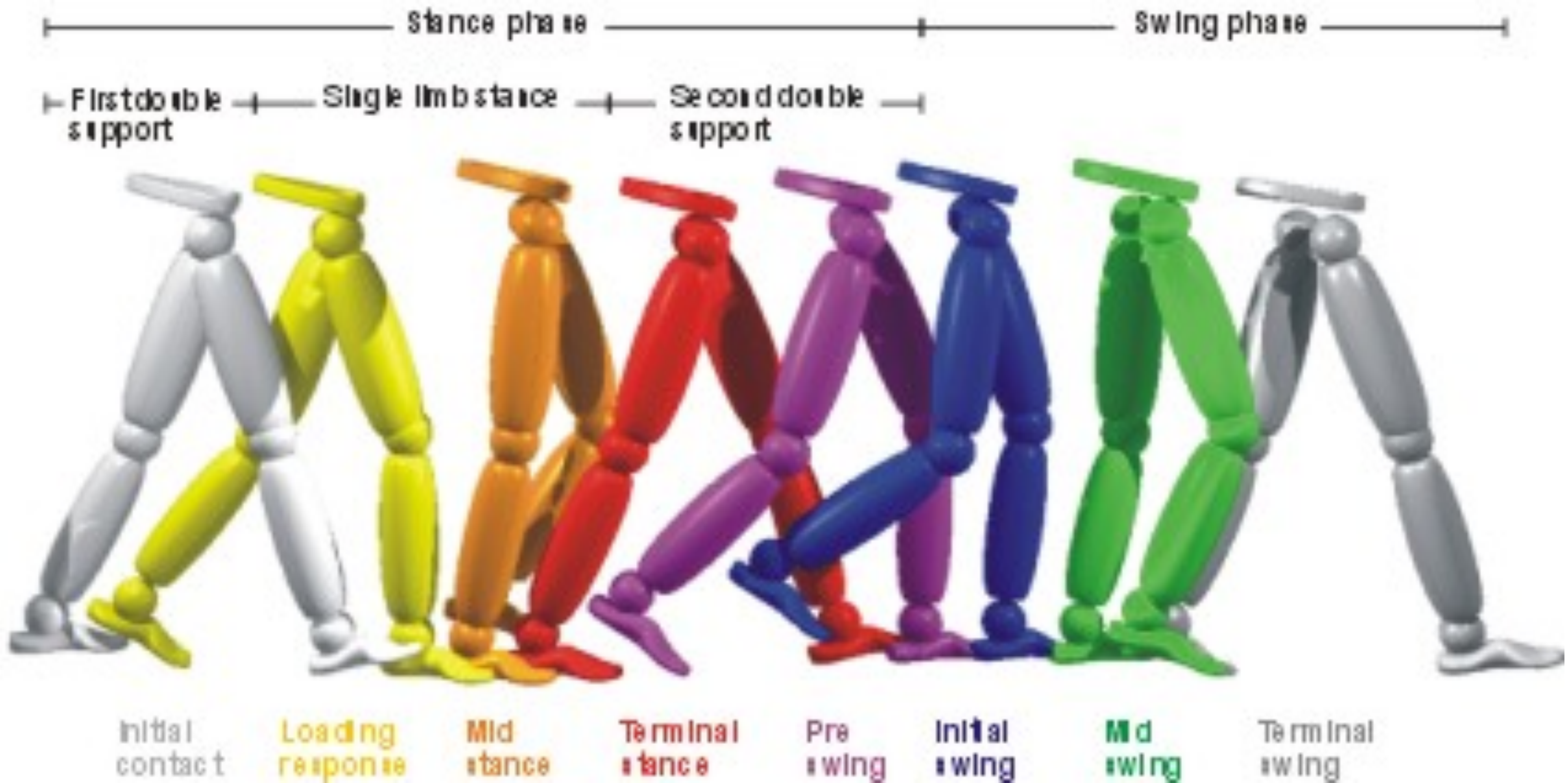
UNDERSTANDING
NORMAL & PATHOLOGICAL
GAIT

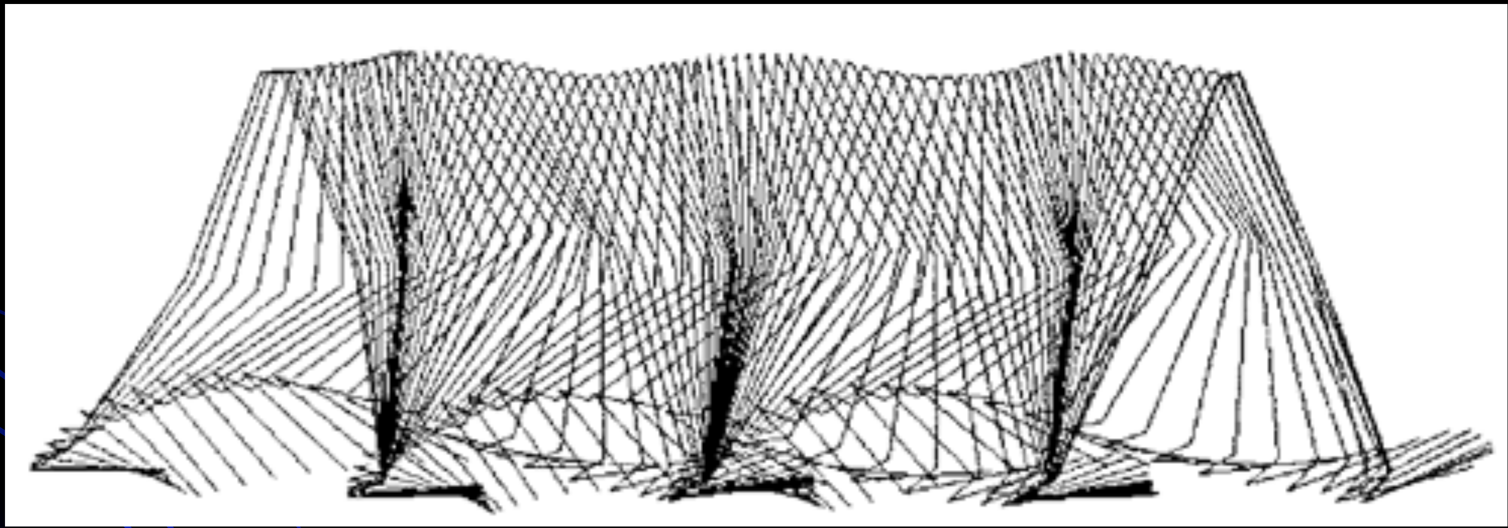
Gait Cycle - Definitions:

- Normal Gait =
  - Series of rhythmical , alternating movements of the trunk & limbs which result in the forward progression of the center of gravity
  - series of ‘controlled falls’

A Single Gait Cycle or Stride



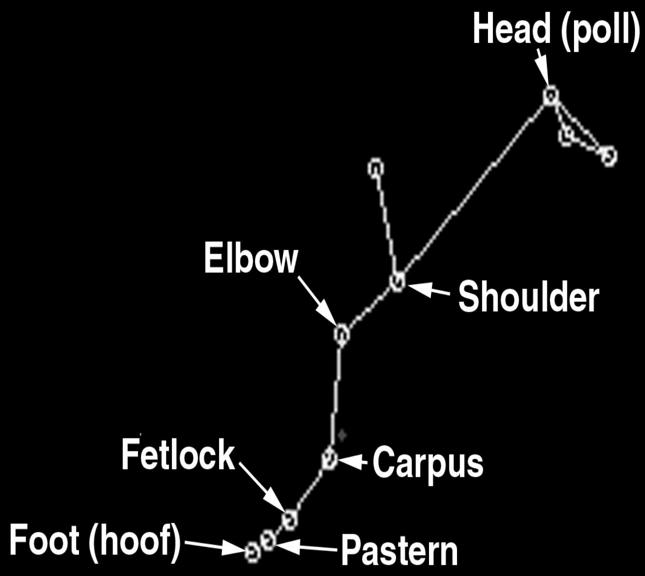
Analysis of Gait Kinematics

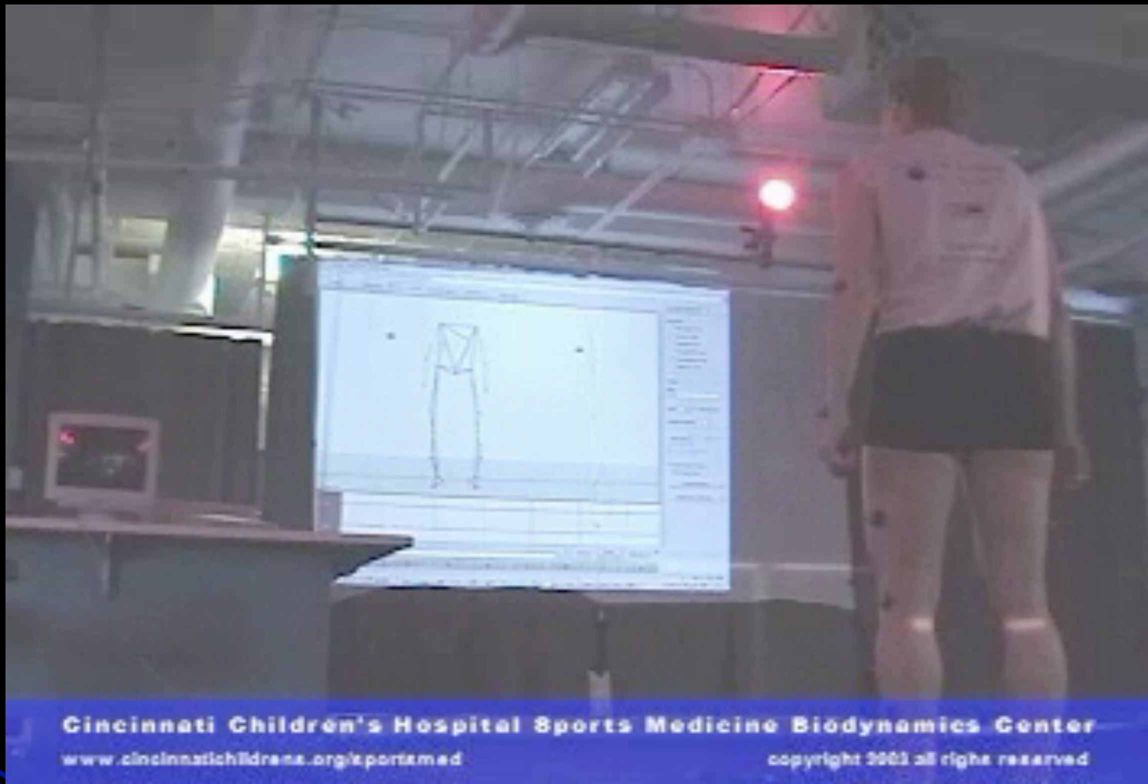


Video-camera based motion measurement systems monitor the displacement of external markers that are placed on the subject's body and aligned with specific bony segments (top). The video sequence is then processed using a computer system and displayed as a "stick diagram" (bottom) for calculation of kinematic parameters, e.g., the ankle flexion during gait.

Difficult Problem

- Wealth of information.
- Complexity of motion.
- Uncertainty about gait data quality.
- Mild lameness problem difficulty.
- **Formulating a generalized method**





Cincinnati Children's Hospital Sports Medicine Biodynamics Center
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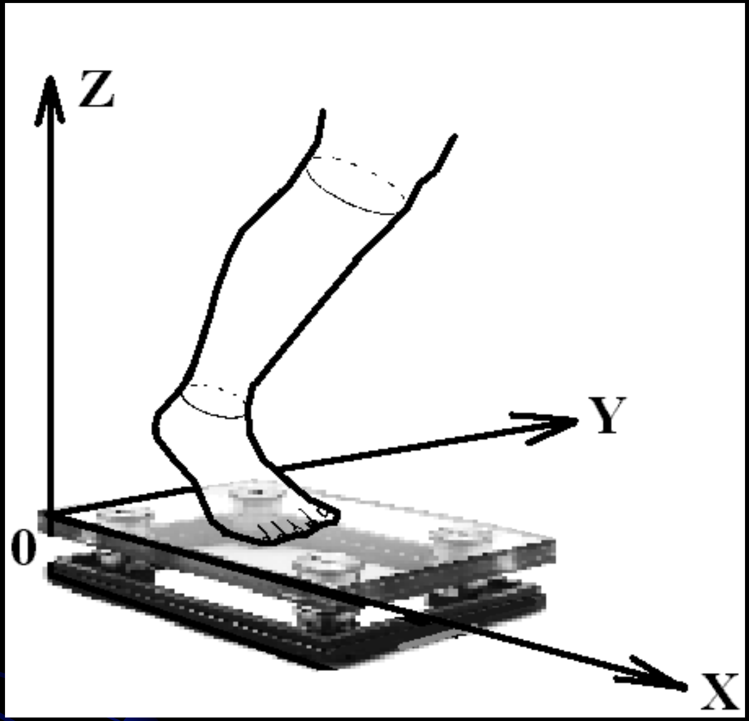
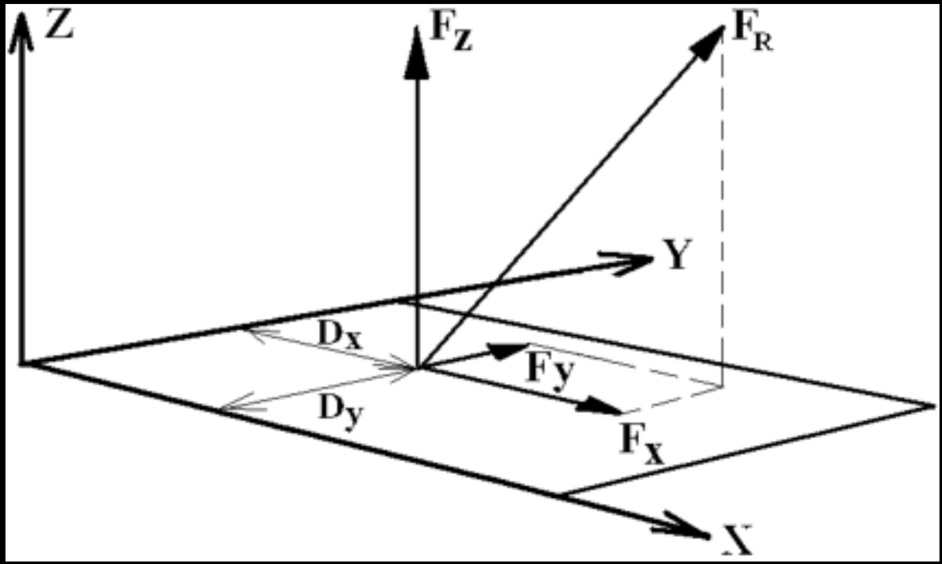
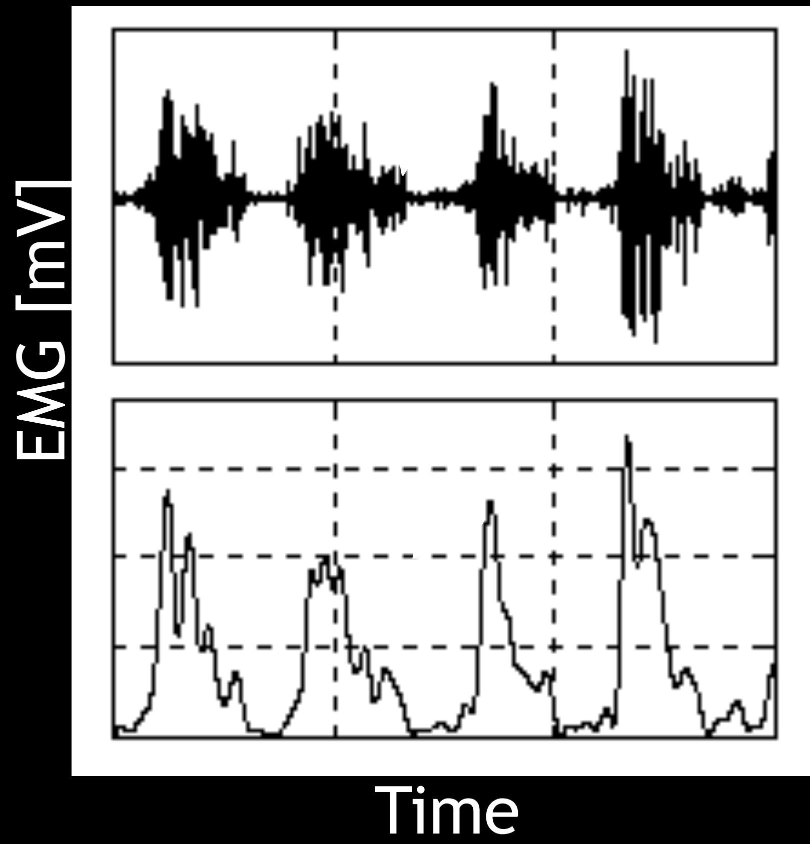
Analysis of Gait Dynamics (a): Reaction Forces





Force plate (Kistler) installed for measuring the reaction forces of the ground acting on a subject's foot during gait: (a) a view of the foot and plate showing the XYZ global reference frame; (b) the force plate is used to measure the three components (F_x, F_y, F_z) of the ground reaction force F_R and evaluate its position (center of pressure) by specifying the coordinates D_x and D_y.

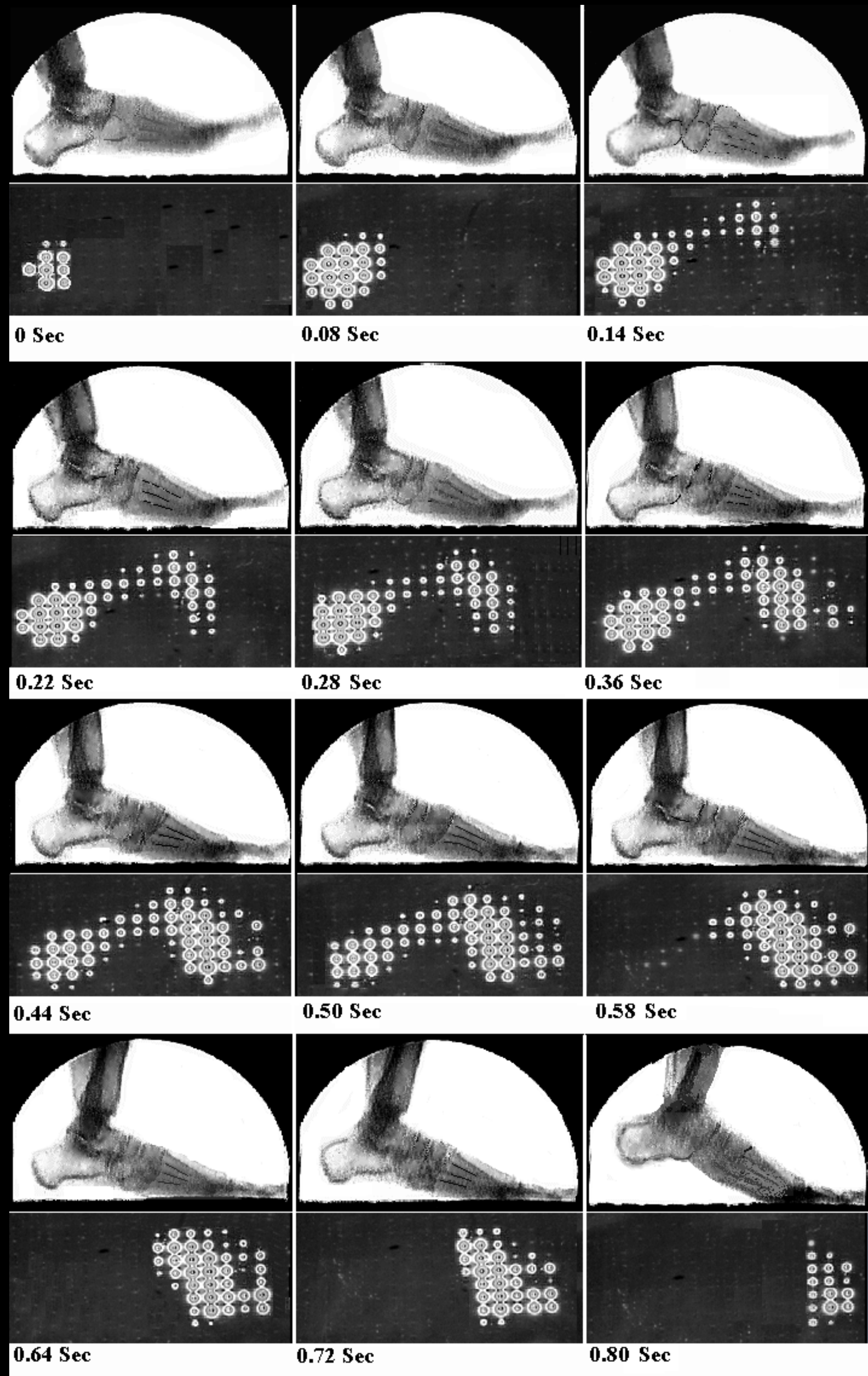
Analysis of the Lower-Limb Muscular Activity During Gait



Gait Analysis

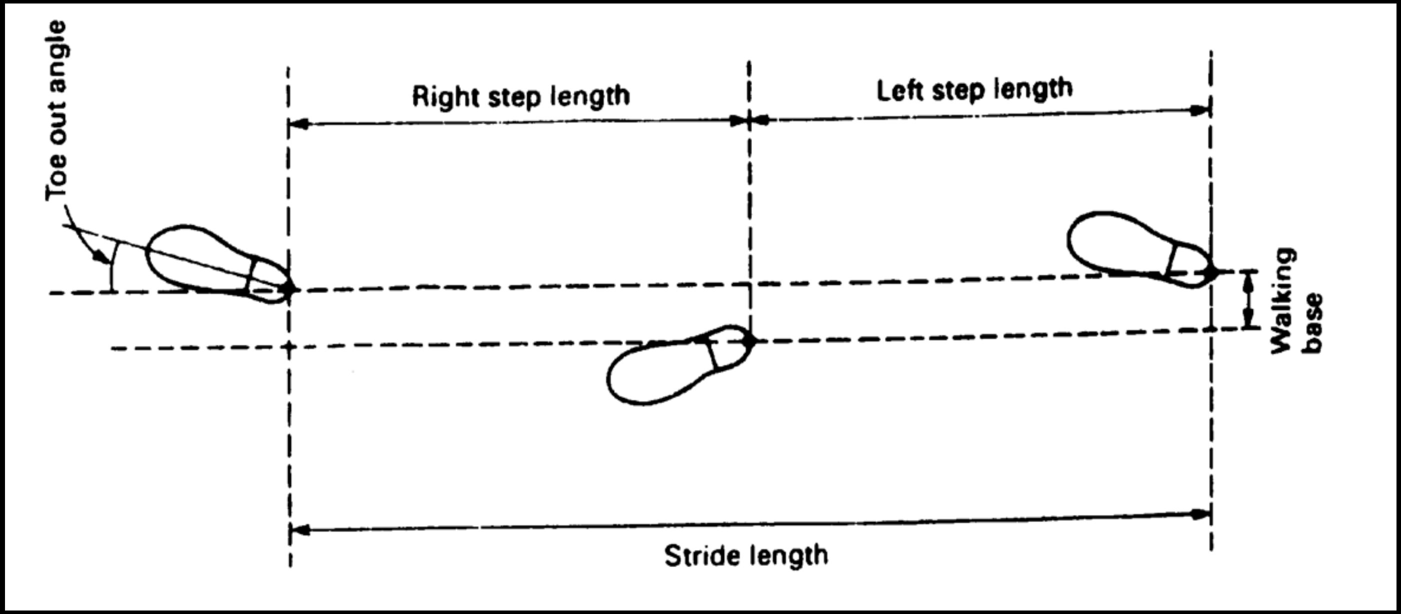
- Barefoot
  - Heel Strike
  - Midstance
  - Heel off
  - Propulsion
- With Current Footwe
  - Same as barefoot

INTEGRATED KINEMATIC/DYNAMIC ANALYSIS OF THE FOOT STRUCTURE DURING THE STANCE PHASE OF GAIT



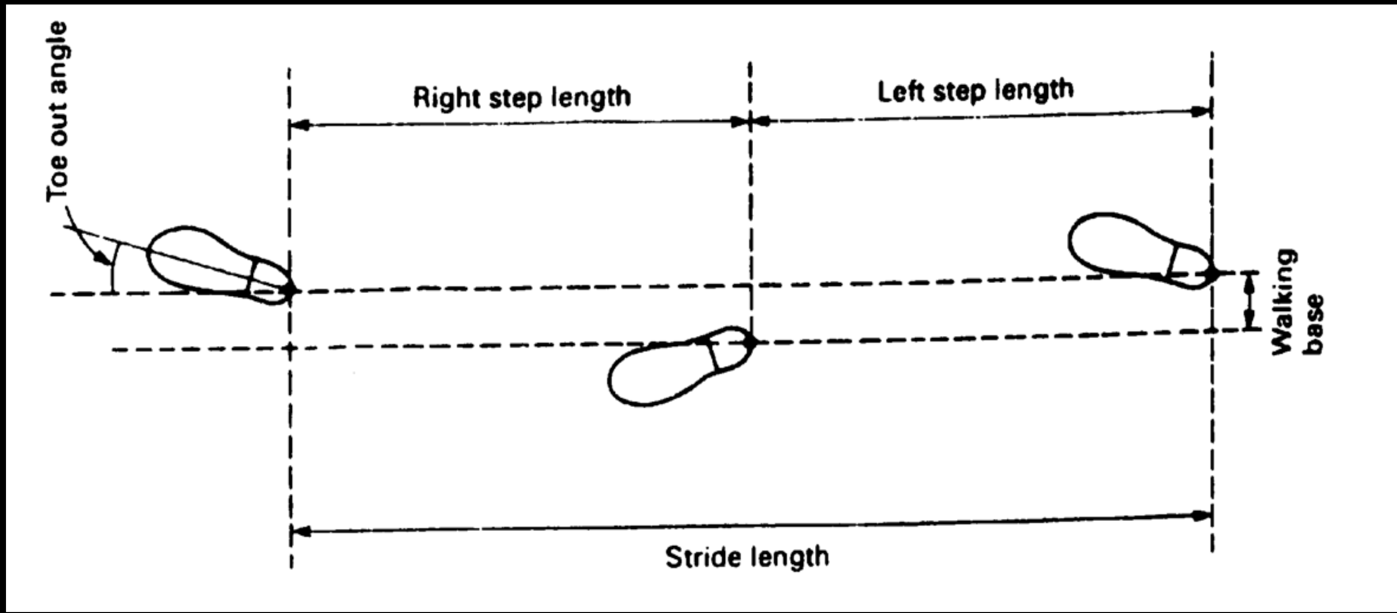
Representative DRF/CPD data of a normal foot structure during various discrete stages of the stance phase - gait velocity 0.5 m/sec.

Gait Cycle - Definitions:



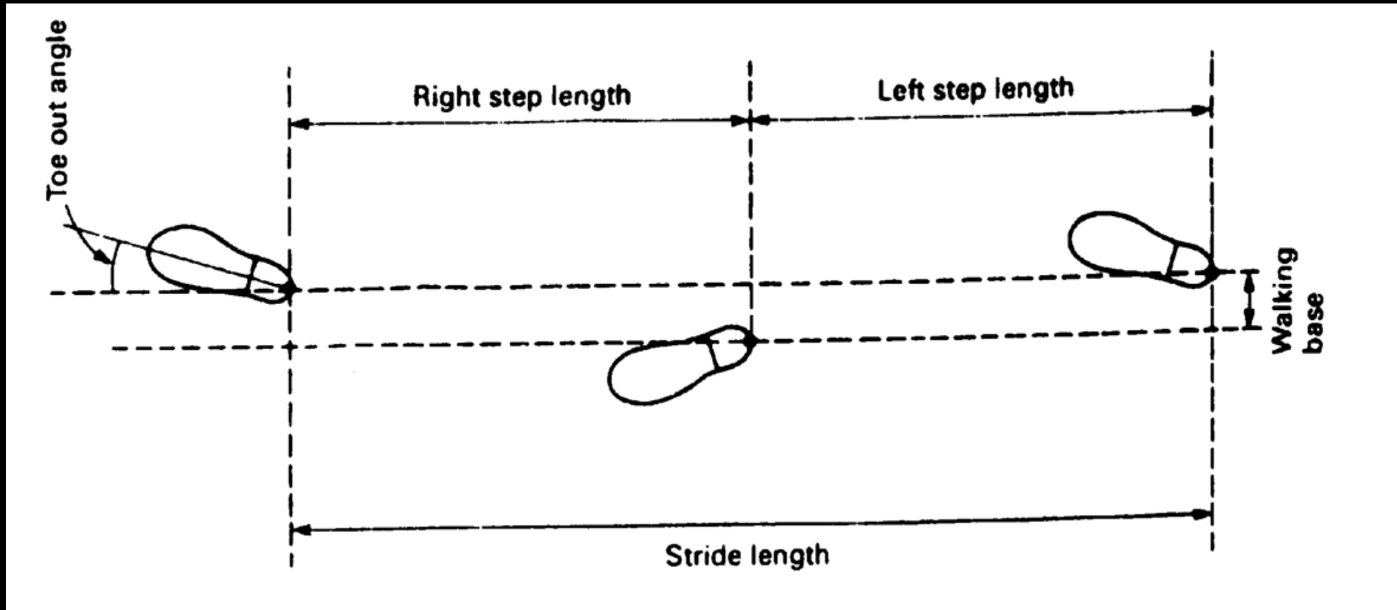
- Gait Cycle =
  - Single sequence of functions by **one limb**
  - Begins when reference font contacts the ground
  - Ends with subsequent floor contact of the same foot

Gait Cycle - Definitions:



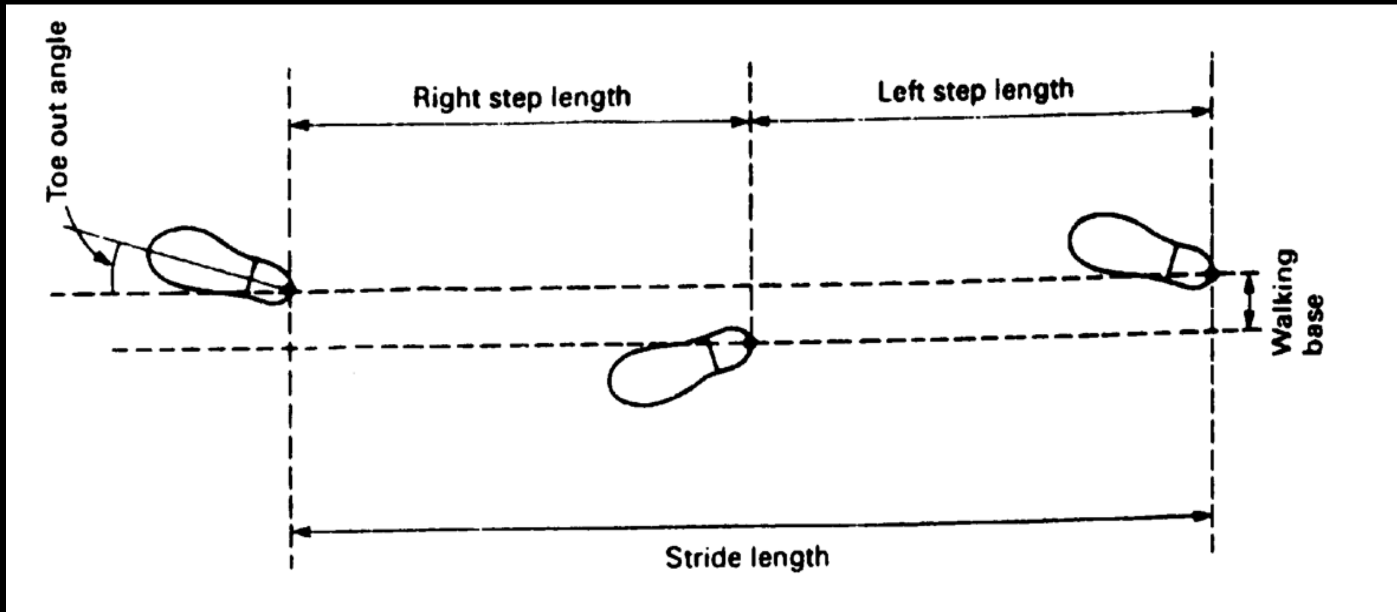
- Step Length =
  - Distance between corresponding successive **points of heel contact of the opposite feet**
  - Rt step length = Lt step length (in normal gait)

Gait Cycle - Definitions:



- <u>Stride Length</u> =
  - Distance between successive points of heel contact of the **same foot**
  - Double the step length (in normal gait)

Gait Cycle - Definitions:



- Walking Base =
  - Side-to-side distance between the line of the two feet
  - Also known as ‘stride width’

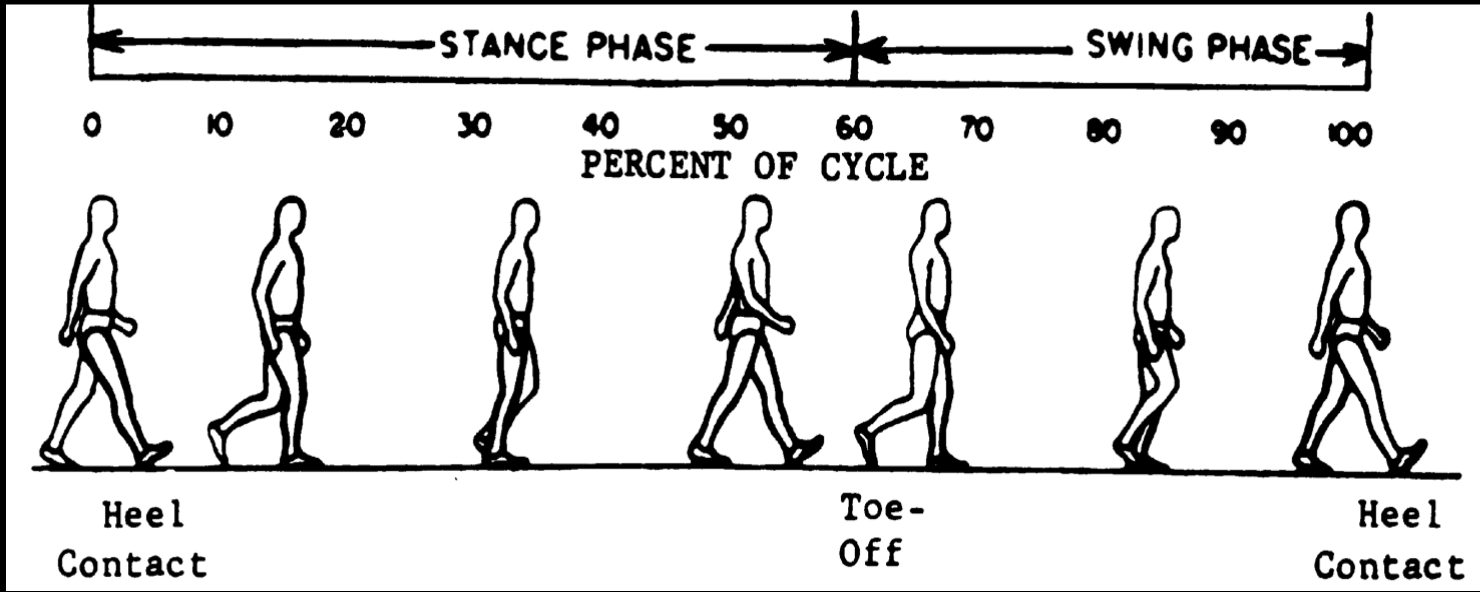
Gait Cycle - Definitions:

- Cadence =
  - Number of steps per unit time
  - Normal: 100 – 115 **steps/min**
  - Cultural/social variations

Gait Cycle - Definitions:

- Velocity =
  - Distance covered by the body in unit time
  - Usually measured in **m/s**
  - Instantaneous velocity varies during the gait cycle
  - Average velocity (m/min) = step length (m) x cadence (steps/min)
- Comfortable Walking Speed (CWS) =
  - Least energy consumption per unit distance
  - Average= **80 m/min** (~ 5 km/h , ~ 3 mph)

Gait Cycle - Components:

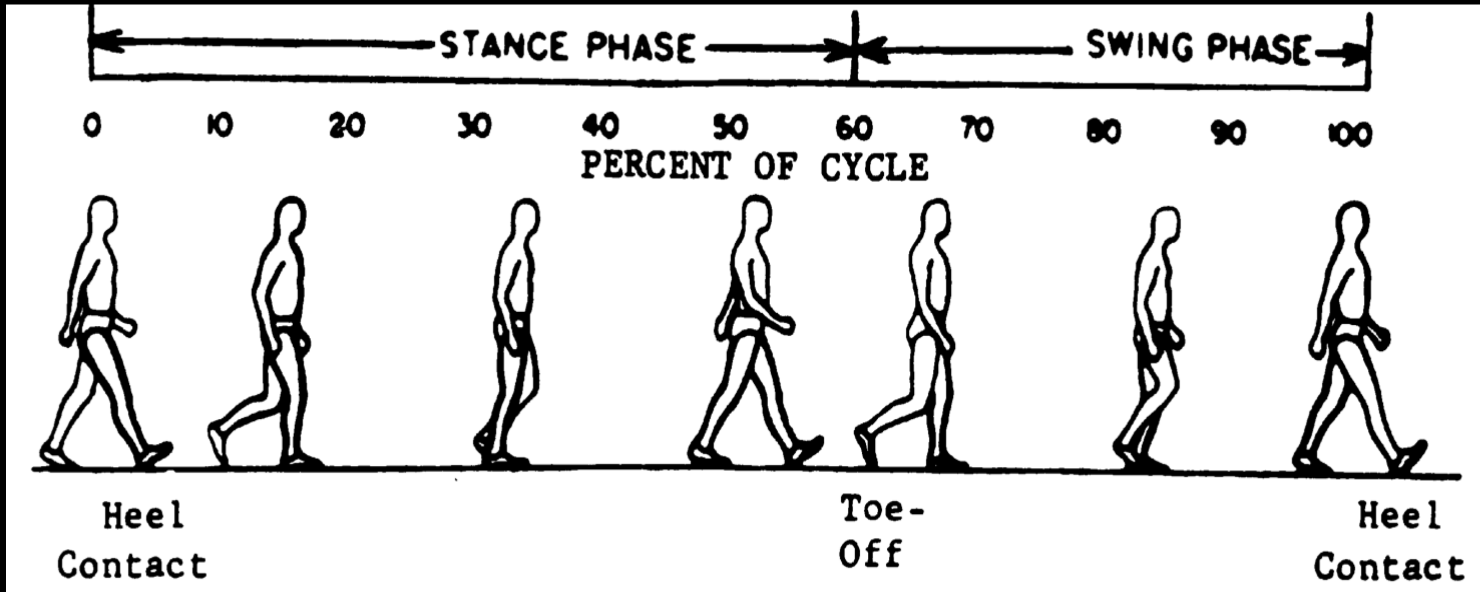


- <u>Phases</u>:

(1) <u>Stance Phase</u>:
reference limb
in contact
with the floor

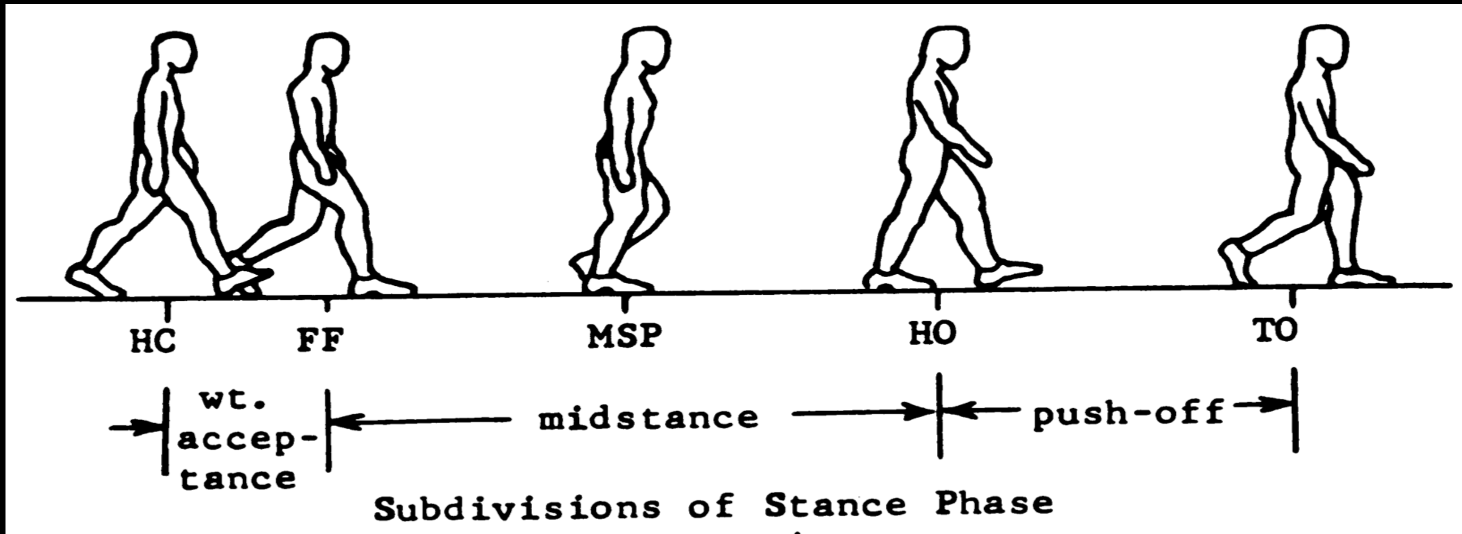
(2) <u>Swing Phase</u>:
reference limb
<u>not</u> in contact
with the floor

Gait Cycle - Components:



- Support:
  (1) Single Support: only one foot in contact with the floor
  (2) Double Support: both feet in contact with floor

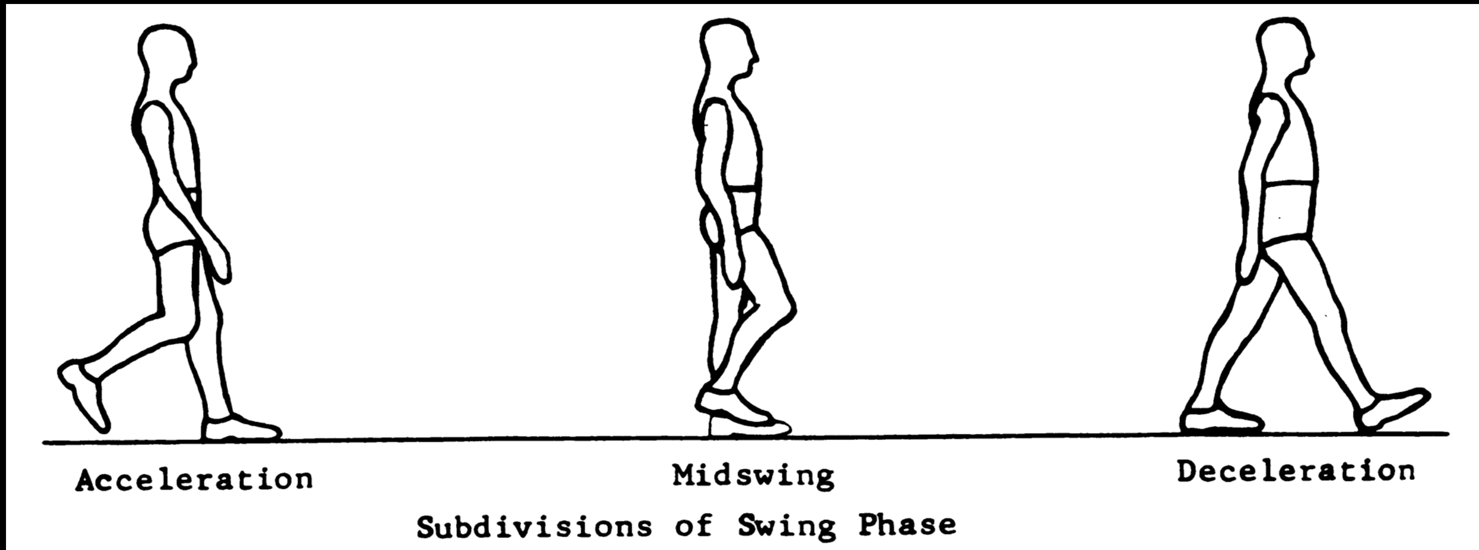
Gait Cycle - Subdivisions:



A. <u>Stance phase:</u>

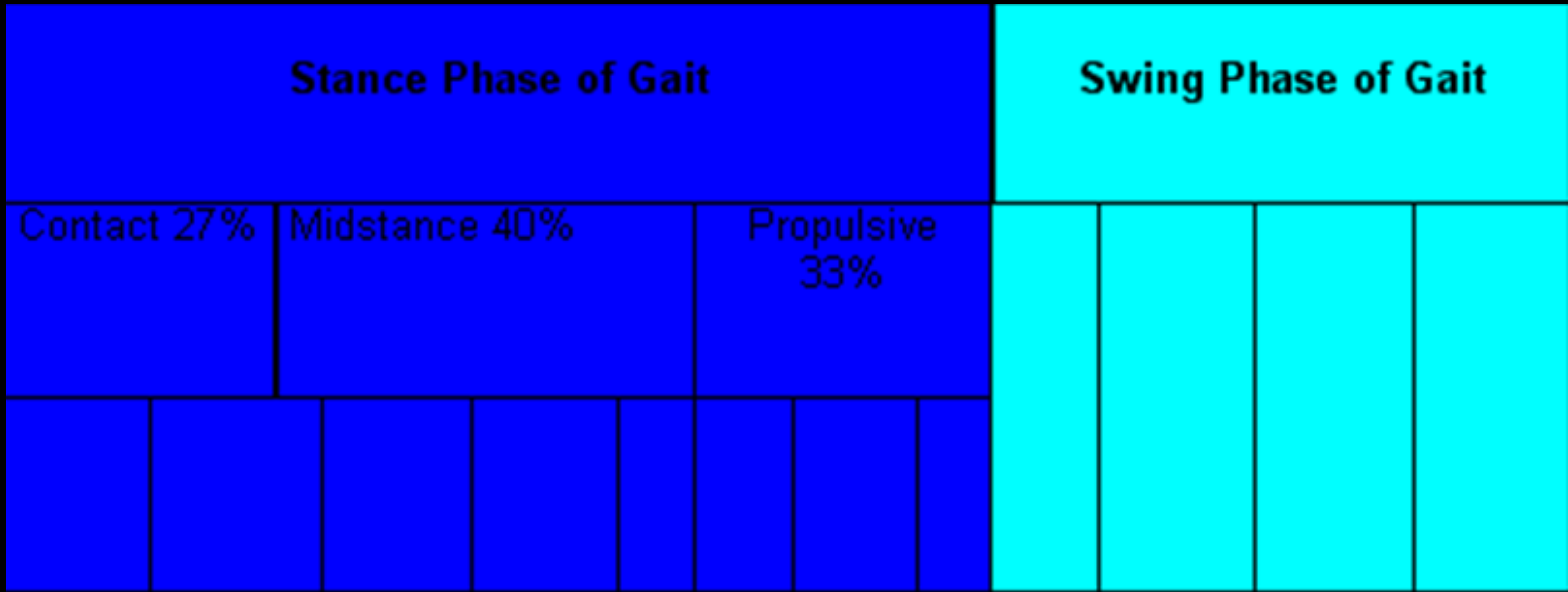
1. **Heel contact:** 'Initial contact'
2. **Foot-flat**: 'Loading response', initial contact of forefoot w. ground
3. **Midstance**: greater trochanter in alignment w. vertical bisector of foot
4. **Heel-off**: 'Terminal stance'
5. **Toe-off**: 'Pre-swing'

Gait Cycle - Subdivisions:



B. Swing phase:

1. **Acceleration**: ‘Initial swing’
2. **Midswing**: swinging limb overtakes the limb in stance
3. **Deceleration**: ‘Terminal swing’



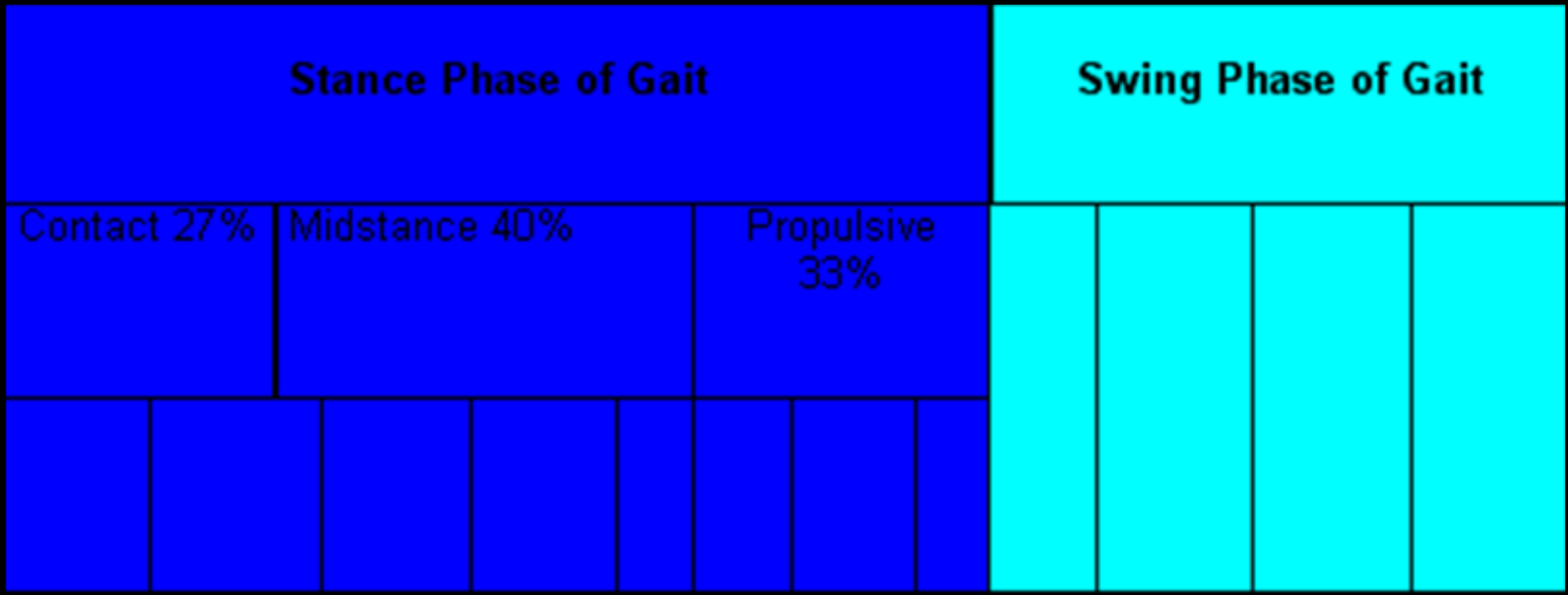
- Time Frame:

A. Stance vs. Swing:

- Stance phase = 60% of gait cycle
- Swing phase = 40%

B. Single vs. Double support:

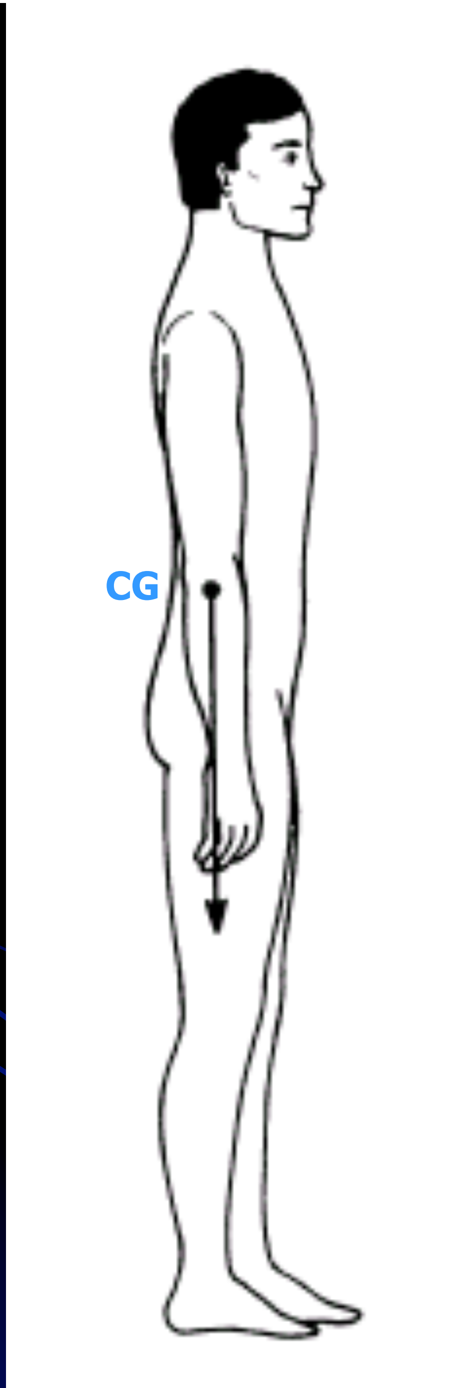
- Single support= 40% of gait cycle
- Double support= 20%

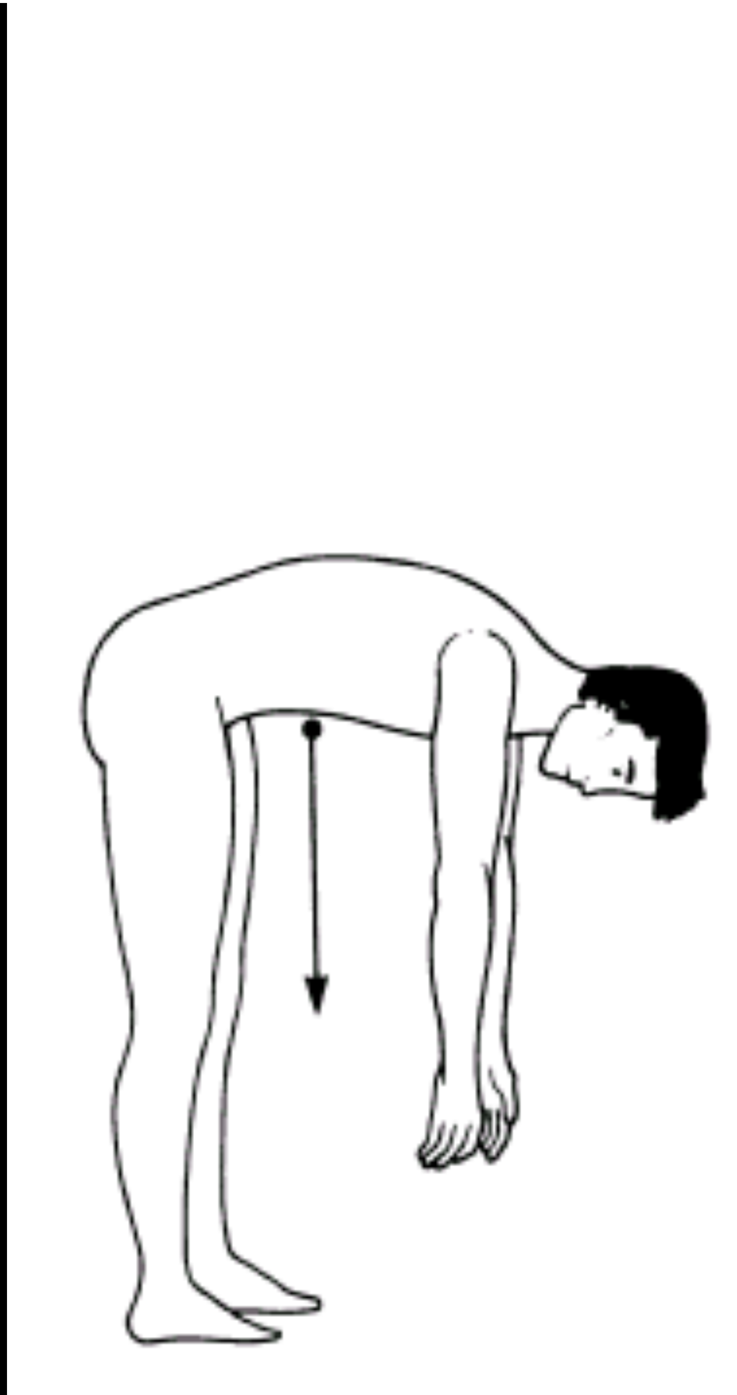


- With increasing walking speeds:
  - Stance phase: decreases
  - Swing phase: increases
  - Double support: decreases
- Running:
  - By definition: walking without double support
  - Ratio stance/swing reverses
  - Double support disappears. ‘Double swing’ develops

Path of Center of Gravity

- Center of Gravity (CG):
  - midway between the hips
  - Few cm in front of S2
- Least energy consumption if CG travels in straight line

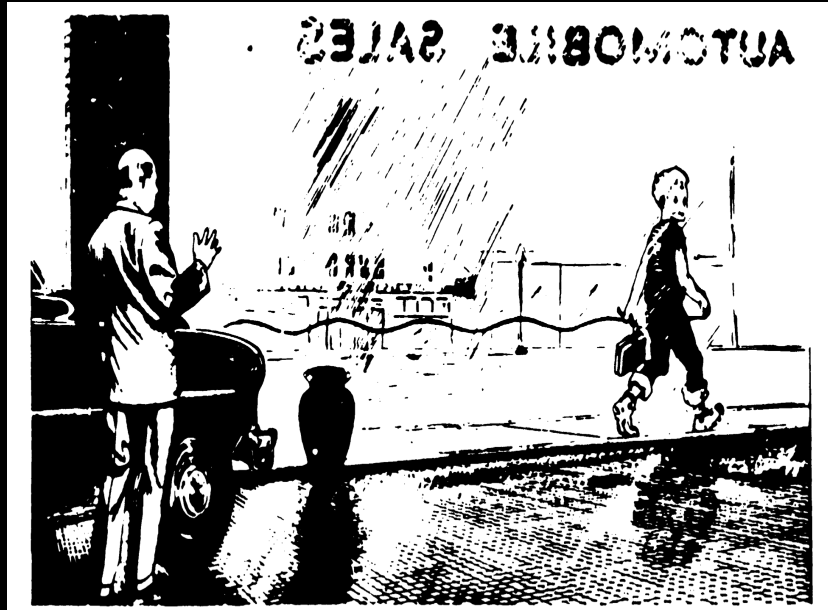

CG



Path of Center of Gravity

A. <u>Vertical displacement</u>:

- Rhythmic up & down movement
- Highest point: midstance
- Lowest point: double support
- Average displacement: 5cm
- Path: extremely smooth sinusoidal curve

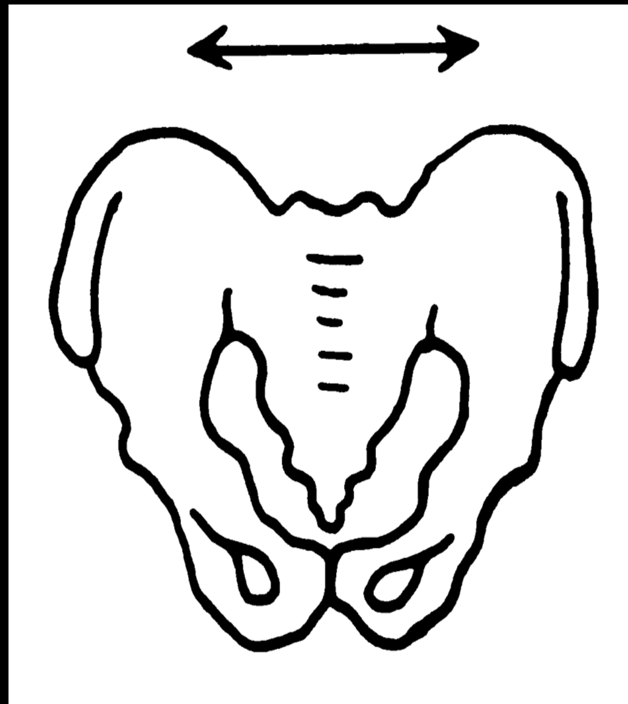


The line drawn on the glass window represents the approximate pathway of the center of gravity of the body.

Path of Center of Gravity

B. Lateral displacement:

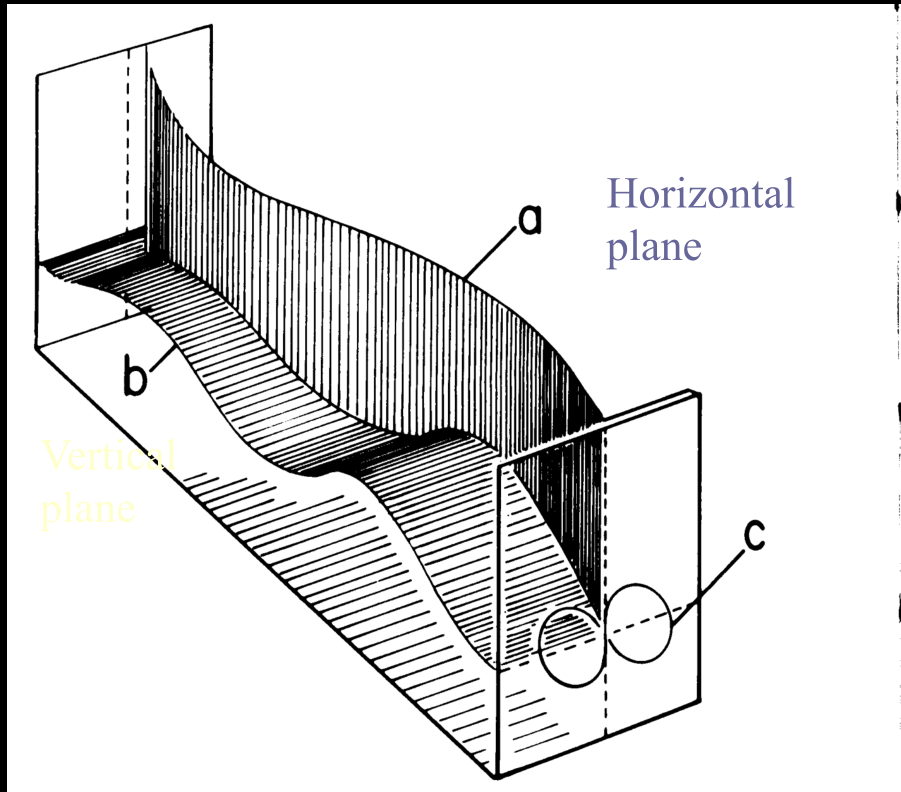
- Rhythmic side-to-side movement
- Lateral limit: midstance
- Average displacement: 5cm
- Path: extremely smooth sinusoidal curve



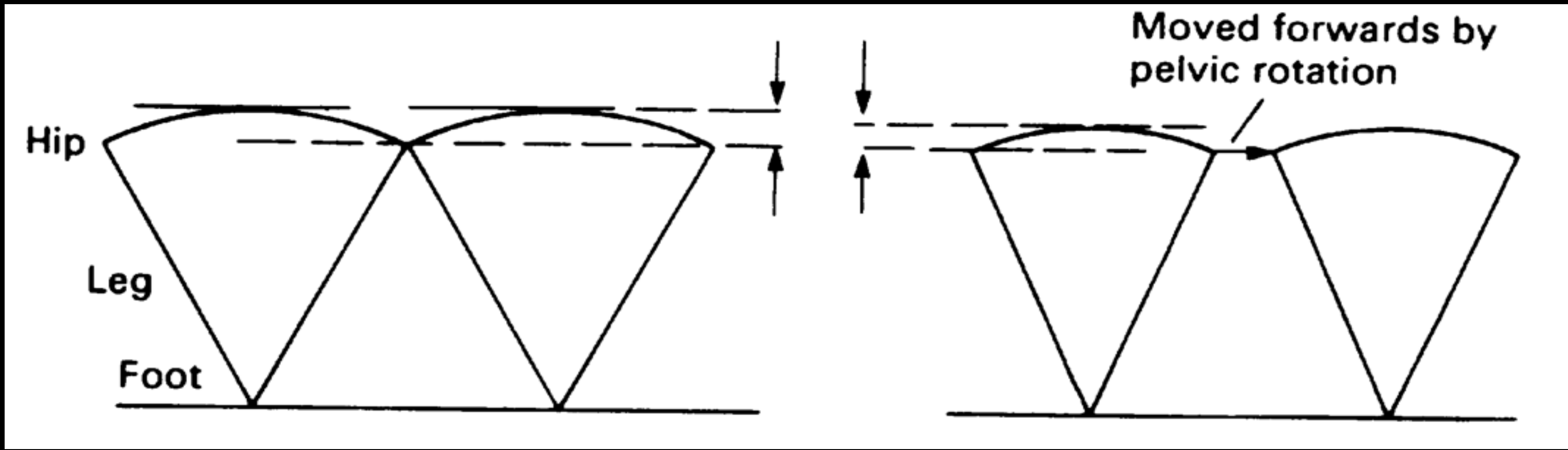
Path of Center of Gravity

C. <u>Overall displacement</u>:

- Sum of vertical & horizontal displacement
- Figure ‘8’ movement of CG as seen from AP view

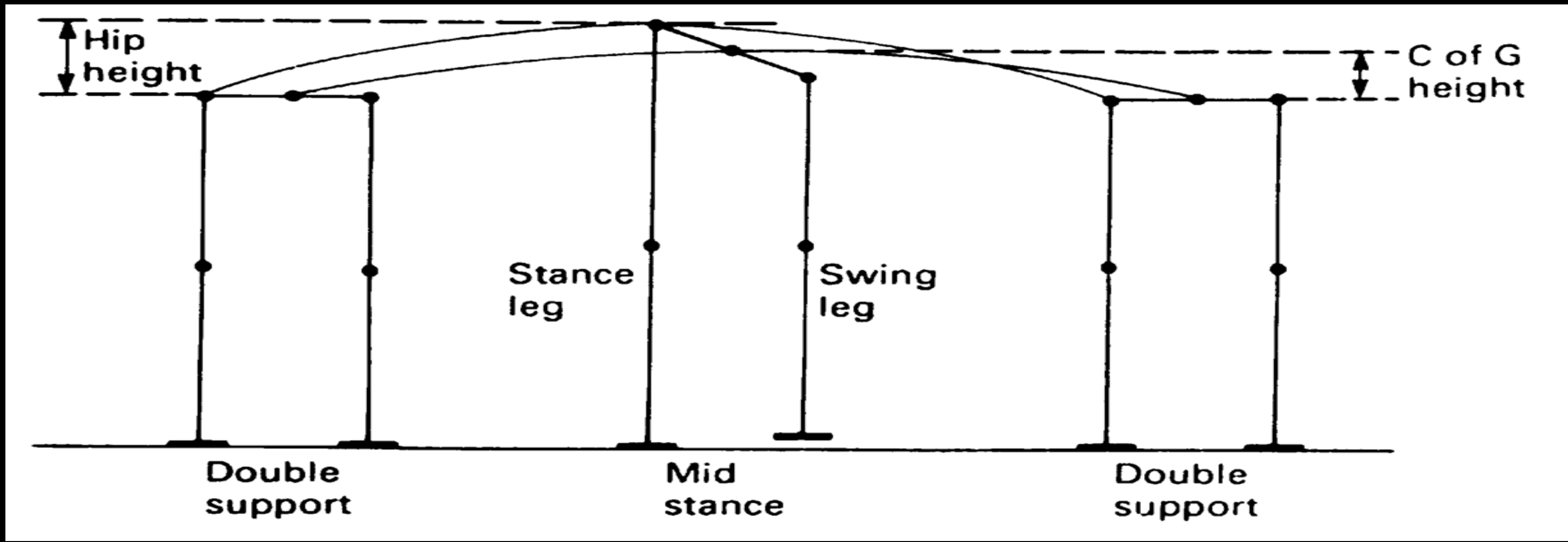


Determinants of Gait :



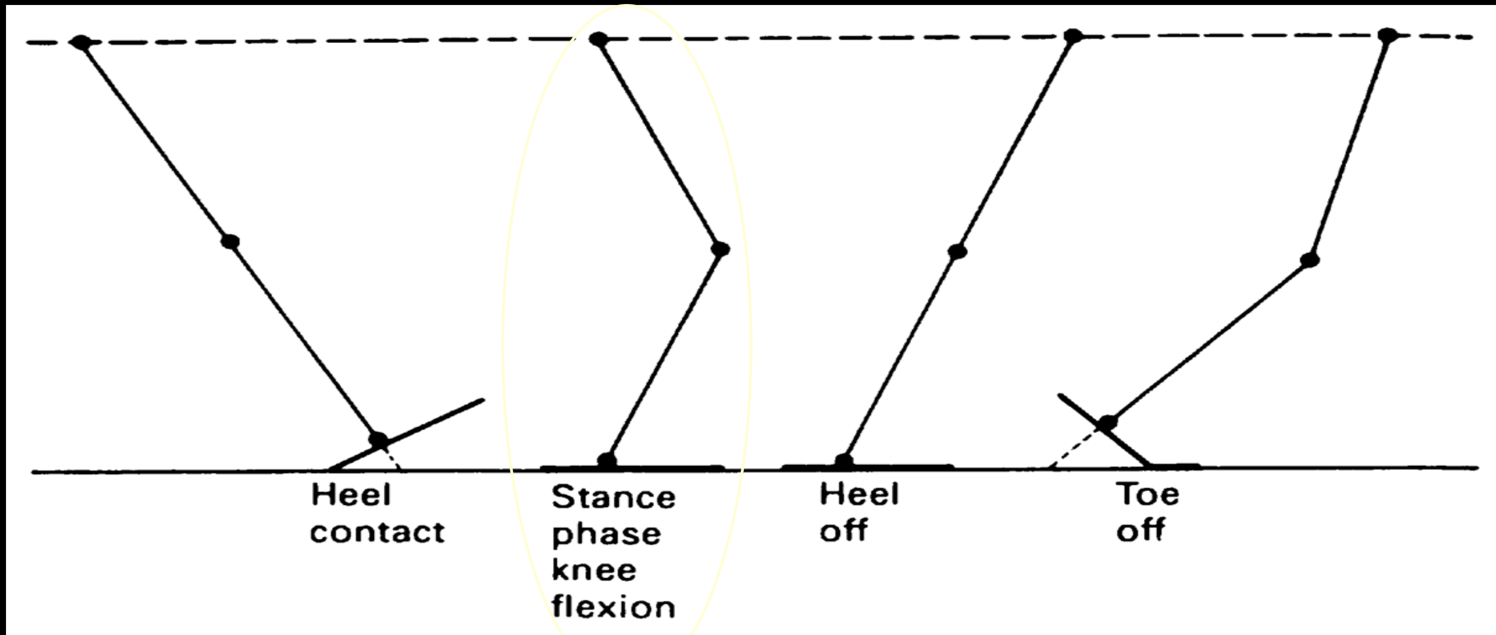
- (1) Pelvic rotation:
  - Forward rotation of the pelvis in the horizontal plane approx. 8^o on the swing-phase side
  - Reduces the angle of hip flexion & extension
  - Enables a slightly longer step-length w/o further lowering of CG

Determinants of Gait :



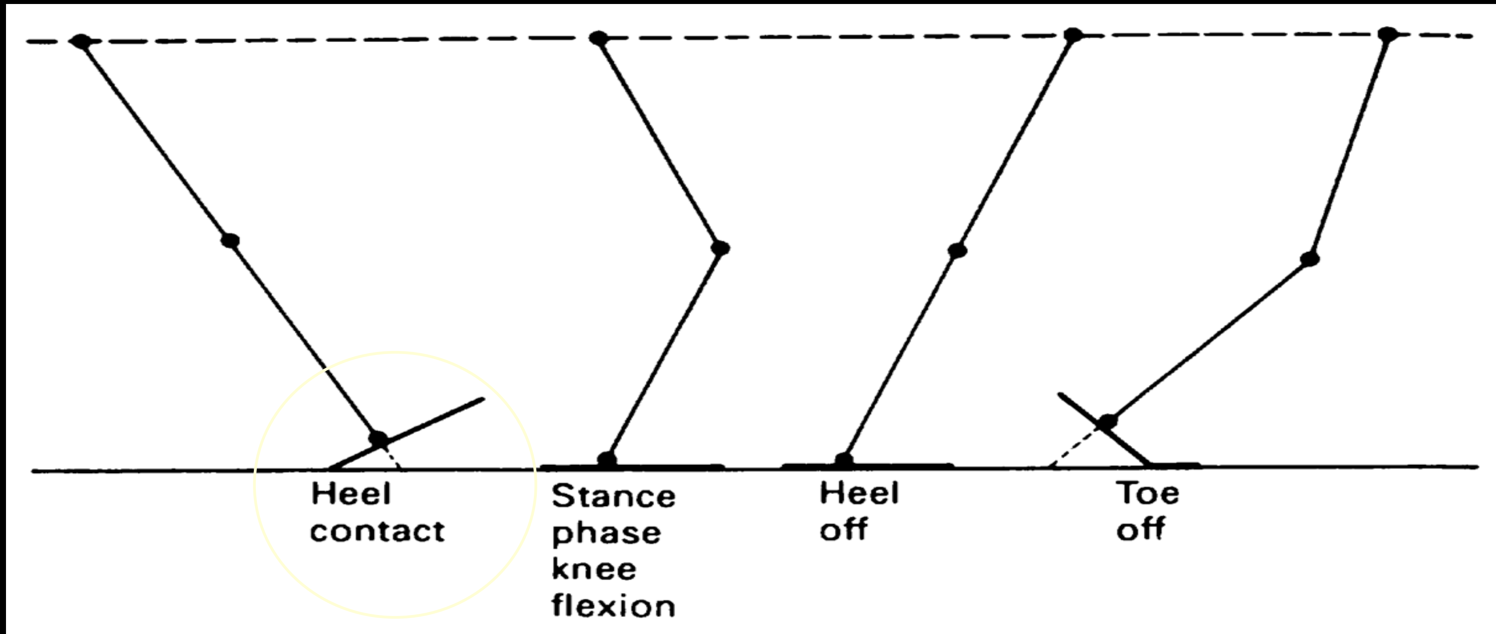
- (2) Pelvic tilt:
  - 5º dip of the swinging side (i.e. hip adduction)
  - In standing, this dip is a positive Trendelenberg sign
  - Reduces the height of the apex of the curve of CG

Determinants of Gait :



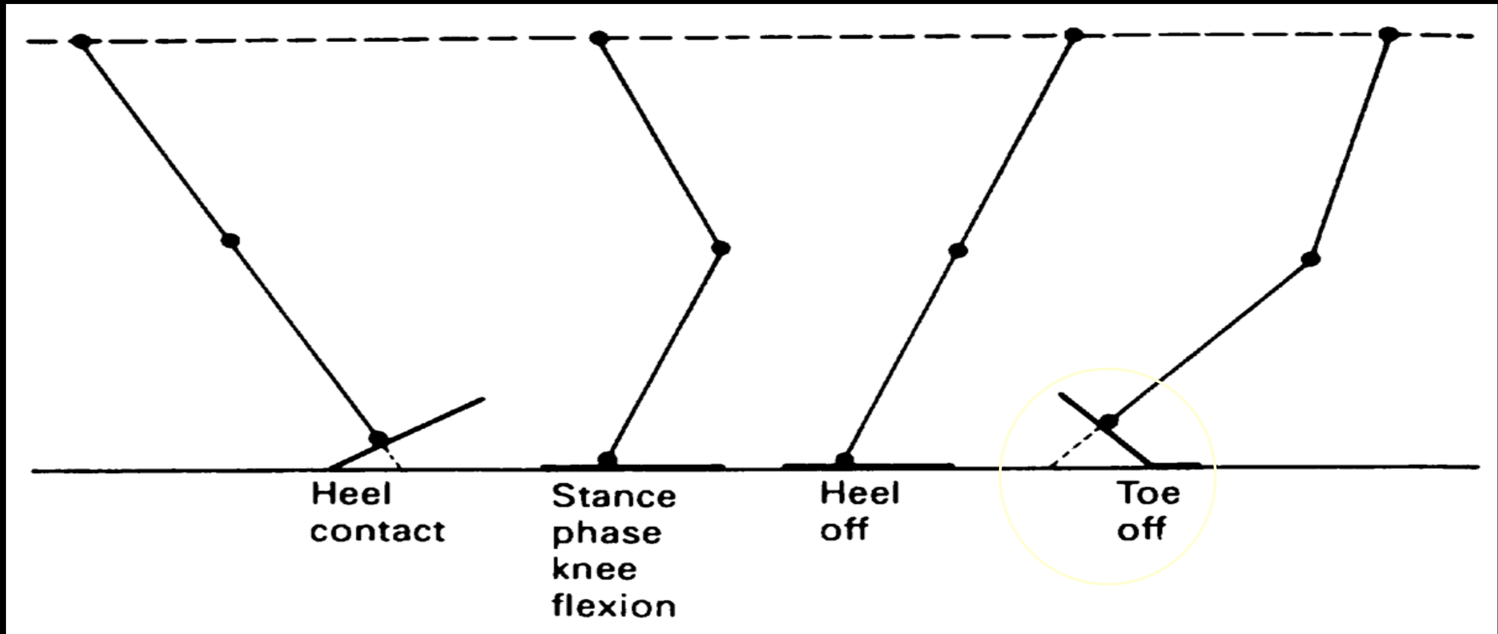
- (3) Knee flexion in stance phase:
  - Approx. 20º dip
  - Shortens the leg in the middle of stance phase
  - Reduces the height of the apex of the curve of CG

Determinants of Gait :



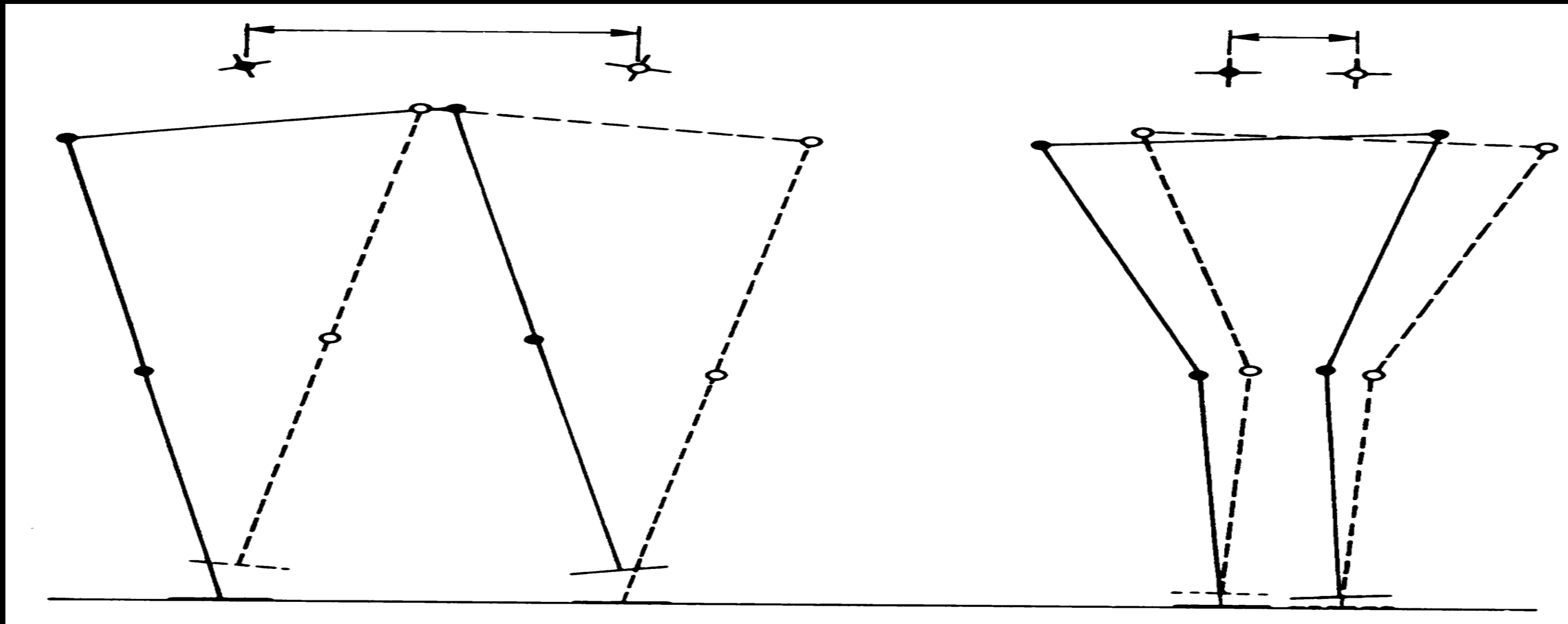
- (4) Ankle mechanism:
  - Lengthens the leg at heel contact
  - Smoothens the curve of CG
  - Reduces the lowering of CG

Determinants of Gait :



- (5) Foot mechanism:
  - Lengthens the leg at toe-off as ankle moves from dorsiflexion to plantarflexion
  - Smoothens the curve of CG
  - Reduces the lowering of CG

Determinants of Gait :



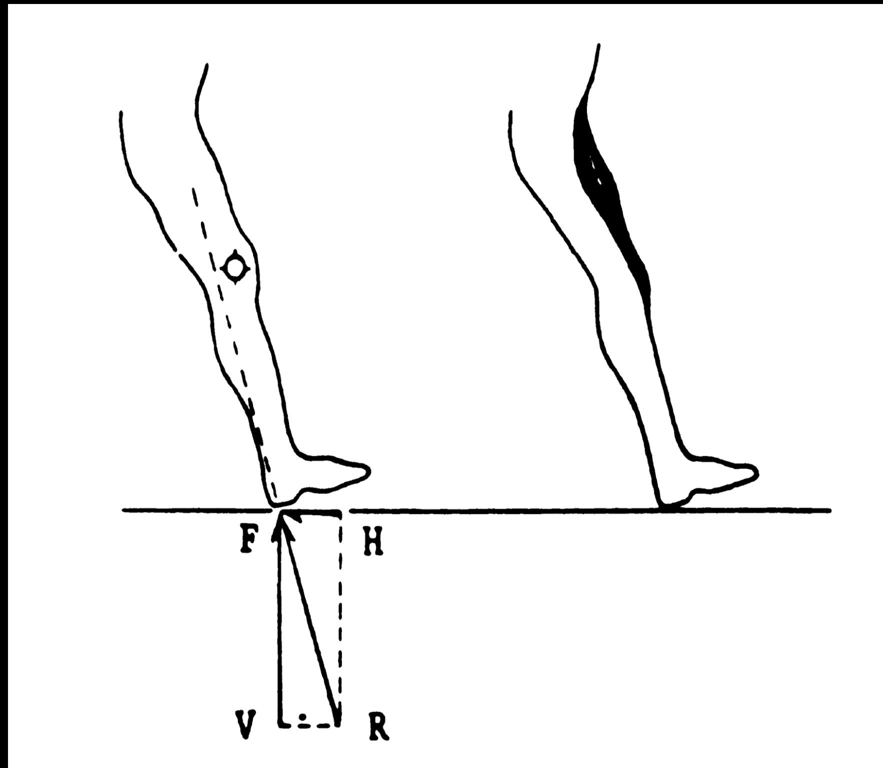
- (6) Lateral displacement of body:
  - The normally narrow width of the walking base minimizes the lateral displacement of CG
  - Reduced muscular energy consumption due to reduced lateral acceleration & deceleration

Gait Analysis – Forces:

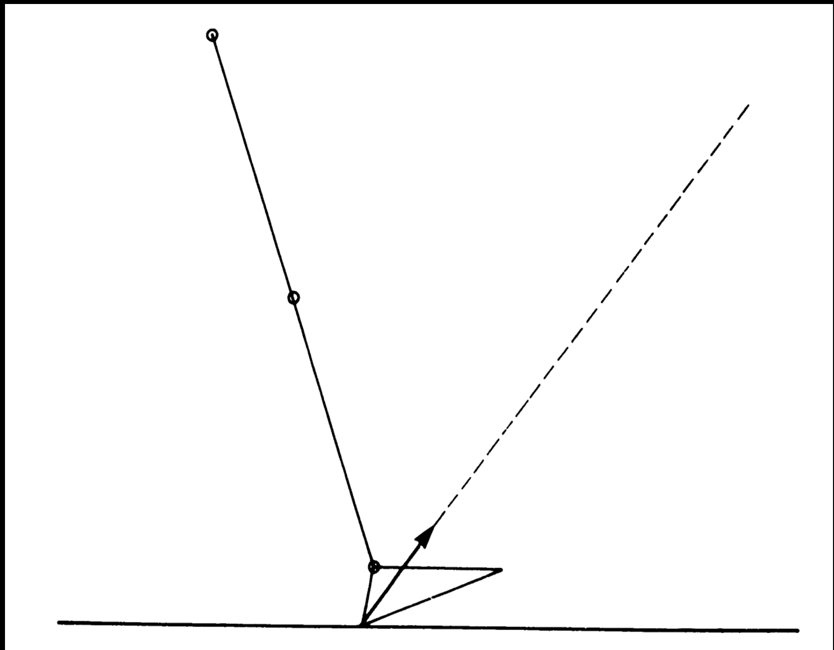
- Forces which have the most significant Influence are due to:
  - (1) gravity
  - (2) muscular contraction
  - (3) inertia
  - (4) floor reaction

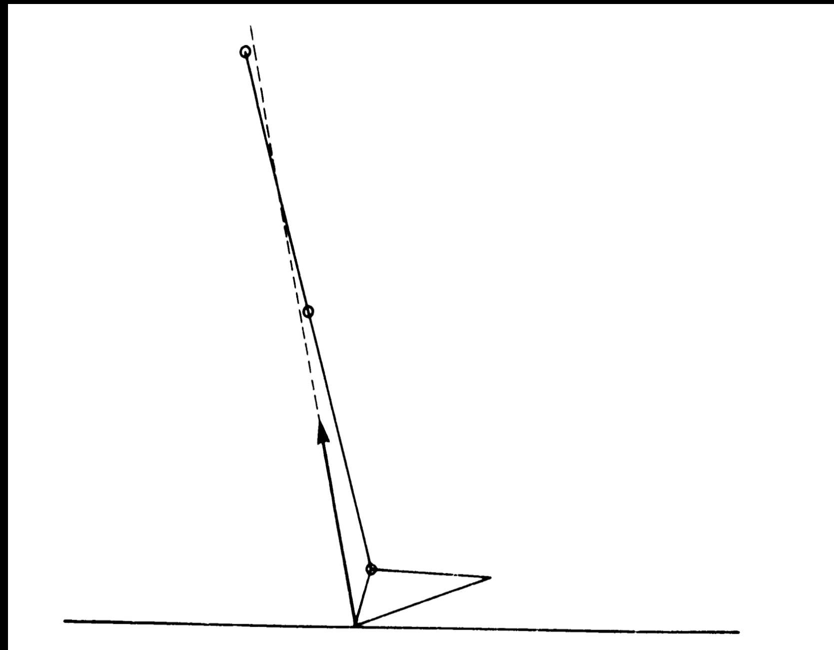
Gait Analysis – Forces:

- The force that the foot exerts on the floor due to gravity & inertia is opposed by the ground reaction force
- Ground reaction force (RF) may be resolved into horizontal (HF) & vertical (VF) components.
- Understanding joint position & RF leads to understanding of muscle activity during gait



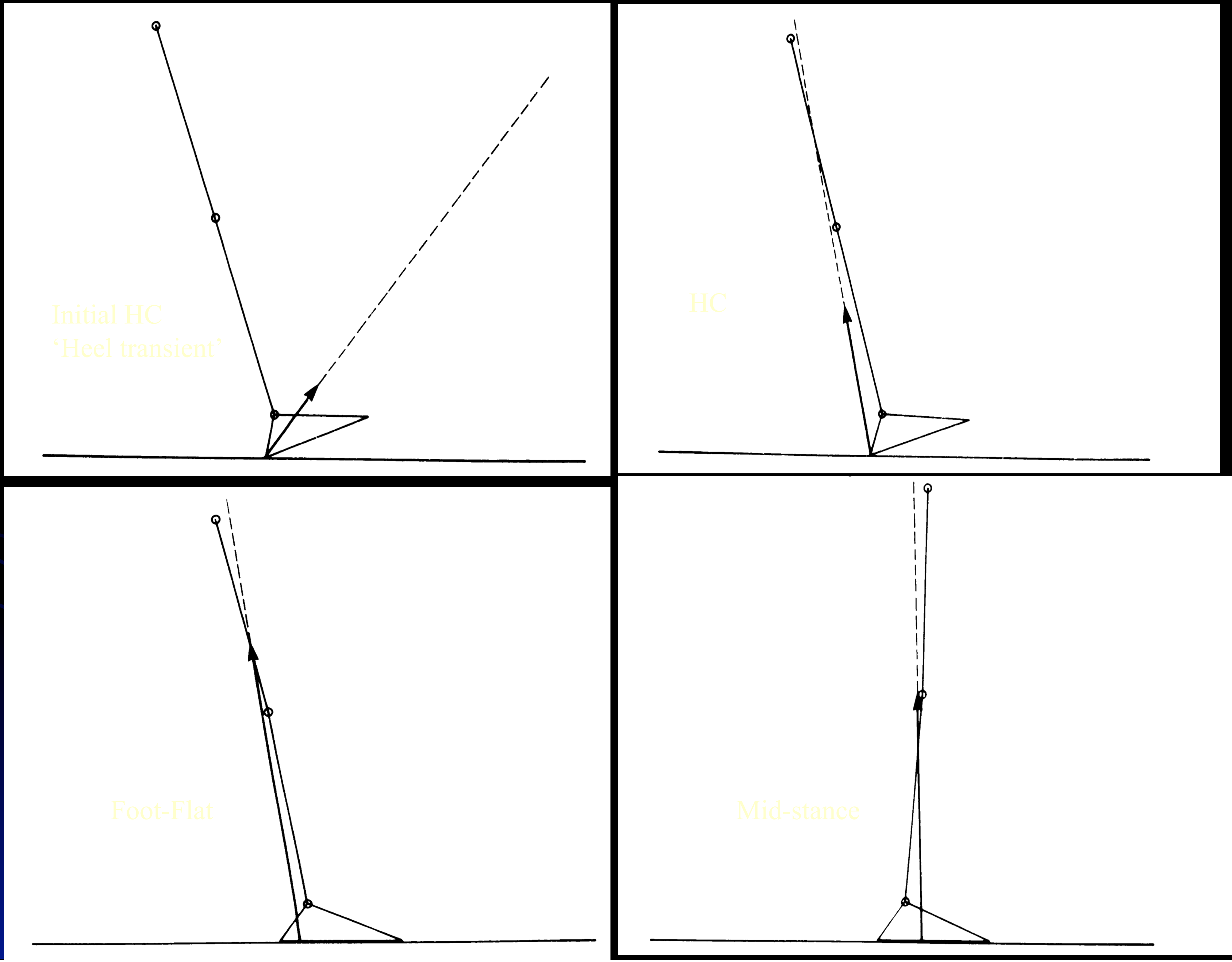
Gait Analysis:



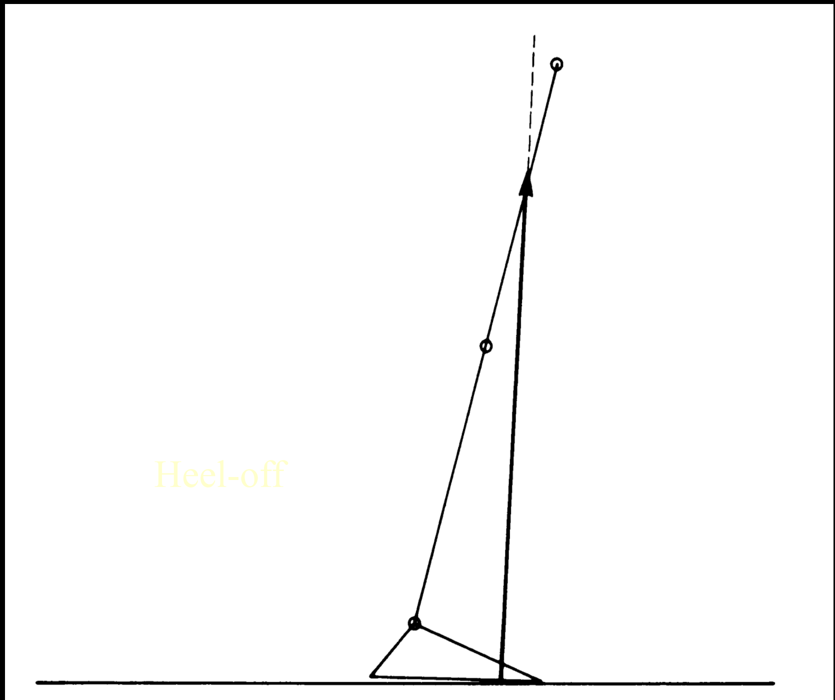


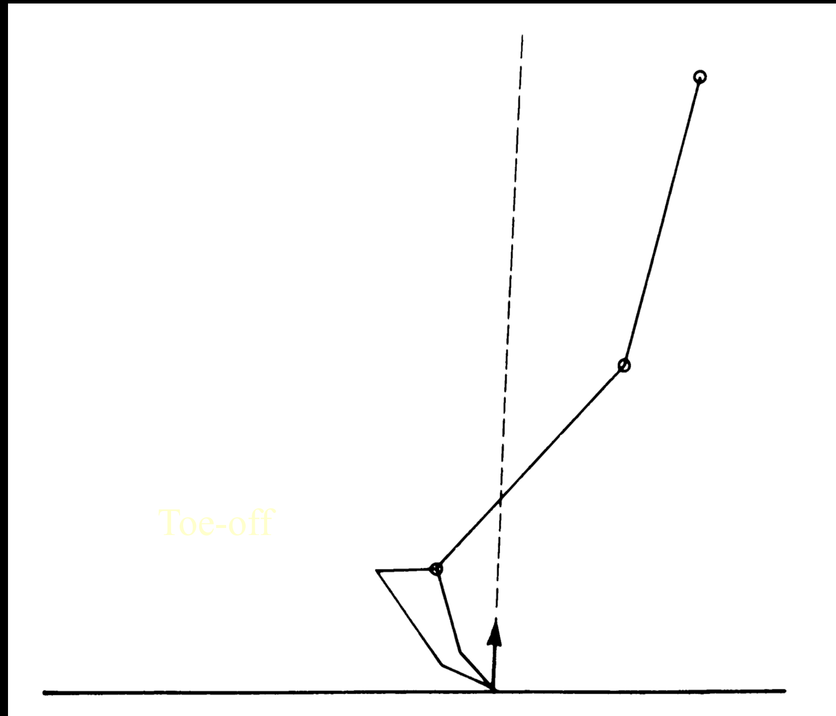
- At initial heel-contact: ‘heel transient’
- At heel-contact:
  - Ankle: DF
  - Knee: Quad
  - Hip: Glut. Max&Hamstrings

Gait



Gait





GAIT

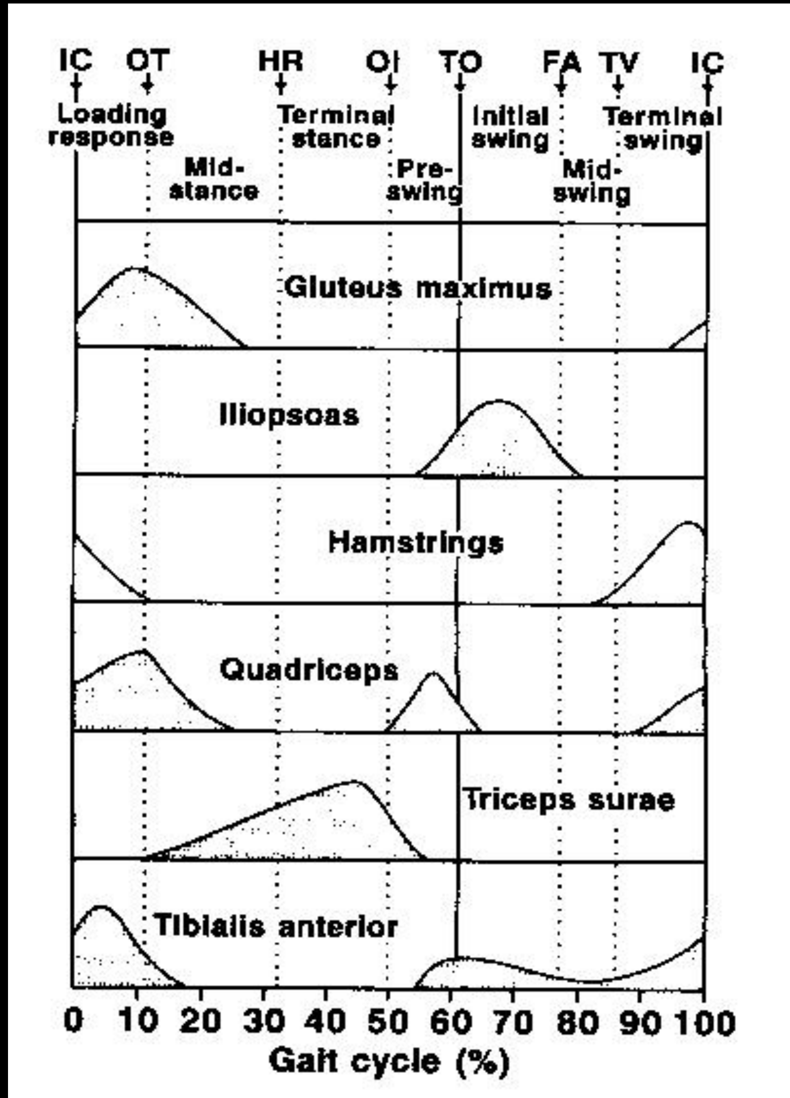
- **Low muscular demand:**
  - **~ 20-25% max. muscle strength**
  - **MMT of ~ 3^+**

COMMON GAIT ABNORMALITIES

A. Antalgic Gait
B. Lateral Trunk bending
C. Functional Leg-Length Discrepancy
D. Increased Walking Base
E. Inadequate Dorsiflexion Control
F. Excessive Knee Extension

Activity of major muscle groups during the gait cycle

- Key:
- IC= Initial Contact
- OT= Opposite Toe Off
- HR= Heel Raise
- OI= Opposite Initial Contact
- TO= Toe Off
- FA= Feet Adjacent
- TV= Tibia Vertical



Three Designs of the Running Shoe

- Motion control shoes help prevent pronation.
- Stability shoes allow pronation.
- Cushioning shoes promote pronation.

To Fit or Not to Fit?

- How about that 20 pounds in a 10-pound bag?

- How about that 10 pounds in a 20-pound bag?

- How about that "V" fit?

The Perfect Fit

- A shoe is like a car tire. If you over inflate or under inflate it, it works but not the way it was engineered or designed to work.
- Laces should be parallel.
- The "toe box" should have the width of your thumbnail from the longest toe to the front of the shoe.