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Normal gait

Increasing the Conformance of Academia towards Rehabilitation Engineering (i-CARE)

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INTRODUCTION

- **Walking is a common activity of daily living and at the same time a very complex one**. It involves all levels of the nervous system and many parts of the musculoskeletal apparatus as well as the cardiorespiratory system.
- Human gait depends on a complex interplay of major parts of the **nervous, musculoskeletal and cardiorespiratory systems**.
- Safe walking requires **intact cognition and executive control**.
- **The prevalence of gait disorders** increases from 10% in people aged 60–69 years to more than 60% in community dwelling subjects aged over 80 years.

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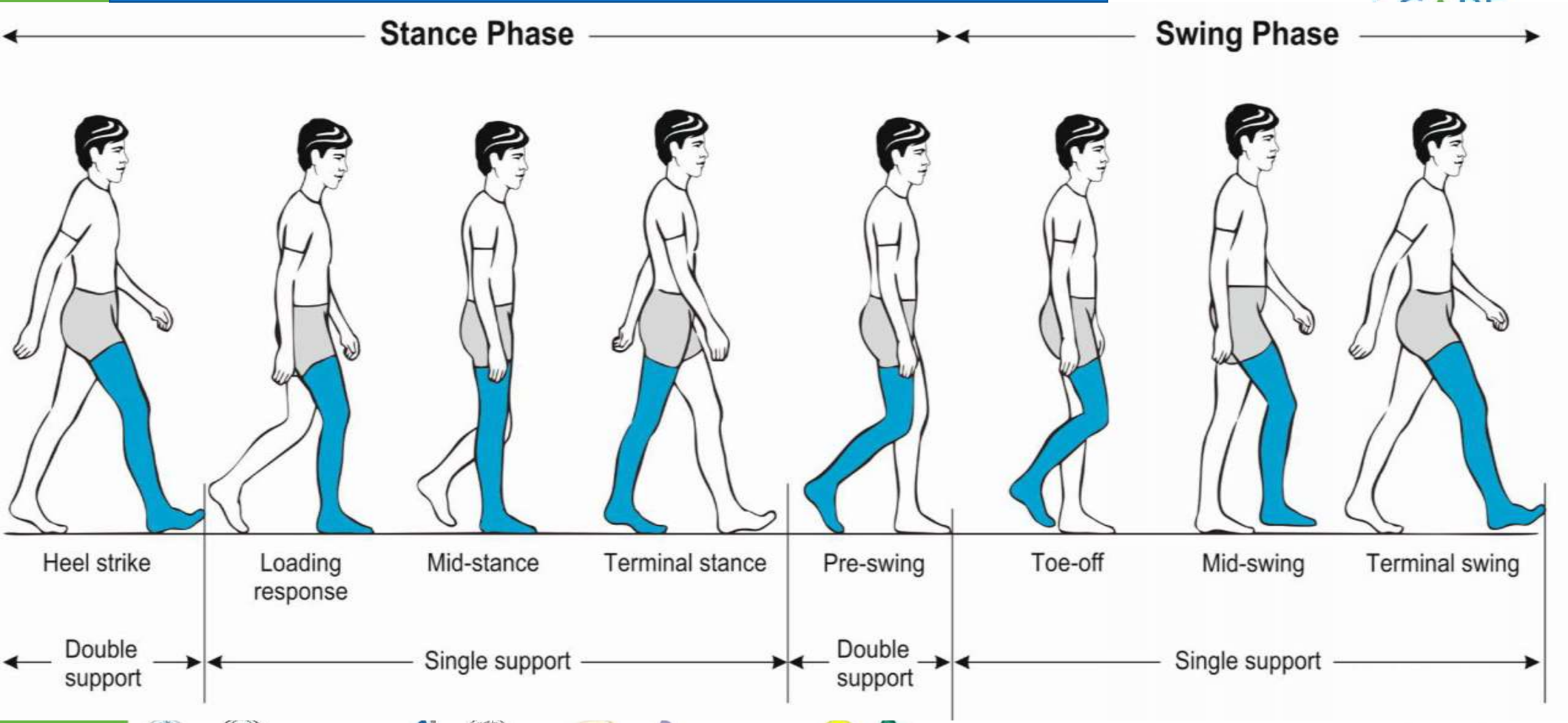
Phases of the normal gait cycle



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INTRODUCTION

- Walking is a sensitive indicator of overall health status and the self-selected walking speed closely correlates with individual life expectancy in elderly persons [4].
- **Afferent nerves from the visual, vestibular and proprioceptive systems provide essential information on the position of the body and its parts**.
- A centrally integrating system, which involves areas in the frontal cortex, the basal ganglia, the brain stem and the cerebellum, interprets the information received and selects the motor programs required for walking.

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INTRODUCTION

- **The efferent system comprises descending pathways including the pyramidal tract, peripheral nerves, neuromuscular end plate and muscles**.
- Initiating gait requires a stable upright body position.
- Functioning postural reflexes are necessary to assume and sustain a stable body position
- **A person's gait pattern is strongly influenced by age, personality and mood.**

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Control of normal gait

- **For normal gait all of the following functions and systems are required to be intact**:
- locomotor function (for initiating and sustaining rhythmic gait),
  balance,
- postural reflexes,
- sensory function .
- sensorimotor integration,
- motor control,
- the musculoskeletal apparatus
- and cardiopulmonary functions.

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Normal walking

- **A centrally integrating system**, which involves areas in **the frontal cortex, the basal ganglia, the brain stem and the cerebellum**, interprets the information received and selects the motor programs required for walking.

The efferent system comprises descending pathways including

1. **the pyramidal tract,**
2. **peripheral nerves,**
3. **neuromuscular end plate and**
4. **muscles**.

- In primates, brain stem centers have a central role in generating automatic walking, in particular the so-called **midbrain locomotor center, .**

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The gait cycle

- The gait cycle is divided into **the stance** and **swing** phase.
- **The stance phase** constitutes approximately 60% of the gait cycle and is subdivided into:

1. initial contact (heel strike),
2. loading response,
3. mid-stance,
4. terminal stance and
5. pre-swing.

Both feet are on the ground at the beginning and end of the stance phase. Each of these two double support periods lasts for approximately 10–12% of the gait cycle.

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The gait cycle

- **The swing phase** takes up about 40% of the gait cycle and is subdivided into:

1. initial swing (toe-off),
2. mid-swing (tibia vertical)
3. and terminal swing,

terminated by the heel striking the ground.

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Important measures of gait

Important measures of gait include:

1. **Walking speed**,
2. **cadence** (number of steps per unit of time),
3. **walking base width** (measured from midpoint to midpoint of both heels),
4. **step length** (measured from the point of foot contact to the point of contralateral foot contact) and
5. **stride length** (linear distance covered by one gait cycle).

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Important measures of gait

- The preferred **walking speed** in healthy adults up to the age of 59 years is approximately **1.4 m/s** .
- Average **stride lengths** in healthy adults range

  between 150 and 170 cm.
- The average **cadence** in young adults was reported to range **between 115 and 120 steps/min**.
- **Ageing is associated with a decline in gait speed and step length whereas cadence remains relatively stable.**

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Normal walking

- To start walking, one leg is raised and directed forward by flexing the hips and knee.
- **Activation of the supporting contralateral leg and trunk muscles moves the body's center of gravity over the weight-bearing leg and forward.**
- The heel of the swinging leg is then placed on the ground.
- The body weight is gradually shifted to the sole and then onwards to the toes.
- During mid-stance, the opposite leg is lifted and moves forward until the heel strikes the ground.
- Meanwhile, the body is held upright, the shoulders and pelvis remain relatively level and each arm swings in the direction opposite to that of its ipsilateral leg.

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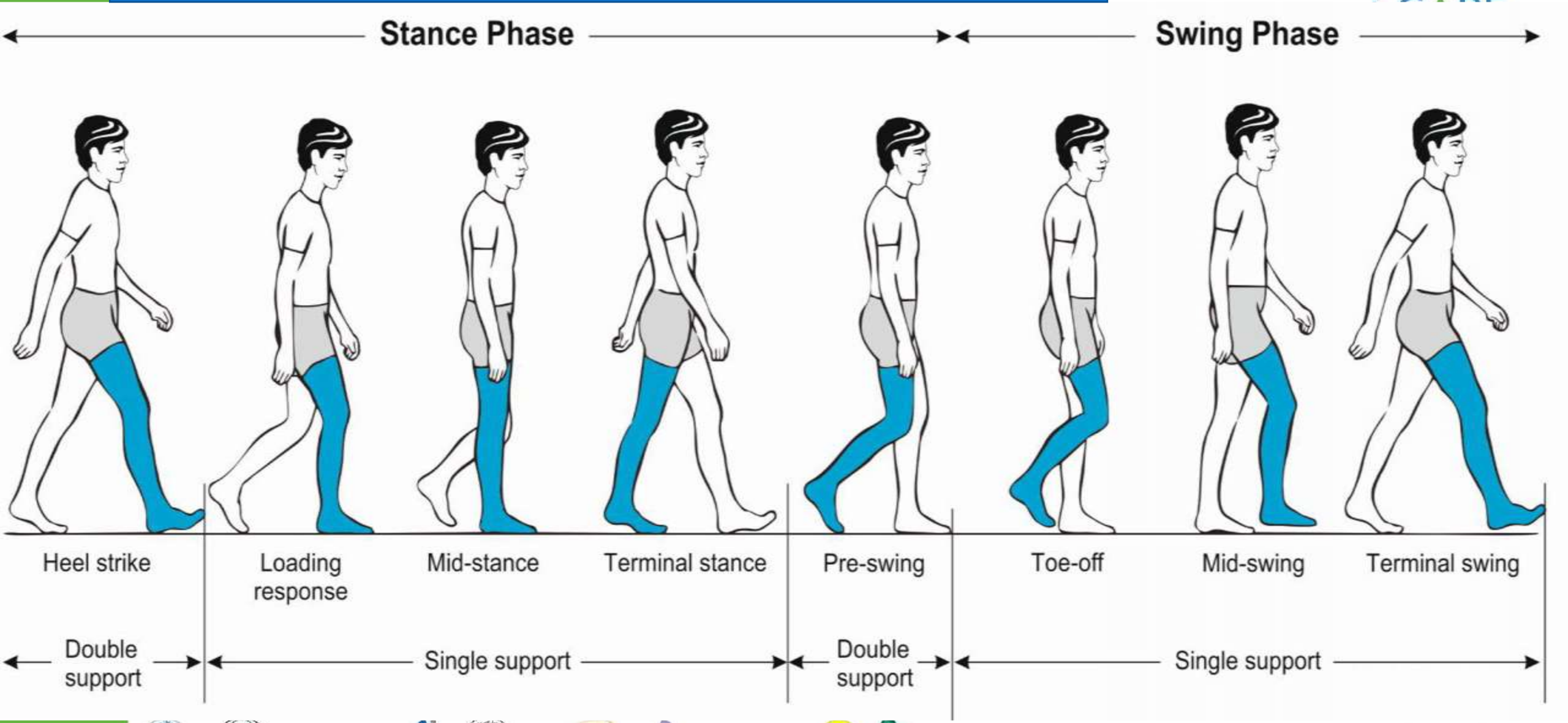
Phases of the normal gait cycle



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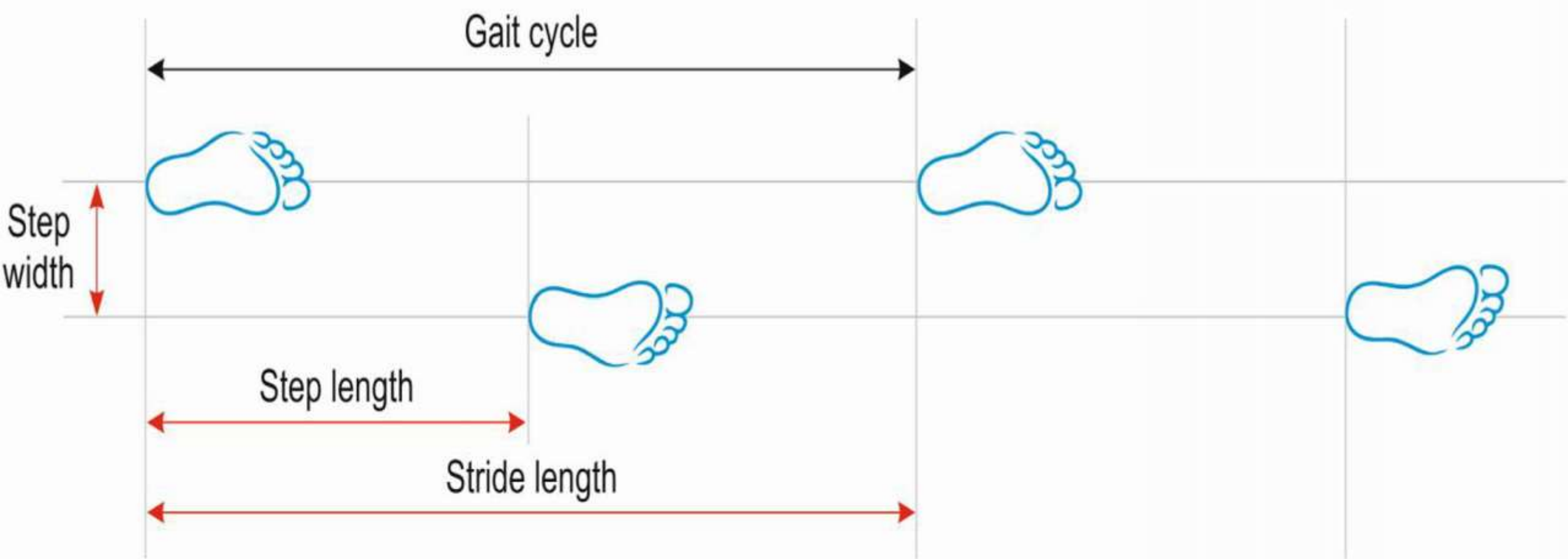
Basic terminology describing the gait cycle



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Clinical examination of gait

- **The clinical examination of gait provides a quick but integrative overview of the function of the structures involved in walking.**
- It is important to observe the entire patient, from the front and from all sides, while walking over a distance of at least several meters without obstacles. If possible, walking should be observed without the subject wearing shoes.
- **Normal walking appears rhythmical, flowing, effortless, with freely swinging legs and with an upright body posture.**
- **Normal walking is accompanied by movements of the head, the trunk and the arms** (in the direction opposite to the movement of each leg).

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The Reported parameters

The parameters that should be clinically examined, which include:

1. step length,
2. stride length,
3. step width,
4. rhythm,
5. speed,
6. posture,
7. swinging of arms
8. and legs and
9. the duration and type of contact with the floor.

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Parameters for the clinical examination of gait

- Sitting unaided
- Standing up from a sitting position (unaided and with/without use of upper limbs)
- Posture (trunk, neck and head, upright, bent or asymmetrical)
- Stance (narrow/wide base)
- Gait initiation (blockage)
- Walking (smooth, stiff, insecure, symmetrical, limping)
- Step length, lifting of feet, contact with ground, wide/narrow base
- Speed
- Arm swing
- Freezing
- Turning
- Postural reflexes (pull or push test)
- Sitting down (“motor recklessness”)

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Complex tests of stance and gait

1. Tandem stance
2. Tandem gait
3. Romberg's test (standing with eyes closed and narrow base)
4. Blind gait
5. Walking backwards
6. Walking fast
7. Walking slowly (in a deliberate manner)
8. Running
9. Turning quickly
10. Turning on the spot
11. Unterberger's test (walking on the spot with eyes closed)
12. Standing and walking on heels
13. Standing and walking on toes
14. Hopping on one foot
15. Dual task maneuver (walking while talking or carrying objects)
16. Functional reach

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Role of cognition

- **Investigations over the past two decades have demonstrated the strong effects of cognition on gait , including the role of gait speed and gait disorders in older age as an indicator for the future development of dementia and of life expectancy .**
- **Cognitive control is relevant for circumnavigating obstacles and for choosing the optimal route.**
- Frontal executive functions, visuospatial perception and attention all contribute to walking safely.
- Psychological factors also influence gait.
- **Further investigations have shown that patients with dementia walk slowly but in relation to their motor and cognitive deficits, they actually walk too fast leading to an increased risk of falling.**
- In situations where there is a risk of falling, healthy persons adopt **a posture first strategy**, which prioritizes the maintenance of balance over other tasks. This strategy is lost in patients with Parkinson's disease.

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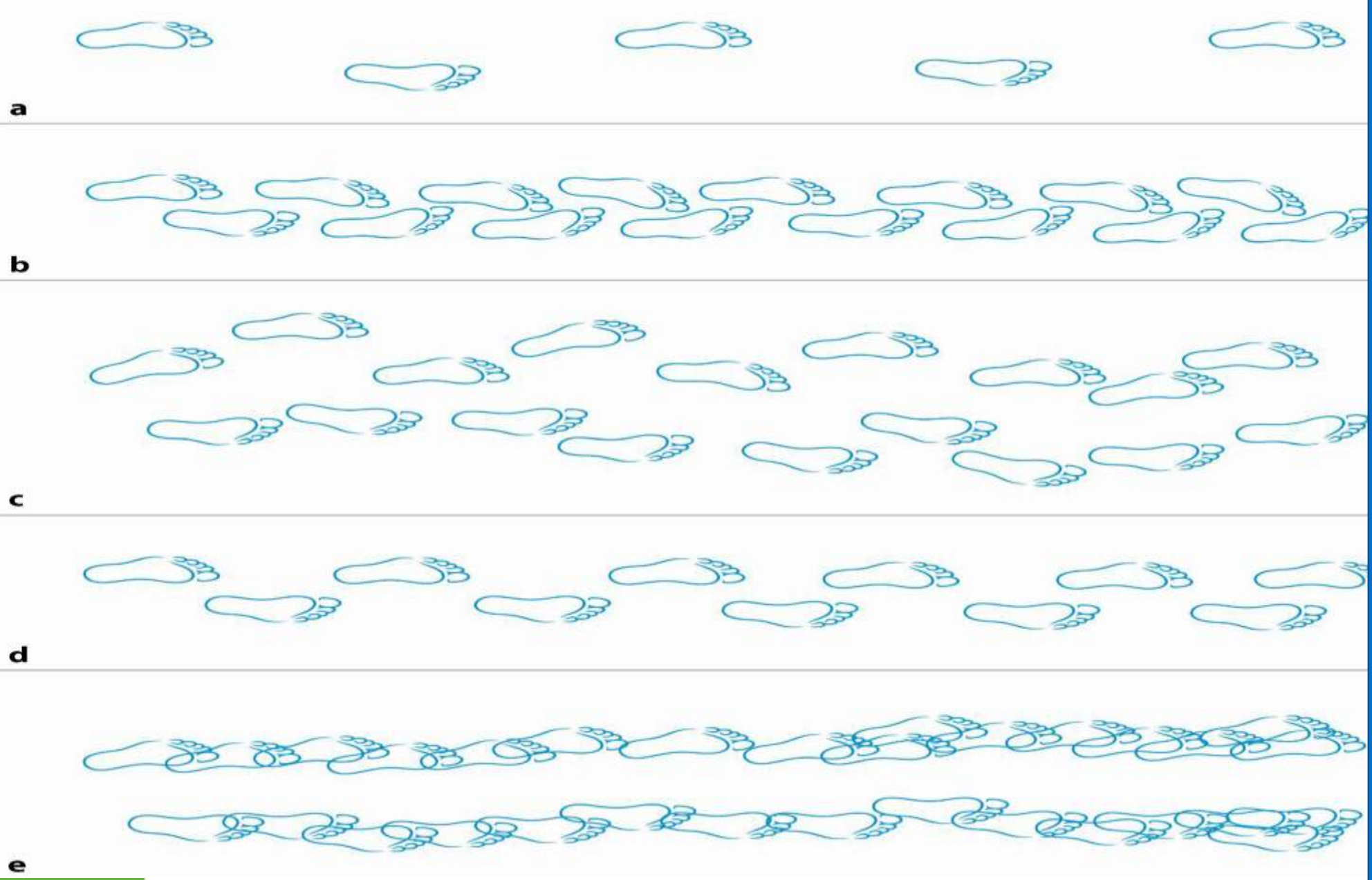

a normal gait,
b spastic paraparetic gait,
c cerebellar ataxic gait,
d parkinsonian gait
e frontal gait.
Note narrow step width and inwards rotation in paraspastic gait, **Broadened base and marked irregularity in cerebellar gait**, shortened and mildly irregular step length in parkinsonian gait and broad-based, short stepped, irregular walking in frontal gait disorder

i-CARE

Abnormal gaits

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