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by Orthopedic & Sports P.T. Assoc. OSPTA
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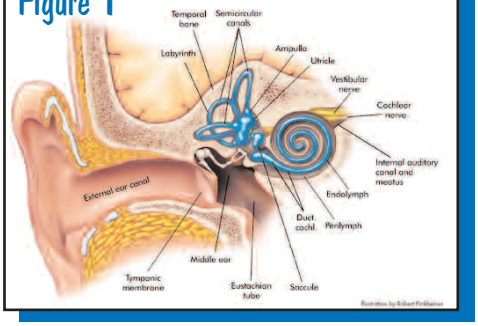
Vestibular Dysfunction

INTRODUCTION

Vestibular Dysfunction is an impairment of 1 of the 3 primary sensory modalities that contribute to postural stability, balance and control. The somatosensory and visual systems are the other two contributing sensory modalities. Patients with vestibular dysfunction report postural instability, dizziness, sensations of abnormal movement and vertigo. Vertigo refers to the illusion of rotation, forward or backward movement, or tilt caused by vestibular input imbalance.

Figure 1



Many patients complain of unsteadiness when they walk or climb stairs. Postural instability may worsen when the other sensory inputs are altered. Walking in the dark is an example. Other patients experience perceptions of the world moving or jumping, making normal activities such as reading or driving problematic. Activities of daily living (ADL's) may be impeded because head movement may worsen dizziness or lead to falls.

42% of the adult population is estimated to complain of vertigo or dizziness to their physicians. In 85% of patients presenting with these symptoms, the cause is vestibular system dysfunction.

ANATOMY AND PHYSIOLOGY OF THE VESTIBULAR SYSTEM

The vestibular system has **3 major components**:

1. **Peripheral Sensory Apparatus (PSA):** responsible for detecting and relaying information about head linear and angular velocity to the central processing system. The PSA also orients the head with respect to gravity, and is located in the inner ear (Figure 1).

2. **Central Processing System (CPS):** processes the information from the PSA in conjunction with the visual and somatosensory systems to provide accurate information about the movement and position of the head in space. The CPS is located in the vestibular nuclear complex in the brain stem and the cerebellum.

3. **Motor Output System:** generates compensatory eye movements for gaze stability and compensatory body movements for postural stability during locomotion, head movements and posture. Mediated through the vestibular-spinal reflex (VSR) and the vestibular-occular reflex (VOR).

Vestibuloocular reflexes (VOR): The primary function of the VOR is to maintain gaze stability during head motion.

Glossary

Ataxia:	inability to coordinate voluntary muscular movement.
Diplopia:	disorder of vision in which (2) images of a single object are seen.
Nystagmus:	a rapid involuntary oscillation of the eyeballs.
Tinnitus:	a sensation of noise in the ear.
Vertigo:	dizziness

Vestibulospinal reflexes (VSR) affect whole body equilibrium by the inhibition and the facilitation of skeletal extensor muscle activity.

PERIPHERAL SENSORY APPARATUS (PSA)

The peripheral vestibular system in each inner ear is comprised of a **bony labyrinth,** a **membranous labyrinth,** and **specialized hair cells** that detect motion.

The **bony labyrinth (BL)** is located within each temporal bone of the skull. The BL contains a central chamber called the vestibule. Perilymphatic fluid fills the BL and the membranous labyrinth (ML) is suspended in this fluid.

The **membranous labyrinth (ML)** consists of the **otolith** and **3 semicircular canals.**

The otolith has 2 swellings which are the utricle and saccule located within the vestibule. The utricle detects horizontal plane linear accelerations, while the saccule responds to vertical linear accelerations of the head in the sagittal plane. They are also sensitive to head tilts with respect to gravity, and are sensitive to lower frequency motion (motion that occurs while standing).

The semicircular canals lie perpendicular to each other, sense angular acceleration of the head, and are sensitive to higher frequency movement such as locomotion. Each canal is sensitive to movement in the same plane as the canal.

Specialized hair cells within each of the sensory organs convert mechanical information into neural firing. Specialized hair cells are the basic sensory unit of the PSA, and are present in the otoliths and the semicircular canals. Each hair cell is innervated by an afferent neuron, and has a large number of small cilia and a large cilium called the kinocilium.

Overlying each set of hair cells in the semicircular canals is a gelatinous membrane called the **cupula.** Calcium carbonate crystals are located within the gelatinous membrane, and rest on top of the hair cells of the otoliths. These crystals are called **otoconia.**

Head movement causes endolymph flow, displacing the cilia and transducing movement into an electrical response that the vestibular nerve carries to the brain.

CENTRAL PROCESSING SYSTEM

The central processors of the vestibular system are the cerebellum and the vestibular nuclei. The otoliths and the semicircular canals send afferent input along the vestibular nerve to the cerebellum and the vestibular nuclear complex, which is located in the pons and the medulla oblongata.

The vestibular nuclei receive input from a multitude of sources:

1. Ipsilateral vestibular nerve
2. Contralateral vestibular nuclear complex
3. Cerebellum
4. Brainstem reticular activating system
5. Spinal cord
6. Somatic, visual, and auditory sensory systems

Output [efferent signals] from the vestibular nuclei goes to the occuolomotor nuclei, cerebellum, brainstem reticular activating system, parietal cortex, ipsilateral vestibular spinal tract and the contralateral vestibular nuclear complex

MOTOR OUTPUT SYSTEM

The vestibular system functions both as a motor system and a sensory system. During movement, the vestibular sensory organs relay information to the CNS. This information is constantly being influenced and altered by motor signals originating from the vestibular system. The efferent output from the central vestibular system goes to the ocular muscles, and to the spinal cord to serve the VOR and the VSR. These reflexes work in conjunction with both motor systems to provide gaze stability and whole-body equilibrium during posture, head movement and locomotion.

DISORDERS OF THE VESTIBULAR SYSTEM

Disorders can be categorized by their location, either **peripheral** or **central.**

PERIPHERAL VESTIBULAR DISORDERS

Reduced vestibular functions are conditions that

result in reduced sensitivity of the peripheral sensory apparatus to stimuli. Examples include direct damage to the vestibular nerve, labyrinth, or hair cells. The damage may be unilateral, bilateral, partial or complete. Etiologies such as brain trauma, age related degeneration of hair cells, labyrinthitis, neuronitis, or drug-induced ototoxicity may produce reduced vestibular function.

1. Patients with unilateral pathology often have vertigo, disequilibrium, and impaired gaze stability. Patients with bilateral pathology may have no vertigo due to any left/right asymmetry but may have disequilibrium, gait ataxia, and the inability to stabilize am image on the retina (oscillopsia).

2. Distorted vestibular functions are conditions that result in inaccurate transduction of sensory stimuli within the PSA. This is usually due to a mechanical disruption. A common example of this type of dysfunction is benign paroxysmal positional vertigo (BPPV), a disruption that occurs when otoconia from the utricle are free floating in the endolymph or are displaced into the cupula of one of the semicircular canals. Either situation causes the involved canal to become gravity sensitive producing abnormal input to the vestibular nuclei. Patients with distorted vestibular function often have position or motion induced vertigo and may have disequilibrium.

3. Fluctuating vestibular function refers to conditions that produce occasional disruptions in vestibular input within the PSA. Periods of abnormal function may be followed by periods of normal function. Examples of conditions that may result in fluctuating vestibular function are Endolymphatic Hydrops (EH) and Perilymphatic Fistulas (PF). Patients with fluctuating vestibular function may have episodic or persistent vertigo, generalized dizziness, hearing loss tinnitus and disequilibrium. EH is characterized by fluid and electrolyte control fluctuations in the inner ear. PF are characterized by pressure changes between the inner and the middle ear. The etiology of these conditions may be due to brain trauma, infection, autoimmume, or idiopathic diseases.

CENTRAL VESTIBULAR DISORDERS

Central vestibular disorders may result from ischemia, hemorrhage, or vascular disorders to the brainstem or cerebellum. Tumors in the brain stem or cerebellum may affect the vestibular nuclei or vestibulocerebellum.

Patients with central vestibular disorders may have many symptoms, including vertigo, nausea, nystagmus, ataxia, dysequilibrium, visual field deficits, diplopia, headache and hemiparesis.

VESTIBULAR REHABILITATION

Vestibular rehabilitation is an exercise approach that has been used for the last 15 years to manage persistent dizziness and disequilibrium in people with vestibular dysfunction. Our next issue will cover examination, management, goals, and expected outcomes following a physical therapy rehabilitation program.

Core Purpose:

OSPTA provides rehabilitation services to allow patients to maximize their functional abilities.

Core Values:

1. *OSPTA is dedicated to quality care by providing a positive rehabilitation atmosphere, focusing on therapeutic outcomes, achieving high patient satisfaction, and maintaining cost effective treatments.*
2. *OSPTA provides personalized patient care by emphasizing a teamwork approach and "hands on" care by our office and clinical staff.*
3. *OSPTA is a close knit corporation that desires the respect, loyalty, and dedication of its employees.*
4. *OSPTA is committed to providing a high level of satisfaction to its patients, physicians, payers, and employees.*
5. *OSPTA is dedicated to the ethical and professional standards set forth by the American Physical Therapy Association.*