GAIT ANALYSIS

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THE GAIT CYCLE

- Bear weight
- Provide a means for locomotion
- Maintain equilibrium

LOCOMOTION

Position of the Lower Extremity

- Weight bearing / Fixed (Closed chain) i.e. foot is on the ground
  - body moves over the leg

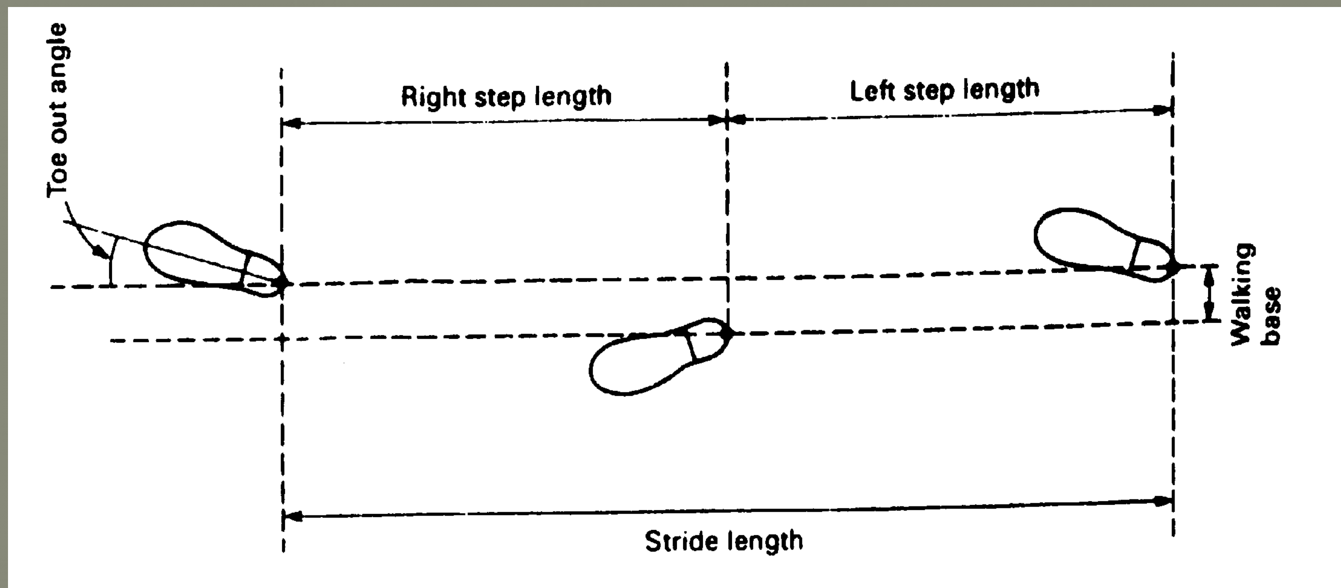
- Non weight bearing / Free (Open chain) i.e. foot is off the ground
  - leg moves under the body

- Same relative motion occurs in both position - different bones will move

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’

Gait Cycle - Definitions:

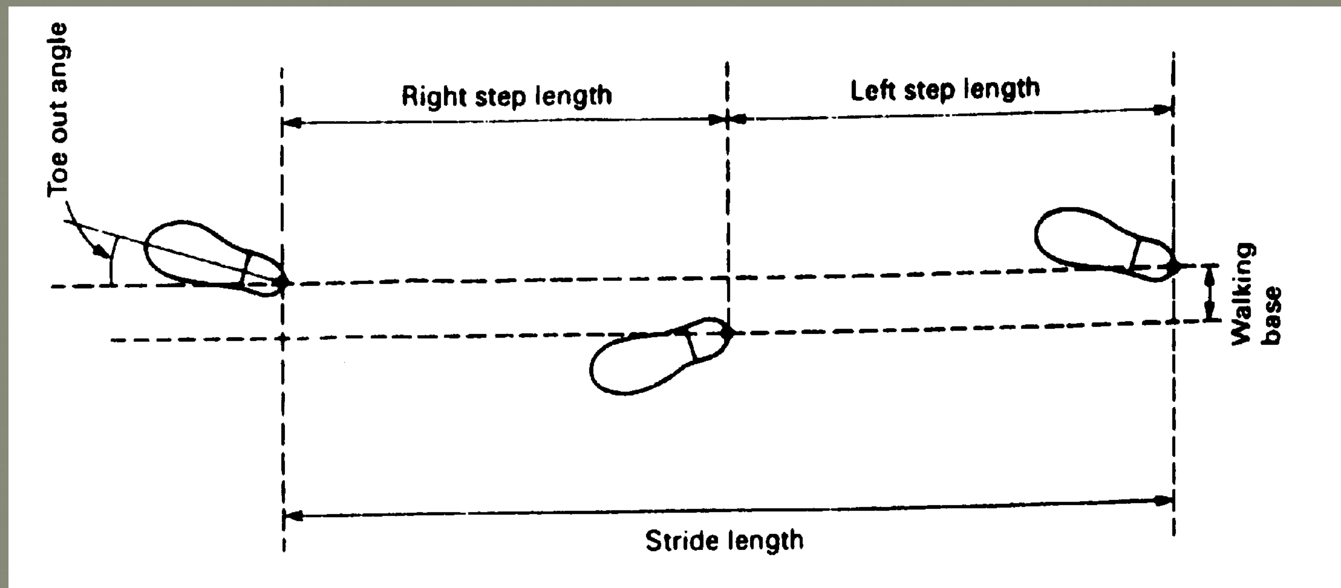


- <u>Gait Cycle</u> =
  - Single sequence of functions by **one limb**
  - Begins when reference foot contacts the ground
  - Ends with subsequent floor contact of the <u>same foot</u>

Basic Gait Phase Terminology

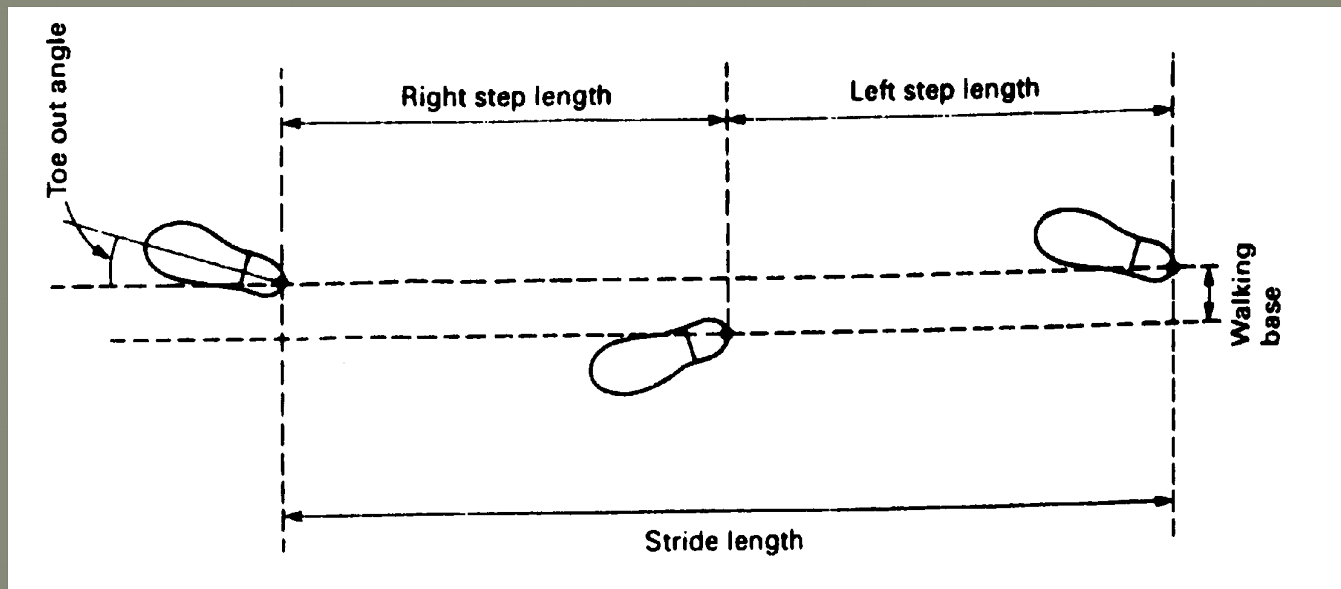
- Gait Cycle
- Stance and Swing
- Stride Length
- Step Length
- Stride (gait) Width
- Stride Time
  - Stance Time
  - Swing Time
- Cadence
- Velocity

Gait Cycle - Definitions:



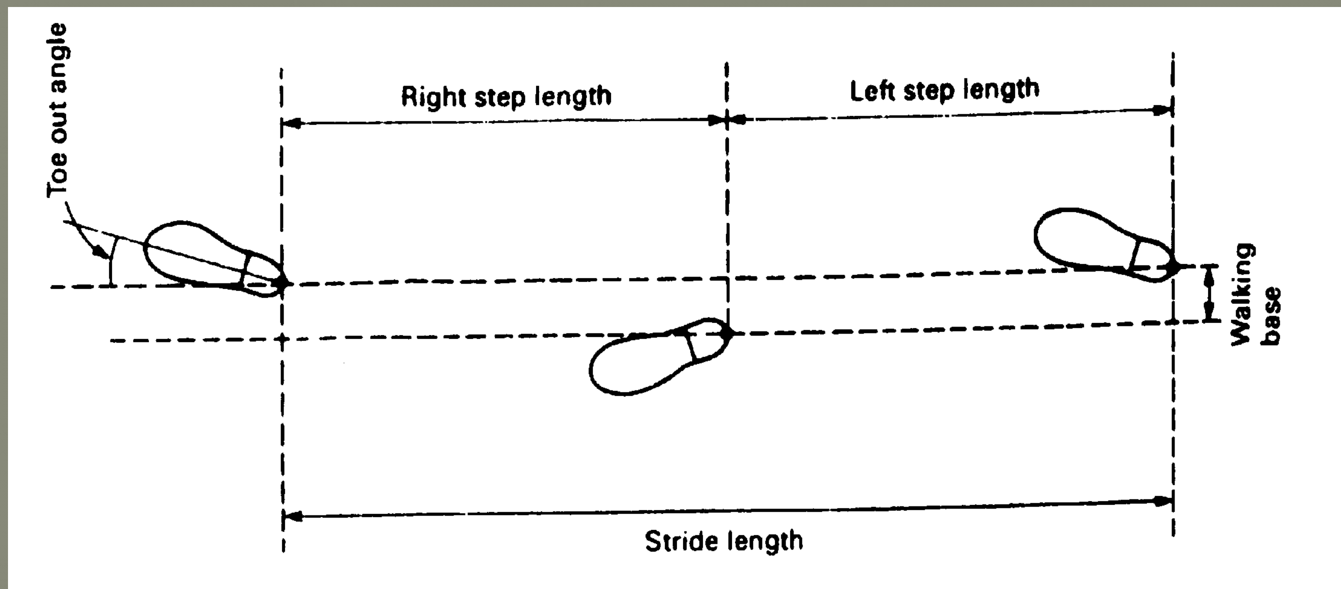
- <u>Step Length</u> =
  - Distance between corresponding successive **points of heel contact of the opposite feet**
  - Rt step length = Lt step length (in normal gait)

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:



- <u>Walking Base</u> =
  - Side-to-side distance between the line of the two feet
  - Also known as 'stride width'

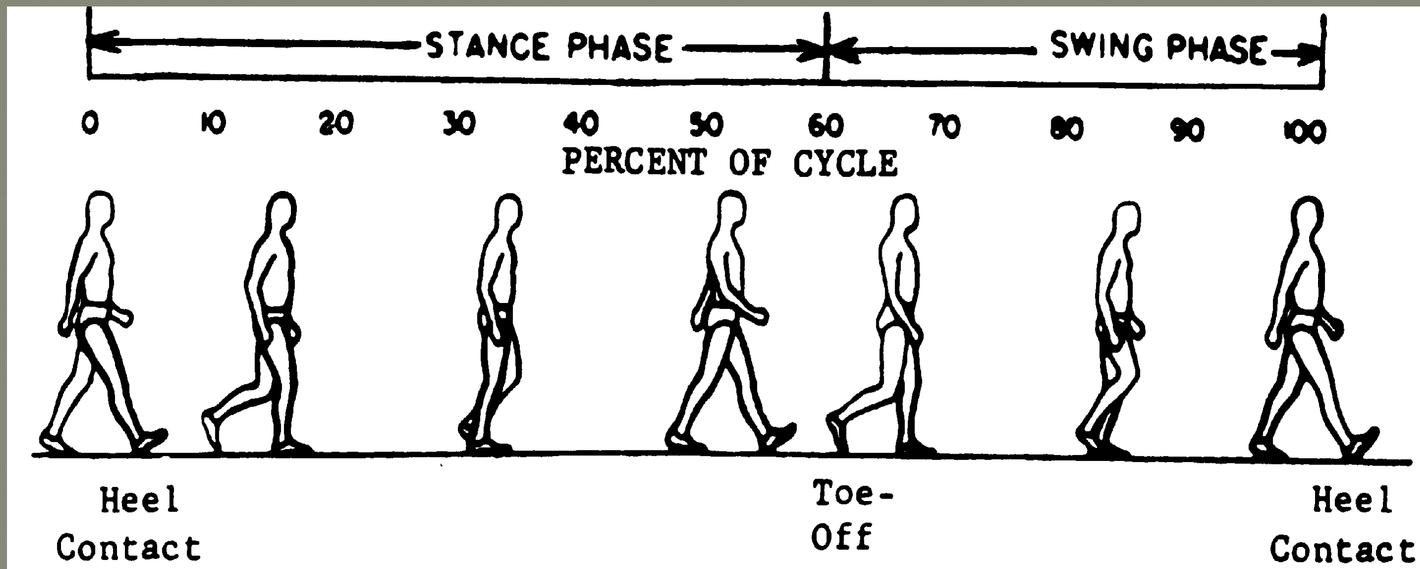
Gait Cycle - Definitions:

- 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:



- Phases:

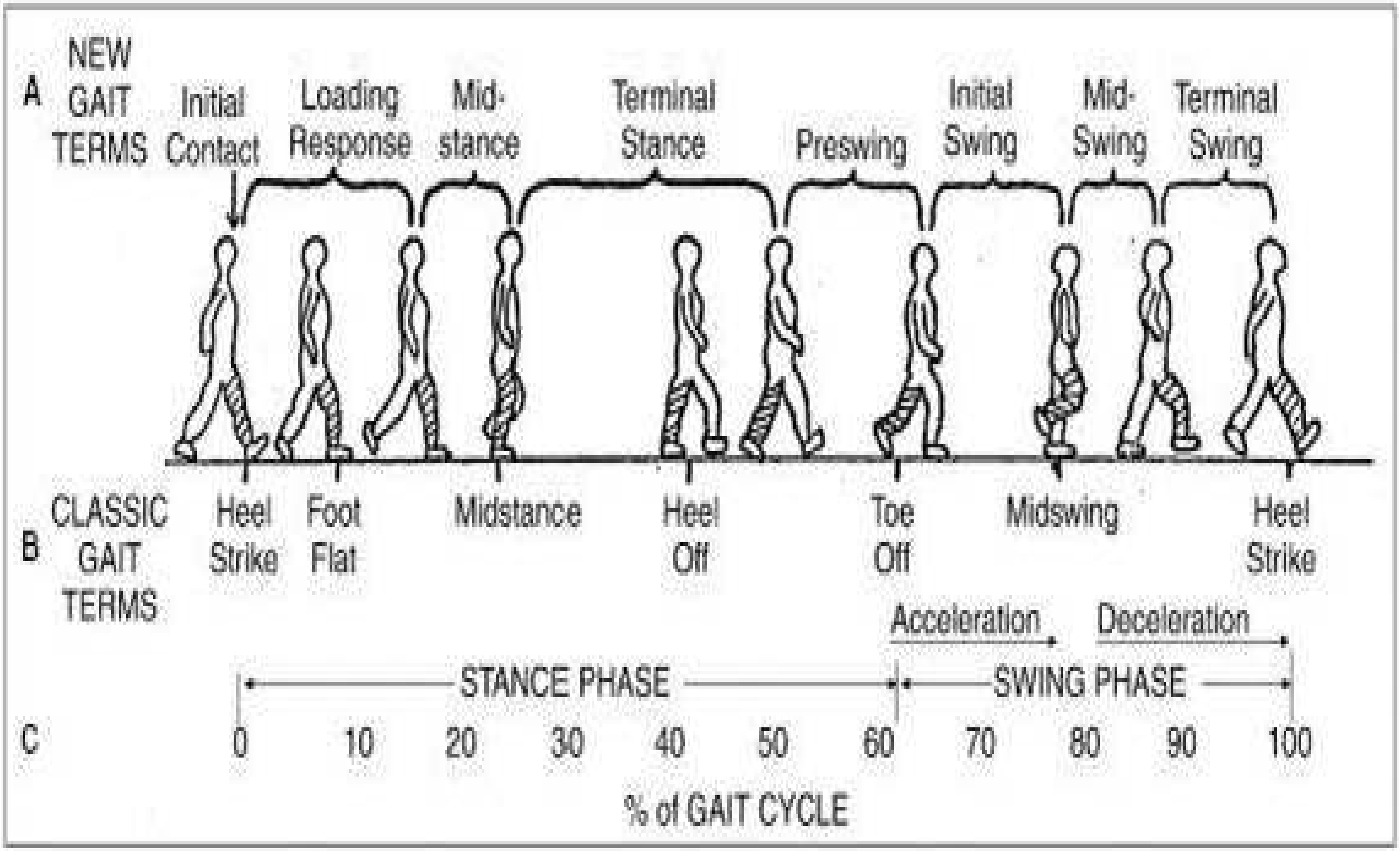
(1) Stance Phase: reference limb in contact with the floor

(2) Swing Phase: reference limb not in contact with the floor

Comparison of classification

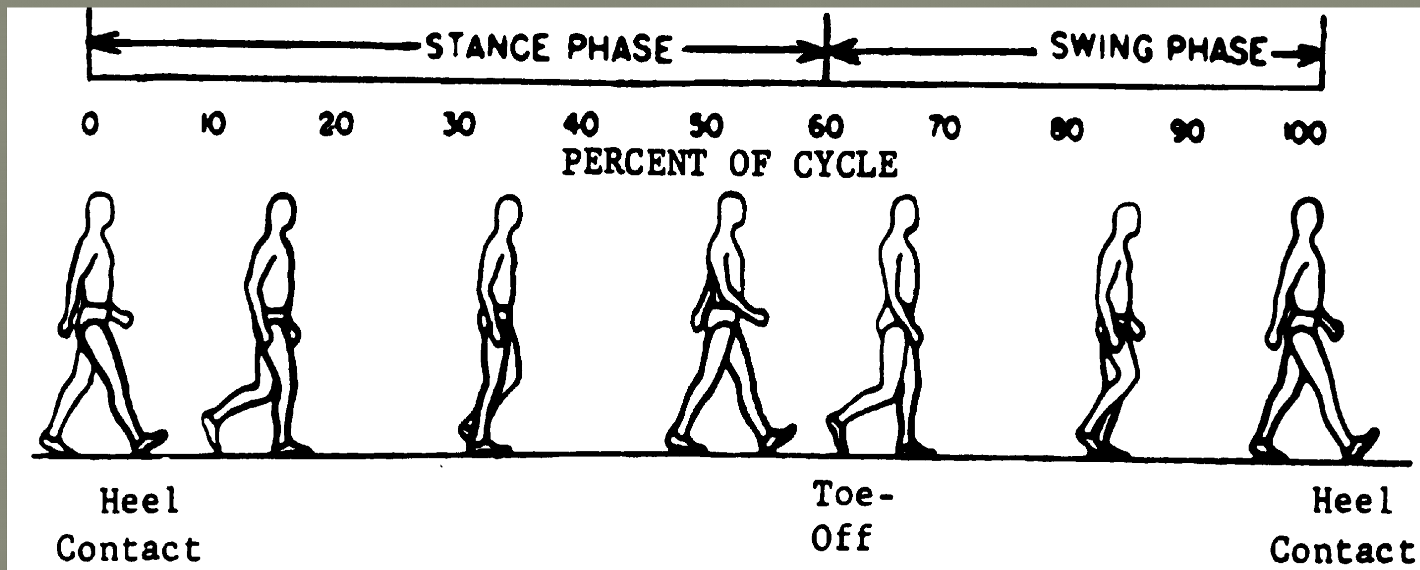
Phases	RLA	Traditional
Stance	Initial contact	Heel strike
	Loading response	Foot flat
	Mid stance	**Mid stance**
	Terminal stance	Heel off
	Pre swing	Toe off
Swing	Initial swing	Acceleration
	Mid swing	**Mid-swing**
	Terminal swing	Deceleration

RLA stands for RANCHO LOS AMIGOS



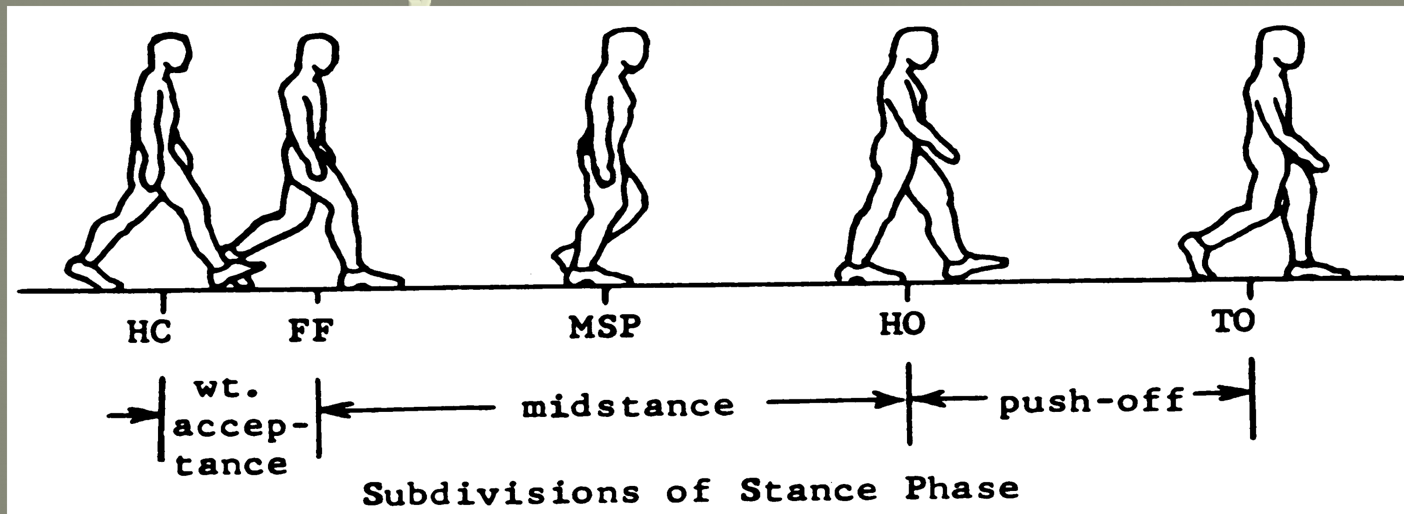
A
NEW GAIT TERMS
Initial Contact
Loading Response
Mid-stance
Terminal Stance
Preswing
Initial Swing
Mid-Swing
Terminal Swing
B
CLASSIC GAIT TERMS
Heel Strike
Foot Flat
Midstance
Heel Off
Toe Off
Midswing
Heel Strike
Acceleration
Deceleration
STANCE PHASE
SWING PHASE
C
0
10
20
30
40
50
60
70
80
90
100
% of GAIT CYCLE

Gait Cycle - Components:



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

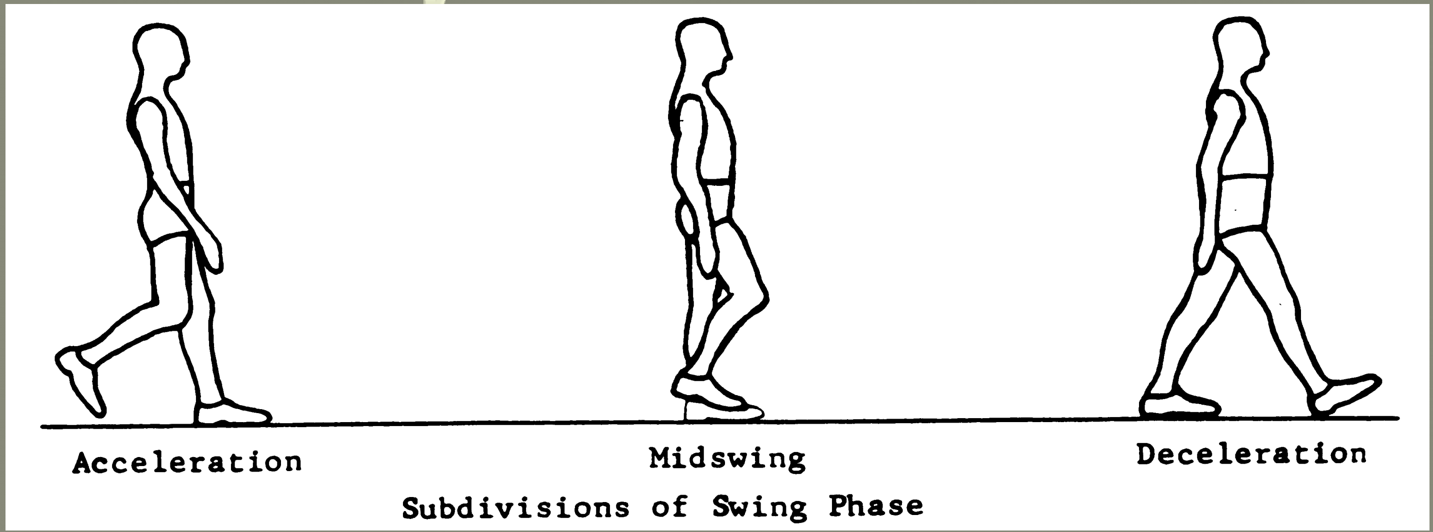
Gait Cycle - Subdivisions:



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

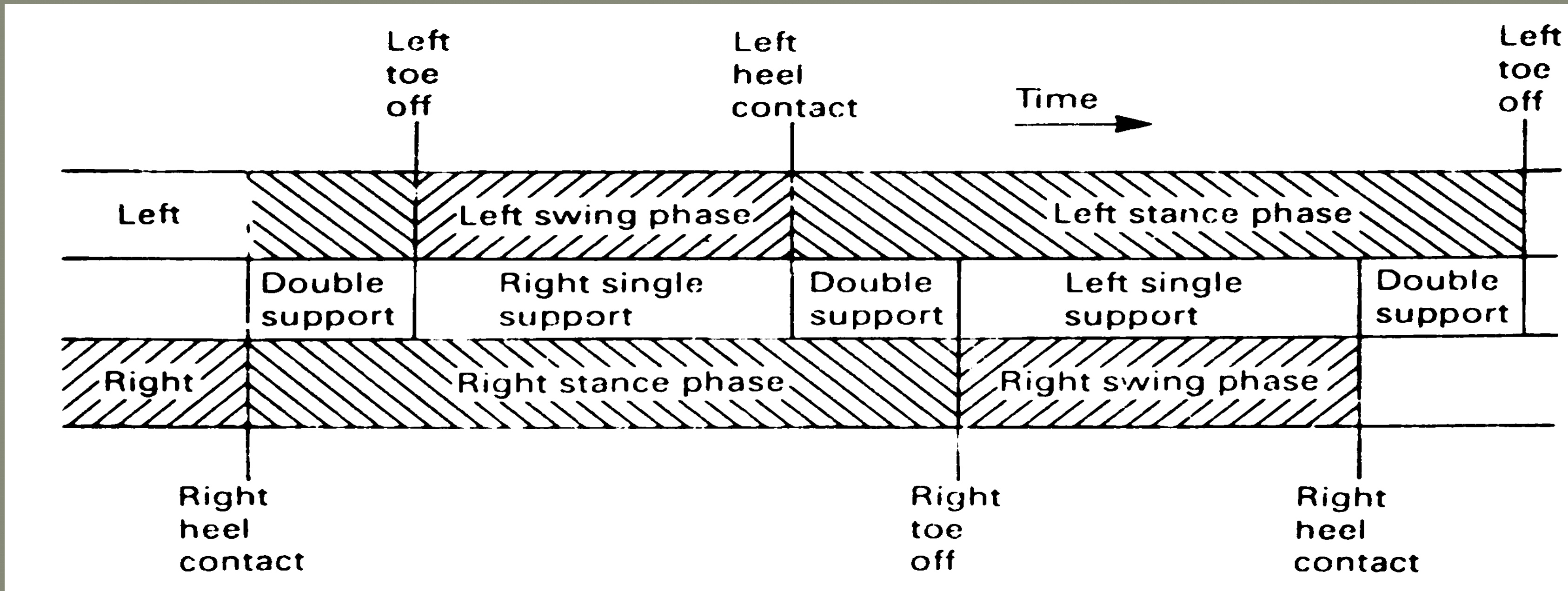
1. **Heel contact**: 'Initial contact'
2. **Foot-flat**: 'Loading response', initial contact of forefoot w. ground
3. **Mid stance**
4. **Heel-off**: 'Terminal stance'
5. **Toe-off**: 'Pre-swing'

Gait Cycle - Subdivisions:

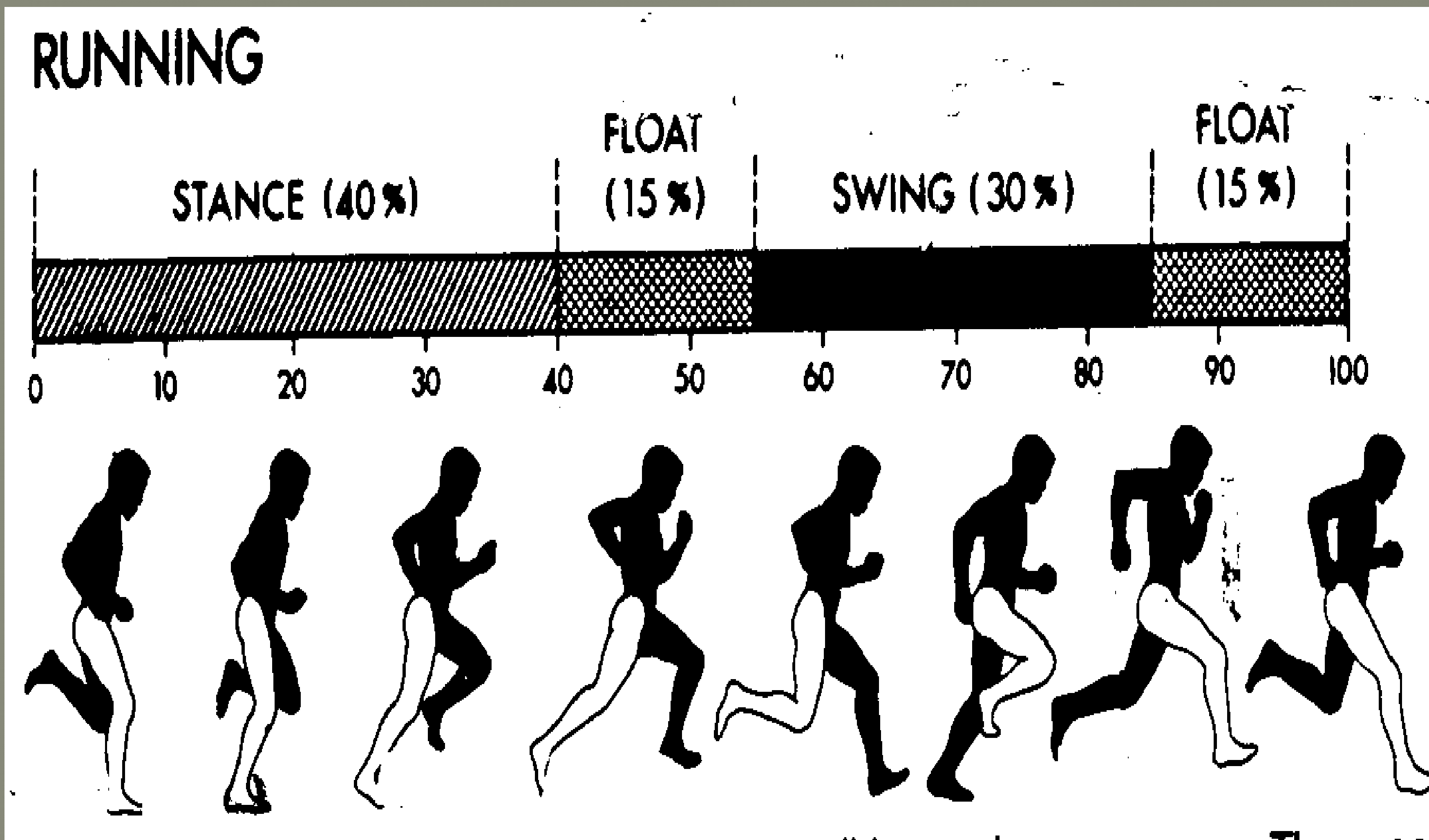


B. Swing phase:

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



- With increasing walking speeds:
  - Stance phase: Decreases
  - Swing phase: Increases
  - Double support: Decreases
- <u>Running</u>:
  - By definition: walking without double support
  - Ratio stance/swing reverses
  - Double support disappears. 'Double swing' develops


RUNNING
STANCE (40%)
FLOAT (15%)
SWING (30%)
FLOAT (15%)
0
10
20
30
40
50
60
70
80
90
100

Gait Events

- Support Events
  - Foot (Heel) Strike
  - Foot Flat
  - Midstance
  - Heel Off
  - Foot (Toe) Off
- Swing Events
  - Pre swing
  - Midswing
  - Terminal swing

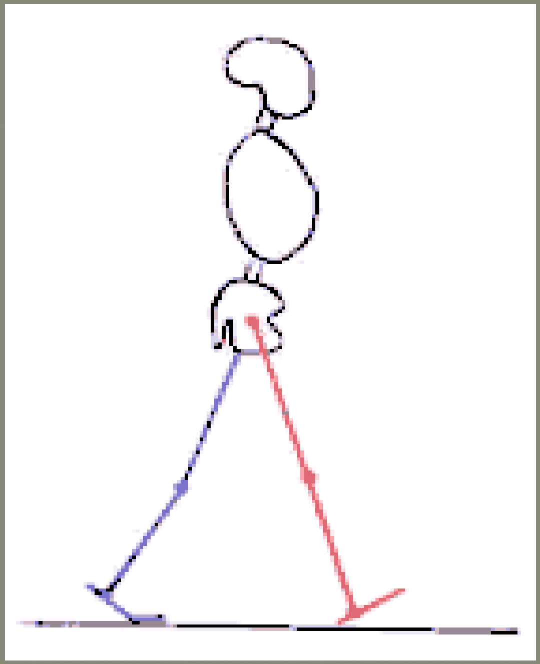
Gait Events
Foot (heel) Strike

Initial Contact

Beginning of Loading

Foot Position may vary, but is generally supinated

Represents end of single support on the opposite side



Gait Events
Foot Flat

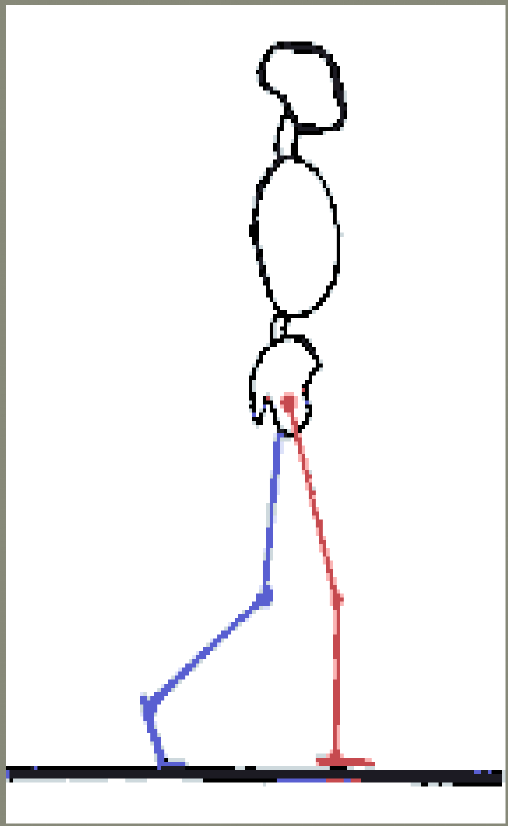
Maximum Impact Loading occurs

Controlled by the Tibialis Anterior

Foot rapidly moves into pronation

Weight has been shifted to the support leg

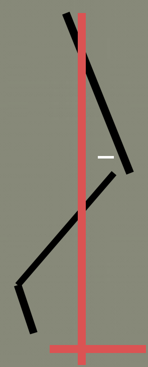
Coincides with end of the Initial period of Double Support on the Opposite side

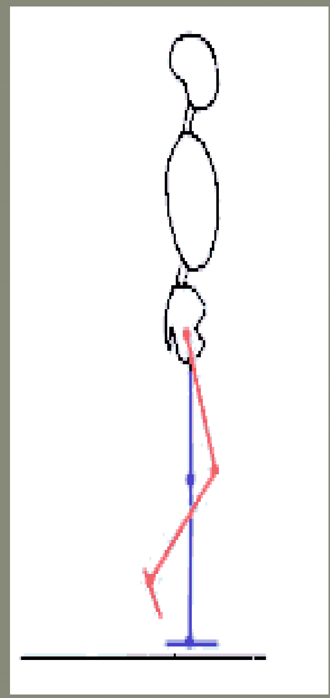


Gait Events

Mid-Stance

- Single Support
- Balance Critical
- All weight supported by single leg
- Foot remains pronated initially then re-supinates
- Late mid-stance is the period of max propulsion
- Swing occurring on opposite





Gait Events
Heel-Off

Un-loading of limb and preparation for swing

Foot Strike on Opposite Side

Weight Shift to opposite side begins

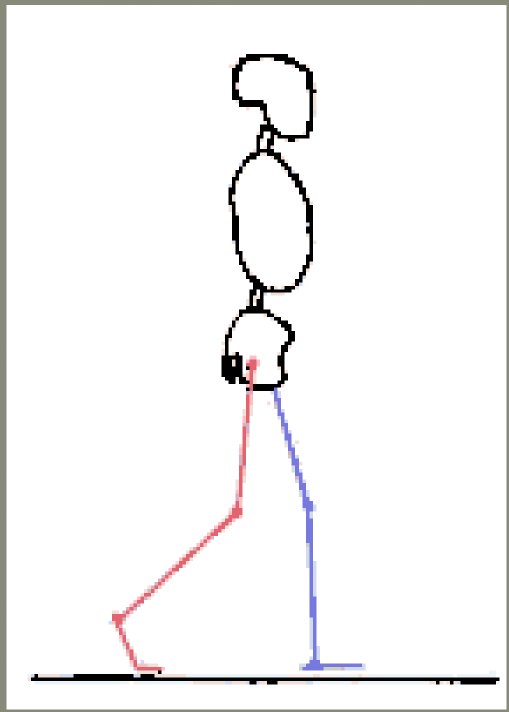
Gait Events

Toe-Off

Weight transition to opposite side completed

Hip flexion has been initiated to facilitate swing

Coincides with beginning of single support on the opposite side



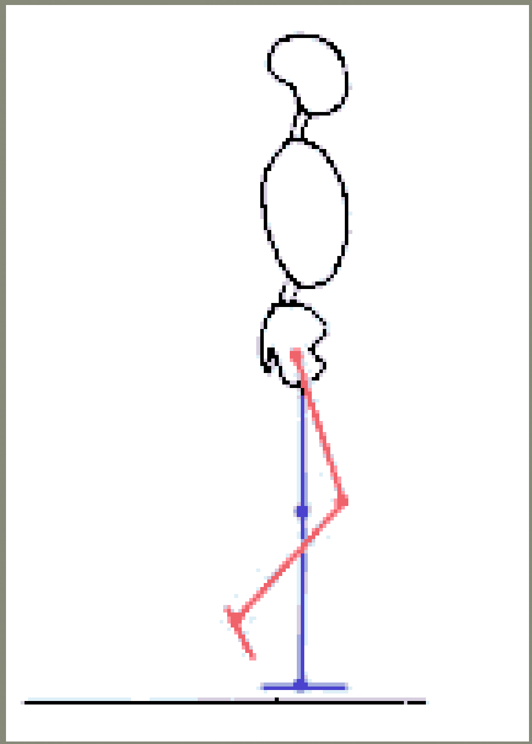
Gait Events

Mid-swing

Leg shortened (ankle Dorsiflexion) and hip elevated (abducted) to facilitate swing

Mid-stance on the opposite side

C. Of G. directly over opposite supporting foot



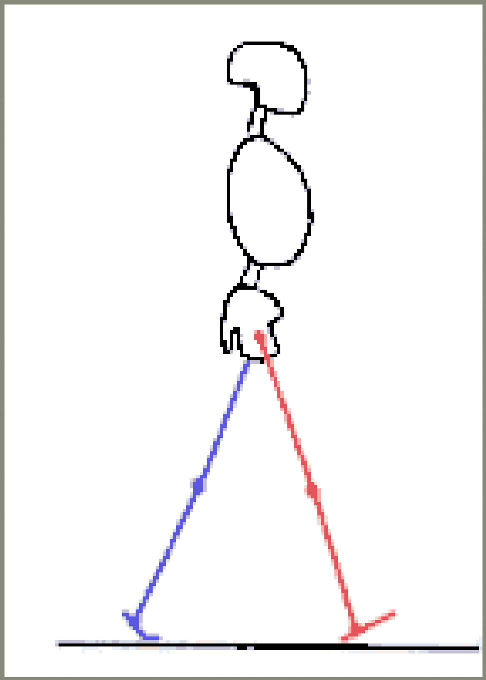
Gait Events
Terminal Swing

Hip flexion stopped and knee extended

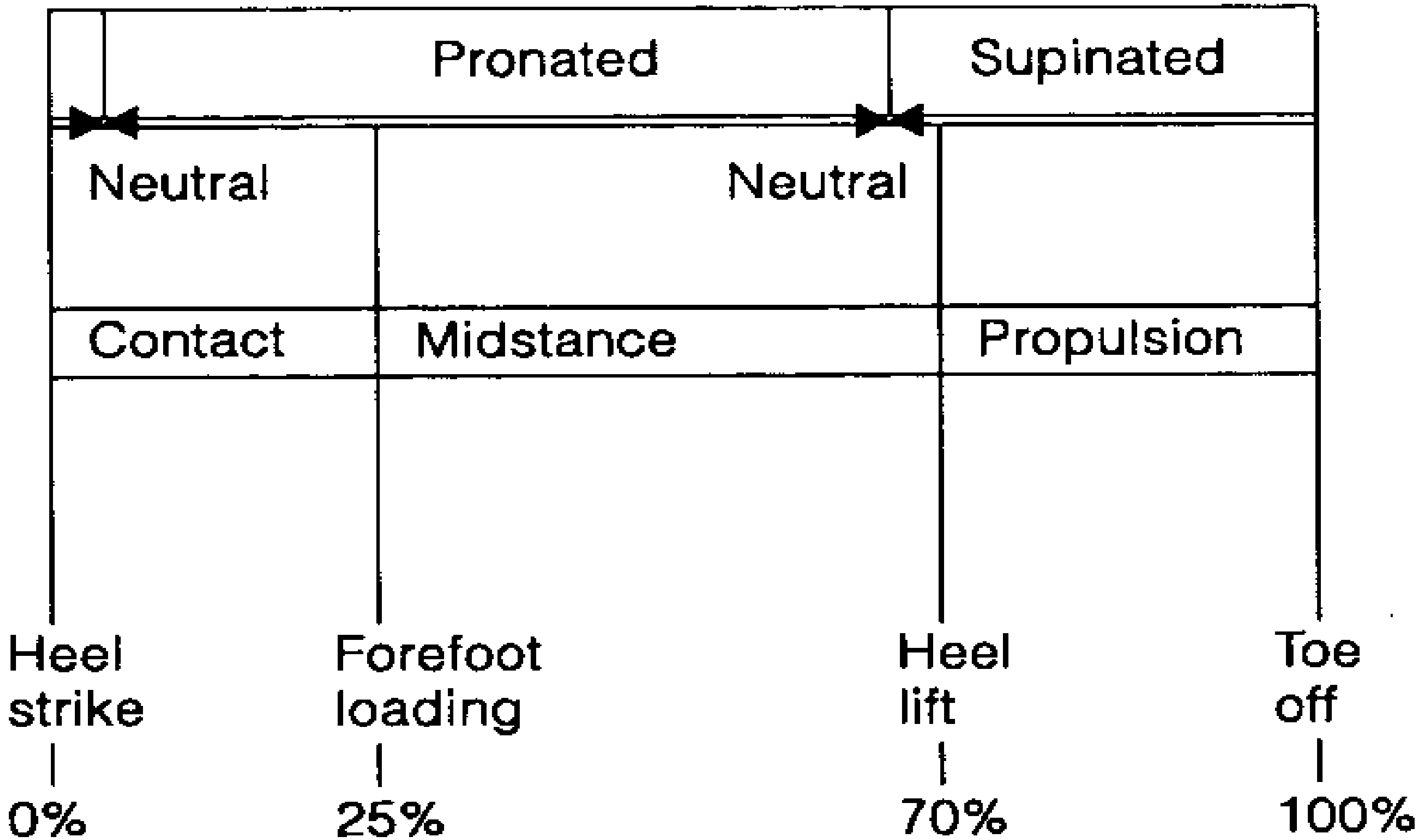
Foot supinated and positioned for foot strike

Coincides with the end of the second DS phase on the opposite side

The Sequence Begins Again



Stance phase of gait



Efficiency

Movement Requires Force

↓

Work = Force x Distance

Increases in force and/or distance reflect increased work

↓

Amount of Work Determines Energy Expenditure

Efficiency

Non-functional Movement of the C. of G. is *Energy Expensive !!!*

** Efficiency **

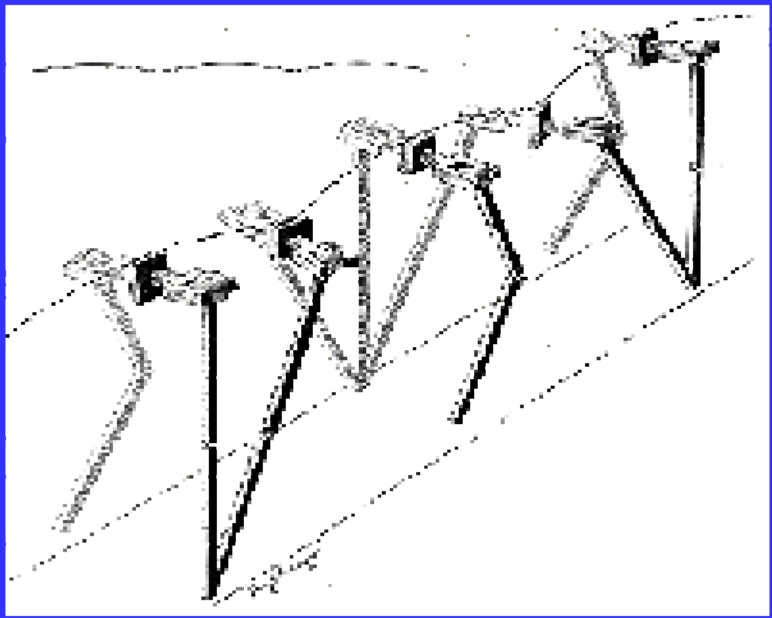
Factors Determining Energy Cost

- Determinants on Gait: (Saunders, Inman, Whittle, etc.)
  - Knee Flexion During Stance
  - Pelvic Rotation (transverse plane)
  - Pelvic Lateral Tilt (Obliquity)
  - Ankle Mechanism (Dorsiflexion)
  - Ankle Mechanism (Plantarflexion)
  - Step Width

Pelvic Lateral Tilt

Lateral Pelvic Tilt (or Drop)

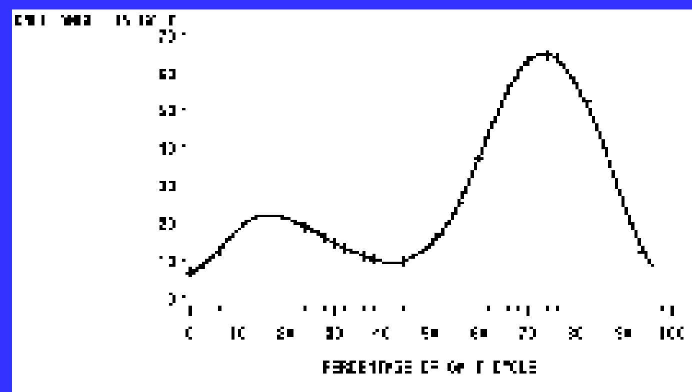
- Lateral pelvic tilting (dropping on the unsupported side) during midstance prevents an excessive rise in the body's center of gravity.



Knee Flexion During Stance

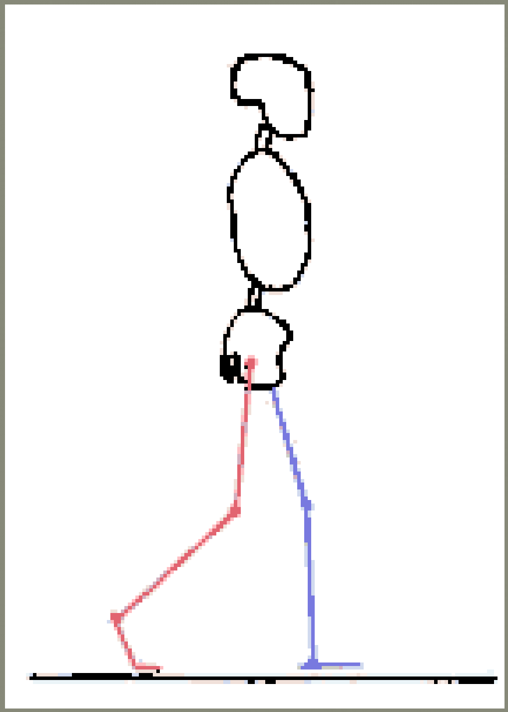
KNEE MOVEMENT DURING GAIT CYCLE:

- FLEXES DURING LOADING RESPONSE
- EXTENDS DURING MIDSTANCE AND TERMINAL STANCE
- FLEXES TO 60 DEGREES DURING INITIAL SWING



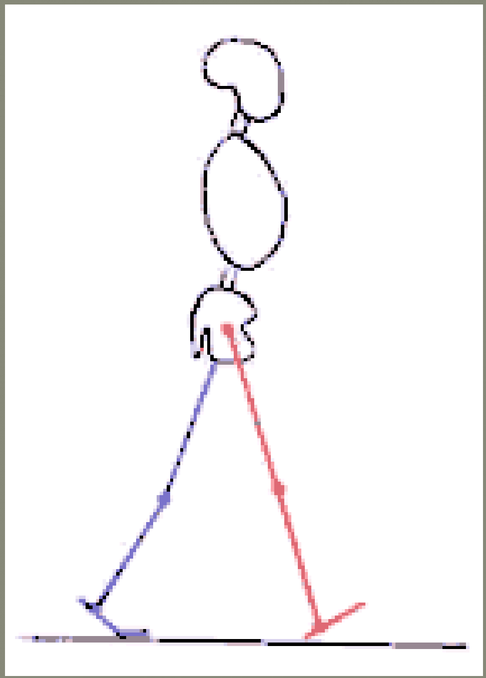
Ankle Mechanism
Plantar Flexion

Lengthens the leg during stance



Ankle Mechanism Dorsiflexion

Lengthens Leg During Swing, prior to foot contact

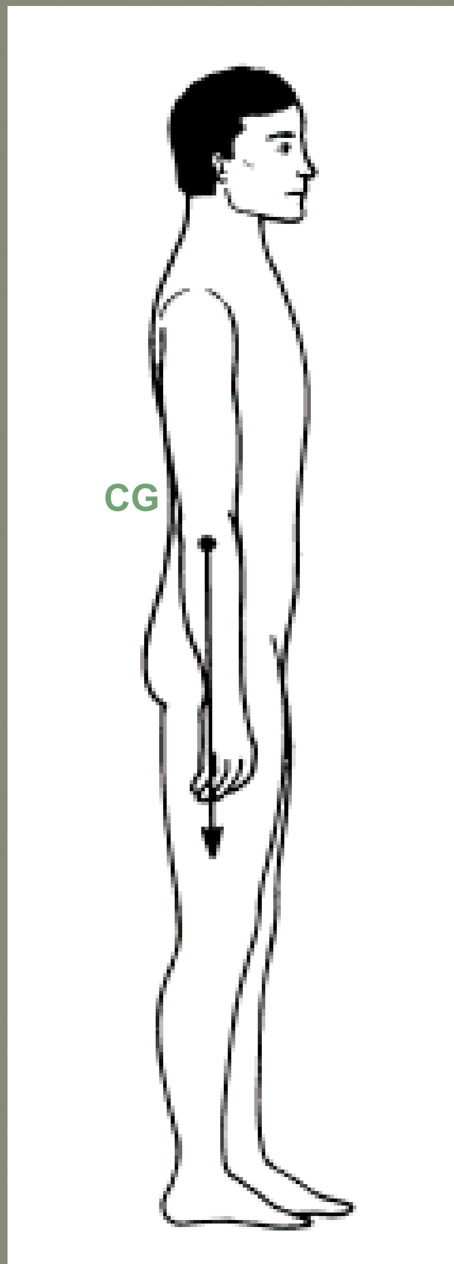
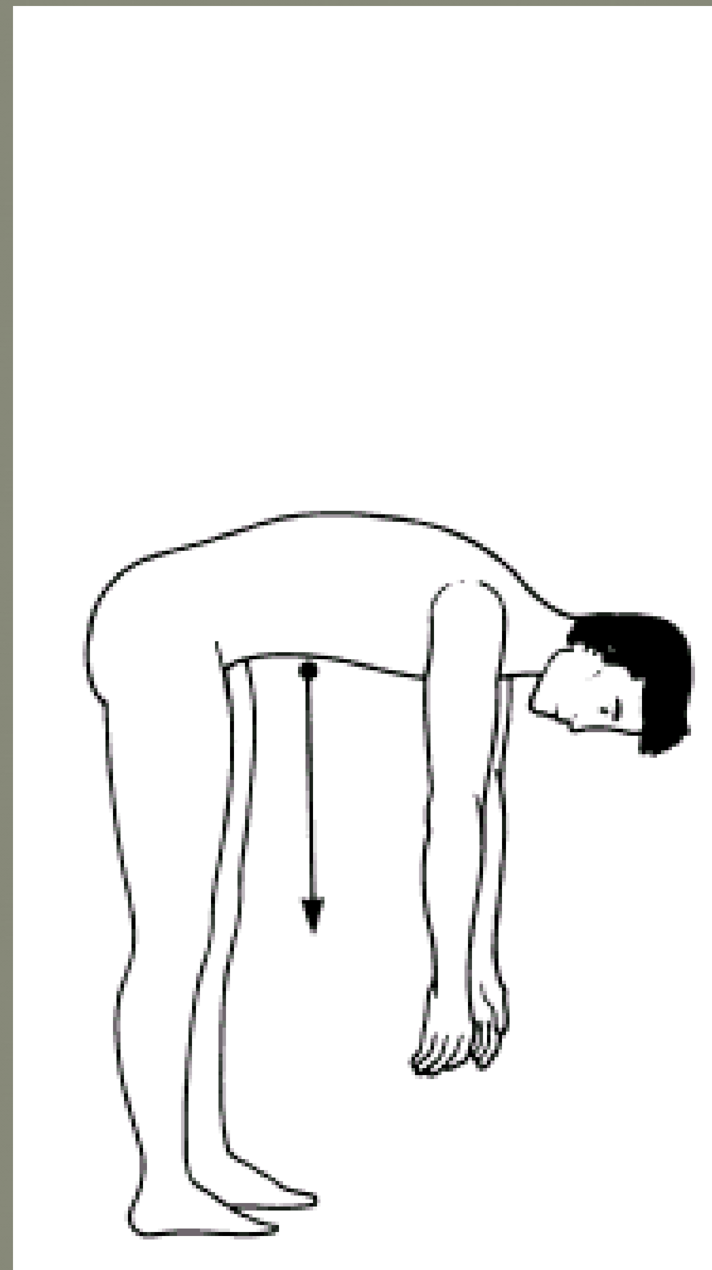


Step Width

Narrowing the base during double stance reduces lateral motion

Path of Center of Gravity

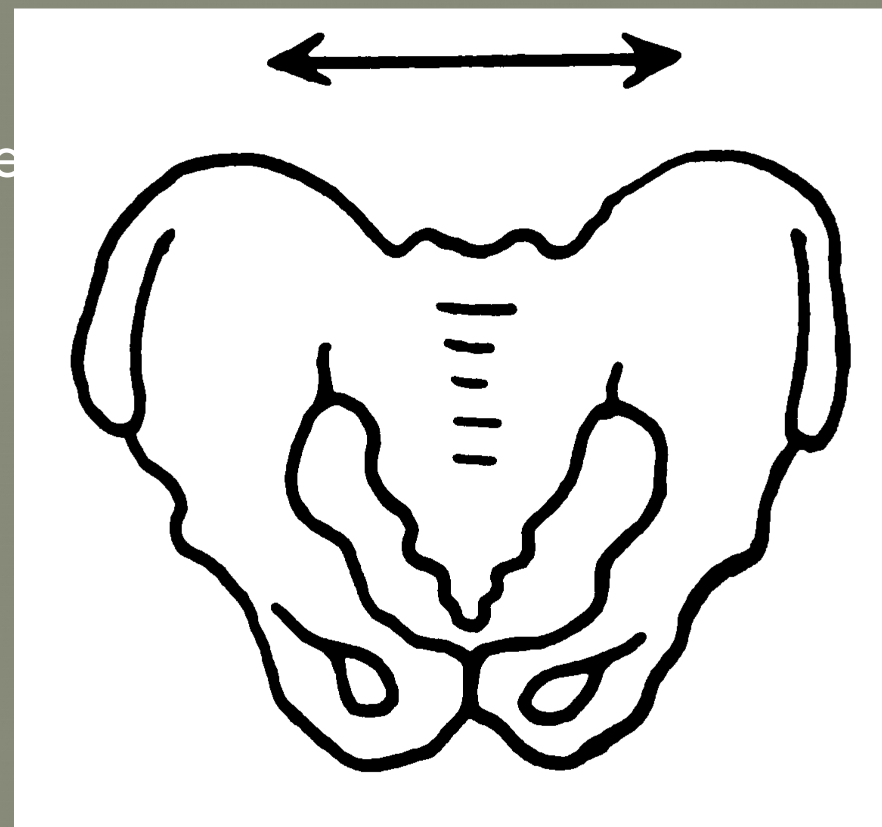
- Center of Gravity (CG):
  - Midway between the hips
  - Few cm in front of S2
- Least energy consumption if CG travels in straight line


CG


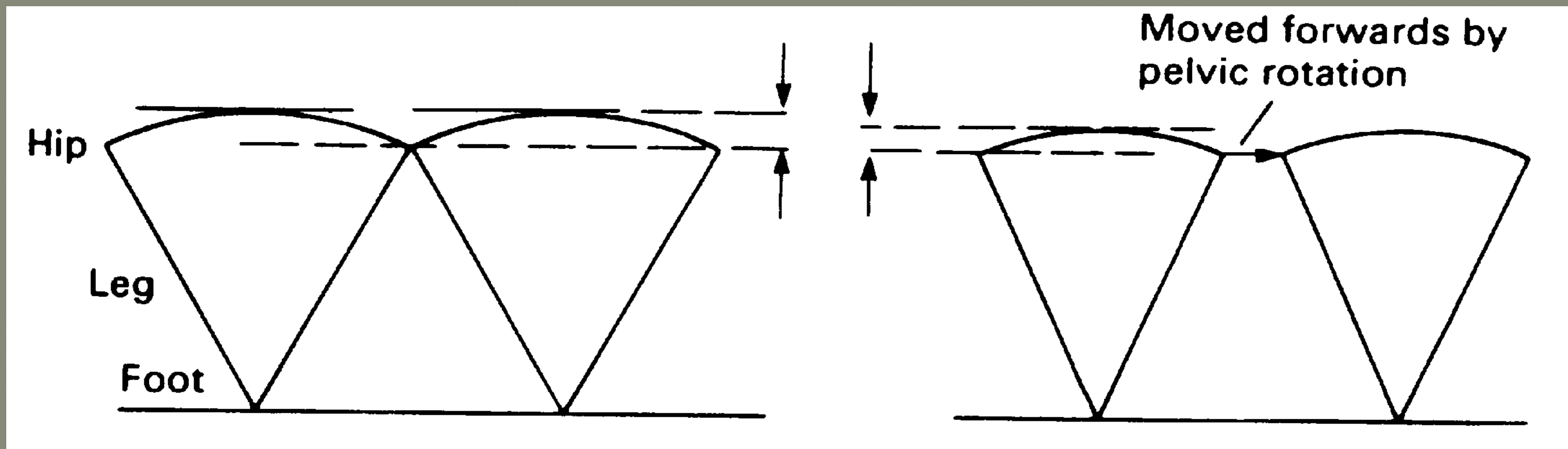
Path of Center of Gravity

B. <u>Lateral displacement</u>:

- Rhythmic side-to-side moveme
- Lateral limit: mid stance
- Average displacement: 5cm
- Path: extremely smooth sinusoidal curve

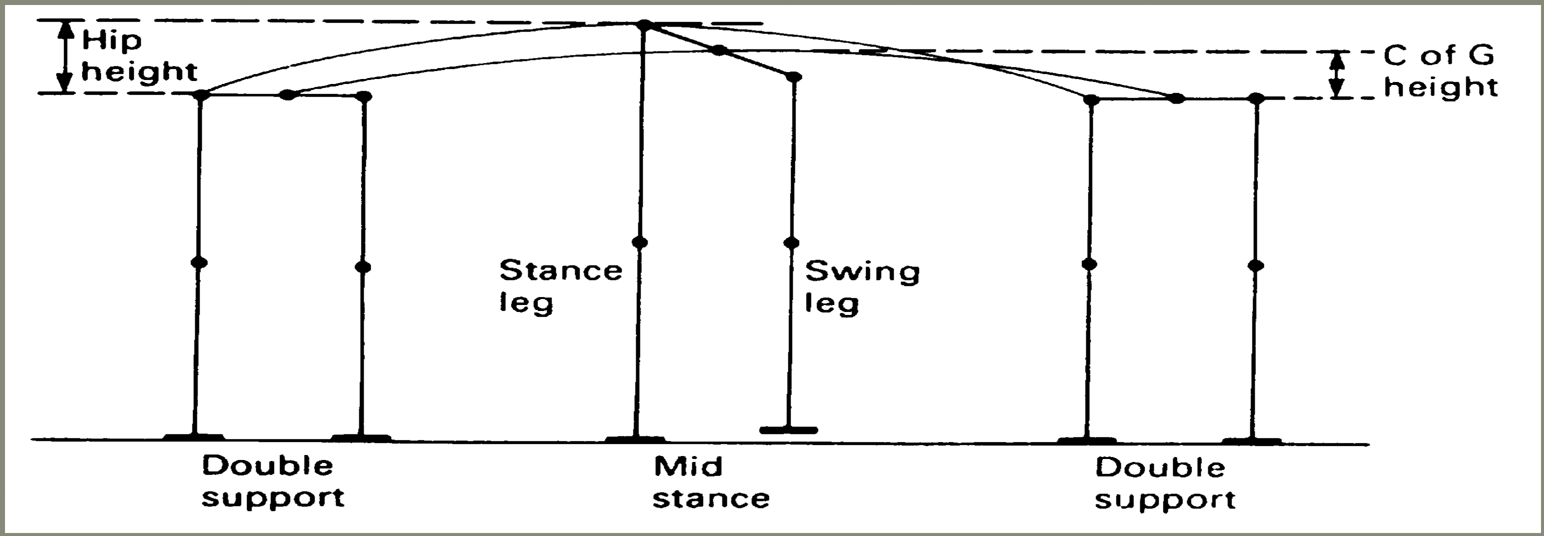


Determinants of Gait :



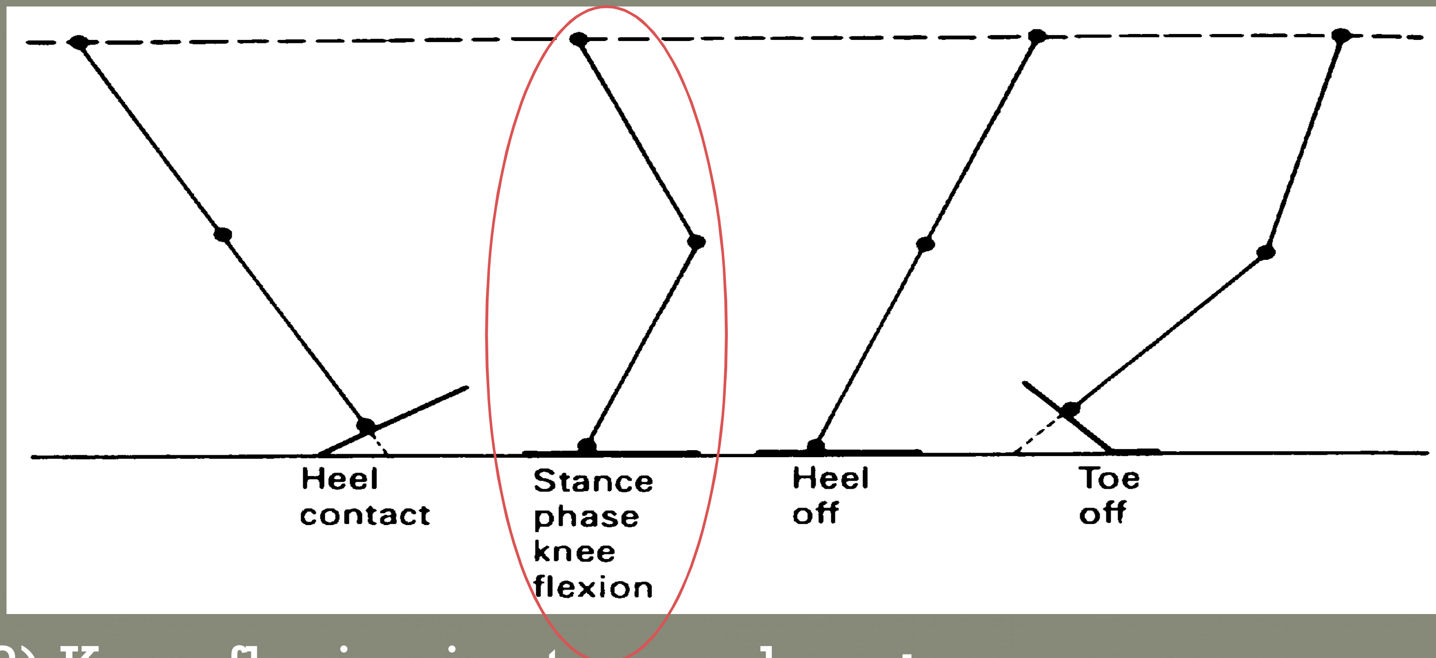
- (1) Pelvic rotation:
  - Forward rotation of the pelvis in the horizontal plane approx. 8° on the swing-phase side
  - Reduces the angle of hip flexion & extension
  - Enables a slightly longer step-length w/o further lowering of CG

Determinants of Gait :



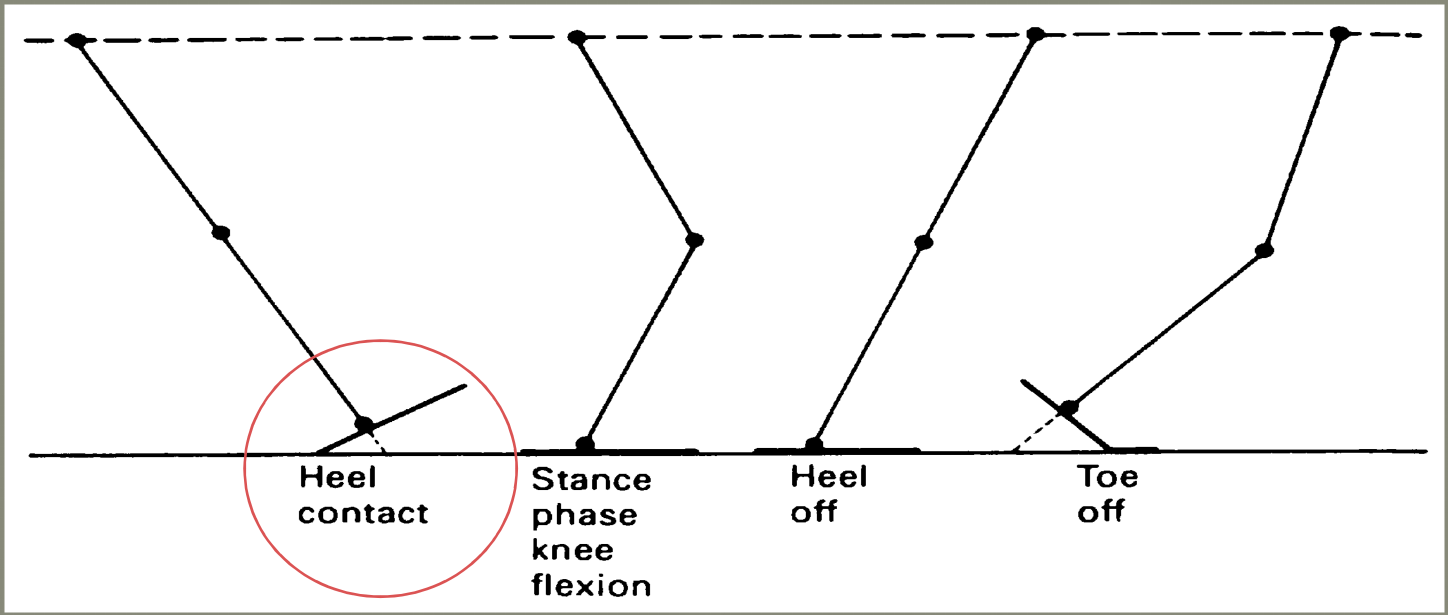
- (2) <u>Pelvic tilt</u>:
  - 5° dip of the swinging side (i.e. hip adduction)
  - In standing, this dip is a positive Trendelenberg sign
  - Reduces the height of the apex of the curve of CG

Determinants of Gait :



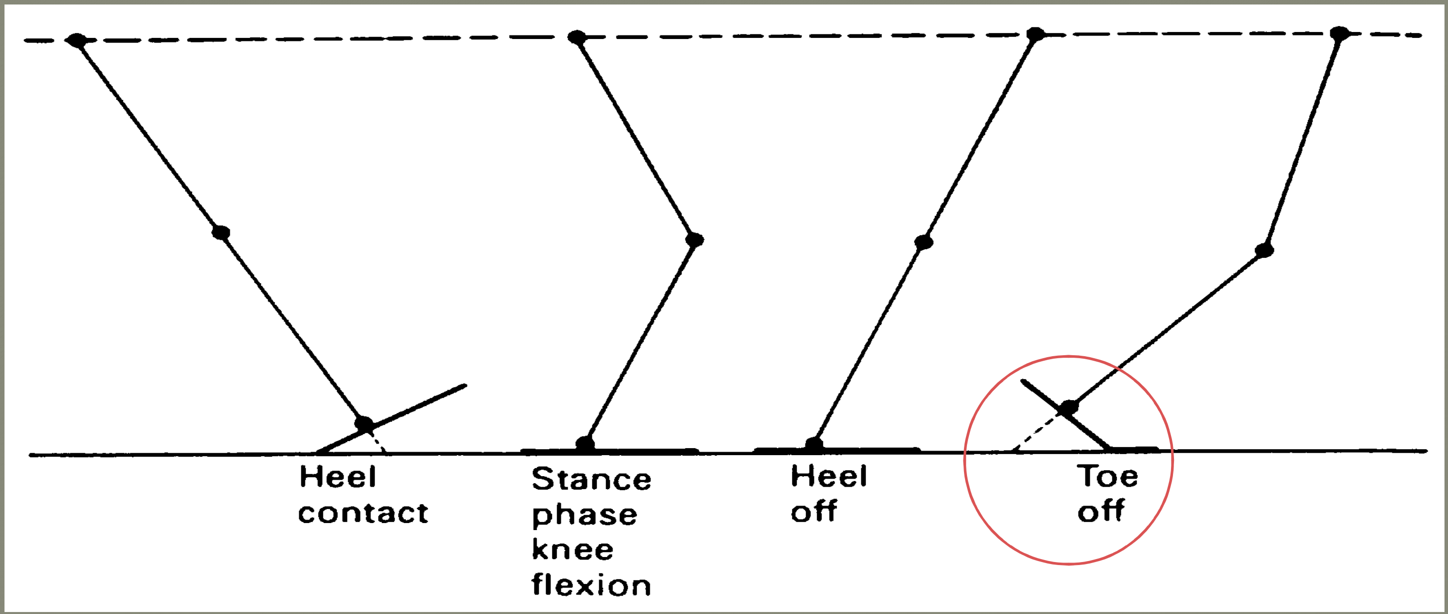
- (3) Knee flexion in stance phase:
  - Approx. 20° dip
  - Shortens the leg in the middle of stance phase
  - Reduces the height of the apex of the curve of CG

Determinants of Gait :



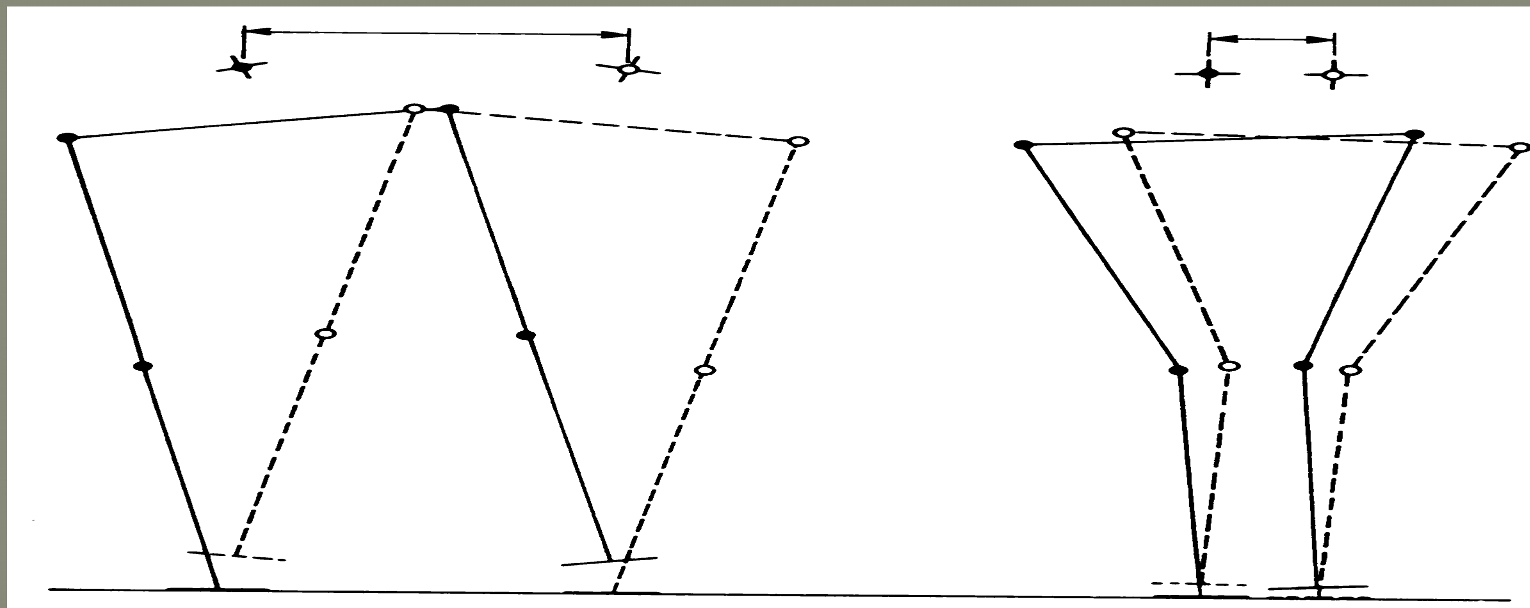
- (4) Ankle mechanism:
  - Lengthens the leg at heel contact
  - Smoothens the curve of CG
  - Reduces the lowering of CG

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 :



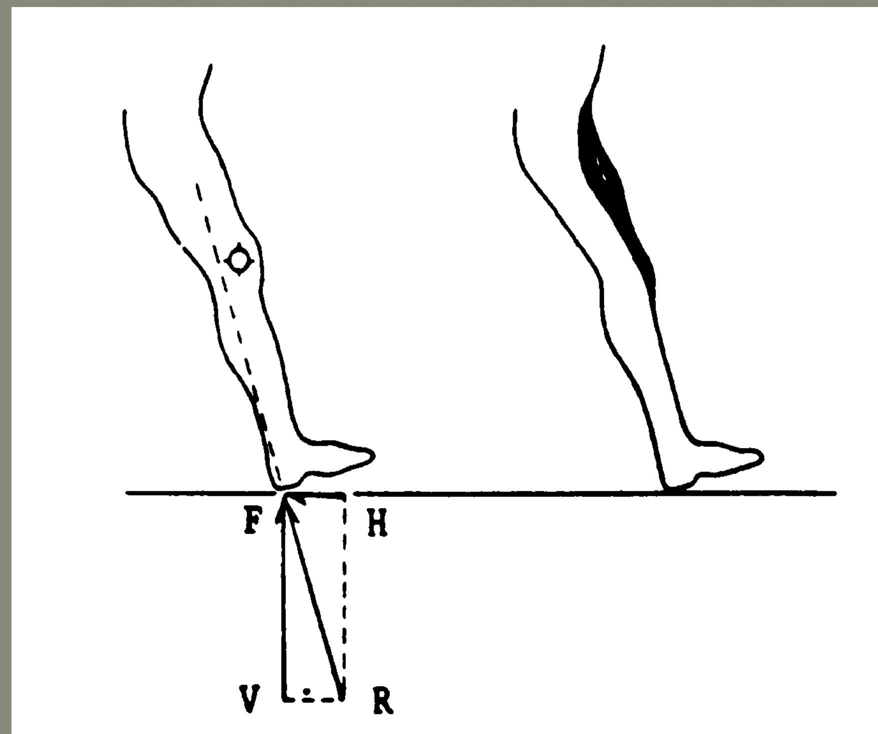
- (6) Lateral displacement of body:
  - The normally narrow width of the walking base minimizes the lateral displacement of CG
  - Reduced muscular energy consumption due to reduced lateral acceleration & deceleration

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:

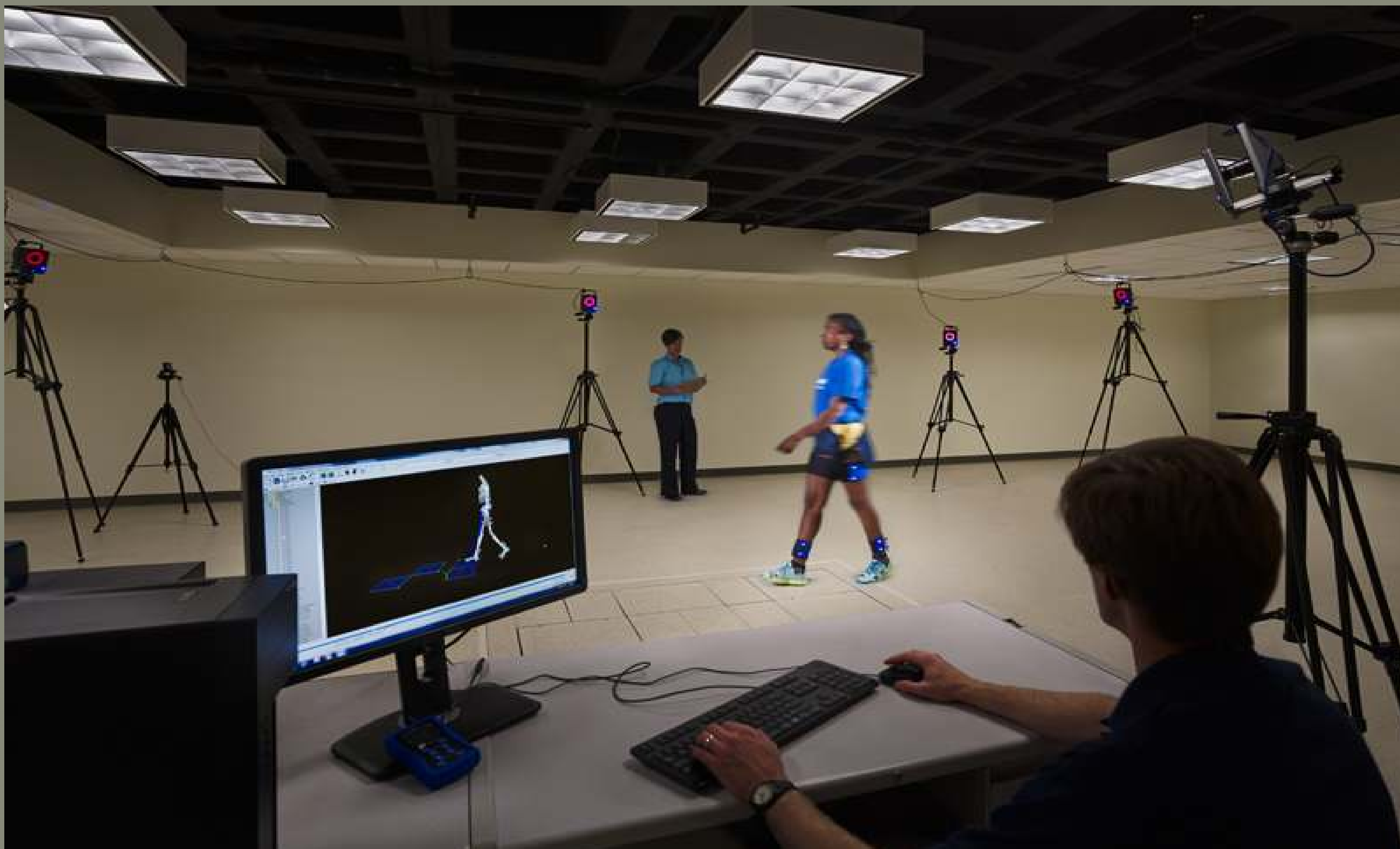
- The force that the foot exerts on the floor due to gravity & inertia is opposed by the ground reaction force
- Ground reaction force (RF) may be resolved into horizontal (HF) & vertical (VF) components.
- Understanding joint position & RF leads to understanding of muscle activity during gait



Muscular Control

- Muscle activation patterns are also cyclic during gait
- In normal individuals, agonist- antagonist co activation is of relatively short duration
- The presence of prolonged or out-or-phase agonist antagonist co activation during gait in individuals with pathology may indicate skeletal instability as well as motor control deficiencies

Gait Analysis Lab




DIGIVEC

Abnormal Gait Syndromes

- In general gait deviations fall under four headings:
  - Those caused by weakness
  - Those caused by abnormal joint position or range of motion
  - Those caused by muscle contracture
  - Those caused by pain

Abnormal Gait Syndromes

- Antalgic Gait
  - The antalgic gait pattern can result from numerous causes including joint inflammation or an injury to the muscles tendons and ligaments of the lower extremity
  - The antalgic gait is characterized by a decrease in the stance period on the involved side in an attempt to eliminate the weight from the involved leg and use of the un-injured body part as much as possible

Abnormal Gait Syndromes

- Equinus Gait
  - Equinus gait (toe-walking), one of the more common abnormal patterns of gait of patients with spastic diplegia, is characterized by forefoot strike to initiate the cycle and premature plantar flexion in early stance to midstance

Abnormal Gait Syndromes

- Gluteus maximus Gait
  - The gluteus maximus gait, which results from weakness of the gluteus maximus, is characterized by a posterior thrusting of the trunk at initial contact in an attempt to maintain hip extension of the stance leg
  - The hip extensor weakness also results in forward tilt of the pelvis, which eventually translates into a hyperlordosis of the spine to maintain posture

Abnormal Gait Syndromes

- Quadriceps Gait
  - Quadriceps weakness can result from a peripheral nerve lesion (femoral), a spinal berve root lesion, from trauma, or from disease (muscular dystrophy)
  - Quadriceps weakness requires that forward motion be propagated by circumducting each leg. The patient leans the body toward the other side to balance the center of gravity, and the motion is repeated with each step

Abnormal Gait Syndromes

- Spastic Gait
  - A spastic gait may result from either unilateral or bilateral upper motor neuron lesions
    - Spastic hemiplegic (hemiparetic) gait. This type of gait results from a unilateral upper motor neuron lesion and is frequently seen following a completed stroke
    - Spastic paraparetic gait. This type of gait results from bilateral upper motor neuron lesions (e.g., cervical myelopathy in adults and cerebral palsy in children)

Abnormal Gait Syndromes

- Ataxic Gait
  - The ataxic gait is seen in two principal disorders: cerebellar disease (cerebellar ataxic gait) and posterior column disease (sensory ataxic gait)

Abnormal Gait Syndromes

- **Steppage Gait**
  - This type of gait occurs in patients with a foot drop
  - A foot drop is the result of weakness or paralysis of the dorsiflexor muscles due to an injury to the muscles, their peripheral nerve supply, or the nerve roots supplying the muscles
  - The patient lifts the leg high enough to clear the flail foot off the floor by flexing excessively at the hip and knee, and then slaps the foot on the floor

Abnormal Gait Syndromes

- Trendelenburg Gait
  - This type of gait is due to weakness of the hip abductors (gluteus medius and minimus)
  - The normal stabilizing affect of these muscles is lost and the patient demonstrates an excessive lateral list in which the trunk is thrust laterally in an attempt to keep the center of gravity over the stance leg

Abnormal Gait Syndromes

- Parkinsonian Gait
  - The parkinsonian gait is characterized by a flexed and stooped posture with flexion of the neck, elbows, metacarpophalangeal joints, trunk, hips, and knees
  - The patient has difficulty initiating movements and walks with short steps with the feet barely clearing the ground. This results in a shuffling type of gait with rapid steps

Abnormal Gait Syndromes

- Hysterical Gait
  - The hysterical gait is non-specific and bizarre
  - It does not conform to any specific organic pattern with the abnormality varying from moment to moment and from one examination to another
  - There may be ataxia, spasticity, inability to move, or other types of abnormality
  - The abnormality is often minimal or absent when the patient is unaware of being watched or when distracted

Posture

- Good posture is a subjective term reflecting what the clinician believes to be correct based on ideal models.
- Generally speaking muscles can be subdivided into:
  - Postural muscles
  - Phasic muscles

Posture

- The ability to maintain correct posture is related to a number of factors, which includes but is not limited to:
  - Energy cost
  - Strength and flexibility
  - Structural deformities
  - Disease
  - Pain

THANKS