

The Physiology of Balance and Falls



Intended Learning Outcomes

At the end of the lecture students should be able to describe;

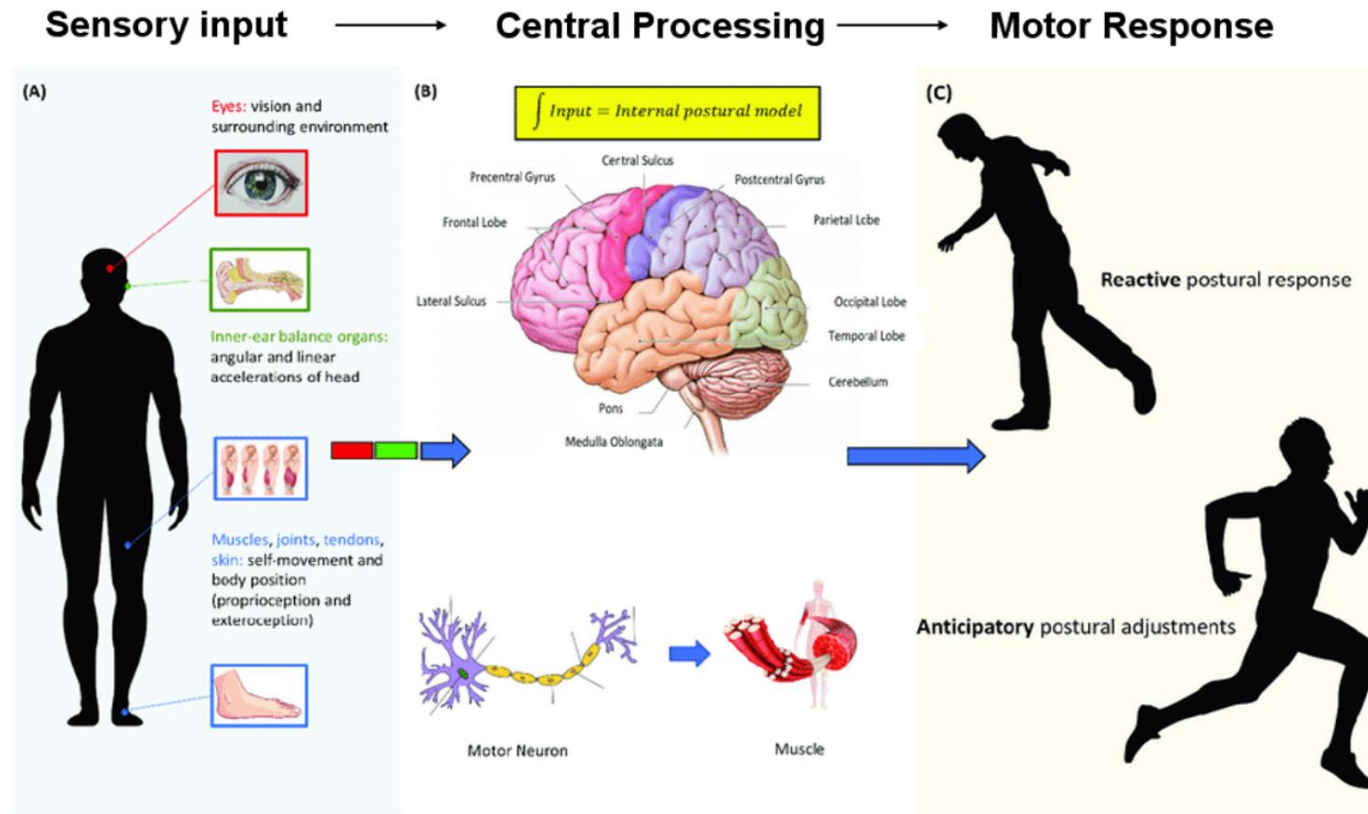
balance in aging

biomechanics of balance, gait and falls

Importance of Balance

- **Balance** is the ability to maintain the position of the body (its centre of mass) within specific boundaries of space (stability limits).
- Poor balance is a significant contributor to falls in people aged 65 years and older
- Balance requires the integration of different sensory information (visual, vestibular, proprioceptive) and the ability to generate appropriate motor responses

Physiological Systems for Balance



- **An important source of information for the control of balance**
- information about the external environment
- feedback about the position and movements of the body
- **Postural sway increases ~ 30% with eyes closed**

Vision

Ageing affects:

- Visual acuity
- Contrast sensitivity
- Depth perception
- Visual field
- Use of spectacles

Cataracts and Macular Degeneration

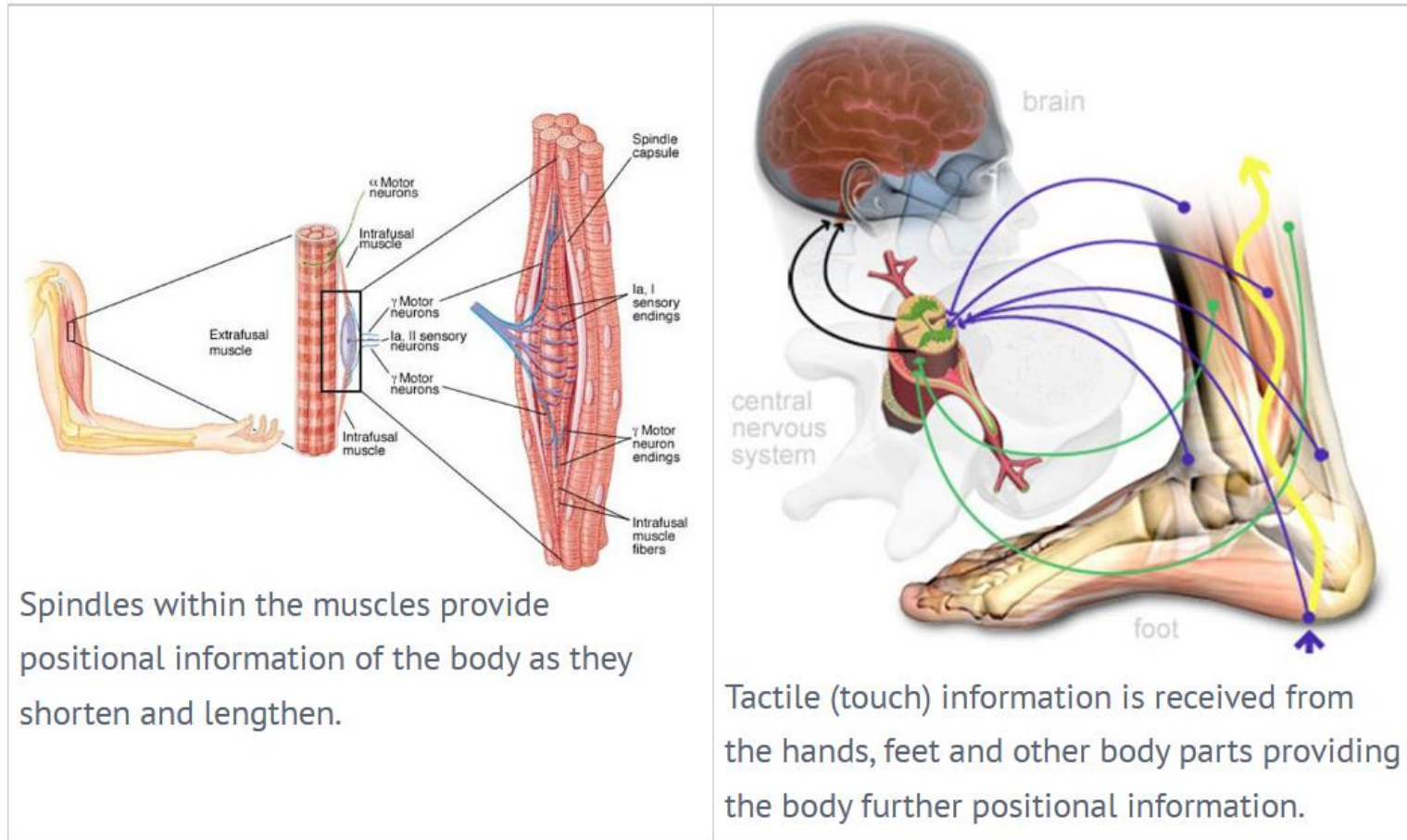
- 16% of people over the age of 65
- Opacity of the lens of the eye, causing clouded vision
- Usually a result of denaturation of lens proteins
- Due to advanced age and diseases such as diabetes



Sensation and Proprioception

Balance relies upon the combination of cues from the

- Proprioceptive system
- Tactile information from hands and feet
- Input from muscles and joints
- Postural sway can be reduced by up to 50% with intact proprioception



Peripheral neuropathy



- Damage to motor, sensory and autonomic nerves located outside of brain and spinal cord
- Causes weakness, pain, numbness/loss of sensation – hands and feet
- Affects balance and gait -> increased risk of falls
- Usually acquired (symptomatic) as a result of another medical condition
- People with peripheral neuropathy will develop numbness or a loss of sensation in their feet which can affect how they balance and move around, increasing the risk of falls

Diabetes Mellitus

- 1 in 6 people aged over 65 have diabetes in Australia¹
- Diabetic neuropathy – high blood glucose levels can damage the peripheral nervous system
- Estimated 21% of people with diabetes in Australia have diagnosed PN.²

Other common causes

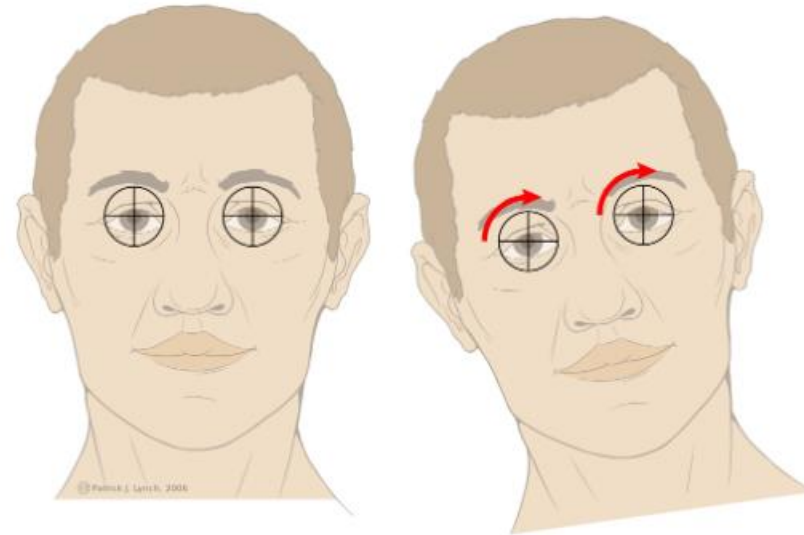
- Chemo-induced PN – neurotoxic drug
- Cancer patients with CIPN are 2.7 time more likely to fall.³

Vestibular Sensation

- Inner ear structures detect position and motion of the head
- Important for posture and coordination of head, eye and body movements
- Reduced sensation with age
- Some evidence suggests that impaired vestibular function may contribute to falls in older people



The inner ear incorporates semicircular canals and otoliths to help the brain detect position and motion of the head.



The vestibulo ocular reflex is a gaze stabilising reflex and helps the brain to match its position as detected by the inner ear with visual input from the eyes.

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Vertigo and dizziness

- Dizziness is common in older people with rates range between 10-30% and increase with age
- Symptoms: spinning sensation, light-headedness, unsteadiness, loss of balance and nausea
- Chronic dizziness associated with increased risk in falls
- Vestibulopathies account for 48% of dizziness reported by older people

Benign paroxysmal positional vertigo (BPPV)

- Sudden brief spell of vertigo (false sensation of spinning) triggered by certain head positions or movement

Meniere's Disease (MD)

- Caused by a build up of fluid in the compartment of the inner ear (labyrinth)
- Fluid interferes with the normal balance and hearing signals between the inner and the brain

Age-Related Muscular Changes

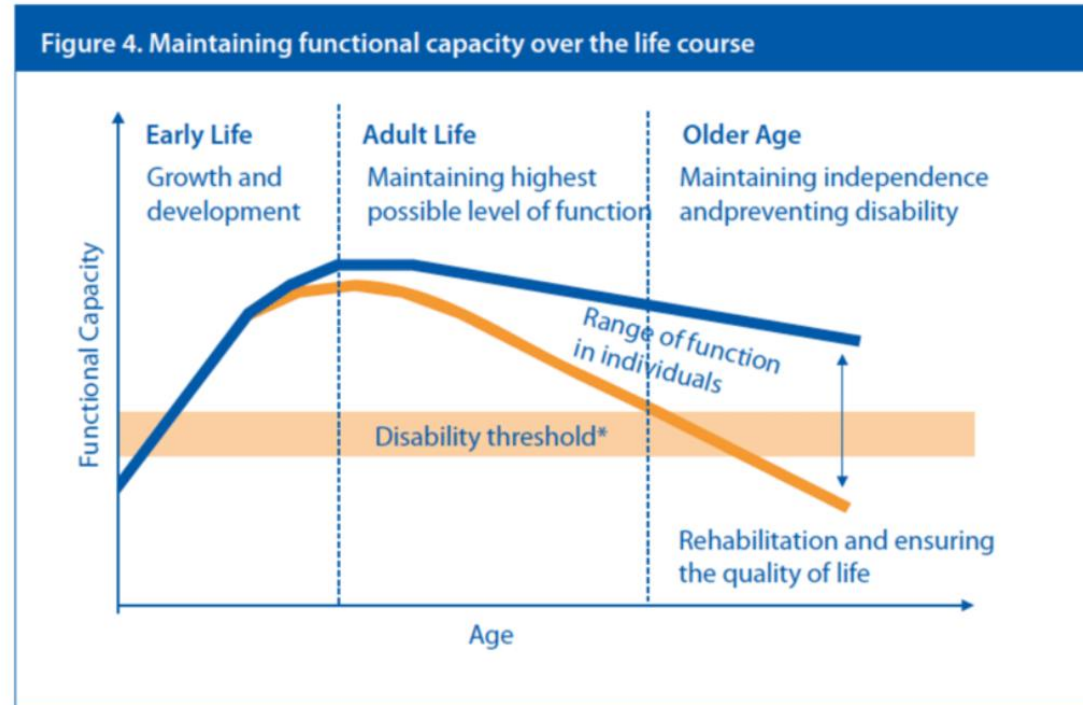
- From mid-twenties, the human body begins a progressive loss of muscle mass
- Muscle mass diminishes by 35-40% by 80 years
- Muscular strength decreases ~50% by the age of 80 years



Young, active

Old, sedentary

Sarcopenia: Effects on Body Composition and Function – Scientific Figure on ResearchGate.
Available from: https://www.researchgate.net/figure/Sarcopenia-Magnetic-resonance-images-through-the-midhigh-of-a-25-year-old-healthy-adult_fig1_8996814 [accessed 3 Nov, 2021]



Source: Kalache & Kickbusch (12).

Ageing: The Response Yesterday, Today and Tomorrow – Scientific Figure on ResearchGate.
Available from: https://www.researchgate.net/figure/Maintaining-functional-capacity-over-the-life-course-Source-WHO-2002-Kalache-and_fig2_26650108 [accessed 3 Nov, 2021]

Muscle Function

- **Strength**
- Reduced hip, knee and ankle strength are associated with an increased risk of falls
- Improvements in hip, knee and ankle strength, following exercise intervention, correspond with improvements in balance
- **Power:** Producing muscle force quickly: important for fast balance responses
- **Endurance:** Ability to do work over long periods of time: avoid end-day fatigue

Muscular changes: Implications

Functional decline

Reduced muscle function results in:

- Increased difficulty with activities of daily life
- Reduced levels of independence and quality of life
- Reduced sense of wellbeing

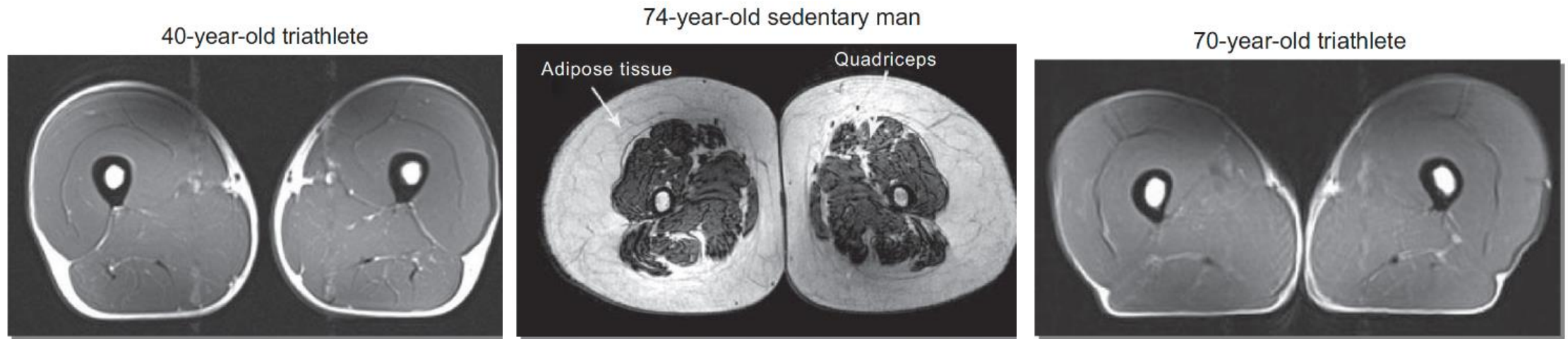


Figure 2: A cross-sectional cut of the thigh of a 40 year old triathlete compared to a 70 year old sedentary man and 70 year old triathlete. There are significant differences in muscle mass and fat composition.

Regular physical activity can slow down the muscle ageing process!



Key message: Keep moving!

Age-related neurological changes



- The human brain loses 10% of its weight by the age of 90 years (loss of nerves)
 - Reduced brain blood flow and metabolism
- Functional problems depend on region of loss/damage
- Reduced speed of impulses along nerves
 - Slower reflexes, delayed response

Reaction Time

- 25% increase in simple reaction time from age 20-60
- Increased simple reaction time is a strong risk factor for falls in older people
- Fallers have particularly slower reaction times in more complicated tasks, such as stepping

Cognitive Functioning

- The basic cognitive functions most affected by age are processing speed, attention and memory.
- Balance control requires attentional resources
 - Balance is affected by one's information-processing ability when performing two or more tasks simultaneously (distracted)

Conclusion

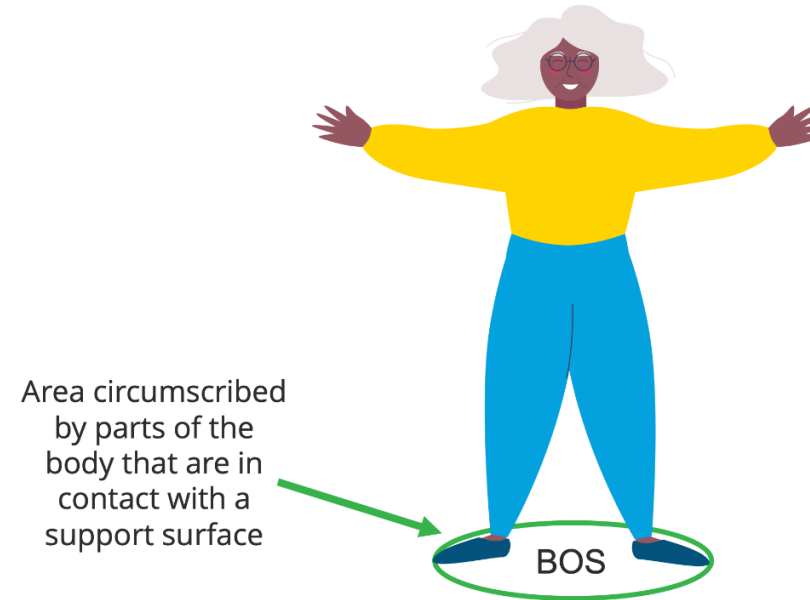
- Balance relies on contributions from
 - visual, vestibular and proprioceptive senses
 - muscle strength
 - reaction time
- All of which are progressively affected by age, contributing to the increased risk of falls
- By understanding risk factors, we can design appropriate strategies to reduce falls in older people

The Biomechanics of Balance, Gait and Falls



Biomechanics of Balance

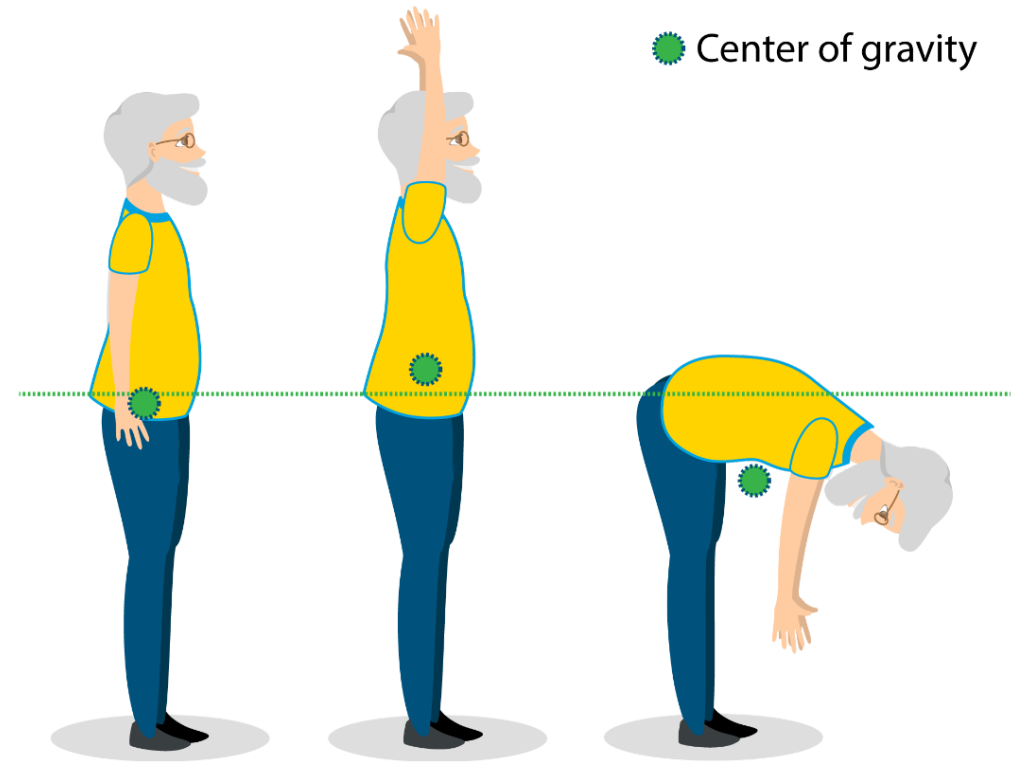
- **Balance** is maintaining the body's centre of mass (COM) within the base of support (BOS).



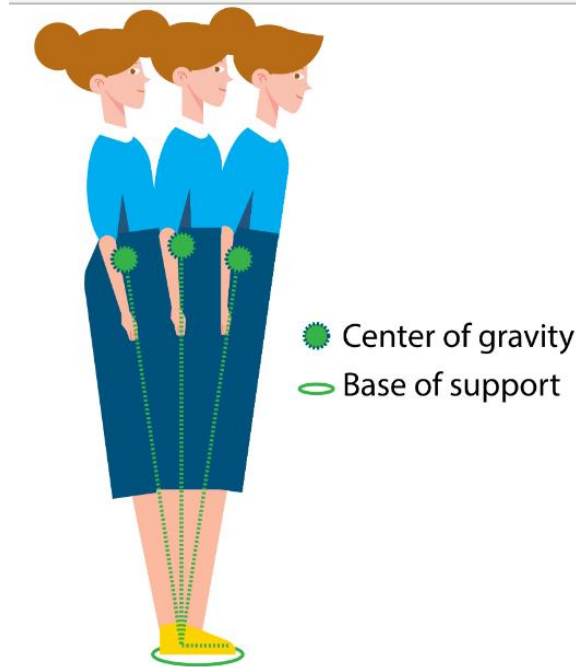
Mechanical Factors Affecting Balance

- **Mass of the body:** the larger an object, the more force required to move it
- **Size of the BOS:** the larger the support area, the more stable
- **Friction:** between the body and the support surface must be sufficient to prevent slipping
- **Position of the COM:** relative to the BOS

- A person's centre of gravity will change based upon their posture and body position.



Standing balance



In standing...

- the body constantly sways about the ankles
- lower leg muscles (**plantar- and dorsi-flexors**) control sway in **anteroposterior** directions
- hip muscles (**abductors**) control sway in **lateral** directions
- greatly altered by touch and vision

Factors Affecting Postural Sway

- Increased age
- Vision
- Proprioception
- Strength

Gait Changes with Age



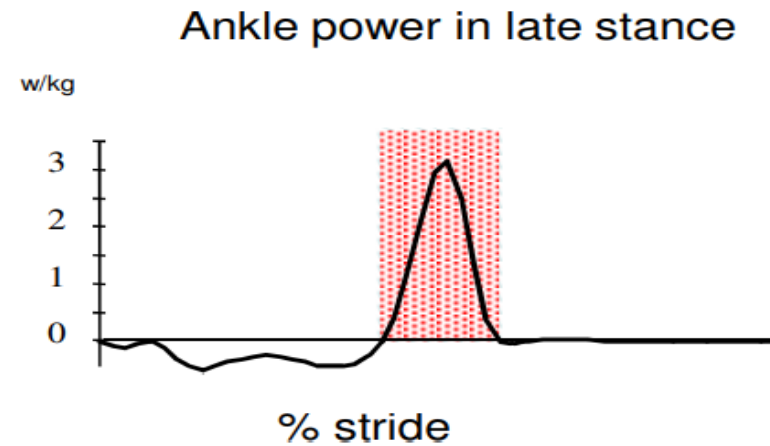
Typical spatiotemporal parameters

| | Cadence (steps/min) | Walking speed (statures/sec) | Stride length (statures) |
|------------------|------------------------|---------------------------------|-----------------------------|
| Males | 112 | 0.8 | 0.86 |
| Females | 118 | 0.8 | 0.81 |
| Older adults | 107 | 0.6 | 0.68 |
| Parkinsonian men | | | |
| mild | 95 | 0.45 | 0.6 |
| moderate | 111 | 0.5 | 0.6 |
| severe | 106 | 0.4 | 0.4 |

Gait changes with age

Joint kinetics

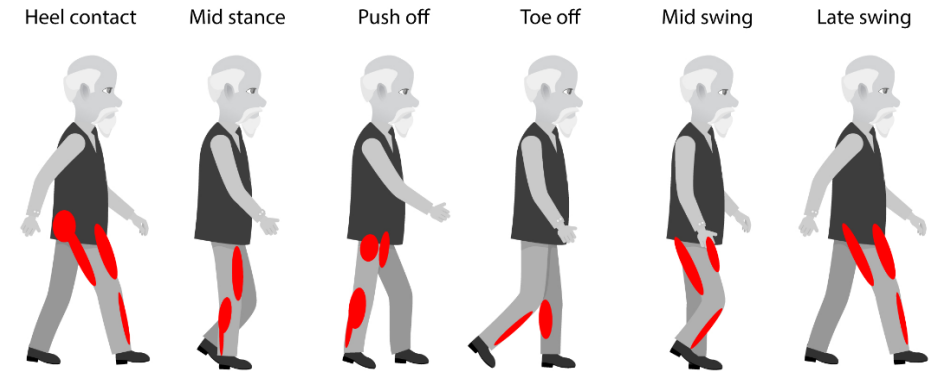
- Reduced push-off power



Muscles Controlling Gait

Muscles controlling gait include:

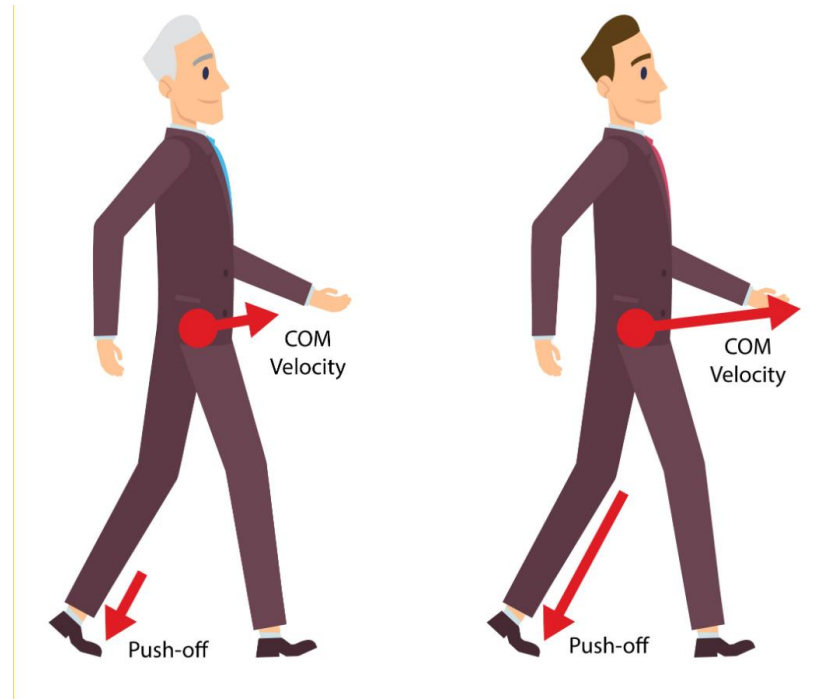
- **Eccentric:** dorsiflexors, plantarflexors, knee extensors
- **Concentric:** plantarflexors, hip extensors
- **Control of swing:** hip flexors, ankle dorsiflexors, knee flexors



Main muscle groups activated through the different stages of gait.

Gait Changes with Age

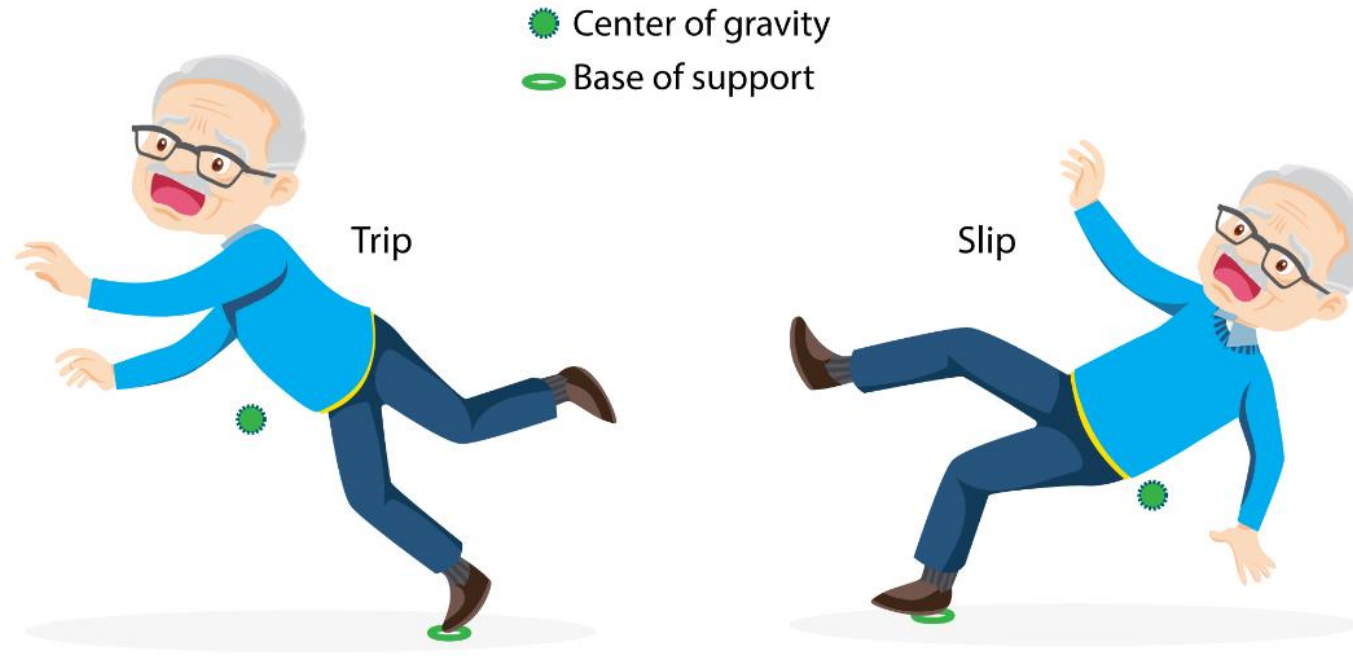
- slowed walking speed
- shorter stride length
- wider stance
- longer time in dual stance
- fewer steps/min (cadence)
- reduced joint range of motion
- Reduced head control
- Reduced push-off power



Perturbations to Gait



- **Stepping around obstacle**
 - Control lateral balance
- **Stepping over obstacle**
 - Longer period of time spent on one leg
 - Risk of the making contact with the obstacle
- **Trips**
 - Body moves forward over the BOS
- **Slips**
 - BOS moves under the body



A trip and slip require very different responses to avoid a fall. During a trip the center of gravity shifts forwards, outside of the base of support while during a slip it will shift backwards.

Summary

Standing balance is:

- controlling the COM position over the BOS

Many gait changes with increasing age, including:

- slower, shorter steps
- reduced joint motion
- wider stance
- poorer control
- reduced push-off power

Main muscle groups driving forward gait:

- ankle plantar and dorsiflexors
- hip flexors
- hip extensors

Gait perturbations include:

- slips, trips and obstacle negotiation

References

- Narinder Kaur Multani, Satish Kumar Verma; Principles of Geriatric Physiotherapy, First Edition : 2007.
- Ganong WF. Review of Medical Physiology, 20th edn, Lange Medical Books/McGraw-Hill Medical Publishing Division, 2001;132-43.
- MacKinnon CD. Sensorimotor anatomy of gait, balance, and falls. Handb Clin Neurol. 2018;159:3-26. doi: 10.1016/B978-0-444-63916-5.00001-X. PMID: 30482322; PMCID: PMC7069605.