Normal and Pathological Gait
Introduction

• Human gait – locomotion
• Bipedal, biphasic forward propulsion of centre of gravity of the human body, in which there are alternate sinuous movements of different segments of the body with least expenditure of energy.
• Normal gait: stability in stance; clearance in swing; adequate step length; energy conservation; support of bodyweight

http://demotu.org/blog/gait-andar-e-marcha-a-re/#more-948
Natural gait:

- Speed increases = walk, jog, skip, run and sprint
- Designed to propel a person forward, but can also be adapted for lateral movement.

<table>
<thead>
<tr>
<th>Walk</th>
<th>Skip</th>
<th>Run</th>
</tr>
</thead>
<tbody>
<tr>
<td>- At least one foot is in contact with the floor at all times.</td>
<td>- Gait children 4-5 yrs. old (Minetti 2015).</td>
<td>- Both feet lose contact with the ground.</td>
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<tr>
<td></td>
<td>- Computational simulations showed that skipping is more efficient and less fatiguing than walking or running (Ackermann and Bogert 2015)</td>
<td></td>
</tr>
</tbody>
</table>
Spatial parameters

Figure 2.1 Step (---) and stride (—) lengths for symmetrical walking.

Figure 2.2 Step (---) and stride (—) lengths for asymmetrical walking.

Baker 2013; Whittle 2007
Temporal parameters

Stride time = duration of one gait cycle

Cadence(steps/minute) = number of steps in a given time.

Speed (m/s) = \frac{\text{stride length (m) \times cadence (steps/min)}}{120}

Baker 2013
Gait cycle

(A) Heel strike (initial contact)  
(B) Loading response (foot flat)  
(C) Midstance  
(D) Terminal stance (heel off)  
(E) Preswing (toe off)  
(F) Initial & Mid-swing  
(G) Terminal swing

**Stance Phase (60%)**  
- Double support (10%)  
- Single support (40%)

**Push Off**  
- Single support (40%)

**Swing Phase (40%)**  
- Double support (10%)  
- Single support (40%)

**Gait Cycle**

- Initial contact
- Mid-stance
- Take off
- Initial swing
- Mid-swing
- Terminal swing
Gait parameters

Approximate range (95% limits) for general gait parameters in free-speed walking by normal FEMALE subjects of different ages

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Cadence (steps/min)</th>
<th>Cycle time (s)</th>
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<tr>
<td>13–14</td>
<td>103–150</td>
<td>0.80–1.17</td>
<td>0.99–1.55</td>
<td>0.90–1.62</td>
</tr>
<tr>
<td>15–17</td>
<td>100–144</td>
<td>0.83–1.20</td>
<td>1.03–1.57</td>
<td>0.92–1.64</td>
</tr>
<tr>
<td>18–49</td>
<td>98–138</td>
<td>0.87–1.22</td>
<td>1.06–1.58</td>
<td>0.94–1.66</td>
</tr>
<tr>
<td>50–64</td>
<td>97–137</td>
<td>0.88–1.24</td>
<td>1.04–1.56</td>
<td>0.91–1.63</td>
</tr>
<tr>
<td>65–80</td>
<td>96–136</td>
<td>0.88–1.25</td>
<td>0.94–1.46</td>
<td>0.80–1.52</td>
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Approximate range (95% limits) for general gait parameters in free-speed walking by normal MALE subjects of different ages

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<td>65–80</td>
<td>81–125</td>
<td>0.96–1.48</td>
<td>1.11–1.71</td>
<td>0.81–1.61</td>
</tr>
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Rockers

https://www.youtube.com/watch?v=QuaEdhgLdKM
Gait in the children

1. The walking base is wider
2. The stride length and speed are lower and the cycle time shorter (higher cadence)
3. Small children have no heel strike, initial contact being made by the flat foot
4. There is a little knee flexion during the stance phase
5. The whole leg is externally rotated during the swing phase
6. There is an absence of reciprocal arm swinging

Whittle 2007
Gait in the elderly

Two influences:
1. The effects of age itself
2. The effects of pathological conditions, such as OA and parkinsonism

- Decreased stride length
- Increase the walking base
- Increase the duration of stance phase
- Speed is reduced

Whittle 2007
Abnormal gait:

Complex interaction between the many neuromuscular and structural elements of the locomotor system.

When studying a pathological gait, it is helpful to remember that an abnormal movement may be performed for one of two reasons:

1. The subject has no choice, the movement being ‘forced’ on them by weakness, spasticity or deformity
2. The movement is a compensation, which the subject is using to correct for some other problem, which therefore needs to be identified.

https://www.youtube.com/watch?v=llOP2RT_9uQ

Whittle 2007
Abnormal gait:

- Neuromuscular
- Musculoskeletal
- Painful due to arthritis
- Weakness
- Drop Foot
Lateral trunk bending

Trendelenburg gait.

https://www.youtube.com/watch?v=ZUPQp5oxXj8

Fig. 3.1 Schematic of double legged stance: the force in each hip joint (226 N) is half the weight of the trunk (452 N). The abductors are not contracting.

Fig. 3.4 Trendelenburg’s sign: due to inadequate hip abductors, the pelvis drops on the unsupported side when one foot is lifted off the ground. To compensate, the subject bends the trunk over the supporting hip.
Trunk bending

Fig. 3.6 Anterior trunk bending: in normal walking, the line of force early in the stance phase passes behind the knee; anterior trunk bending brings the line of force in front of the knee, to compensate for weak knee extensors.

Fig. 3.7 Posterior trunk bending: in normal walking, the line of force early in the stance phase passes in front of the hip; posterior trunk bending brings the line of force behind the hip, to compensate for weak hip extensors.
Functional leg length discrepancy

Circumduction

Hip hiking

Steppage

Vaulting
Excessive knee extension

https://www.youtube.com/watch?v=V02GoT-N58c

Excessive knee flexion

https://www.youtube.com/watch?v=b_j327371fM
Foot

1. Abnormal foot contact
   https://www.youtube.com/watch?v=pmRwDMDDv98
   https://www.youtube.com/watch?v=vfw58BXdCPc

2. Abnormal foot rotation

3. Insufficient push off
Pathological Gait

https://www.youtube.com/watch?v=S3R6DsJOblk
Walking aids

Assistive devices: canes, crutches and frames.

1. To improve stability;
2. To generate a moment;
3. Reduce limb loading
Walking with aids

1. Four-point gait;
2. Three-point gait;
3. Two-point gait;

Fig. 3.20 Four-point gait. One crutch or leg is moved at a time in the pattern: left crutch – right leg – right crutch – left leg.

Fig. 3.21 Three-point step-through gait in someone taking weight on both legs. The legs are advanced together, in front of the line of the crutches, then the crutches are advanced together, in front of the line of the legs.
Amputee gait

1. Above the knee (AK)
2. Below the knee (BK)
3. At the level of the ankle (Syme's)
Spastic cerebral palsy

[Diagram showing different types of cerebral palsy and brain damage involvement]

https://www.youtube.com/watch?v=n6v7HCmVlrU

https://www.youtube.com/watch?v=1S27RaQ-A7Q
Crouch gait

- Consider degrees of severity
- Knee flexion > 30 deg, ankle dorsiflexion > 2SD,
  Reduced hip extension
- Increased oxygen consumption and effort
- Increased joint loads: pain and stress fractures

https://www.youtube.com/watch?v=HLFQM1e-vJw
Hemiplegic gait

- Unilateral weakness
- Leg extended with plantarflexion
- Circumduction due to the weakness of the distal muscles, equinus foot and extension hyperthony of the lower limb.
Diplegic gait

- Spasticity of both limbs. Affecting more lower than upper limb.
- Support base narrow.
- Stiffness of adductor muscles, “scissor” gait.
Neuropathy gait

- Equinus foot (weakness of dorsiflexors).
- Unilateral – paralysis of the fibularis nerve – radiculopathy of L5.
- Bilateral – Amyotrophic Lateral Sclerosis, Charcot-Marie-Tooth
Miopathic gait

- Trendelenburg – weakness of the abductors of the hip.
- Muscular dystrophy.
Ataxic gait

- Abnormal, uncoordinate movements.
- Unsteady, staggering gait because walking is uncoordinated and appears to be ‘not ordered’.
Parkinsonian gait

- 3 classical signals: resting tremor, rigidity, and bradykinesia.
- Head and neck forward, and knee flexed.
- Slow gait with short steps.
- Difficulty in starting the movement.
Miopathic gait
Parkinsonian gait
Ataxic gait