gaze-evoked nystagmus is a sign of a central lesion.

3. *Ocular alignment:* Skew deviations, in which the eye opposite the side of the lesion is elevated, occur because of the loss of the tonic otoliths input from one side. Skew deviations can occur during the acute stage of a unilateral vestibular loss. As with spontaneous nystagmus from UVL, skew deviations from UVL should resolve within 3 to 7 days after onset.^{8,9}
4. *Saccadic eye movements:* This is tested by simply asking the patient to look back and forth between two horizontal or two vertical targets. Peripheral vestibular defects do not impair saccades. They are affected in central vestibular defects.
5. *The VOR cancellation (VORc):* It is a function of the parietal lobe tested by asking the patient to voluntarily fixate on a moving target while the head is moved in the same direction. A lesion in the parieto-occipital frontal cortex, frontal cortex, pontine nuclei, cerebellar vermis or flocculus causes deficits in smooth pursuit and VORc toward the side of lesion. In patients with cerebellar degeneration or other bilateral disorders, they are impaired in both directions.
6. *VOR:* The head thrust and dynamic visual acuity test, both assess the function of VOR.
 - i. The head thrust or head impulse test involves an unpredictable, high-acceleration, small-amplitude
 - ii. The dynamic visual test measures the degradation of visual acuity that occurs with head movement. In this test, the patient is first asked to read a wall eye chart with the head stationary. Then the patient is asked to read the chart while the head is gently oscillated at 2 Hz. In normal individuals, visual acuity changes at most by one line. In patients with uncompensated, unilateral vestibular loss, visual acuity degrades by three or four lines. A computerized system for measuring visual acuity during head movement is now available. Brandt suggests that distance acuity

head thrust in the horizontal plane. The patient sits with the head pitched in 30° of neck flexion and instructed to maintain visual fixation on the examiner's nose. The patient's head is gently grasped, and a small-amplitude but high-acceleration thrust is applied horizontally. When the head impulse stops, the eyes are observed for a corrective saccade, a rapid eye movement that returns the eyes to the target. The sensitivity of the test has been reported to be 54% and specificity to be 100%. People without vestibular disease will be able to maintain fixation during both slow and rapid head movements. People with vestibular deficits often are able to maintain fixation during slow head movements using the pursuit eye movement system but make corrective saccades to regain the target with rapid head movements. During the acute stage or with severe deficits, corrective saccades occur even with slow head rotations.¹⁰⁻¹²

- ii. The dynamic visual test measures the degradation of visual acuity that occurs with head movement. In this test, the patient is first asked to read a wall eye chart with the head stationary. Then the patient is asked to read the chart while the head is gently oscillated at 2 Hz. In normal individuals, visual acuity changes at most by one line. In patients with uncompensated, unilateral vestibular loss, visual acuity degrades by three or four lines. A computerized system for measuring visual acuity during head movement is now available. Brandt suggests that distance acuity

poorer than 20/50 has a significant effect on postural stability. Additionally, visual field loss can also affect balance,⁷⁶ and patients with monocular vision may have particular difficulty with depth perception, which would affect their ability to walk up and down stairs.¹³⁻¹⁸

7. Eye movements are also observed with the use of Frenzel lenses or video-oculography (VOG). Frenzel lenses magnify the eyes, with light inside them to help with visualization, enabling the clinician to observe eye movements and greatly decreasing the patient's ability to stabilize the eyes with visual fixation. The VOG systems permit the examiner to visualize the eyes in all positions, via infrared cameras that record eye movements and transmit the image to either a computer or television monitor. Clinical assessment of oculomotor function using Frenzel lenses should include spontaneous and gaze-evoked nystagmus, head shaking-induced nystagmus, tragal pressure-induced nystagmus, hyperventilation-induced nystagmus and positional nystagmus.¹³

Physiotherapy Diagnosis and the International Classification of Functioning, Disability and Health

Diagnosis is 'the art of distinguishing one disease from another'.¹⁹ In medicine, the identification of a particular

disease leads to specific medical and/or surgical treatment. A physiotherapy (PT) diagnosis (Fig. 6) differs from a medical diagnosis in that, rather than an attempt to identify a particular disease, a constellation of symptoms and signs is identified toward which physical therapy will be directed.²⁰ The International Classification of Functioning, Disability, and Health Model of Disablement (ICF), developed by the World Health Organization, provides a framework for the 'description of health-related states' that includes both positive experiences and negative consequences of disease.²¹ This scheme consists of three domains to describe the effect of different disorders or diseases on a person's health, with a number of environmental and personal factors that affect each of those domains (Box 11). The ICF model differs from other models of disablement in that it provides a more comprehensive depiction of the health of an individual. The model shifts the emphasis away from impairment and disability to a more balanced perspective that includes 'health'.²²

Impairments Due to Dizziness

Dysfunction in the vestibular system can be divided into distortion and deficiency.^{23,24} A deficiency implies that the labyrinthine inputs have been reduced or abolished, resulting mostly in gaze and postural instability. Distortion means that

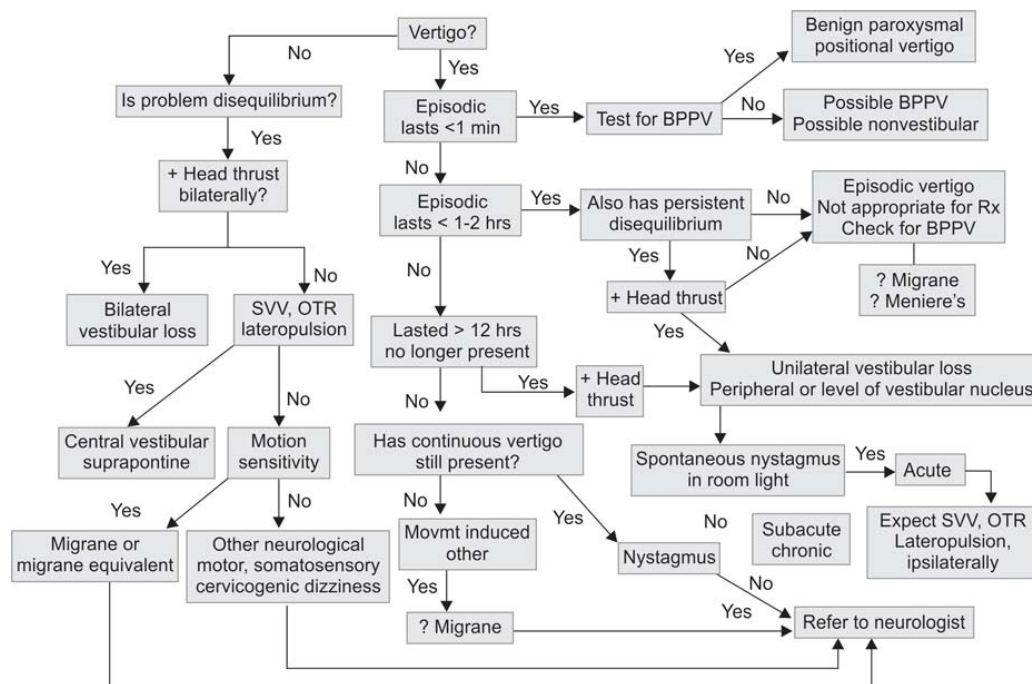


Fig. 6: Diagnostic flowchart of vertigo for physical therapists. Source: Vestibular rehabilitation by Susan J Herdman, 3rd ed, Philadelphia, FA Davies 2007:230 (OTR: Ocular tilt reaction; SVV: Subjective visual vertical; Rx: Treatment)

Box 11: The international classification of functioning, disability and health model of disablement (ICF)

Health condition Normal body function and structure vs Impairments (body level)	Activities vs Limitations (individual level)	Participation vs Restriction (societal level)
Contextual factors		
Environmental factors: Natural environment Support and relationships Attitude of family Attitude of society Services, systems, policies Products and technology		Personal factors: Gender, age Comorbidities Social background Education and profession Past experience Coping and character style

the signal is present but disturbed and does not correspond with expectations about the sensory feedback resulting in vertigo and ataxia. After a thorough investigation, we must list the possible impairments, such as:

1. Gaze instability
2. Abnormal perception of motion
3. Altered perception of orientation in space
4. Poor postural alignment
5. Inappropriate use of balance strategies
6. Impaired ability to use or switch between sensory strategies.

These impairments lead to significant disability and difficulty in performing activities of daily living. Vestibular rehabilitation focuses on prioritizing patient's impairments. Practice is client focused and intervention is evidence based. The management is based on restoring adequate motor behavior by readjusting the input and output relationship of the VOR and VSR and restoring optimal functional independence.

Physiotherapy Program is based on

1. The problem areas identified during the evaluation
2. The patient's diagnosis, e.g. perilymphatic fistula, Meniere's disease, benign paroxysmal positional vertigo (BPPV), etc.
3. The patient's medical history, e.g. diabetes mellitus, orthostatic hypotension, etc.

Vestibular Rehabilitation

Vestibular rehabilitation is an exercise approach to the remediation of disequilibrium and dizziness symptoms associated with vestibular pathology. The role of medications is to suppress vestibular function. Medication has the disadvantage of potential habituation and sedating side effects that limits patient's ability to perform useful activities. The aims of vestibular rehabilitation are to decrease dizziness, increase balance function and increase general activity levels. The exercises are designed dependant

on the impairments identified through evaluation, to promote CNS compensation for the deficits of the vestibular system.

Physiological Basis for Vestibular Rehabilitation

Vestibular rehabilitation is based on the following principles:

1. **Adaptation:** It refers to a long-term improvement in the vestibular systems ability to adapt to head movement, achieved by the movement of an image across the retina. The best stimulus to induce adaptation is one that produces an error signal. Patient is encouraged to continue even if symptoms increase. Adaptation is context specific, i.e. it occurs for the frequency practiced. Adaptation of VOR can occur even in the dark. Concentration on the task is required. Patient should work within limits of his ability (speed should be increased as long as visual target is in focus). For example, Cawtherne Cooksey exercises.²⁵⁻²⁹
2. **Habituation:** It refers to reduction in symptoms and pathological responses produced by repetitive exposure to the provoking stimulus. It is a central process. Movements should be practiced 2 to 3 times per day. The movements performed should be quick and through sufficient range to produce mild to moderate symptoms. As habituation occurs, movements performed should be more vigorous with pauses at the end of every movement until dizziness subsides. It takes 4 weeks for the symptoms to reduce. Elderly patients should be treated with caution.³⁰⁻³⁴ For example, Brandt-Daroff exercise for BPPV, motion sensitivity training.
3. **Substitution:** These exercises synthesize the use of vision and somatosensory cues with vestibular cues to enhance central programming to improve gaze stability and postural stability. Pathology within the vestibular system leads to an alteration in the relative reliance on sensory information. Patients with bilateral vestibular loss substitute vision and proprioception for use of vestibular information. Such patients are increasingly incapacitated in the dark especially in dazzling lights from vehicles while walking on a rough terrain. Therefore, by

performing exercises in environments with altered sensory information, vestibular rehabilitation is able to affect a person's use of sensory information or sensory reweighting, e.g. sensory organization training, virtual reality.

4. **Compensation:** Compensation is a gradual process of functional recovery that is probably of central origin.^{35,36} Patient's with vestibular loss use different compensatory strategies to improve their ability to see clearly during a head rotation.³⁷⁻⁴⁰ Compensatory mechanisms include substitution or modification of a saccade, increased gain of the cervico-ocular reflex, the use of centrally programmed eye movement and possibly, enhancement of smooth pursuit system.

Patients may develop compensatory strategies on their own to use when in situations in which their balance will be stressed. Different patients use different sets of strategies to compensate for loss of VOR and VSR. It is the physiotherapist who will identify the changed behavior and enhance the use of these strategies to optimize function and prevent and ensuing morbidity.

Cawthorne Cooksey Exercises

Cawthorne Cooksey exercises devised in 1940 are till today commonly used to decrease dizziness (Fig. 7). The exercises devised were primarily for unilateral vestibular lesion. Initially, the exercises performed are slow gradually increasing speed as patient tolerates the movement. The

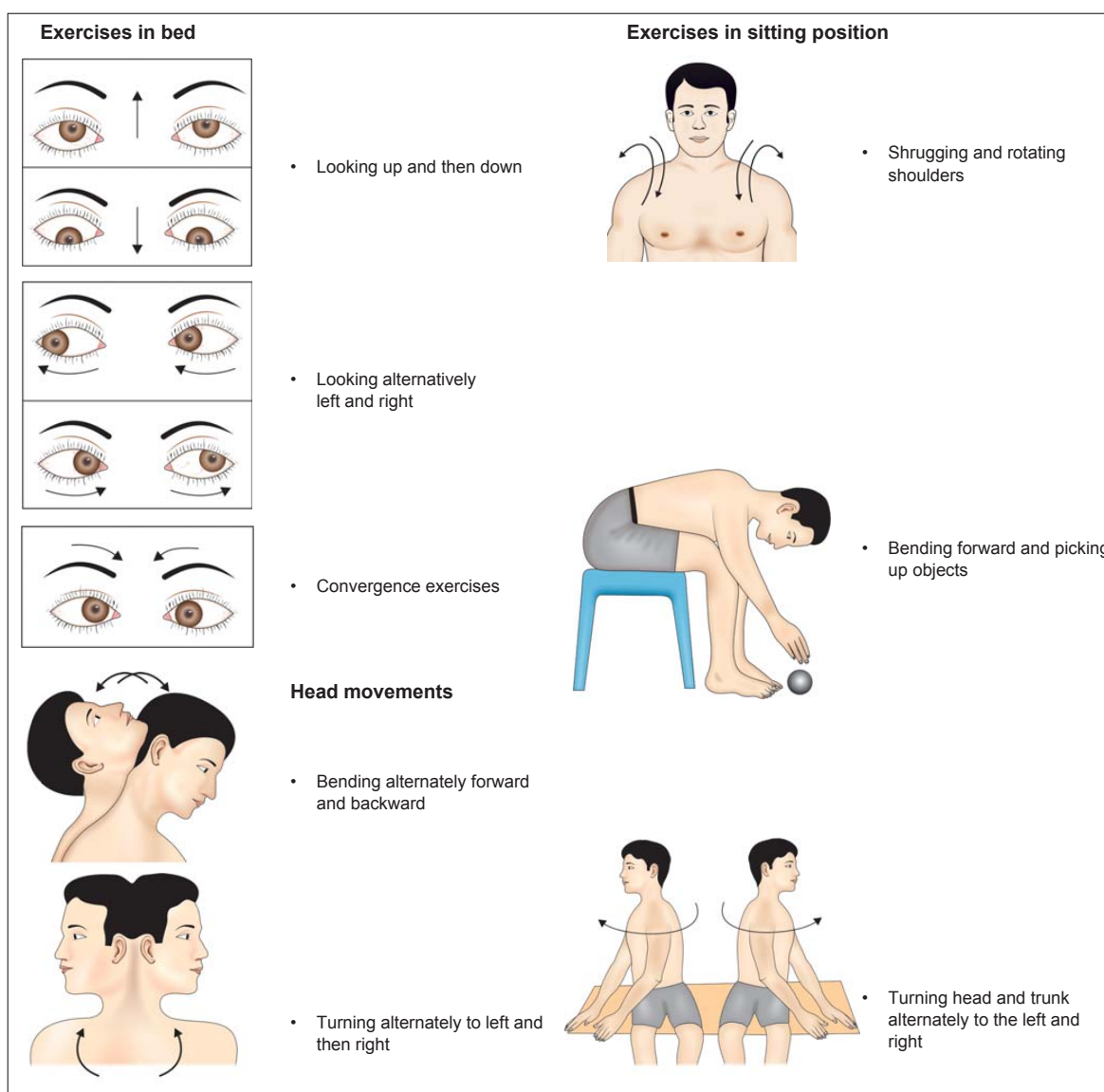


Fig. 7: Cawthorne-Cooksey exercises

patient should experience an increase in symptoms with movement. The exercises performed should be for at least 1 minute several times each day for adaptation to occur. The head is moved at varying frequencies in both horizontal and vertical planes. It exists in form of pamphlets handed out routinely by doctors and pharmaceutical companies. The advantage of these exercises is that they are low-cost and effective. The disadvantage is that they have a high likelihood of being only treatment specific, i.e. patient becomes good at specific exercises without improving functionally. In addition, adaptation is specific to the frequency of head movements performed and the plane of head movements.^{41,42}

Customized Exercises

The problem oriented or customized treatment approach can incorporate adaptation, habituation, substitution and compensatory strategies according to what is needed. In addition, this approach also incorporates functional activities and principles of motor learning and motor control.

Numerous studies show that tailor-made exercises are more effective and satisfying. The patients are more compliant to a program with interesting purposeful activities. These exercises are both function and treatment specific. Adaptation and habituation is only for the function practiced. However, no controlled clinical trial has compared the different treatment approaches (Box 12). For example:

BPPV	Canalith repositioning and Brandt-Daroff maneuver
Gaze stability	VOR and VOR cancellation exercises
Postural stability	Training of motor and sensory strategies

BPPV

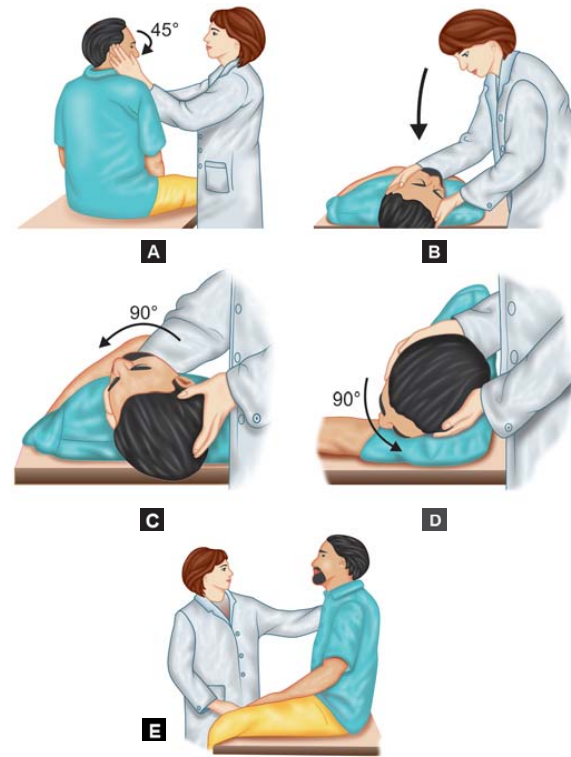
BPPV is characterized by brief episodes of vertigo when the head is moved into certain positions.⁴³ It has been reported in adults of all ages although it is uncommon in children. It may occur spontaneously or may follow head injuries, labyrinthitis or ischemia in the distribution of

anterior vestibular artery. Spontaneous remission is common. Patients with BPPV commonly complain of dizziness triggered by lying down, turning in bed or getting out of bed, bending over and looking up.

Schuknecht, in 1969 proposed the cupulolithiasis theory in which the degenerative debris—fragments of otoconia—from the utricle adhere to the cupula of the semicircular canals, making the ampulla gravity sensitive. It is characterized by immediate onset of vertigo and nystagmus when patient moves into the provoking position and persistence of vertigo and nystagmus as long as the patient's head is kept in the provoking position.⁴⁴

Hall et al proposed a second canalithiasis theory in which the degenerative debris is not adherent to the cupula but is free floating in the endolymph of the semicircular canals. It is characterized by a delay in the onset of the vertigo and nystagmus of 1 to 40 seconds after the patient has moved into the provoking position and a fluctuation in the intensity of vertigo and nystagmus, which increase and then decrease, disappearing within 60 seconds.⁴⁵

Initially, BPPV was believed to involve only the posterior semicircular canal but it has now been recognized that involvement of anterior and horizontal canals also occurs. Proper identification of the involved canal and determination of cupulolithiasis and canalithiasis, dictate which treatment is appropriate (Figs 8 to 10).



Figs 8A to E: CRT maneuver for BPPV

Box 12: Customized treatment options

Diagnosis	Treatment options
BPPV	Canalith repositioning, liberatory, Brandt-Daroff exercises
Unilateral vestibular hypofunction	Adaptation, substitution (habituation)
Motion sensitivity	Habituation
Bilateral vestibular loss	Substitution, adaptation
Central vestibular	Habituation

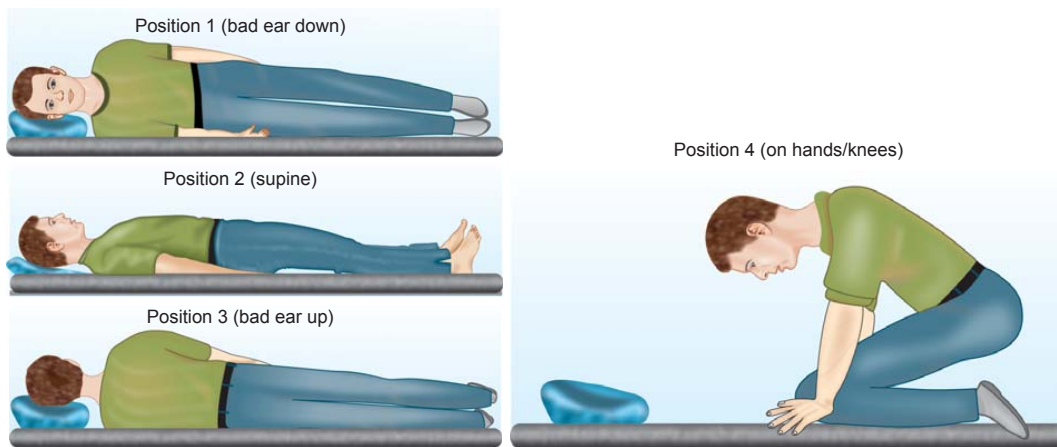


Fig. 9: CRT maneuver horizontal canal

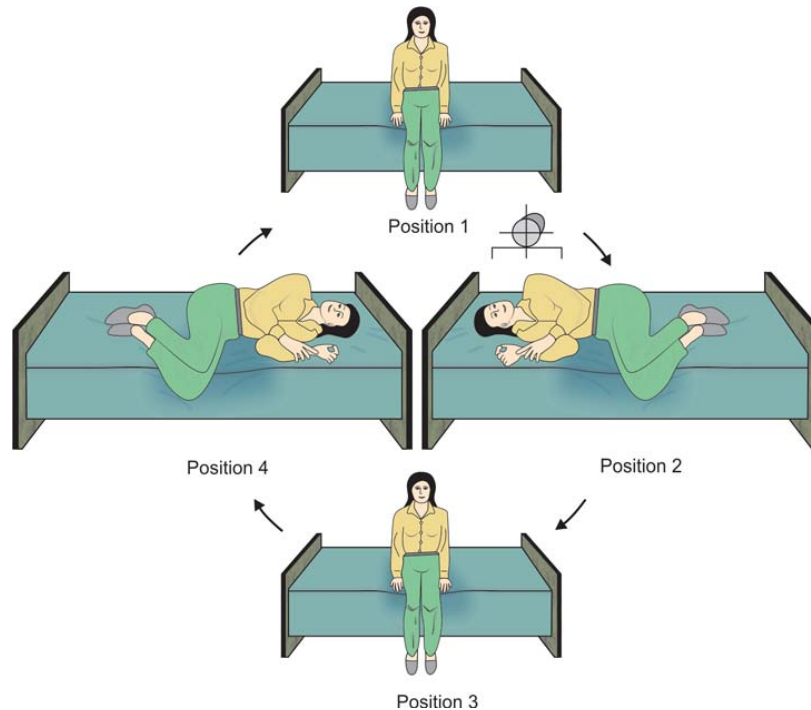


Fig. 10: Brandt-Daroff exercises

Test Series

One can easily assess all three canals for BPPV quickly with the following test procedure. Assuming that patient complains of vertigo on lying on the right side, the test series is as follows:

- i. Perform the Hallpike-Dix test on the left side.
- ii. Perform the Hallpike-Dix on the right side.
- iii. If the patient has no vertigo: Before sitting the patient up from the right side, perform a roll test by turning the patient's head quickly to the left.
- iv. After 30 seconds, turn the head quickly back to the right.
- v. After 30 seconds, have the patient sit-up.

If at any given time during the series, nystagmus and vertigo occur, the testing should be stopped and patient treated (Table 1).

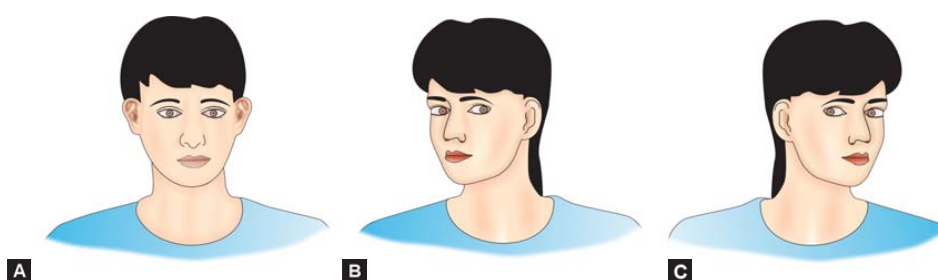
Gaze Stability Exercises

1. A business card or a target with words on it (foveal target) is taped in front of the patient so that the patient can read it. The patient first moves his head horizontally and then vertically for 1 minute keeping the words in focus (Figs 11A to C).
2. Repeat the above exercise with a large pattern, such as a checkerboard.

Table 1: Treatment options and indications for BPPV

Semicircular canal involved	Severe canalithiasis	Mild canalithiasis	Cupulolithiasis
Posterior	CRT* Liberatory maneuver Brandt-Daroff exercises	Brandt-Daroff exercises* CRT Liberatory maneuver	Liberatory maneuver* Brandt-Daroff exercises
Anterior	CRT* Liberatory maneuver- anterior canal Brandt-Daroff exercises	Brandt-Daroff exercises* CRT Liberatory maneuver Anterior canal	Liberatory maneuver* AC Brandt-Daroff exercises
Horizontal	Bar-B-Que roll treatment* Forced prolonged sitting	Bar-B-Que roll treatment* Forced prolonged sitting	Bar-B-Que (quick movements)

*Preferred method is listed first; AC: Anterior canal; CRT: Canal repositioning treatment (*Courtesy: Susan Herdman, Vestibular rehabilitation, 3rd ed, pg 239*)



Figs 11A to C: Gaze stabilization exercises: (A) Look straight ahead, (B) turn your head 45° toward the right, (C) turn your head 45° toward the left

3. Hold a business card in front of the face so able to read it. Move the card and the head in opposite directions (initially horizontally for 1 minute then vertically) keeping the words in focus.
4. In the chronic stage, the patient fixates on a visual target placed on the wall in front while gently bounces up and down on a trampoline (otoliths stimulation).

Patients should be cautioned that the exercises may make them dizzy or nauseated but that they should try to continue for full 1 to 2 minutes, resting between the exercises. The exercises should be performed three times a day and gradually increased to five times a day.

Postural Stability Exercises

1. Patient stands with feet as close together as possible with one or both hands touching the wall to maintain balance if needed. Turn the head to the right and to the left for 1 minute without stopping. Repeat the exercise with feet closer together.
2. Practice turning the head while walking. Initially practice near a wall to prevent falls.
3. Stand with feet close together. Outstretch the hands in front then bring arms close to the body and lastly keep the arms folded across the chest. Maintain each position for 15 seconds. Repeat the exercises by standing in

tandem stance position, i.e by placing one feet in front of the other.

4. Repeat the above exercise with eyes closed.
5. In standing, shift weight from one leg to the other.
6. Stand on a cushioned surface (sofa cushion).
7. Walk backward. The difficulty is increased by asking the patient to count backward while walking.
8. Walk in a large circle then walk in smaller circles and finally in figure of eight.
9. Walk on ramps and uneven surface.
10. Balance training on dynamic surface like vestibular ball or a trampoline.
11. In the community, walk in a mall when it is least crowded. Practice walking in the same direction as the flow of traffic or against the flow of traffic.

General Conditioning Exercises

Patients with vestibular dysfunction maybe significantly deconditioned due to inactivity. Such patients are mostly advised to begin a regular walking program to not only prevent deconditioning but also to provide realistic balance challenges to the CNS, e.g. walking on uneven terrain, crossing a road, etc. Initially, they are advised to walk for 15 to 20 minutes daily gradually increasing to 30 minutes daily and later encouraged to walk in a park and shopping

mall. Patients can be encouraged to return to recreational activities like golf, tennis, badminton, that will help to improve their fitness. Patients with unilateral vestibular lesion can safely perform swimming; however, they should not swim alone. Patients with bilateral vestibular loss, swimming is not advisable as under water, without visual cues, they may not know which way is up.

Tai-Chi, a form of martial arts, is also effective especially in the elderly to improve balance and decrease the risk of falls. It improves postural stability, attentional control and emotional state.

Machine-based Rehabilitation Techniques include Simulation-based Treatment

There was a need to develop enhanced vestibular rehabilitation programs (machine based + customized) for chronic vestibular patients who did not respond to Cawtherne Cooksey exercises and customized exercises. The vestibulo-ocular system is frequency dependant. VOR adapted at a single frequency of head rotation, will have the greatest change in gain only at that frequency. Therefore, in order to improve VOR gain across many frequencies and to best mimic normal motor activity the exercises must require the patient to perform at many frequencies, speed and direction. For example, optokinetic drums, whereby speed, direction and frequency can be controlled and measured in combination with head and body movements, provides better results.

Machine-based rehabilitation provides feedback. Feedback speeds up the rehabilitation process through task understanding and performance accuracy maintaining patient's motivation and enhancing rehabilitation outcomes. The different equipments used in machine-based rehabilitation are as follows:

1. *Optokinetic drum and disks*: To facilitate rehabilitation of gaze stability at various speeds, direction and frequency of movement, motor driven optokinetic drums and disks are used for better carryover to daily function. The patient is safely secured in standing position and instructed to focus on a particular spot while the disk or drum rotates in a clockwise or counterclockwise direction at varying speeds from very slow to very fast.
2. *Dynamic posturography*: It consists of a moving platform which trains the patients to rely on remaining vestibular input, particularly in condition with eyes closed. Training of weight shifts and stability limits is also possible. The moving platform is coupled to a computer monitor. The patient is asked to keep center of posture (CoP) within a box on the screen or to track a

target. To retrain balance the patient is placed on normal and perturbed surfaces and having them move their CoP in concert with visual cues, patterns and mazes. Patients with history of falls, avoid moving their CoP in the direction in which they are prone to falls. By working on the static patterns, the therapist can isolate the directions the patient is most at risk of falling. Maze exercises help to rehabilitate the patient by 'pushing' them toward the directions that he/she tries to avoid.

3. *Virtual reality*: Virtual reality technology offers complex sensory environment in the physical world in the controlled environments of the laboratory. The patients are so immersed in the environment that they feel that they are a part of the same. It is a laboratory created synthetic environment with precise control over a large number of physical variables, which improves behavior while recording physiological and kinematic responses. Patients are exposed to unpredictability of visual environment, e.g. head mounted display: Patients wear this device and can freely move while interacting with the visual images.

Video capture: It permits the patients to observe themselves interacting with virtual objects in the laboratory.

4. *Home rehabilitation videos*: These are videos of optokinetic drum and disk. The patients can use these videos at home with progressive sessions—in different positions, clockwise and counterclockwise, at different distances, speeds and different support surfaces.

SAFETY STRATEGIES

In patient's with bilateral vestibular loss, vestibular rehabilitation may not show complete improvement hence, safety strategies should be taught to the patient. We should teach strategies to increase safety in environment like:

- Use night lights for bathroom.
- Assistive devices in visually active environments like walking the aisle of a grocery store should be used.
- Use flashlight while walking in the dark on a rough terrain.

SUMMARY

- Use the dizziness handicap inventory to find out in which situation the patient is incapacitated.
- Prioritize the situations and identify the movements required to function in these situations.
- Identify the sensory motor kinetic and kinematic requirements of these movements and make a list of impairments.

- Using the best possible evidence to workout a treatment program to reduce/eliminate the impairment (if amenable to change) by using principles of motor control and learning.
 - Improved impairment leads to improved function and eradicates or minimizes the handicap, alleviates depression and improves quality of life so that the patient returns to his optimal functioning level in his community.
- Dizziness cannot be dismissed as a trivial symptom. Thorough examination cannot be more emphasized. A tailor-made exercise program can be devised to restore patient's functional safety and improve quality of life.

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