Normal and Pathological Gait

Claudiane Arakaki
Federal University of ABC
Laboratory of Biomechanics and Motor Control

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-ander-e-marcha-a-re/#more-948

Gage 1991; Baker 2009
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).  - Computational simulations showed that skipping is more efficient and less fatiguing than walking or running (Ackermann and Bogert 2015)</td>
<td>- Both feet lose contact with the ground.</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) = stride length (m) x cadence (steps/min) / 120

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%)  Gait Cycle  Swing Phase (40%)

Double support (10%)  Single support (40%)  Double support (10%)  Single support (40%)

INITIAL CONTACT  MIDSTANCE  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>
<th>Stride length (m)</th>
<th>Speed (m/s)</th>
</tr>
</thead>
<tbody>
<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>96–138</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>
</tr>
</tbody>
</table>

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

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<td>13–14</td>
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<td>0.85–1.25</td>
<td>1.15–1.75</td>
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<tr>
<td>18–49</td>
<td>91–135</td>
<td>0.89–1.32</td>
<td>1.25–1.85</td>
<td>1.10–1.82</td>
</tr>
<tr>
<td>50–64</td>
<td>82–126</td>
<td>0.95–1.46</td>
<td>1.22–1.82</td>
<td>0.96–1.68</td>
</tr>
<tr>
<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>
</tbody>
</table>

Whittle 2007

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 heelstrike, initial contact being made by the flat foot
4. There is very little stance phase knee flexion
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=IIOP2RT_9uQ

Abnormal gait:

- Neuromuscular
- Musculoskeletal
- Painful due to arthritis
- Weakness
- Drop Foot

Whittle 2007
Lateral trunk bending

Trendelenburg gait.

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

![Diagram of Trendelenburg gait and its test](image)

- **Fig. 3.1** Schematic of double legged stance: the force in each hip joint (23.8 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

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

![Diagram of trunk bending](image)

- **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.

https://www.youtube.com/watch?v=yfHZWO17W70
Functional leg length discrepancy

Circumduction

Fig. 3.9 Circumduction: the swinging leg moves in an arc, rather than straight forwards, to increase the ground clearance for the swing foot.

Hip hiking

Fig. 3.10 Hip hiking: the swing phase leg is lifted by raising the pelvis on that side.

Steppage

Fig. 3.11 Steppage: increased hip and knee flexion improves ground clearance for the swing phase leg, in this case necessitated by a foot drop.

Vaulting

Fig. 3.12 Vaulting: the subject goes up on the toes of the stance phase leg to increase ground clearance for the swing phase leg.

Excessive knee extension

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

Excessive knee flexion

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

1. Inadequate dorsiflexion control
   https://www.youtube.com/watch?v=8c4bGhvK0Qs

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

3. Abnormal foot rotation

4. 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;
Amputee gait

1. Above the knee (AK)
   https://www.youtube.com/watch?v=08xFpB1UPbw

2. Below the knee (BK)
3. At the level of the ankle (Syme’s )

Spastic cerebral palsy

https://www.youtube.com/watch?v=n6v7HCmVIrU

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

Gait analysis
Gait analysis

Ground reaction forces
Gait kinematics, kinetics and power

Ângulo articular  Momento articular interno  Potência articular = torque x velocidade angular

Gait analysis report

Figure 2.9 Standard array of graphs, with rows representing levels (pelvis, hip, knee and ankle) and columns representing planes (sagittal, coronal and transverse).

Baker 2009
Gait analysis report

Electromyography

Figure 6.6. A borderline case of a meaningless signal, made out of rhythmic artefacts only, which could be misinterpreted as muscle activity after the application of a high-pass filter, set at 10Hz in this case (Figure from Merlo and Campini 2010 with permission).
Plantar pressure

Diabetic neuropathic

Custom therapeutic insoles based on foot shape and plantar pressure measurement provide enhanced pressure relief.
Owings et al., 2008
Rehabilitation

https://www.youtube.com/watch?v=mL5PR-3-NJU

https://www.youtube.com/watch?v=iETPT250sm0

https://www.youtube.com/watch?v=uq6b3XFdeuQ

https://www.youtube.com/watch?v=zNevwgXEAb0

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

References


http://orthopedia.wikia.com/wiki/Pathologic_Gait_Patterns