Gait Analysis and Motion Capture System

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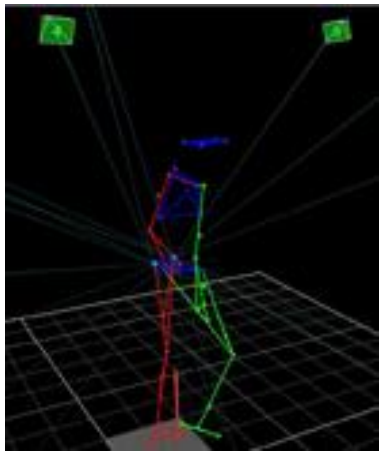


Walking and Gait

• Human walking/running: defined as a method of locomotion involving the use of the two legs, to provide both support and propulsion.

• For walking alone: must add “at least one foot being in contact with the ground at all times”.

• Gait: it is a description of the manner or style of walking (rather than the walking process itself).

• Gait analysis is the systematic study of human walking, using the eye and brain of experienced observers, augmented by instrumentation for measuring body movements and body mechanics and the activities of muscles.

Purposes of Gait

• Transport body through neuromuscular control, safely and efficiently across the ground – level, uphill or downhill:

- Provision of shock absorption
- Prevent collapse
- Maintain balance
- Optimise excursion of the centre of gravity

Motor Functions in Human Gait

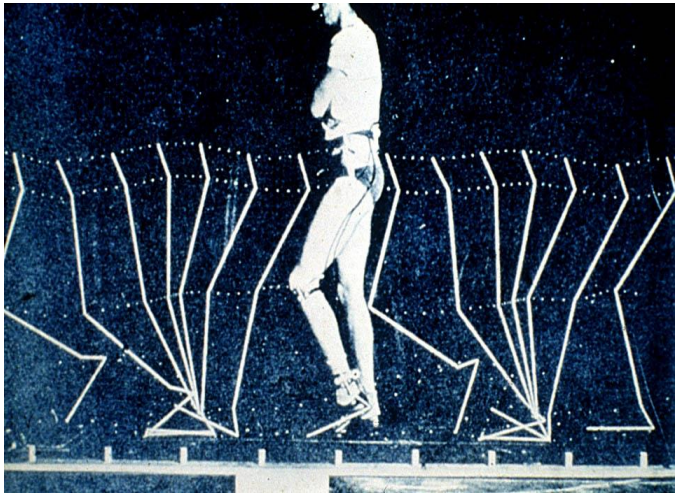
- Maintenance of support of the upper body.
- Maintenance of upright posture and balance of total body.
- Control of foot trajectory to achieve safe ground clearance and gentle foot landing.
- Generation of mechanical energy to maintain or increase forward velocity.
- Absorption of mechanical energy for shock absorption and stability or to decrease forward velocity.

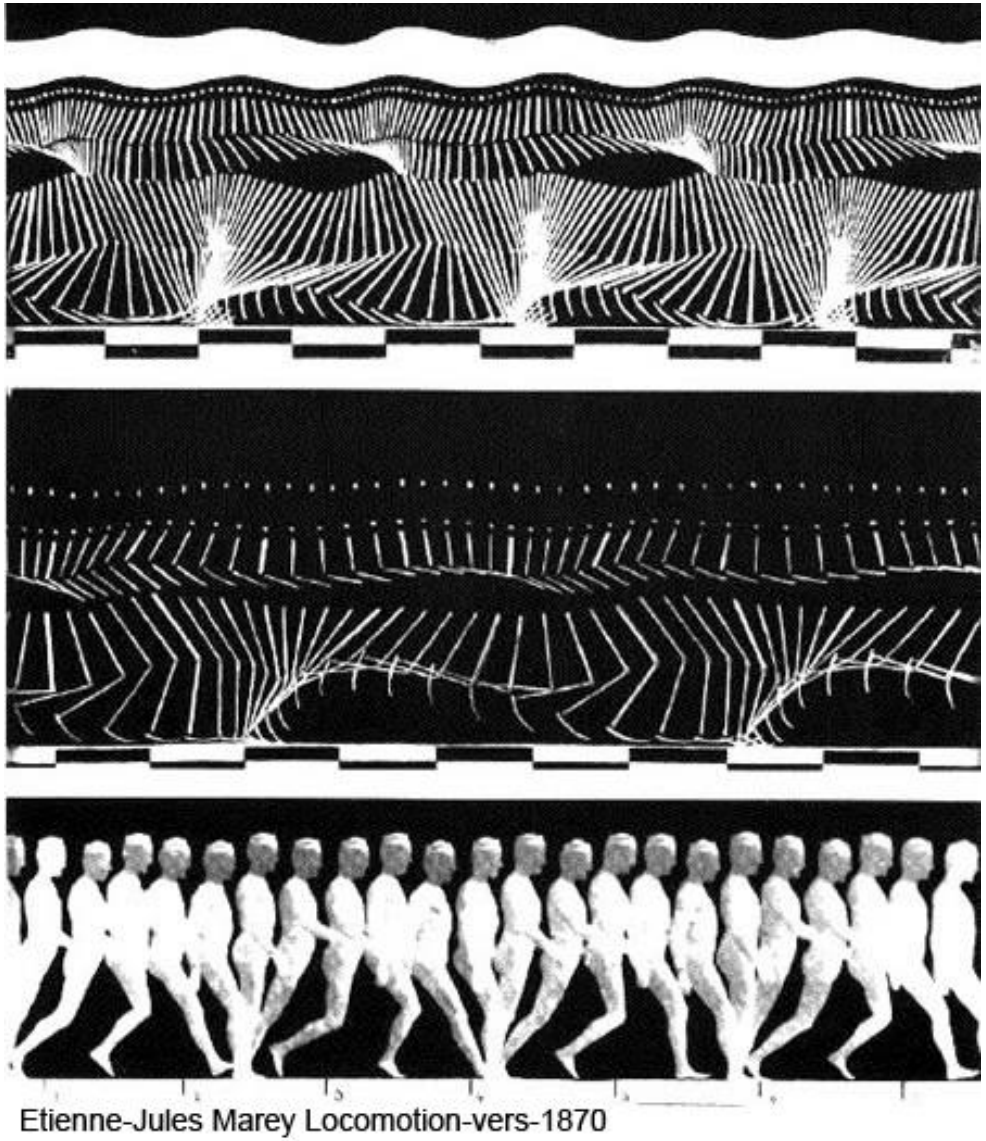
Introduction of Photography

- Etienne-Jules Marey (Paris, 1873)
- Eadweard Muybridge (California, 1878)
- Braune and Fischer (Germany, 1895)
- Nikolai Bernstein (Moscow, 1930’s)

Etienne-Jules Marey (1873)

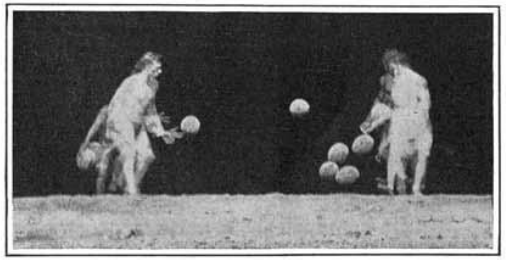
- French physiologist.
- Multiple photographic exposures on a single plate.
- Black subject with illuminated stripes.



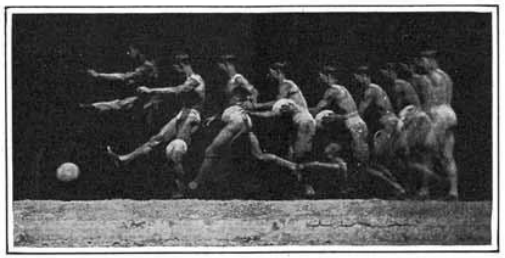


Etienne-Jules Marey Locomotion-vers-1870

Etienne-Jules Marey (1873)

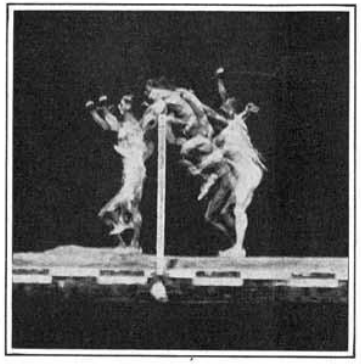


The player on the right has fumbled the ball.

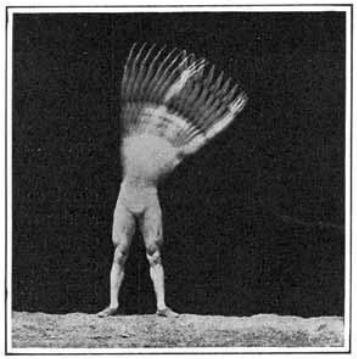


Composite photograph of a bad kick-off.

Composite photograph of a good drop-kick.



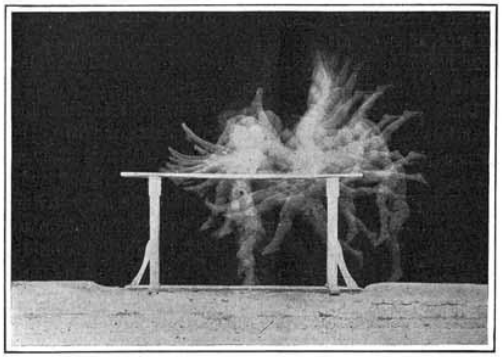
Study of a standing high jump from start to alighting.



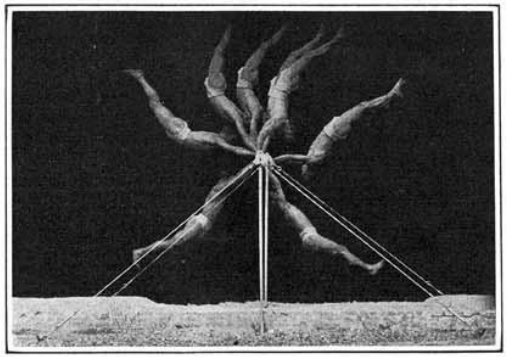
Composite photograph of a familiar calisthenic exercise.

Study of an exercise for developing the abdominal muscles.

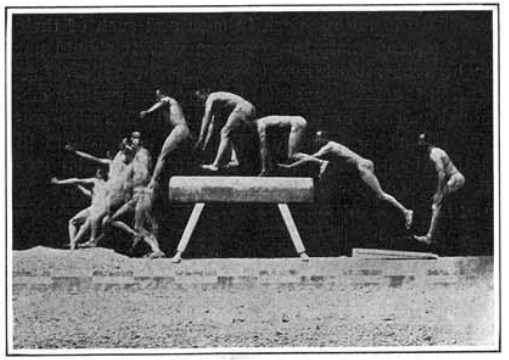
How an athlete jumps from a height to the ground.



Swinging between the parallel bars.



Seven stages of the giant swing.

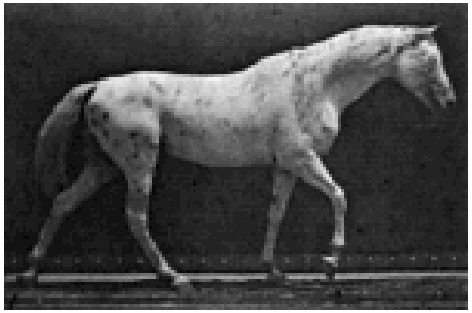


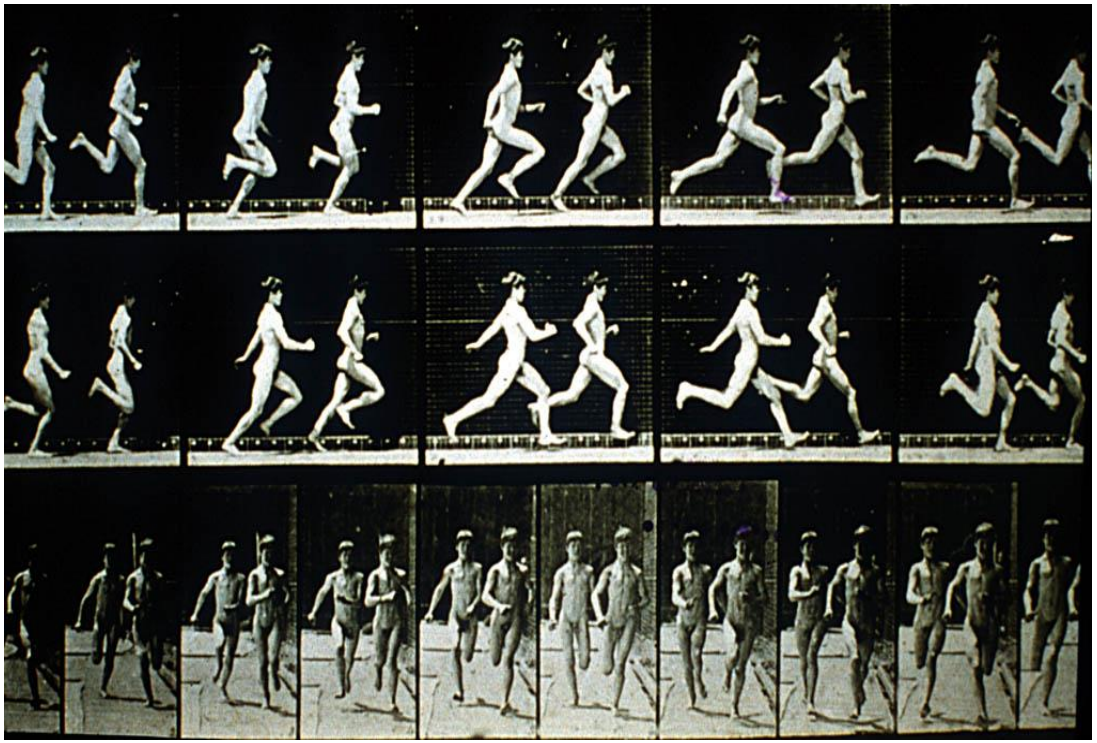
Leaping over a gymnasium horse.

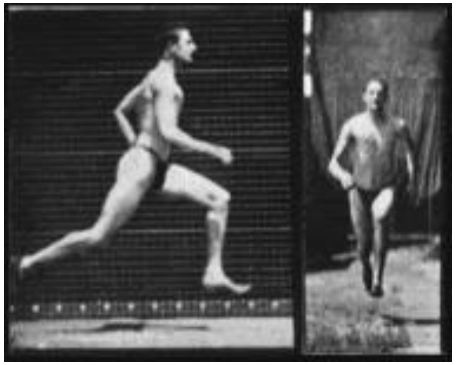
E.J. Marey, Chronophotographs from "The Human Body in Action," Scientific American, 1914

Eadweard Muybridge (1878)

- American photographer.
- Horse trotting using 24 cameras in series.
- Humans walking, running, other activities.

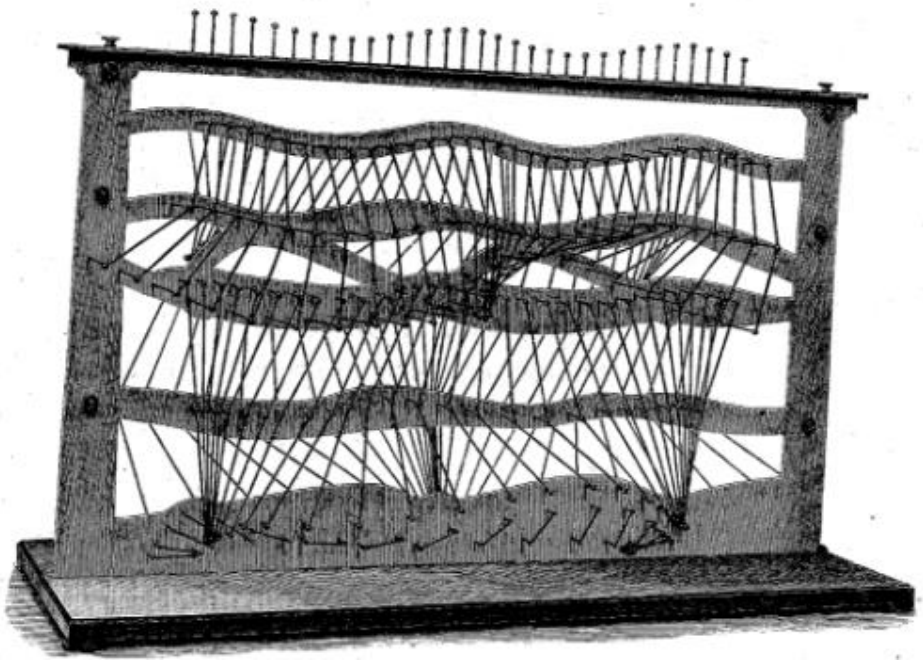






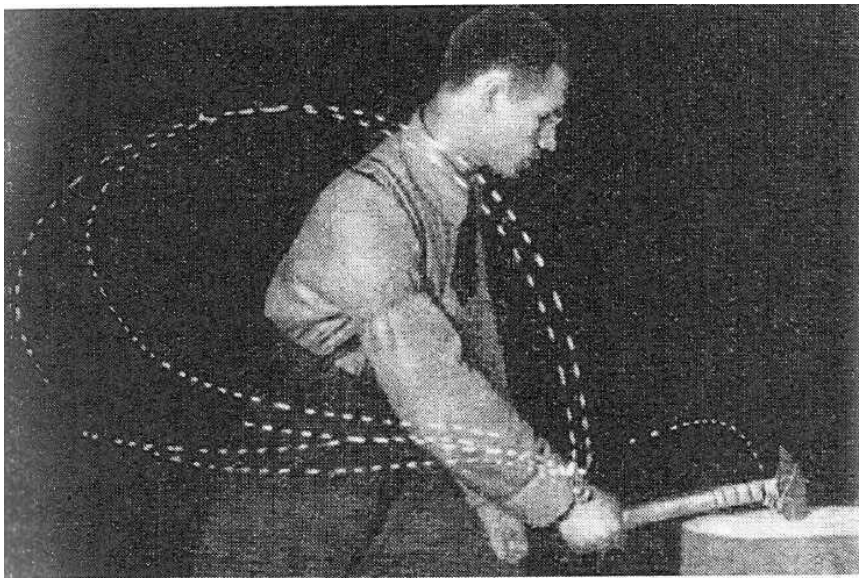
Braune and Fischer (1895)

- Christian Wilhelm Braune, an anatomist.
- Otto Fischer, a physiologist.
- Used fluorescent light strips.
- Determined 3-D trajectories, velocities and acceleration.
- Estimated forces.

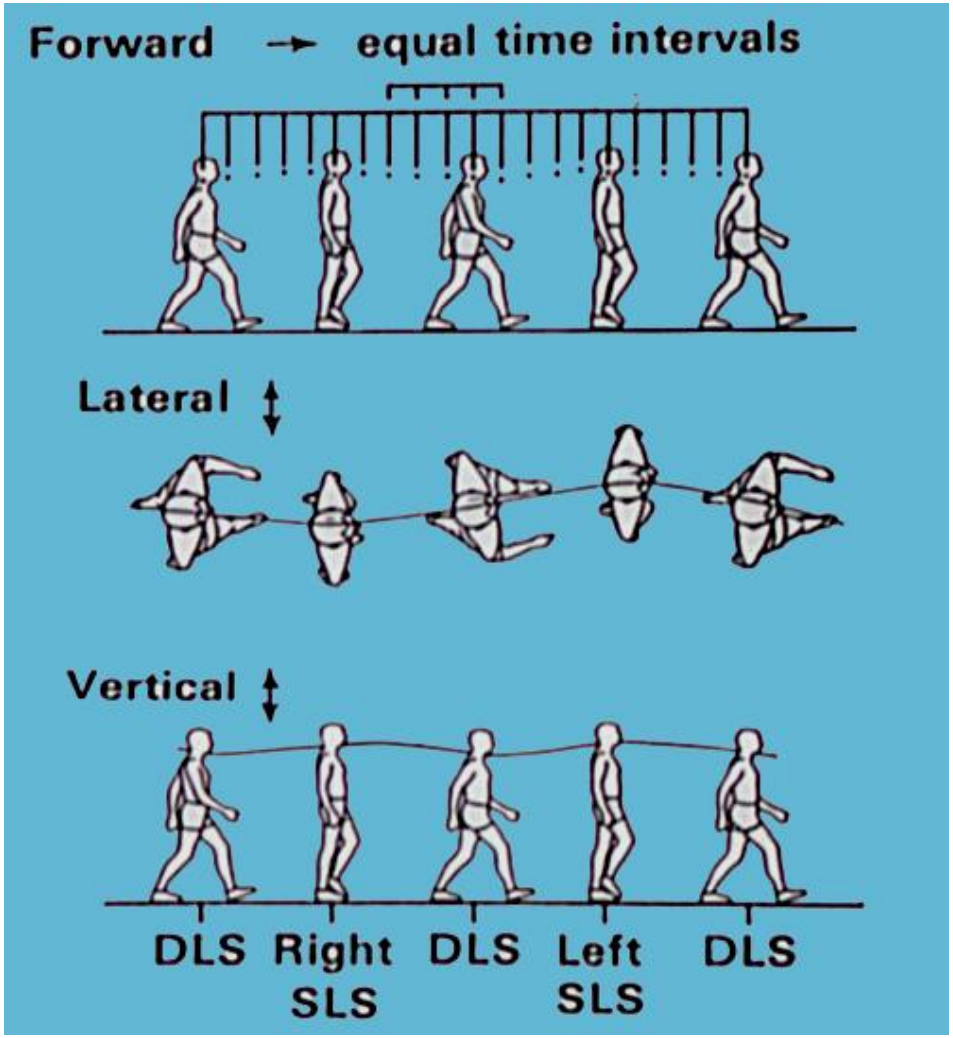


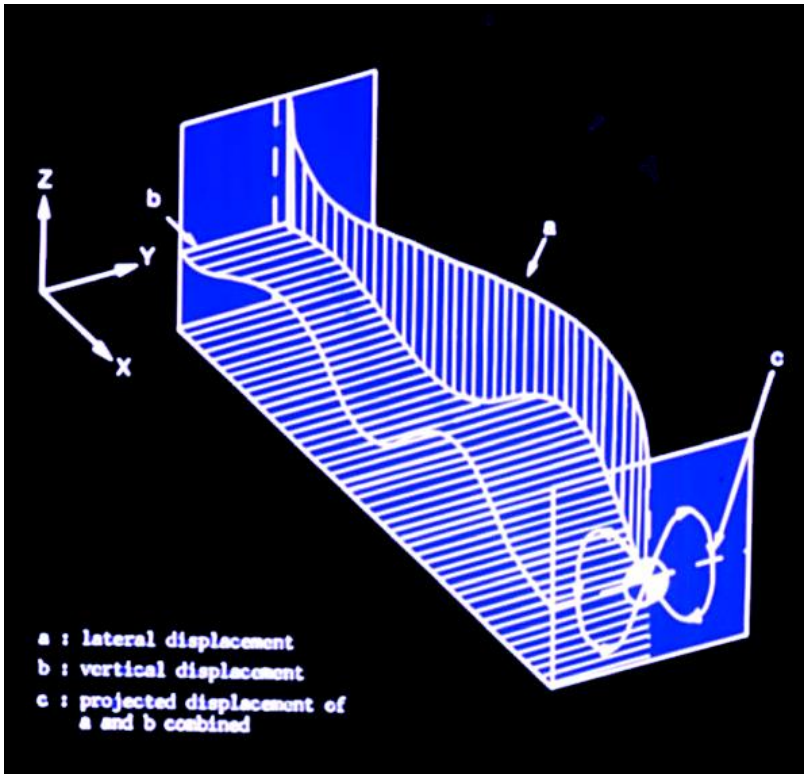
Nikolai Bernstein (1930's)

- Soviet neurophysiologist.
- Photographic techniques.
- Studied over 150 subjects.
- Centre of gravity of body and individual limb segments.



Optimise CG of Body during Gait

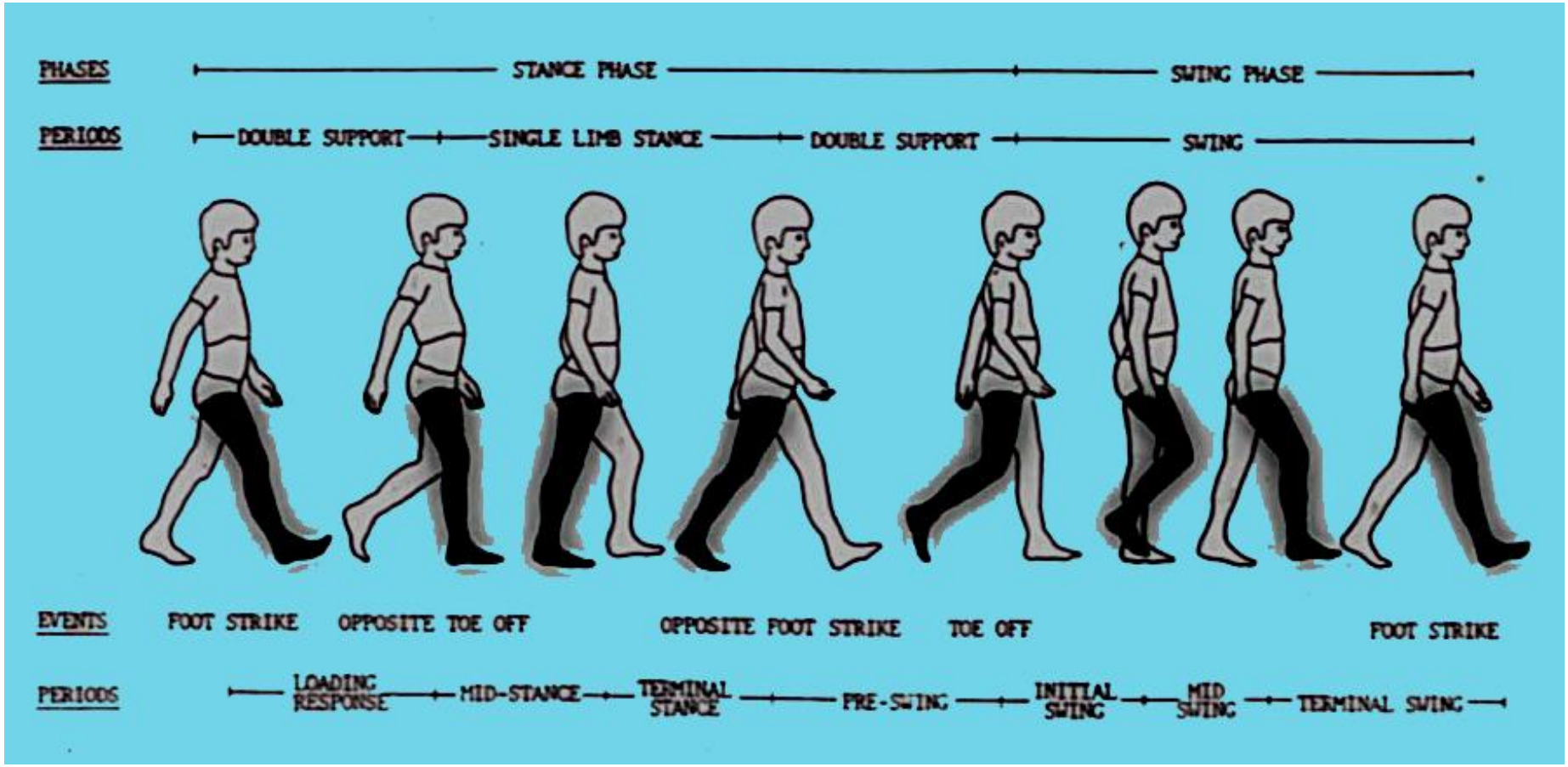




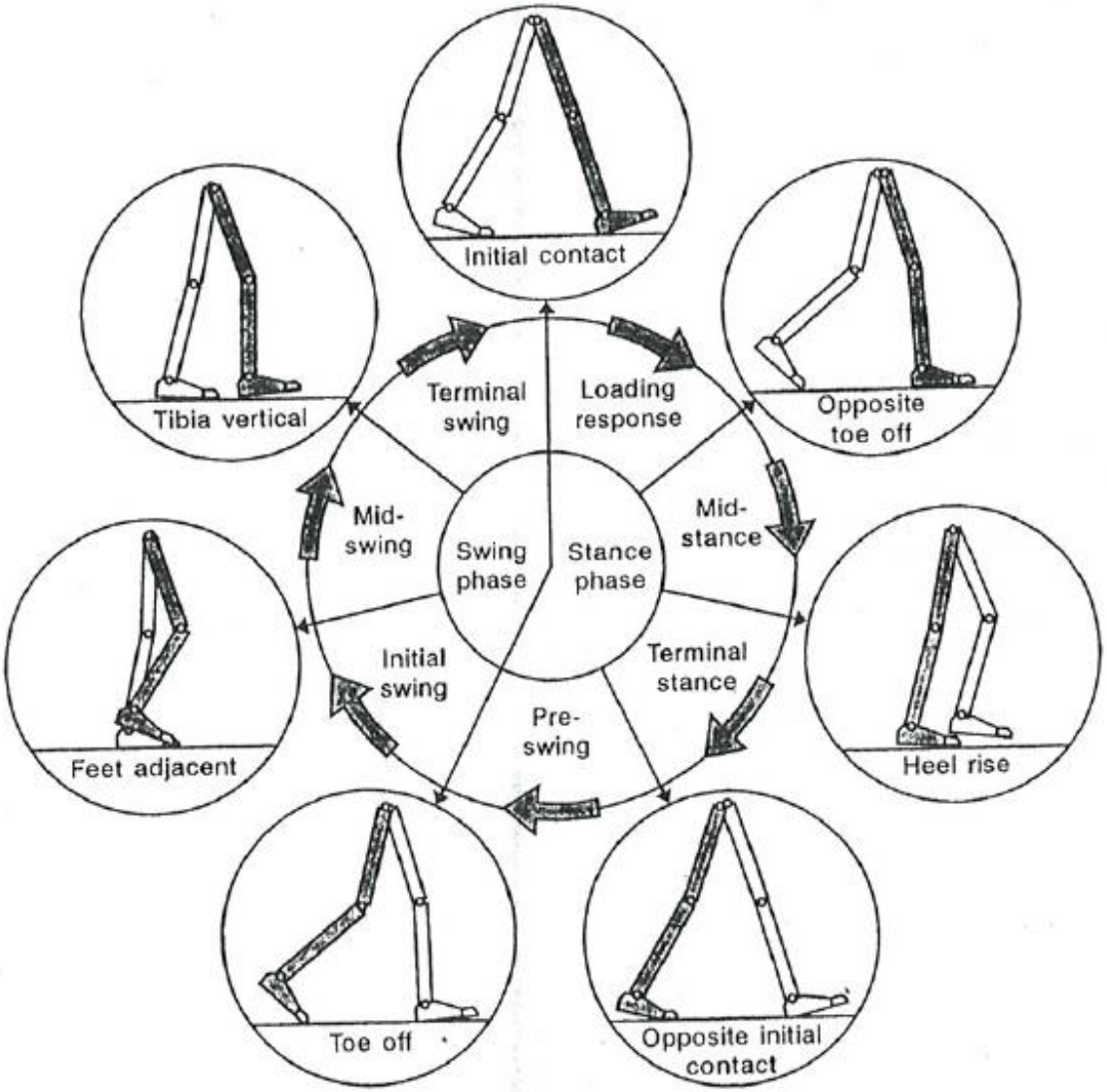
Vertical: 5cm

Medio-Lateral: 5cm

Terminology and Conventions Related to Human Gait

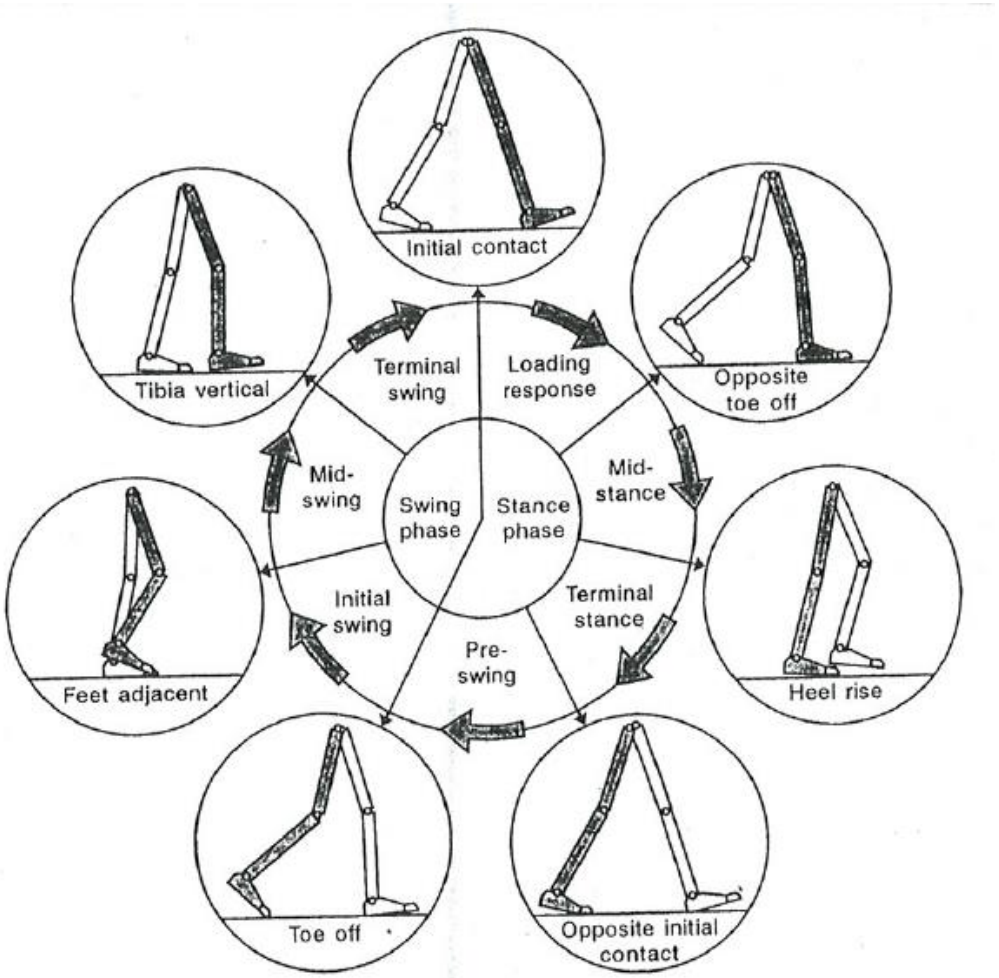


Terminology and Conventions Related to Human Gait



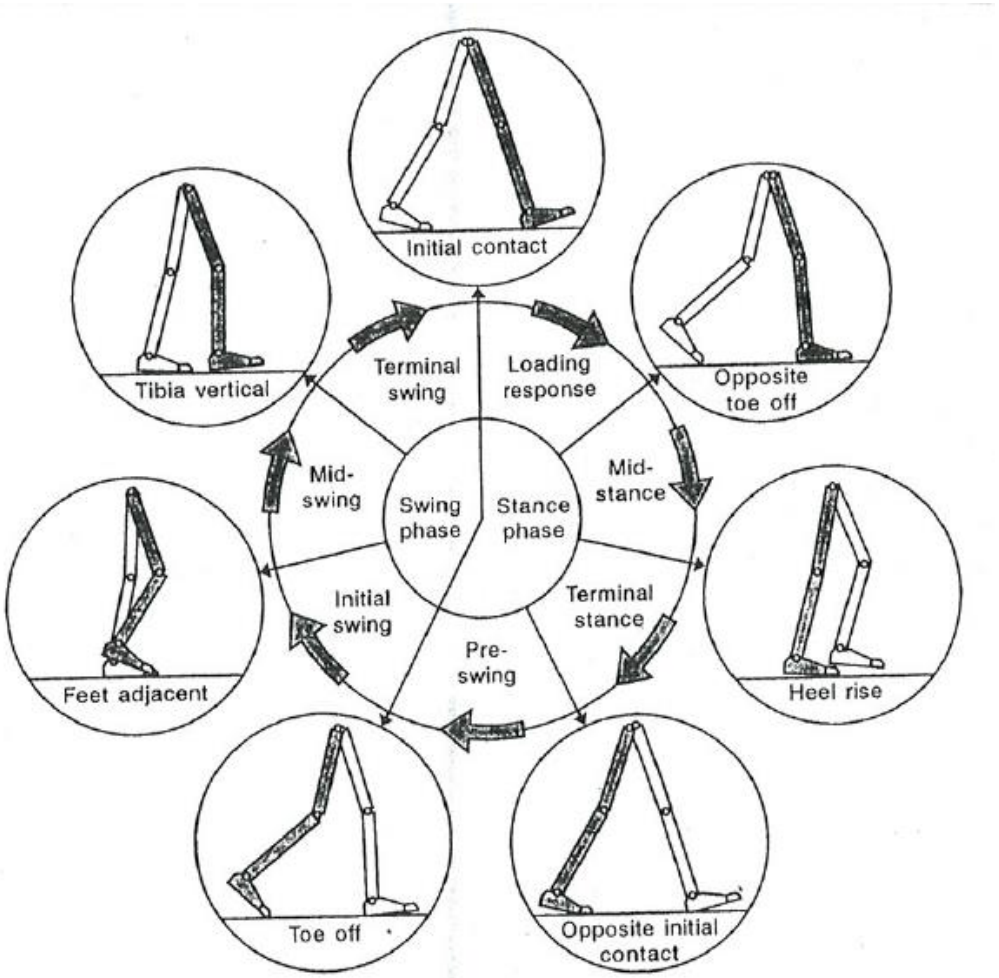
Stance Phase

- Loading response
- Mid-stance
- Terminal stance
- Pre-swing



Swing Phase

- Initial swing
- Mid-swing
- Terminal swing



Measurable Quantities in Human Gait

- **Stride characteristics**
- **Body motion**
- Forces
- Muscle activities
- Energy expenditure

➢**Essential in gait analysis to record the speed of walking.**

Gait Cycle Timing

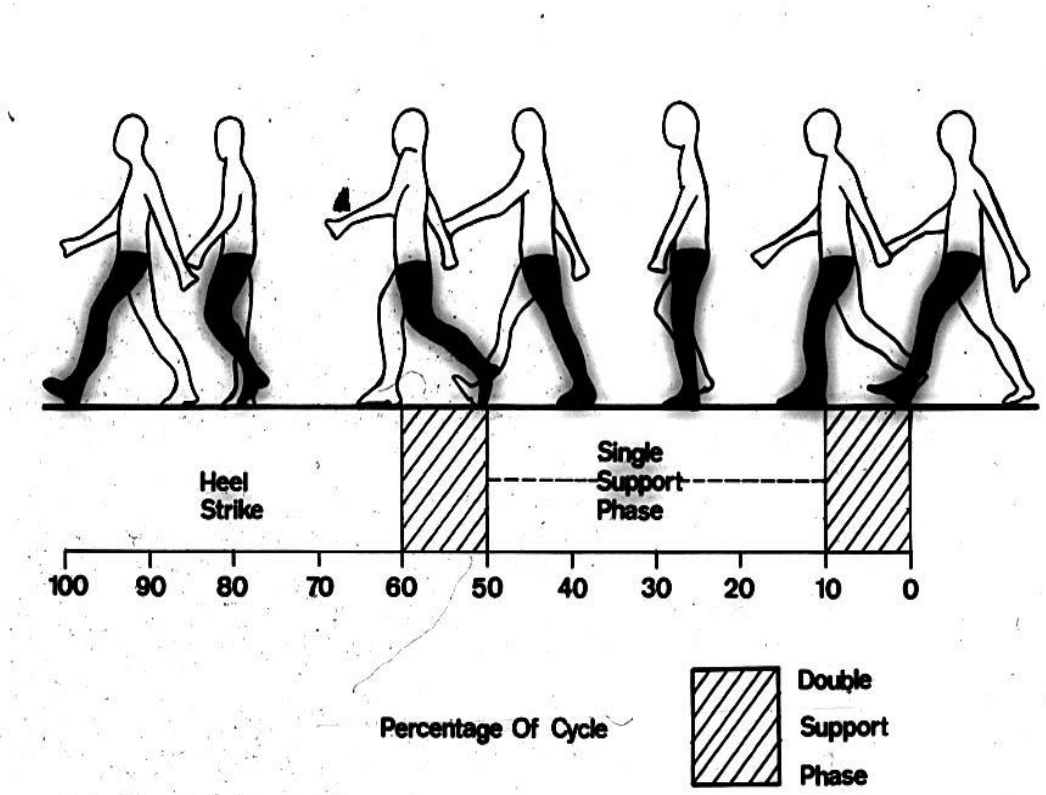
Stance phase - 60%

(foot on ground)

Swing phase - 40%

(foot in the air / moving forward)

Double support - 10% (x 2)



Gait Cycle Timing

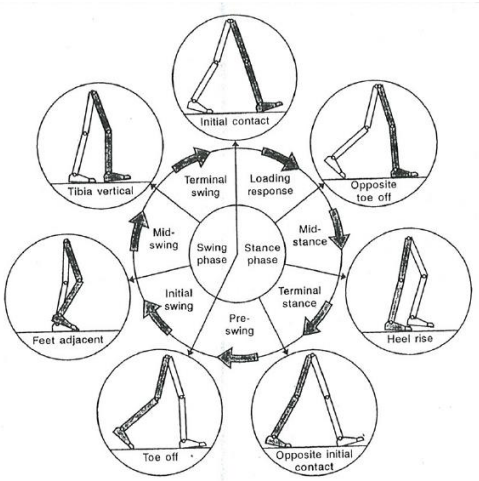
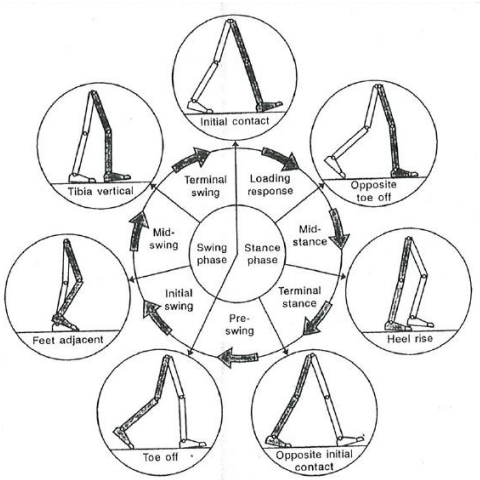
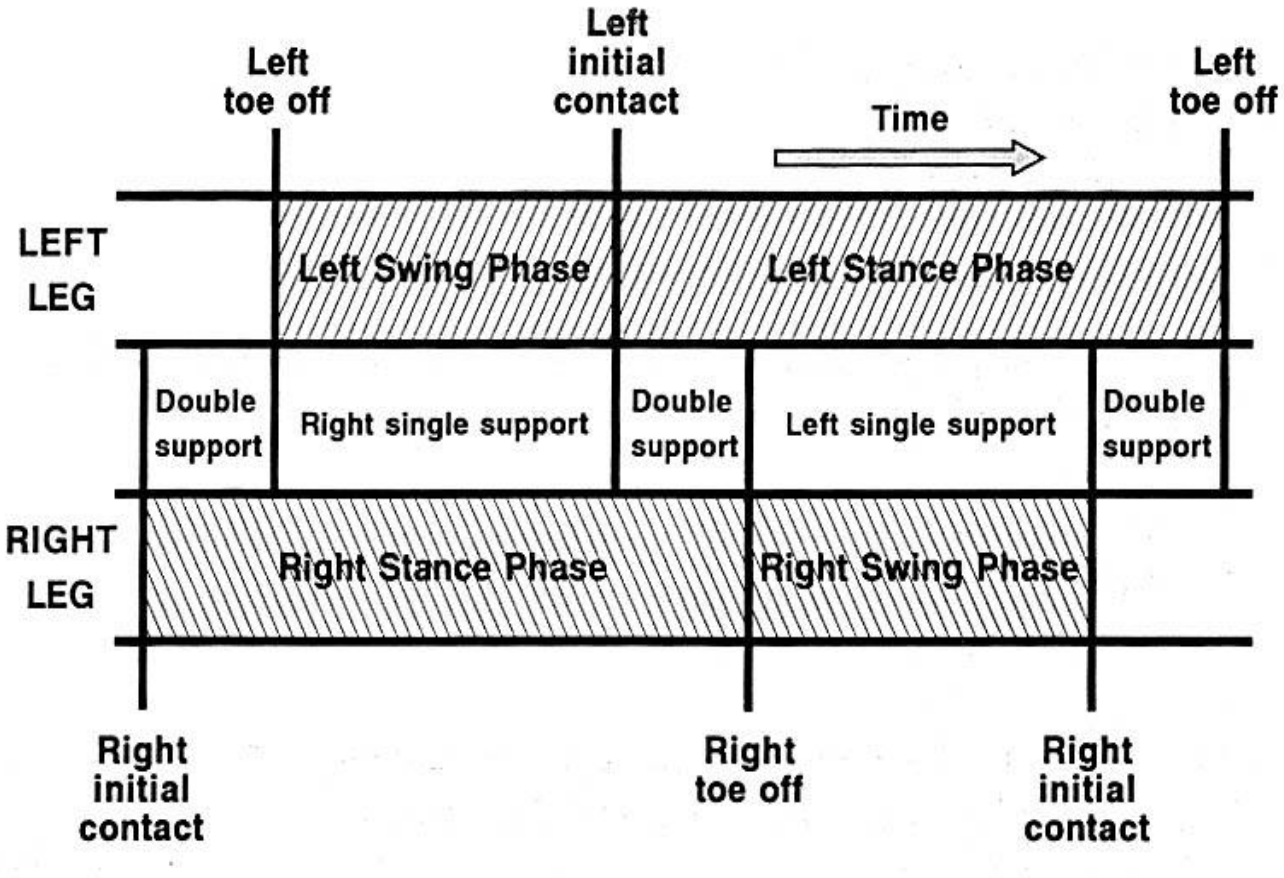


Table 2.1. Gait Cycle: Events, Periods, and Phases

Event	% Gait Cycle	Period	Phase
Foot strike	0	Initial double limb support	Stance, 62% of cycle
Opposite toe-off	12	Single limb support	
Opposite foot strike	50	Second double limb support	
Toe-off	62	Initial swing	Swing, 38% of cycle
Foot clearance	75	Mid swing	
Tibia vertical	85	Terminal swing	
Second foot strike	100		

Gait Cycle Timing





Double Support

- Transition between limb support on the left and limb support on the right.
  - Fine control for the smooth changeover.

- Increased walking velocity.
  - Reduced period of double support.

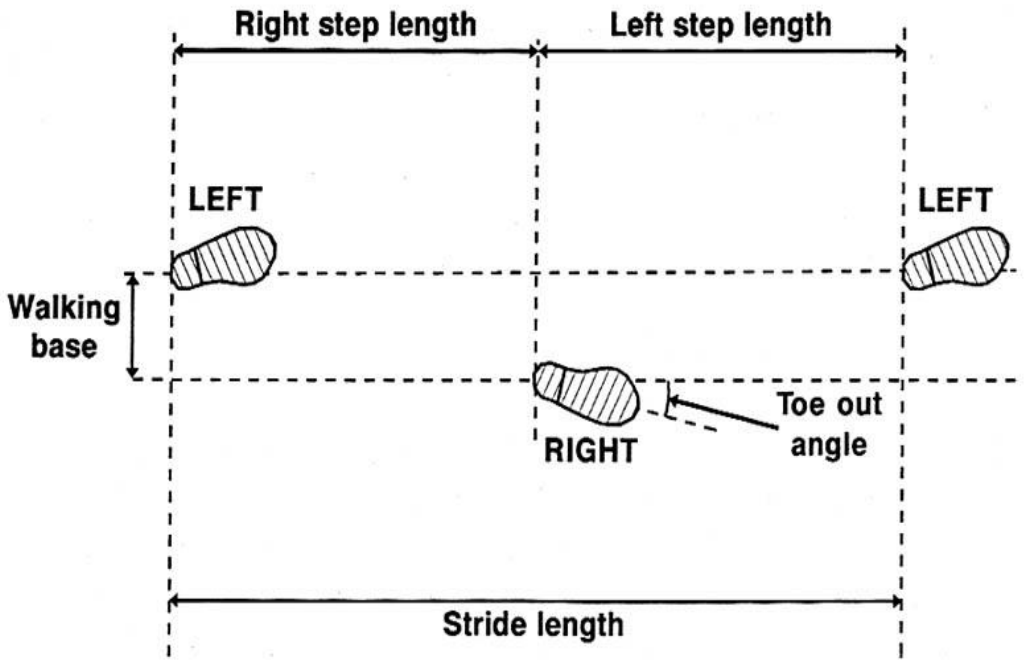
- “Flight phase”.
  - No double support.
  - Olympic classification for “running”.

Walking vs Running

- Walking:
  - At least one foot must be in contact with the ground at all times.
- Running:
  - “Flight” phase.

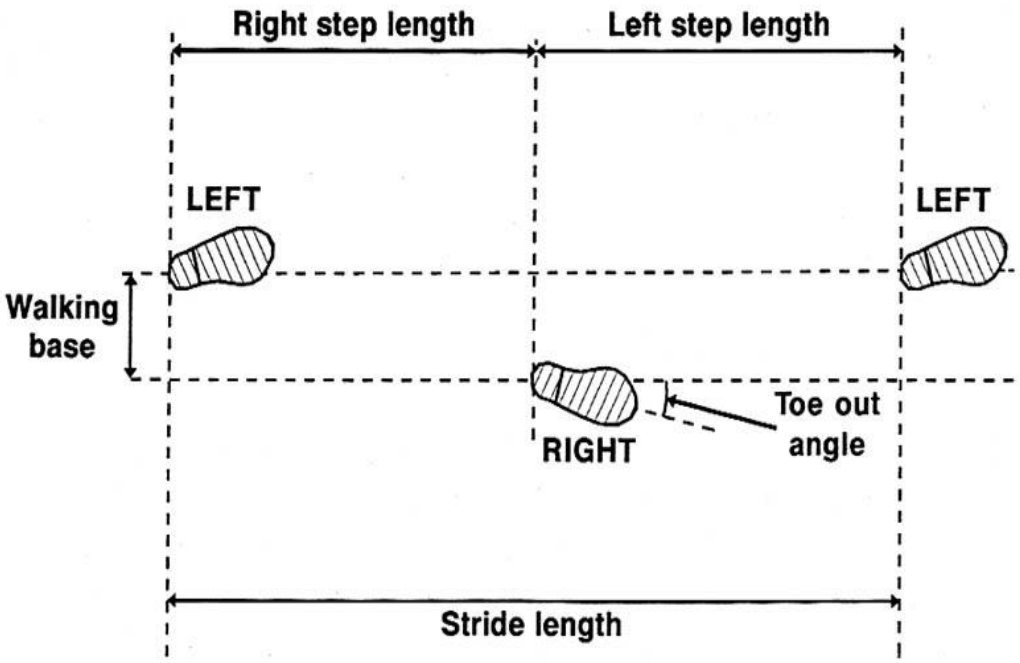
Stride Characteristics

- Stride Length:
  - Distance between initial contact to initial contact of the same foot.
- Step Length:
  - Distance between initial contact of left and right feet.



Stride Characteristics

- Walking Base:
  - Stride width.
  - Side to side distance between the two feet.
- Foot Progression Angle:
  - Toe out angle.
  - Angle made by foot to imaginary straight line in direction of gait.

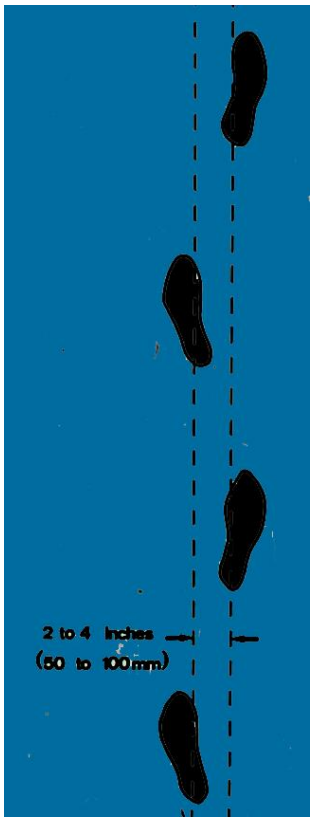


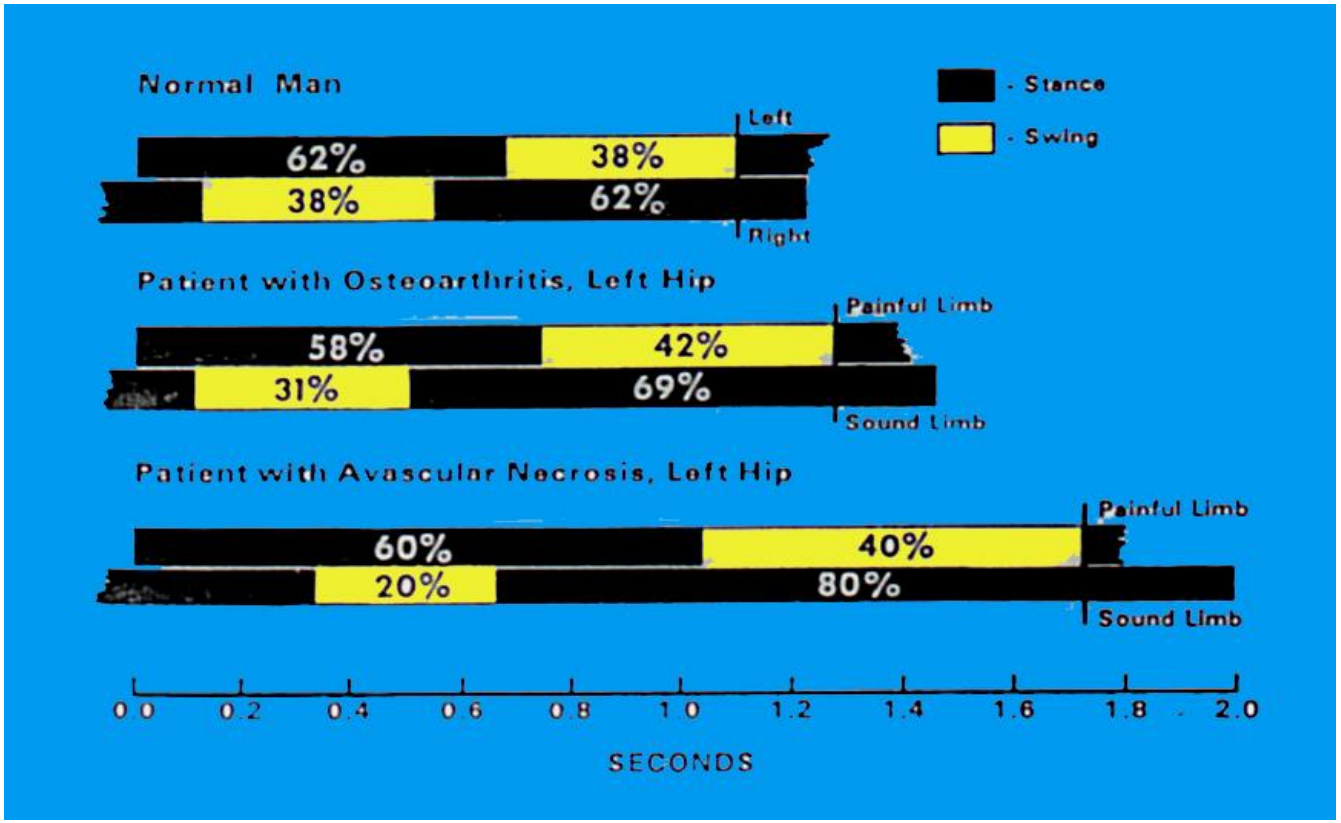
Stride Characteristics

- Cadence:
  - Number of steps per minute.
- Cycle Time:
  - Time taken to complete a single gait cycle (in seconds).
- Speed:
  - Distance covered in a given time (metres per second).

Stride Characteristics

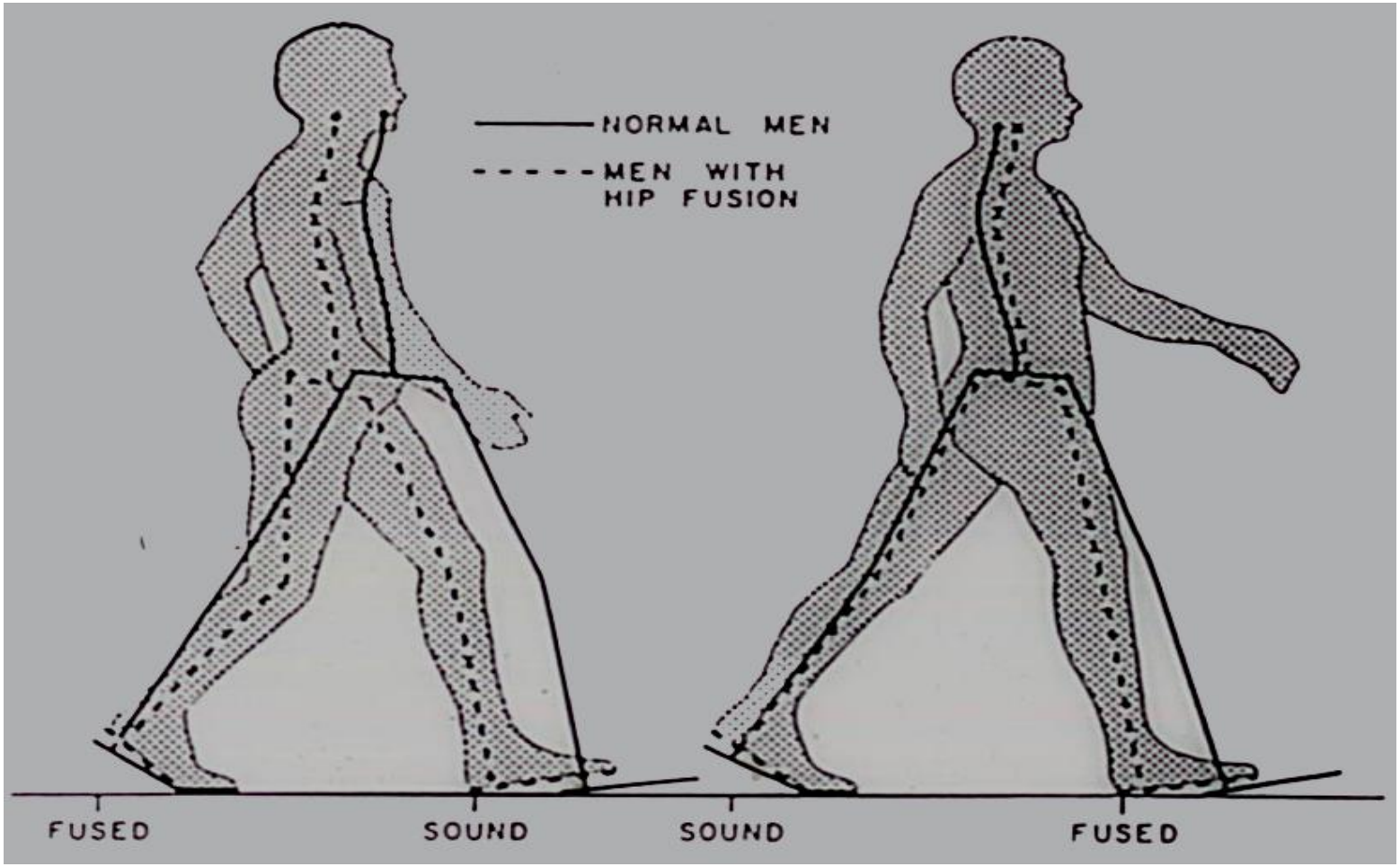
Simple instruments: Stop watch, tape, powder, foot switches, gait mats etc.





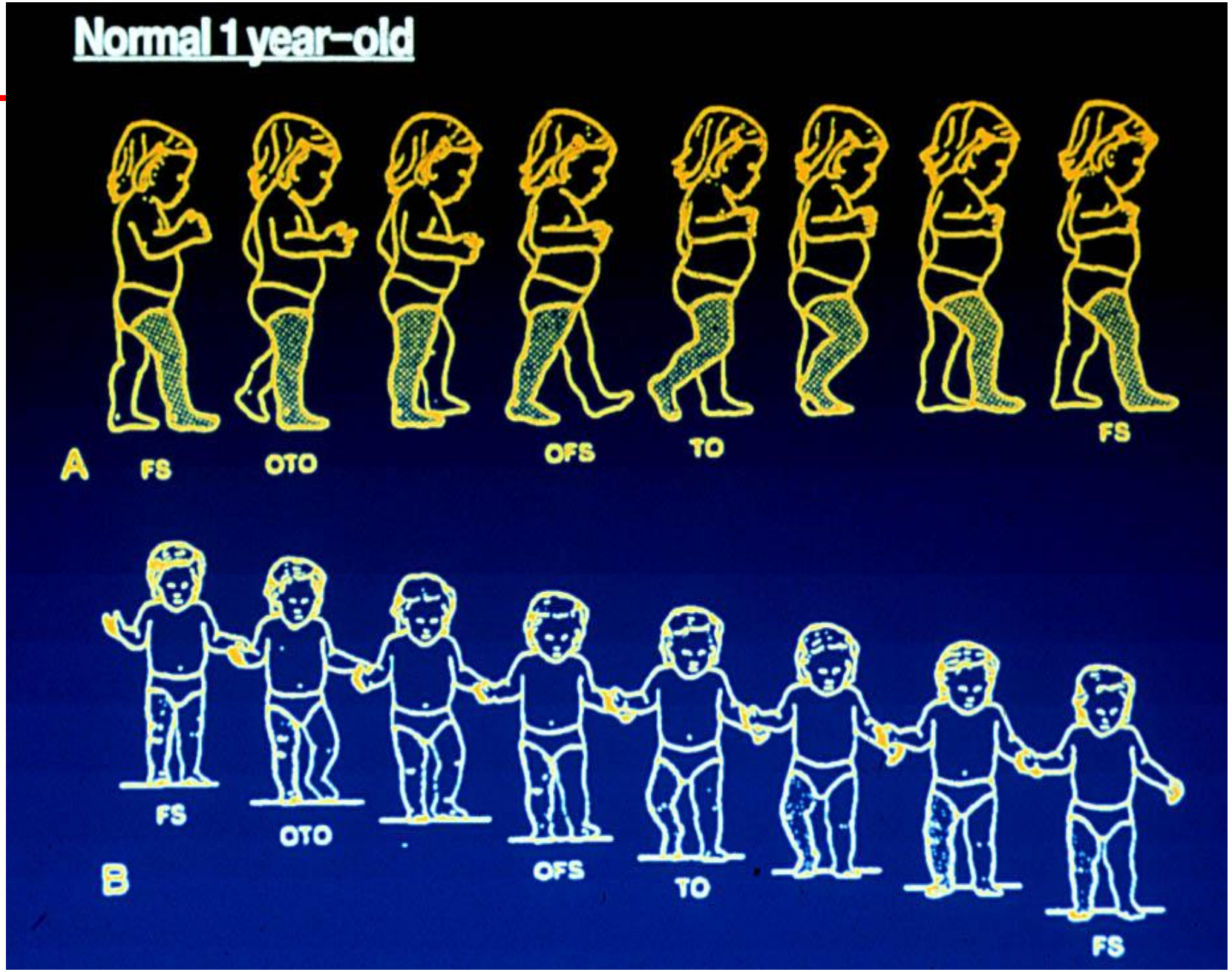
Body Motion

Linear and Angular Displacement/Velocity /Acceleration



Gait in Children

- Shorter stride length
- Lower speed
- Shorter cycle time (higher cadence)
- Wider walking base
- No heel strike
- Little stance phase knee flexion
- Leg externally rotated in swing
- No reciprocal arm swing


Normal 1 year-old
A
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TO
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B
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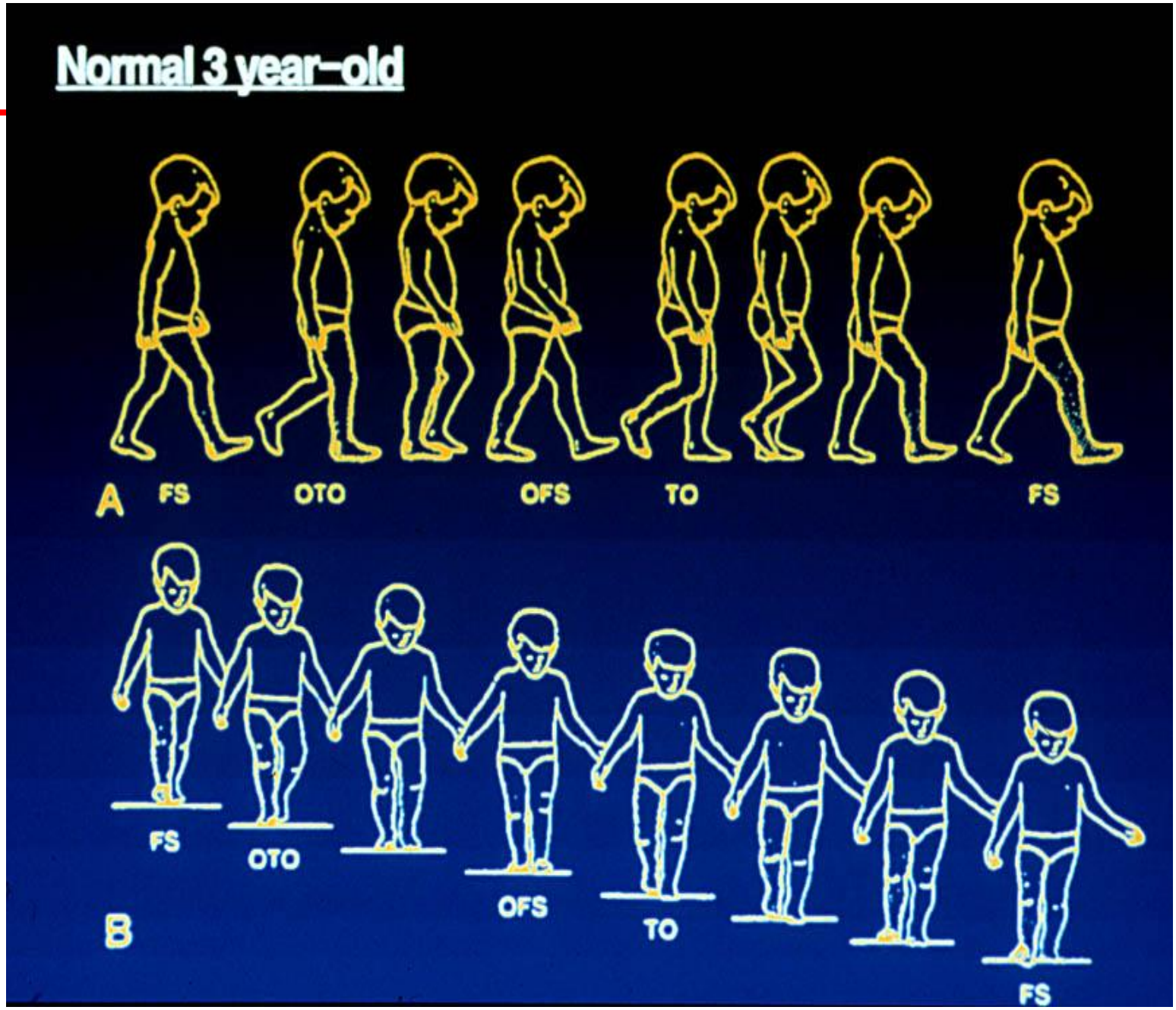
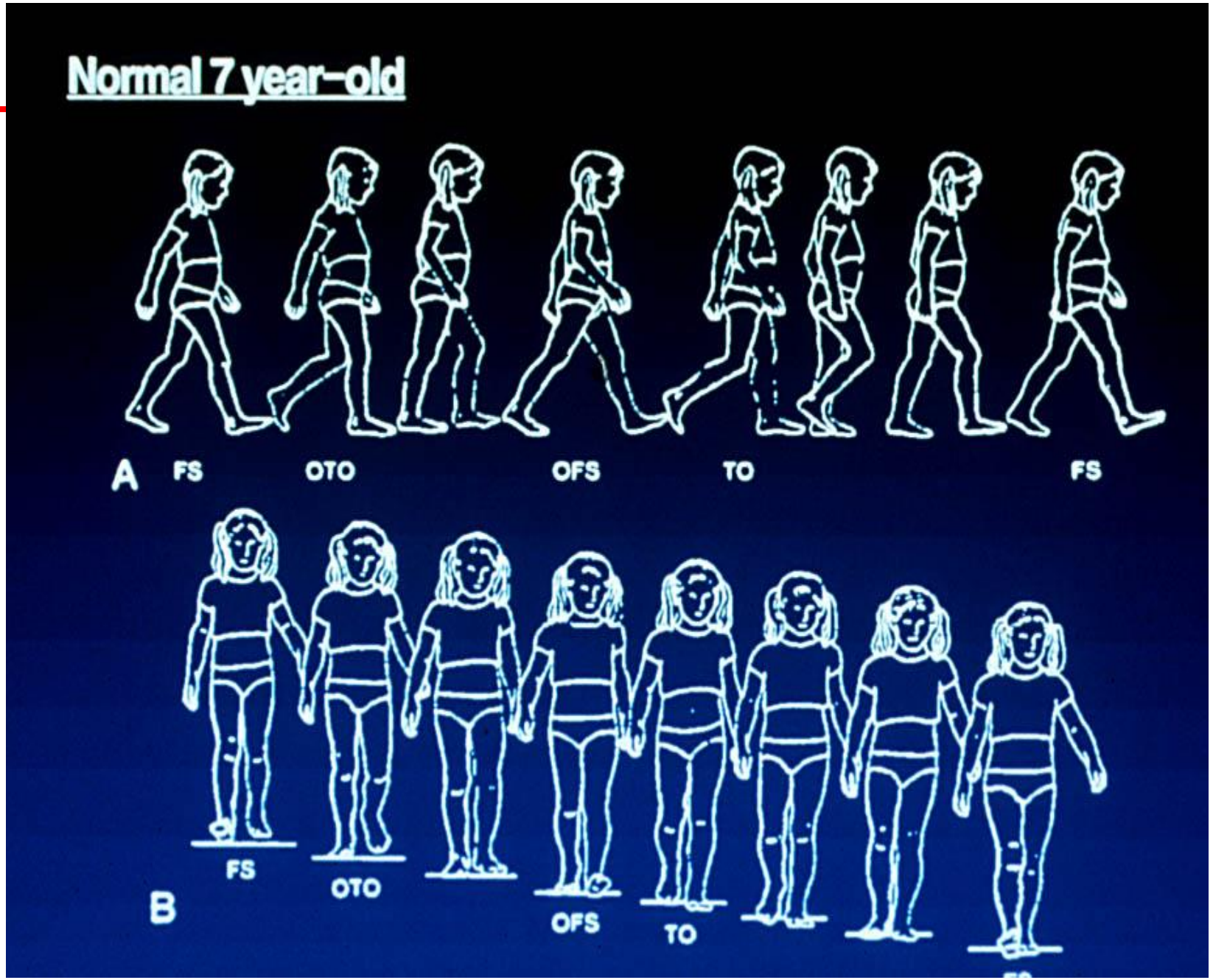
FS

Normal 3 year-old





Gait in Elderly

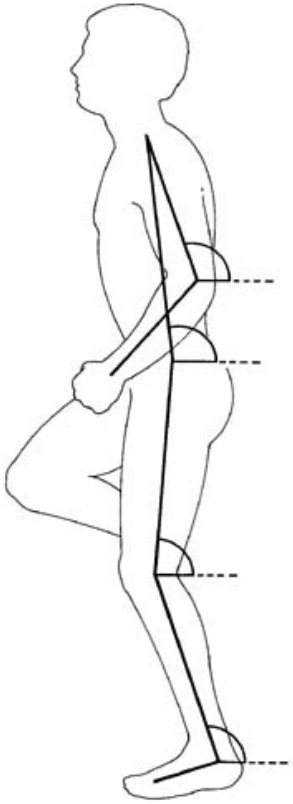
- Usually after 60 years
- Increased cycle time (decreased cadence)
- Decreased stride length
- Wider walking base
- Decreased speed
- May be modified by disease

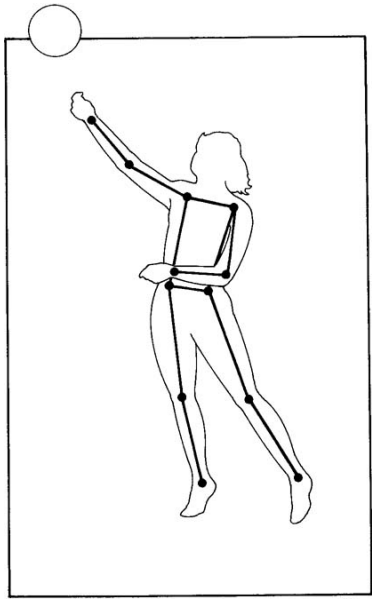
Absolute and Relative Angles

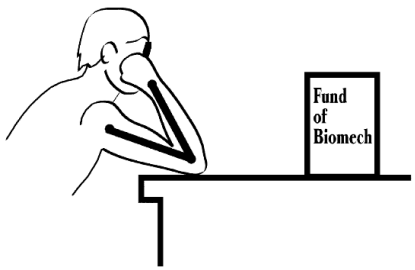
• For human body, joint centres form the vertices of body segment angles.

• **Absolute** angle:
- Angle of inclination of a body segment.
- Measured with reference to an absolute reference line, either horizontal or vertical.

• **Relative** angle:
- Angle at a joint formed between longitudinal axes of adjacent body segments.







• At anatomical reference position, all joint angles are zero.

Body Motion – Joint Angles

Each joint has a convention for describing its magnitude and polarity.

- When knee is fully extended – 0^o flexion.
- When shank moves posteriorly – knee is in flexion.
- Ankle – plantarflexion vs dorsiflexion.

Hip angle:

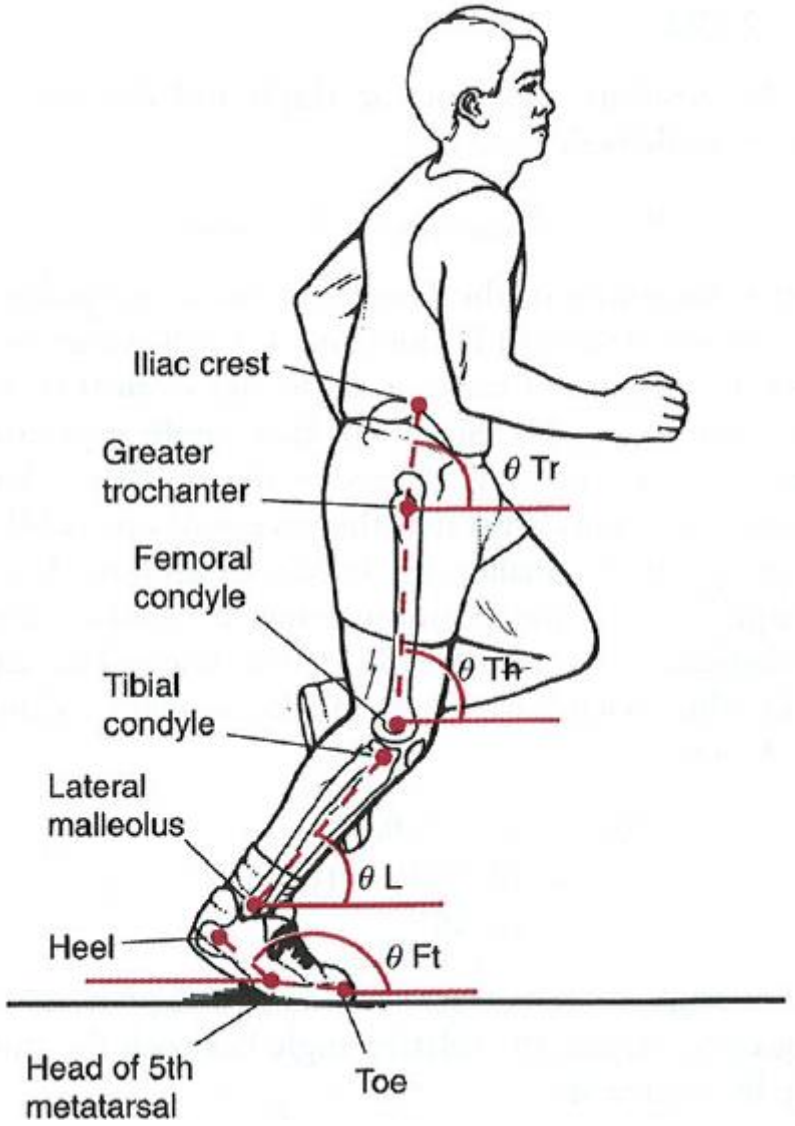
$$\theta_{hip} = \theta_{Th} - \theta_{Tr}$$

Knee angle:

$$\theta_{knee} = \theta_{Th} - \theta_{L}$$

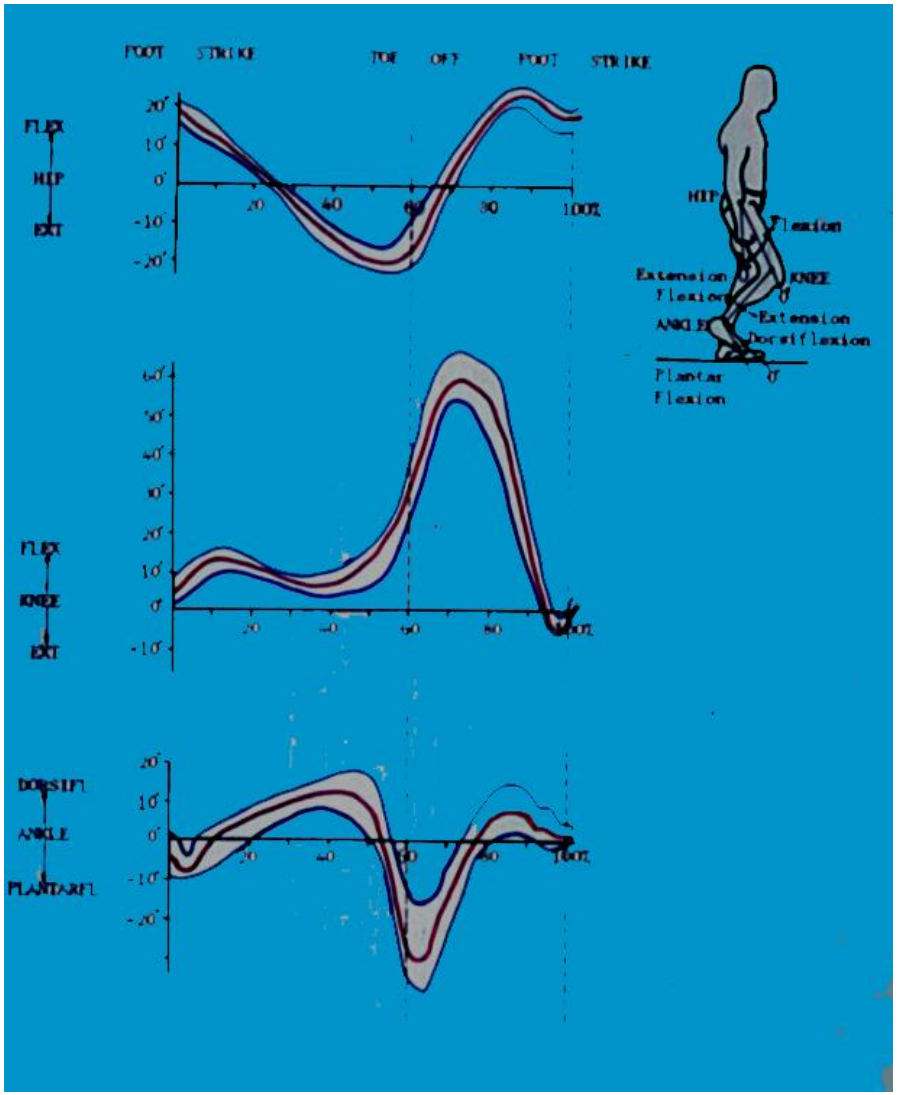
Ankle angle:

$$\theta_{ankle} = \theta_{L} - \theta_{Ft} + 90^o$$

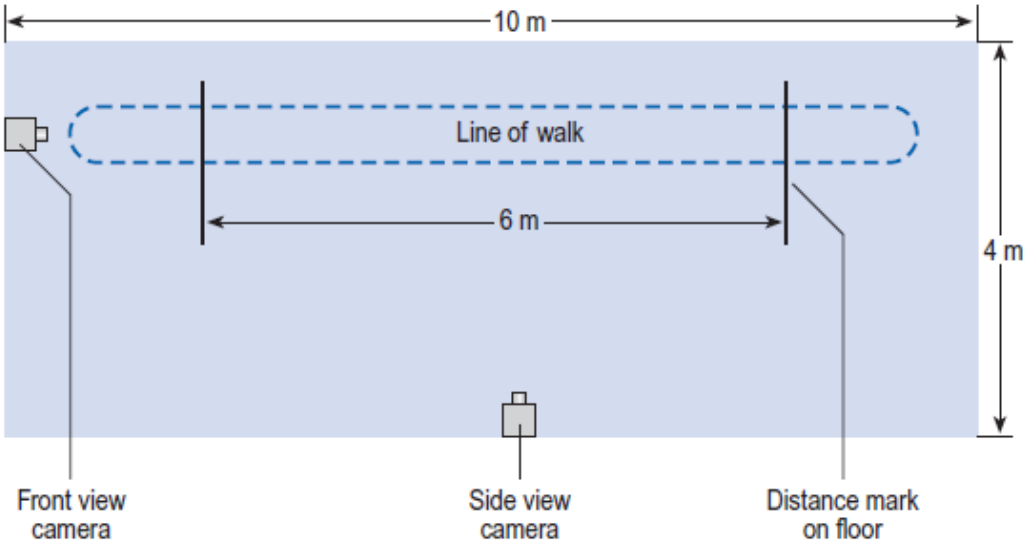


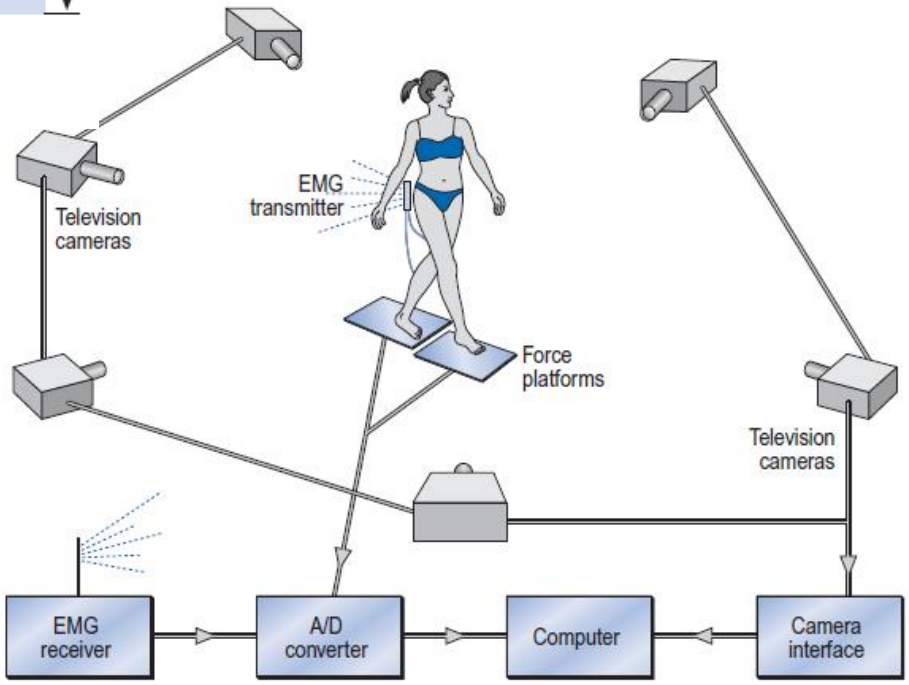
Direct Measurement Technique

Electrogoniometer

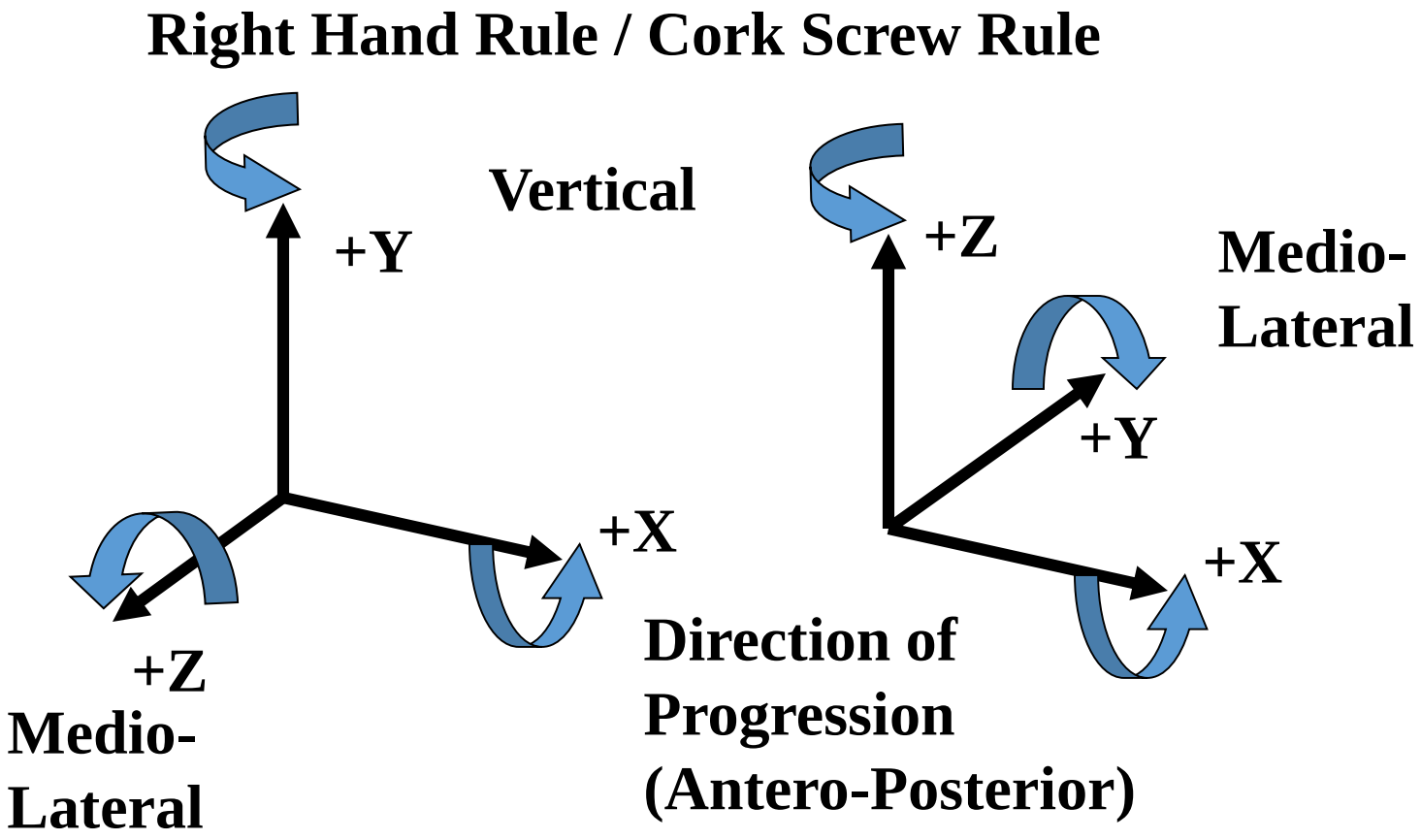


Modern Gait Analysis Laboratory

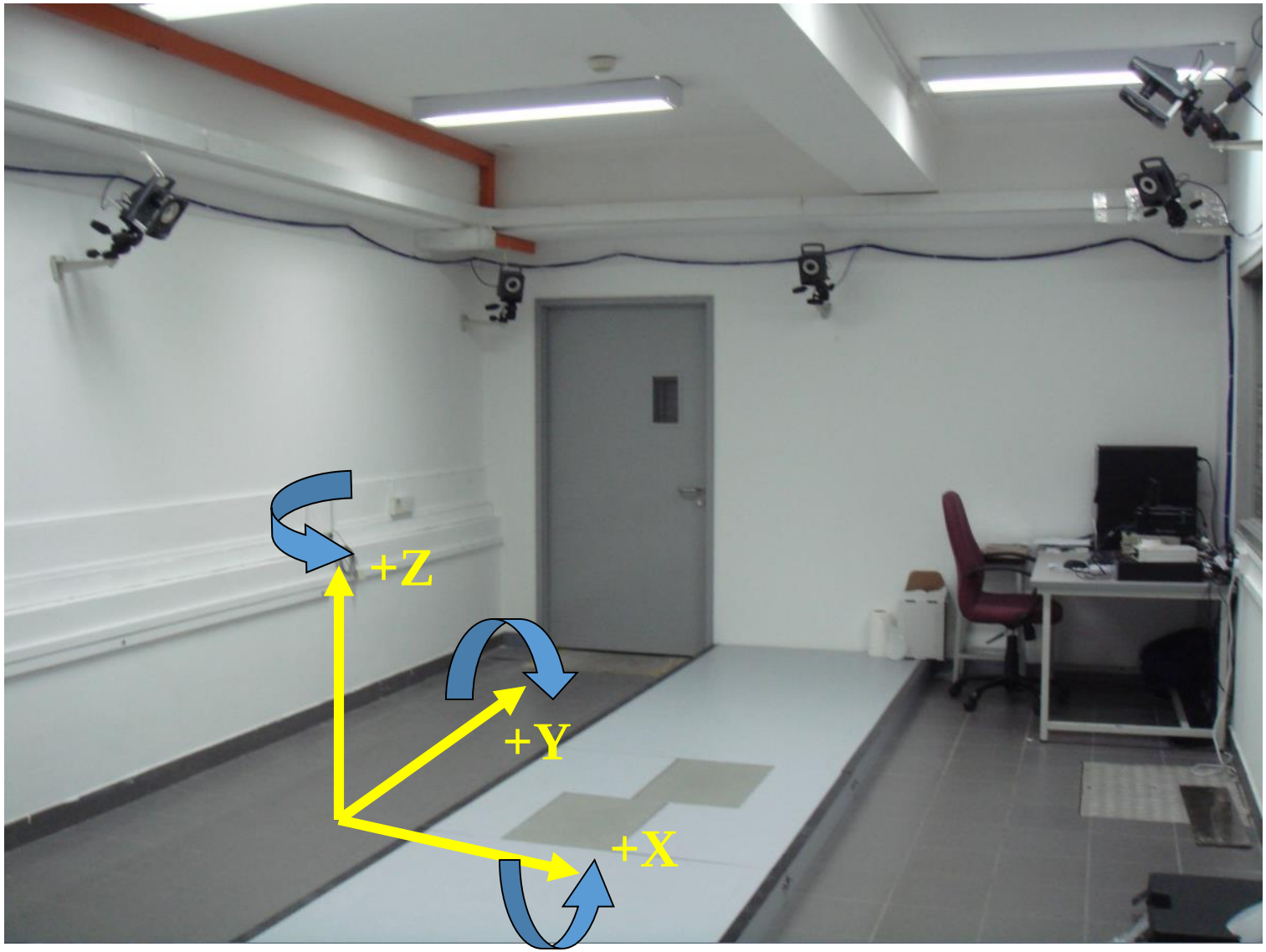




Spatial Reference System



Physical Gait Lab

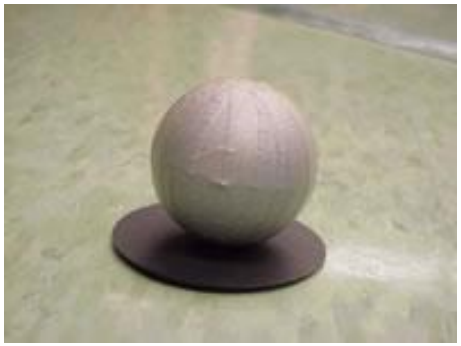


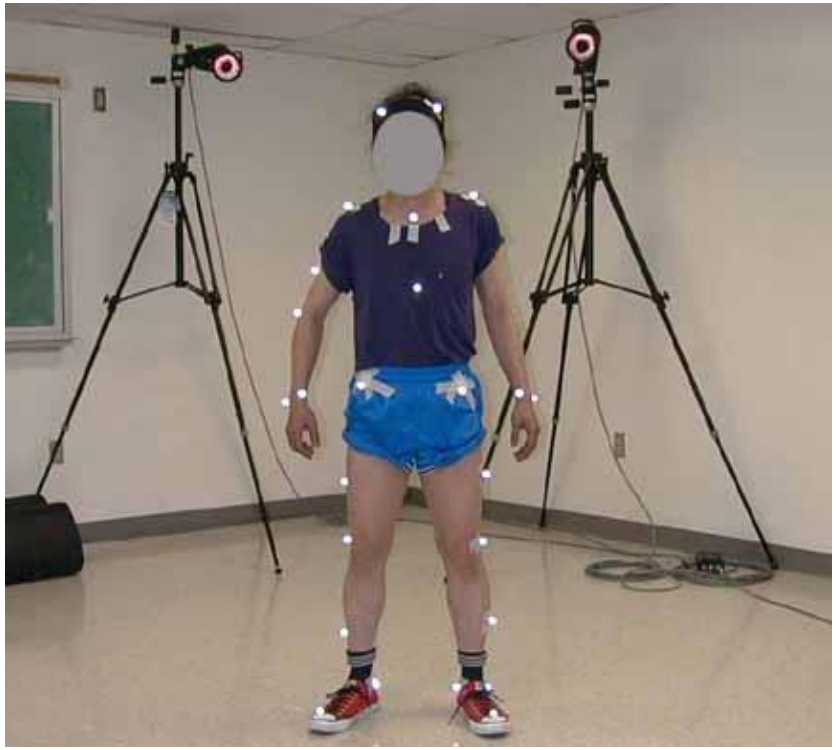
Vicon MX System

- Vicon T-series motion capture cameras (infrared)

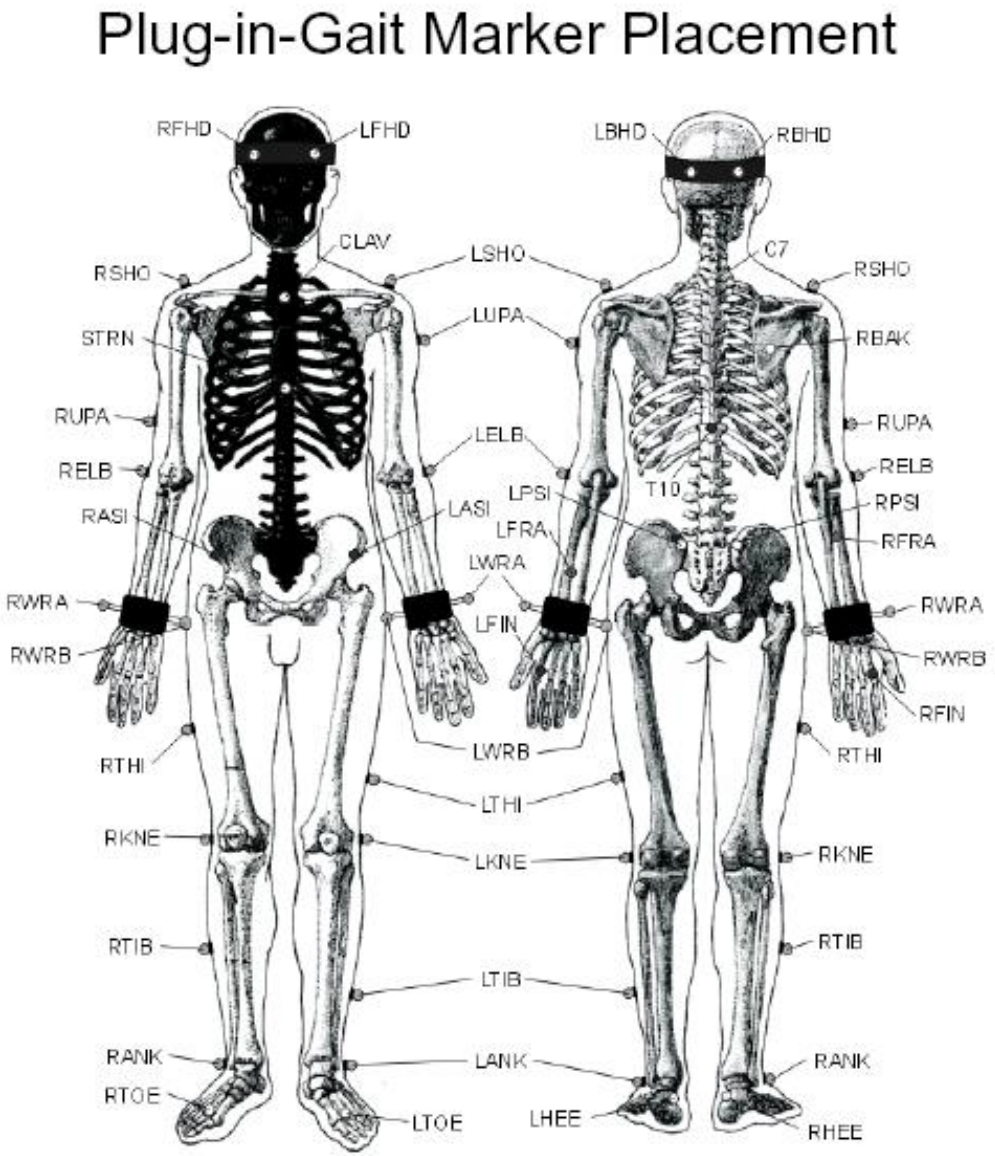
Vicon MX System

- Reflective body markers





Body Markers Placement

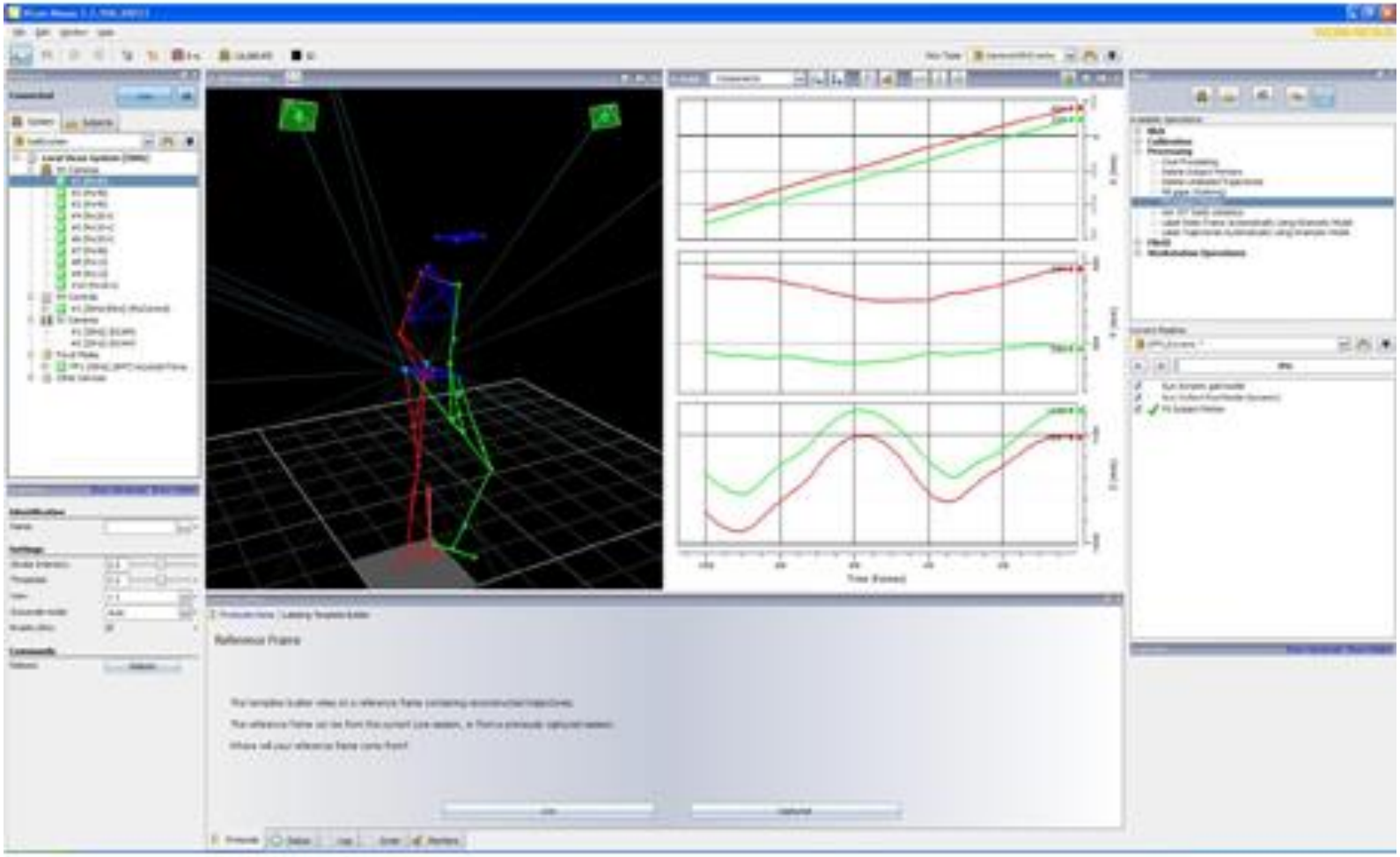


Problems associated with surface markers:

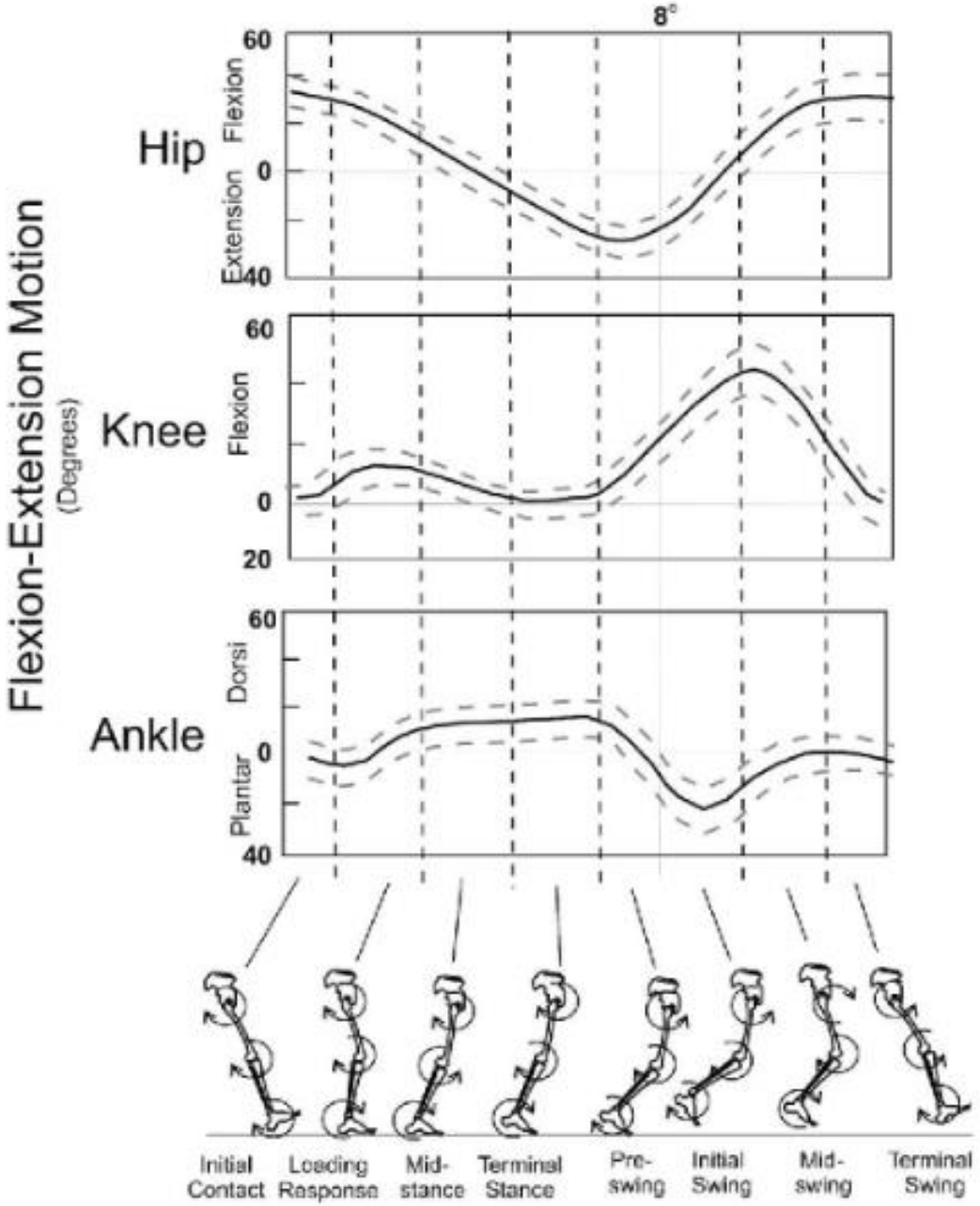
- Accurate placement of markers.
- Relative soft tissue movements.
- Estimation of joint centres.
- Repeatability in marker placement.

Vicon MX System

- Vicon Nexus



ROM of Joints



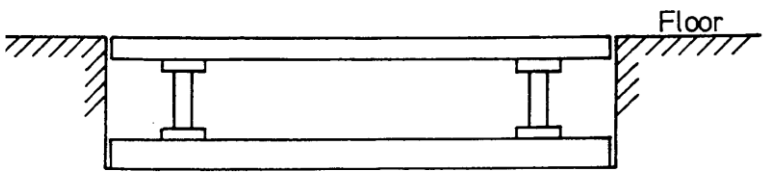
Measurable Quantities in Human Gait

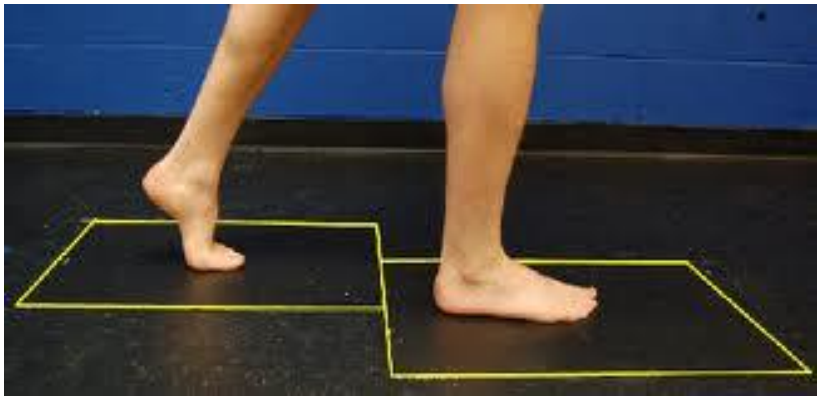
- Stride characteristics
- Body motion
- **Forces**
- **Muscle activities**
- Energy expenditure

Force Plate (platform)

A force plate measures the force applied during gait:

- Platform must be at least the size of a large human foot.
- Flushes with the surface of the floor so that it does not cause an obstruction to the subject walking.
- Deformation of the force platform must be so small that the subject does not feel the floor giving way.
- Response of the instrument must be relatively fast since the foot will be in contact with the platform for less than one second.





Force Plate (platform)

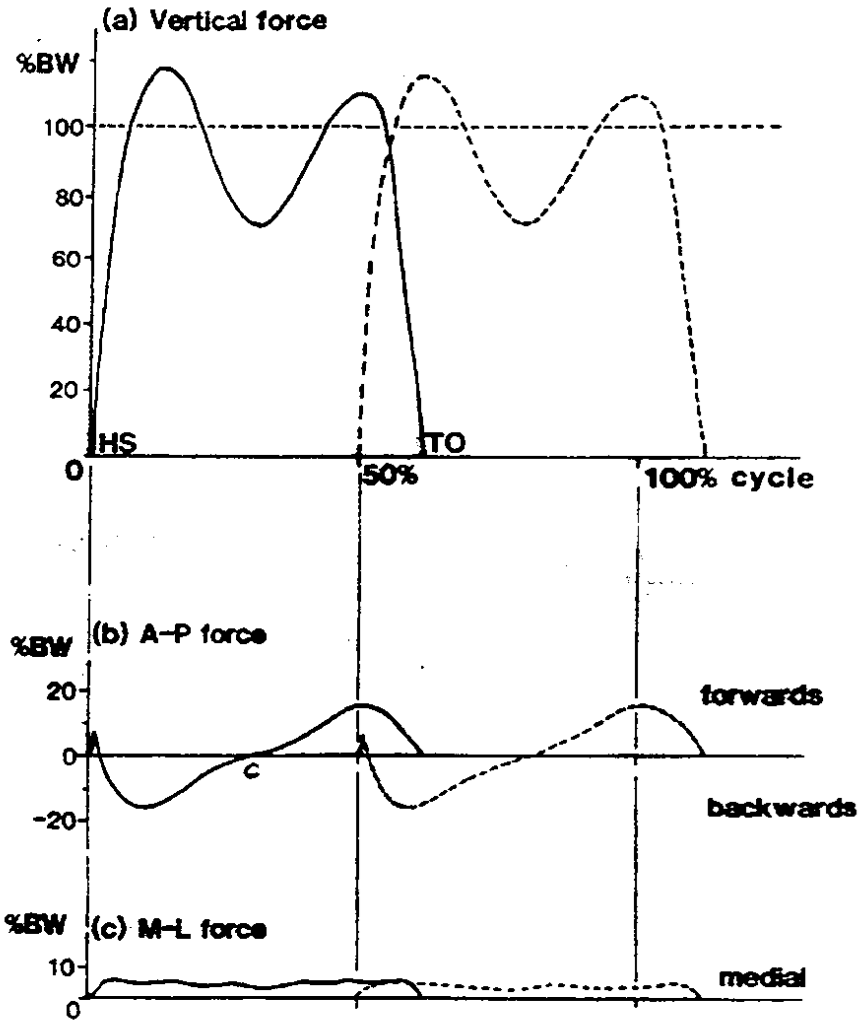
• The platform usually consists of an upper plate supported on a second bottom plate by four legs. Each leg is instrumented to produce an output reading.

Ground Reaction Forces (GRF)

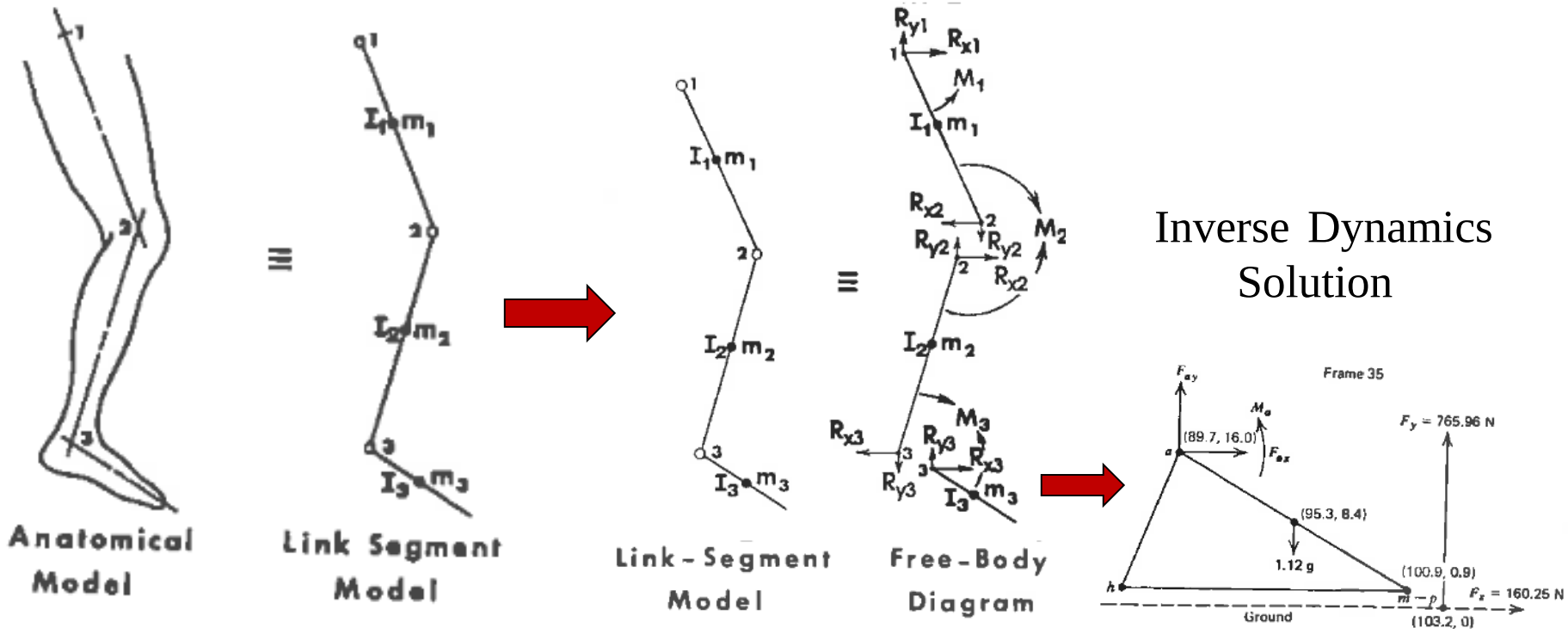
1) Vertical Force

2) Antero-posterior (AP) Force

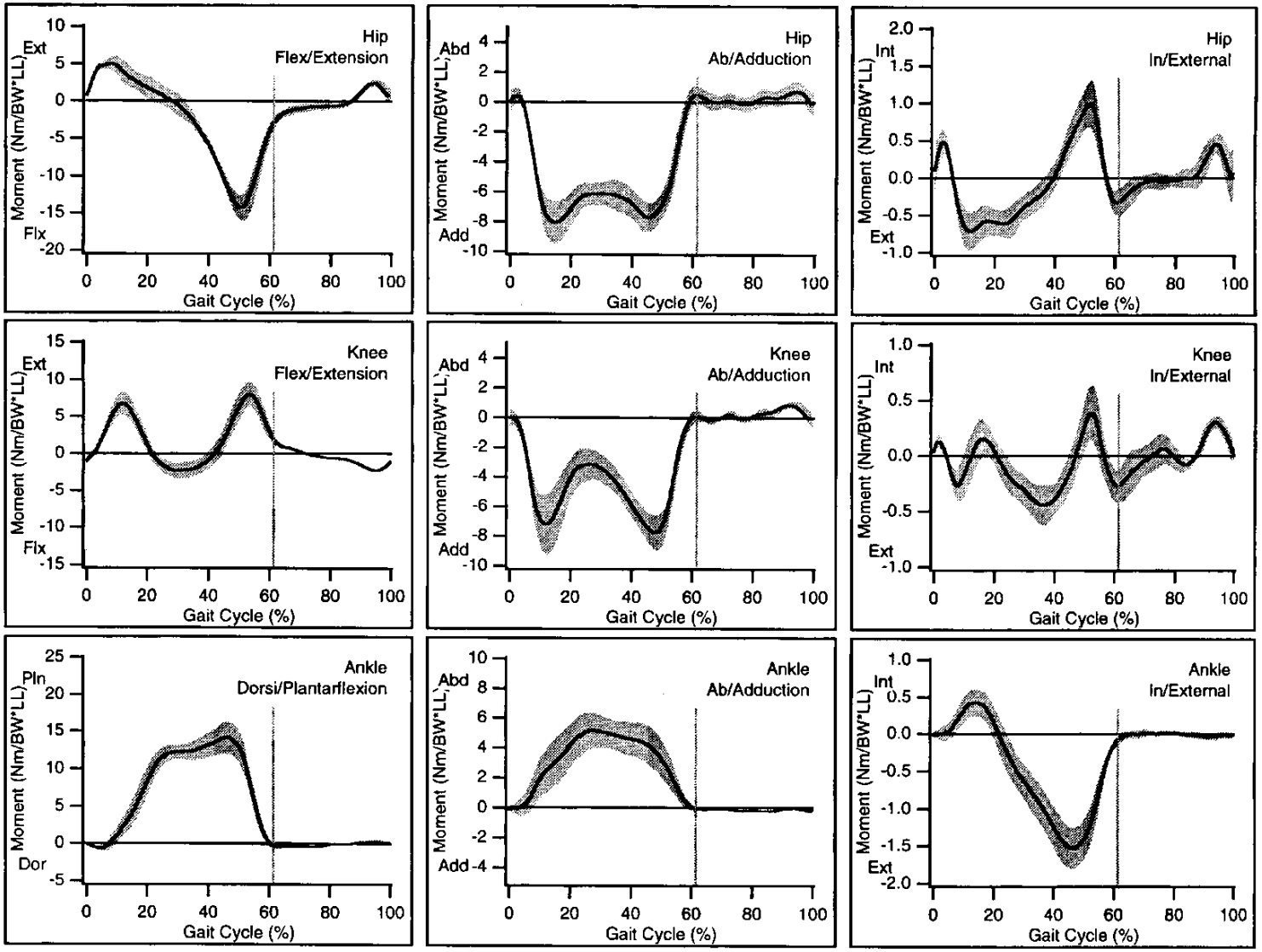
3) Medio-lateral (ML) Force



Link-Segment Modelling



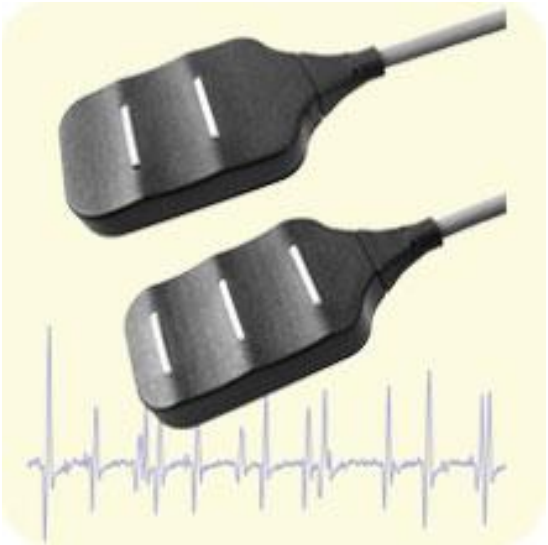
Flexion/Extension, Abduction/Adduction, Int/Ext Rotation Moment



Electromyography (EMG)

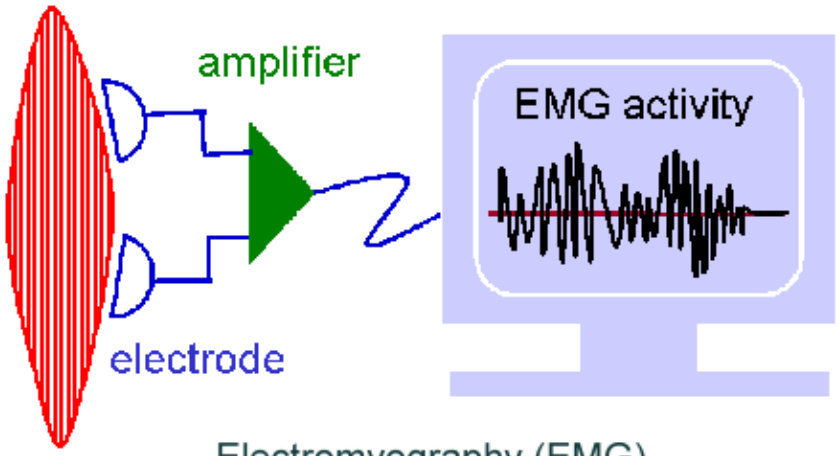
• Electromyography: measurement of the electrical activity of a contracting muscle.
 - not a measure of mechanical activity, EMG cannot be used to distinguish between concentric, eccentric and isometric contractions.

• Surface electrodes are used.



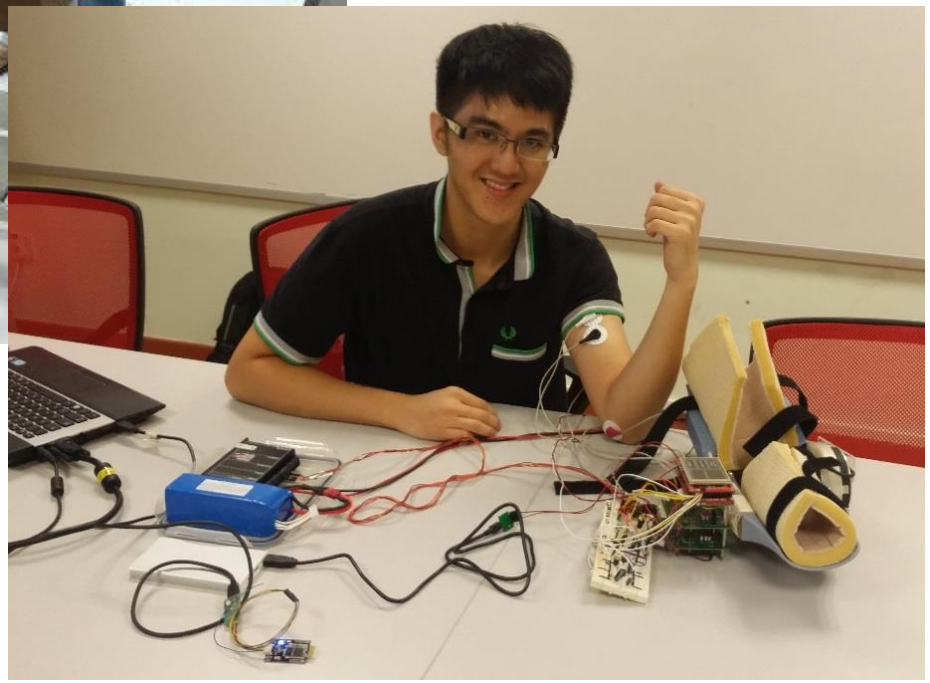
Electromyography (EMG)

- Measurements:



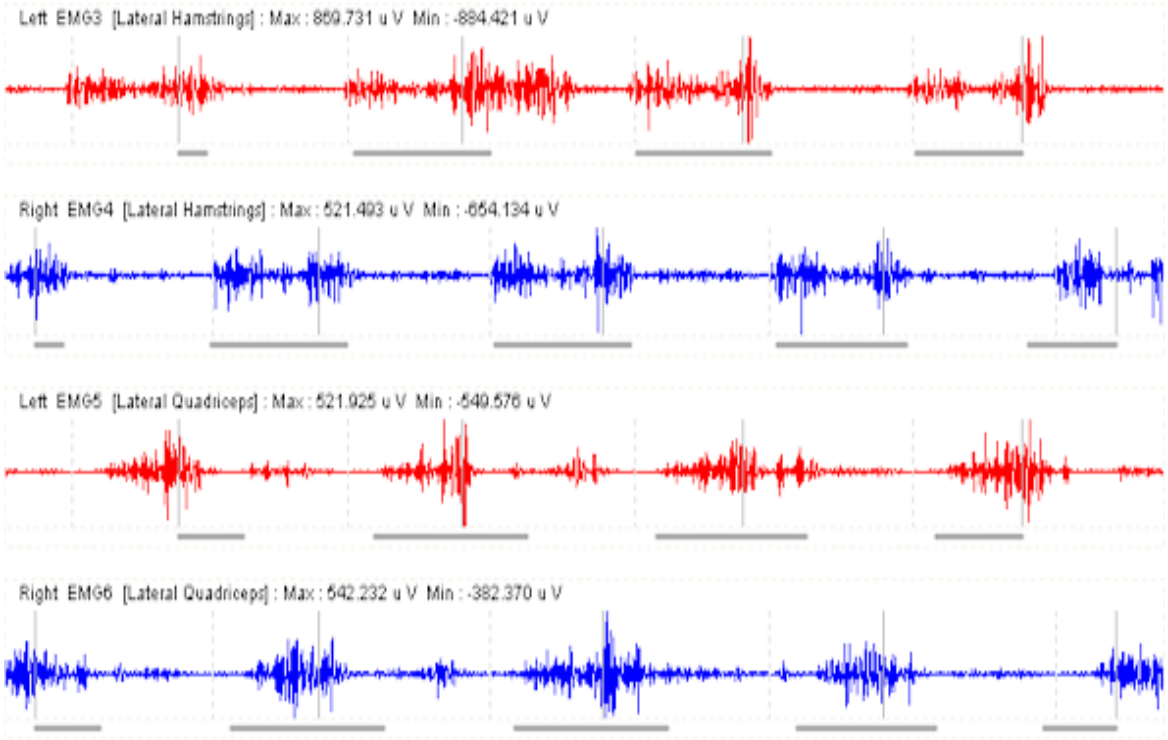
Electromyography (EMG)

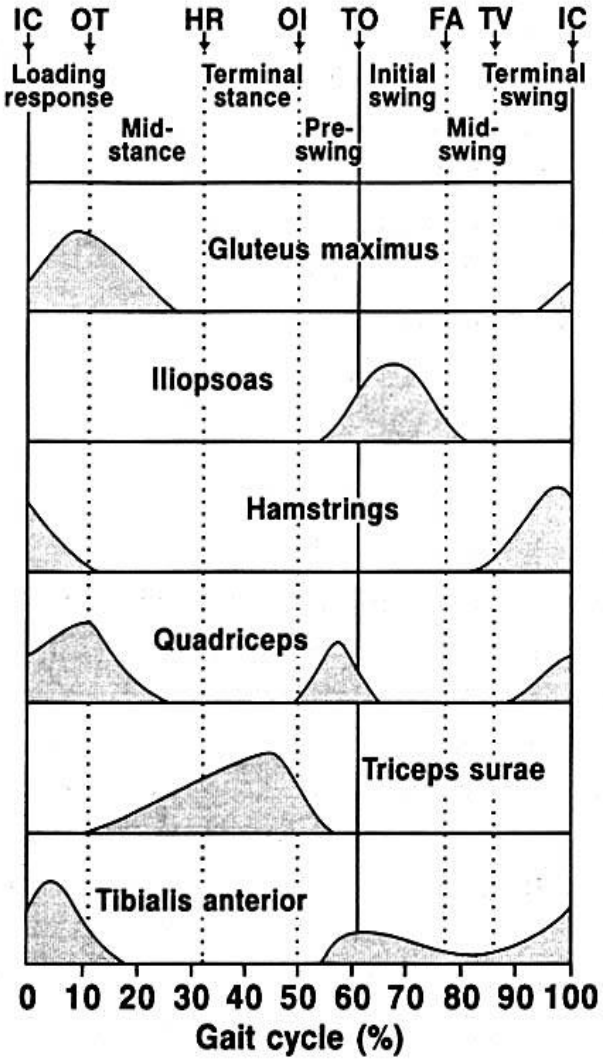
Electromyography (EMG)



Electromyography (EMG)

- During walking:





Electromyography (EMG)

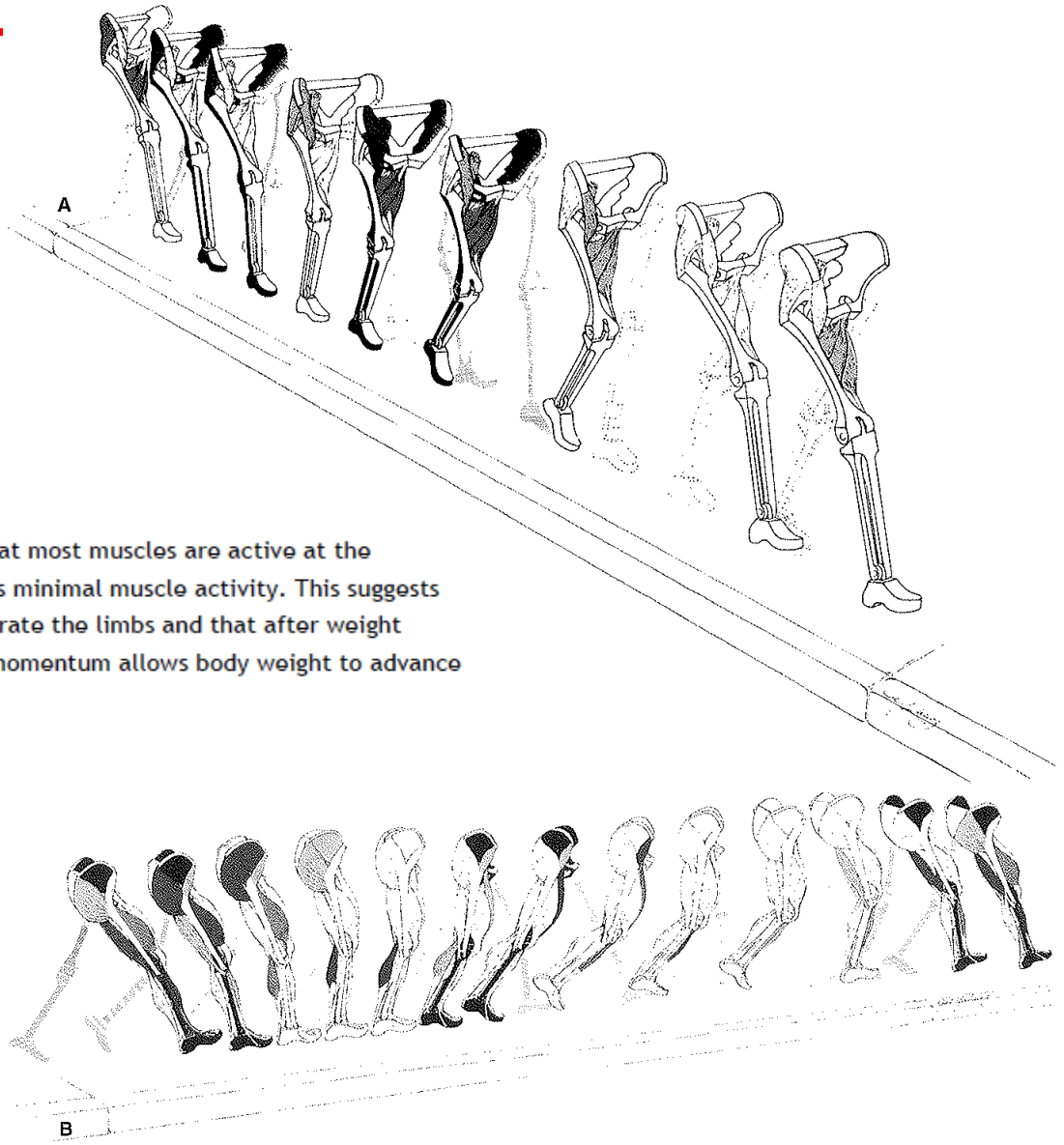


FIGURE 6-20. Phasic action of major muscle groups. Note that most muscles are active at the beginning and end of swing phase. During midstance, there is minimal muscle activity. This suggests that the main function of muscle is to accelerate and decelerate the limbs and that after weight acceptance, the metabolic demands of muscle decrease as momentum allows body weight to advance forward.