# Introduction to Balance

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# What is balance?

- Definition:

"The process by which we control the body's centre of gravity (COG) in relation to its stationary or moving base of support (BOS)"

# What is balance?

- Stability

Instability

Avoiding instability

Anticipating instability

Recovering from instability

# Balance

- Balance/postural control is the ability to control one's position in space to achieve orientation & stability

- Postural control is needed:
  - To maintain a steady state position
  - To accompany voluntary movement
    - Proactive/anticipatory balance

  - In response to external perturbation
    - Reactive balance

    Balance is an emergent property. There is an inbuilt genetic component with basic reactions, but it is then something that we learn.

# Steady State Balance

- IS ACTIVE
- Aims to keep the centre of mass (COM) within the base of support (BOS)
- Aims control anterior & posterior postural sway (lateral)
- Provide postural orientation

# Steady State Balance

- Postural sway

  - For many years thought that system worked as an inverted pendulum with activity around the ankle to correct and maintain balance.

  - Recruitment of activity at either ankle or more proximally also depends on speed of sway frequency

  - Low frequency –recruitment of activity around the ankle
  - Higher sway frequency – recruitment of activity around hip/pelvis.

# Control of postural sway

- Muscles involved: glut med, TFL, iliopsoas, thoracic erector spinae, gastrosoleaus & intermittent abdominals & tib. Ant.

- Sensory integration: vision, proprioception & vertibular.

# Sensory Systems

- The initial stimulus for balance/movement may be driven by the receipt of sensory information but it is not necessarily reliant on it

- Sensory information is however necessary for both the control /modulation/refining of balance/movement & for its updating/learning

# Sensory systems

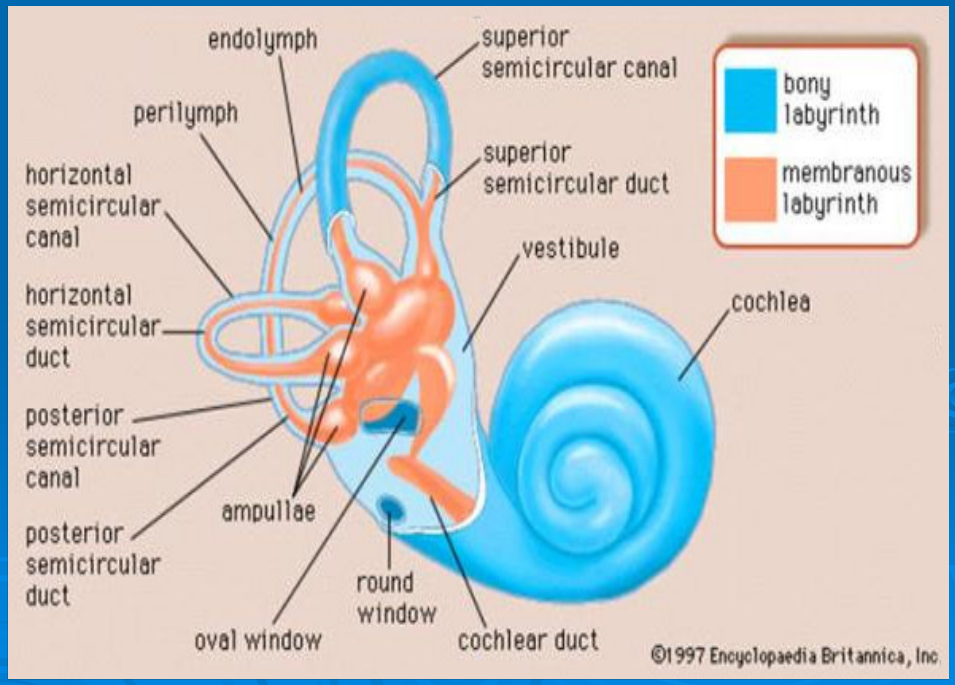
- For balance/movement, the main three systems that are important for providing information:
  - Visual System
    - Reference to objects & the environment (esp. verticality)
  - Vestibular System
    - Reference to head position/motion/gravity
  - Somatosensory System –both cutaneous & proprioception input
    Reference to supporting surface & body alignment

# Sensory systems

- Maintaining balance requires coordination of input from these three sensory systems

# Vestibular system

- Sense organs that regulate equilibrium; directional information as it relates to head position (internal gravitational, linear, and angular acceleration)



# Somatosensory system

- Senses of proprioception of joints
- Information from skin and joints (pressure and vibratory senses)
- Spatial position and movement relative to the support surface
- Movement and position of different body parts relative to each other

# Visual system:

- Orientates the body in space

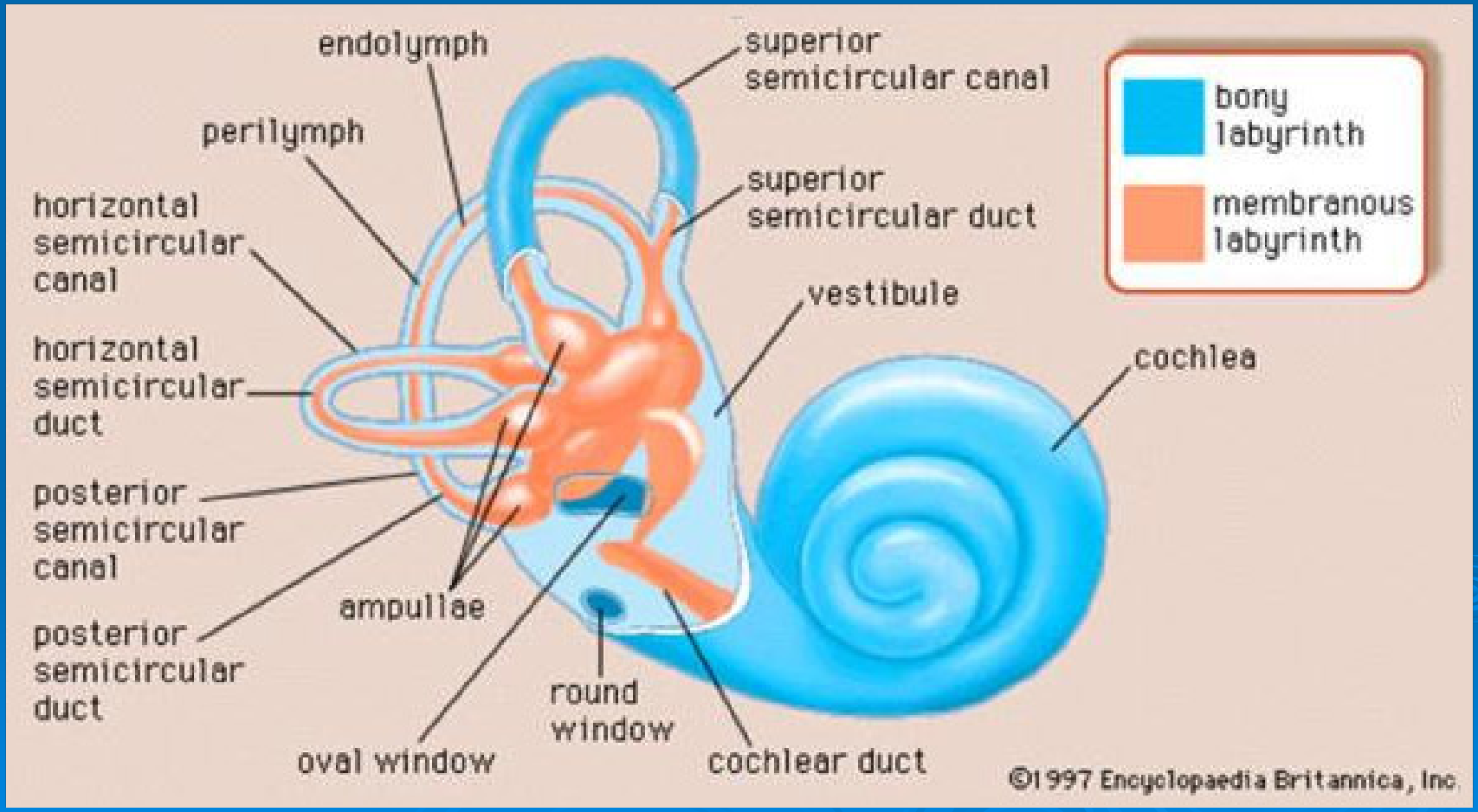
Provides info on body parts position in relation to each other and the environment.

# Sensory Systems

- These senses must detect changes of body position with respect to the base of support, regardless of whether the body moves or the base moves or changes size. There are environmental factors that can affect balance such as light conditions, floor surface changes etc.

# Vestibular system

- Located within the inner ear
- Vestibular system contains three semicircular canals in each labyrinth. They are at right angles to each other, and are called the *horizontal* (or *lateral*) canal, the *anterior* semicircular canal and the *posterior* semicircular canal.
- These Semicircular canals (horizontal, anterior & posterior) – detect angula acceleration in all three dimensions.
- Otholith organs (Utricle and saccule) – detect linear acceleration (gravity & translational movements)


endolymph
superior semicircular canal
perilymph
bony labyrinth
membranous labyrinth
superior semicircular duct
horizontal semicircular canal
vestibule
horizontal semicircular duct
cochlea
posterior semicircular canal
ampullae
posterior semicircular duct
round window
oval window
cochlear duct
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# Vestibular system

Involved in the control of movement/balance through:

- Detection and perception of head in relation to neck movement / position
- The initiation of compensatory eye mvts during head mvts to keep images in the visual field still ; vestibular–occular reflex

# Vestibular system

Vestibular system and aging:

- Changes in the vestibular system are common with increasing age – related to changes in the peripheral apparatus and associated with VIII cranial nerve
- Average 40% reduction in hair cells by 70yrs
- Changes in otolithic membrane, alterations in calcium metabolism & microvascular ischemia.

# Vestibular system

- Examples of peripheral causes of dysfunction
  - Bacterial/viral labyrithithitis
  - Vestibular neuronitis
  - Menieres Disease
  - BPPV
  - Trauma
  - Acoustic neuroma
  - Drug induced – (ototoxic meds)

- Examples of central causes of dysfunction
  - Cerebella degeneration
  - Tumours
  - MS
  - TBI
  - Brainstem stroke
  - Migraine
  - Concussion

# Somatosensory system

- Provides information regarding the position of the body with respect to the supportive surface from sensory receptors & of one body part in relation to another.

# Somatosensory system

Different types and sites of receptors:

- Muscle spindles
- Golgi tendon organs
- Joint receptors
- Cutaneous and pressure receptors in the skin
- Perception of proprioception, touch, pressure, vibration

# Somatosensory system

Changes to the somatosensory system with age:

- Receptors – Decrease use results in changes in the muscle spindles
- Age related changes in relation to a reduction in numbers of receptors in joints/ligaments
- Peripheral nerves – with aging reduction in the density of myelination as well as in the degree of myelination itself

# Visual system

Visual system – provide information on both

- The position of head/ body in relation to both its body parts and in respect to objects and the environment
- Object identification itself and the determination of their movement in respect to self.

# Visual system

For spatial orientation, two visual systems.

- Focal (related to central vision)
- Ambient (related to peripheral vision)

# Visual system

- Vision = is process of receiving light and converting this light energy into a recognised entity

  - Light rays project on to the retina are converted into two dimensional images, which in turn are projected via the thalamus, hypothalamus or midbrain to the primary visual cortex in the occipital lobe where they take on different properties (colour,mvt,form,depth) and turn them into the perception of a 3D entity

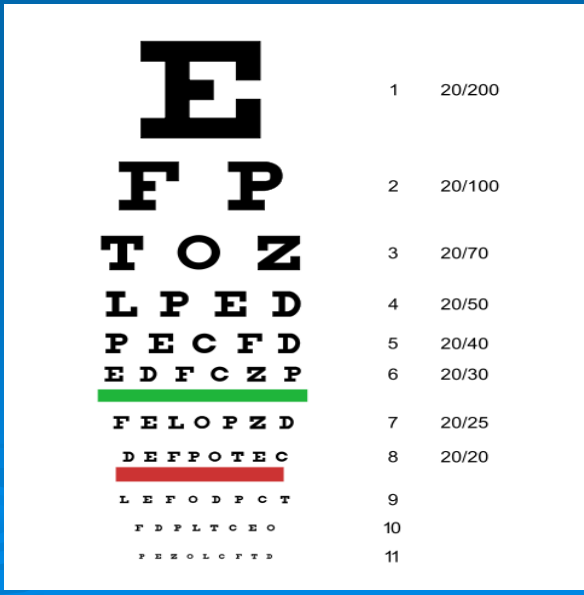
# Visual system

- Deficits in vision that impact on posture & balance are largely linked with reduced visual acuity
  - Both reduced distance contrast sensitivity and reduced depth perception →increased postural sway → increased risk of falls

  Need to be able to see edge contrast & detect low contrast hazards as well as judge objects at a distance in relation to spatial constraints

  Shown that in those with blurred vision → takes longer to initiate a task (e.g. stepping task by 11%)

Visual field loss is also a risk factor for falls but not as much as the loss of visual acuity.



# Vision

- Normal ageing leads to alterations in vision in relation to…

  - The receipt of information into the eye

  - Altered/reduced neural transition.

  - Overall loss of visual acuity, visual field, contrast sensitivity and depth perception.

- 60 % of healthy elderly are recognised as being permanently visually impaired.

# Vision

Management of visual loss on postural control.

- Regular eye tests (yearly)
- Correct glasses - NOT MULTI FOCALS.
- Ax of lighting
- Ax of head on trunk ROM
- If vision is limited → compensate through other systems, particularly somatosensory system.

# Vision

- When these three systems are isolated and balance is tested, it has been found that vision is the most significant contributor to balance, playing a bigger role than either of the two other intrinsic mechanisms

# Age: What are the effects?

- **Vestibular System:**

  People with vestibular deficits are likely to have increased sway when provoked by varying positional changes

- **Sensory System:**

  Sensory abnormalities such as impaired proprioception or touch sensitivity are associated with falls and postural instability

  Altered sensory input is thought to be associated with increased postural sway when standing with eyes closed.

# Age: What are the effects?

- **Musculoskeletal System:**

  Muscle weakness

  Joint stiffness

  Reduced ability to use postural strategies

- **Central System:**

  Cognitive impairment associated with fallers

  Performance of a cognitive task whilst maintaining a steady stance influences balance more in people with impaired postural control.

# Age: What are the effects?

- **Central System (cont):**

  Performance of tasks requiring CNS processing are slower

  Slower decision making at central regions (CNS processing), likely why older adults are unable to perform saving reactions as quickly

  Slowing of movement and initiaient of movement

# Case Study 1

- Margaret is 75 years old and was diagnosed six months ago with Parkinson's disease. She complained of loss of confidence when waking and fear of falling, although she hasn't actually fallen. She is becoming increasingly dependent on her husband to do the domestic chores as she cannot stand to do dishes, move around the kitchen when preparing meals or hang out the washing. She now spends most of the day sitting in a chair watching television.

  She has long standing OA of both knees and restricted movement of the neck due to an old injury.

  On examination she has a flexed trunk posture, particularly when walking. She tends to furniture walk around the house although she can generate quite a fluent gait with a stick. She occasionally gets "stuck" in doorways or when trying to turn. She uses her arms when rising from a chair and complains of pain in her knees when doing so. She finds it difficult to get out of bed due to inability to rotate her head & trunk.

# Case Study 2

- John is a 45 year old man with secondary progressive MS. In the last six months he has needed to use a stick to walk and has experienced several falls or near falls, particularly when turning. He is no longer able to “walk & talk” or to carry things when walking. He occasionally experiences short spells of dizziness. He wears glasses for reading or to watch television but can’t concentrate for long. His work as a part time secondary school teacher is becoming increasingly difficult.

  On examination John has good use of both upper limbs although there is some loss of proprioception in the fingers bilaterally and reduced accuracy when reaching for a target. He has a rather flexed trunk posture in sitting but can correct this with prompting, although it is hard for him to maintain a more upright posture and when he does some mild truncal ataxia is evident. In the lower limbs there is a significant weakness of the hip and knee extensor muscles more on the right (grade 3-) than the left (grade 3). He has weak dorsiflexion/plantar flexion bilaterally, again more on the right (grade 2) than the left (grade 3). There is reduced co-ordination and control when he is asked to perform heel-to-shin movements, right >left. There is reduced proprioceptive awareness at the ankle (right) and the toes (left).

  Ability to localise light touch is impaired in the right foot but intact on the left.

# Case Study 3

- Gertrude is a 65 year old lady who suffered a right middle cerebral artery infarct in September 2012. She lives at home with her husband who is her main carer. She can transfer herself from bed to wheelchair but needs to wear a rigid AFO on the left leg and is supervised for this. She can bring herself into standing using her right arm to push up but finds it difficult to stand straight and tends to lean over to the right. She has physio once a week and has started to walk at the end of the treatment session with the AFO & assistance. Gertrude's goal is to be able to take herself to the toilet independently.

  She has marked left hemiplegia with some volitional activity at the shoulder and elbow into flexion, but no hand function. She can activate her gluets, quads, hamstrings, but has no independent movement of the ankle. She has developed some marked compensatory strategies such that she tends to fix strongly with the right arm & resist weight transfer over the left leg. In sitting her trunk is reasonably symmetrical but flexed. In standing there is marked left trunk side flexion to the head to the right. There is some sensory & proprioceptive loss in the left hand and foot.

# Outcome Measures

- Berg Balance Scale

  - Developed in 1993

  - Shown to be a good predictor of falls in the community dwelling older adults without neurological impairment

  - Good reliability and validity

  - Limitations

    - Ceiling affect

    - Low responsiveness

    - Redundancy of some items

# Outcome Measures

- Mini-BESTest

- Developed from the BESTest in 2009 for those with Parkinsons

- Structured around a systems approach:

  -Anticipatory postural control

  -Postural responses

  -Sensory orientation

  -Balance during gait

- Psychometric properties

  -Similar to the BBS, good reliability & validity shown

  - Lower ceiling affect compared to the BSS

- High sensitivity (therefore likely to detect those with a clinically important change) also better able to detect fallers from non-fallers.

# Outcome Measures

- Multiple Task Test
  - Walking over 3m with turn (As per TUG)
    - -Comfy pace
    - +answering questions
    - +avoiding obstacles
    - + carrying a tray
    - + tray with 3 eggs (Or equivalent)
    - + tray with 3 eggs with slippery shoes
    - + tray with 3 eggs with slippery shoes touching the floor
    - + tray with 3 eggs with slippery shoes touching the floor + sunglasses

- Originally designed for those with Parkinson's
  - -Scored as normal, hesitant, block.