Normal & Pathological Gait

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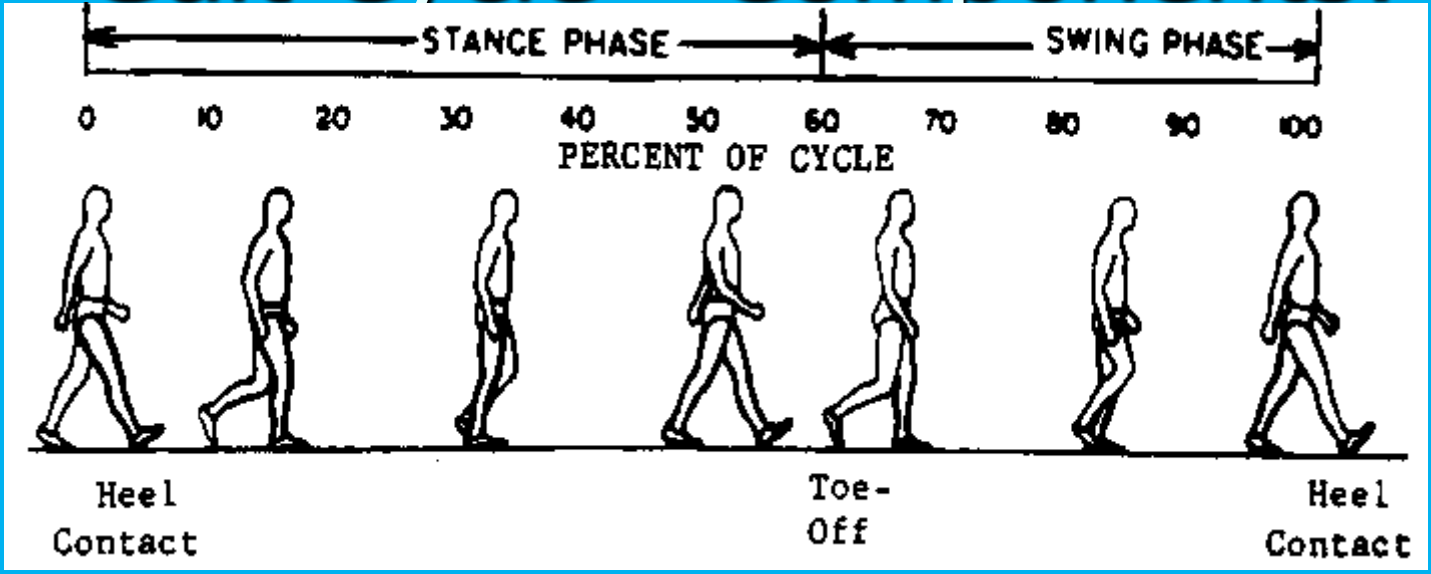
Gait Cycle - Definitions:

- 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'

Task involves in walking

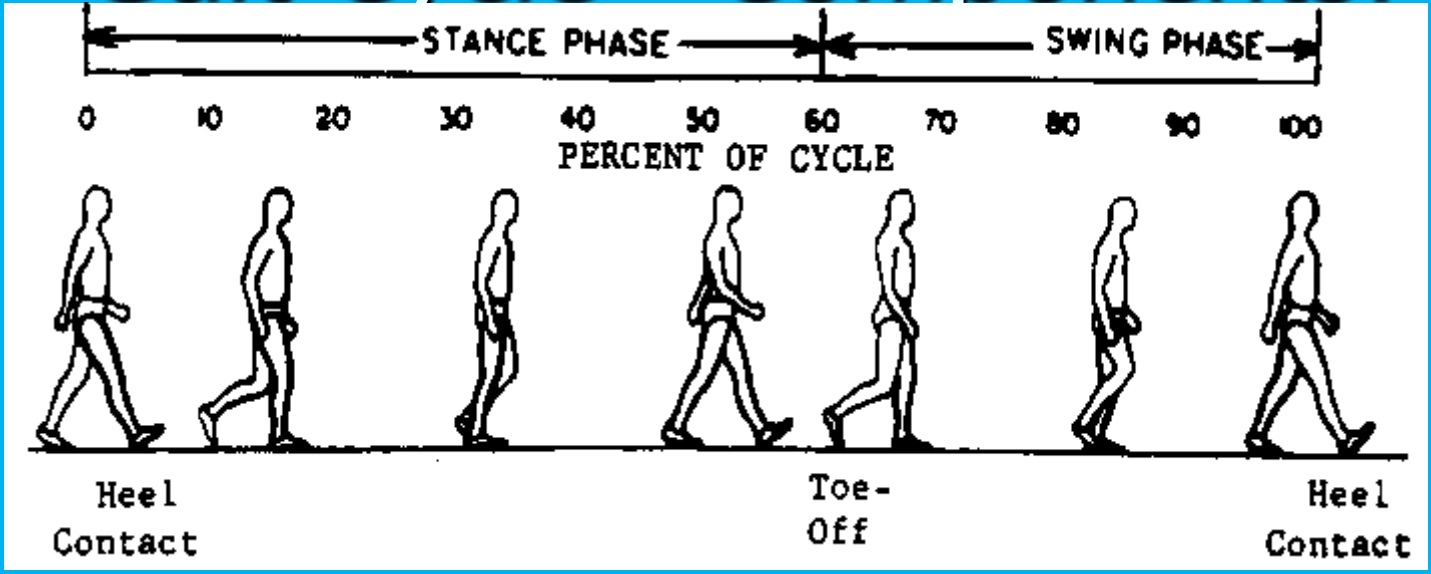
- According to "Rancho Los Amigos" (RLA), California
  - Weight acceptance
  - Single limb support
  - Swing limb advance

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**

Gait Cycle - Components:



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

Kinematics of gait

Phases of gait

- Stance phase
- Swing phase

Stance phase

- It begins at the instant that one extremity contacts the ground & continuous only as long as some portion of the foot is in contact with the ground.
- It is approx 60% of normal gait duration.

Swing phase

- It begins as soon as the toe of one extremity leaves the ground & ceases just before heel strike or contact of the same extremity.
- It makes up 40% of normal gait cycle.

Double support

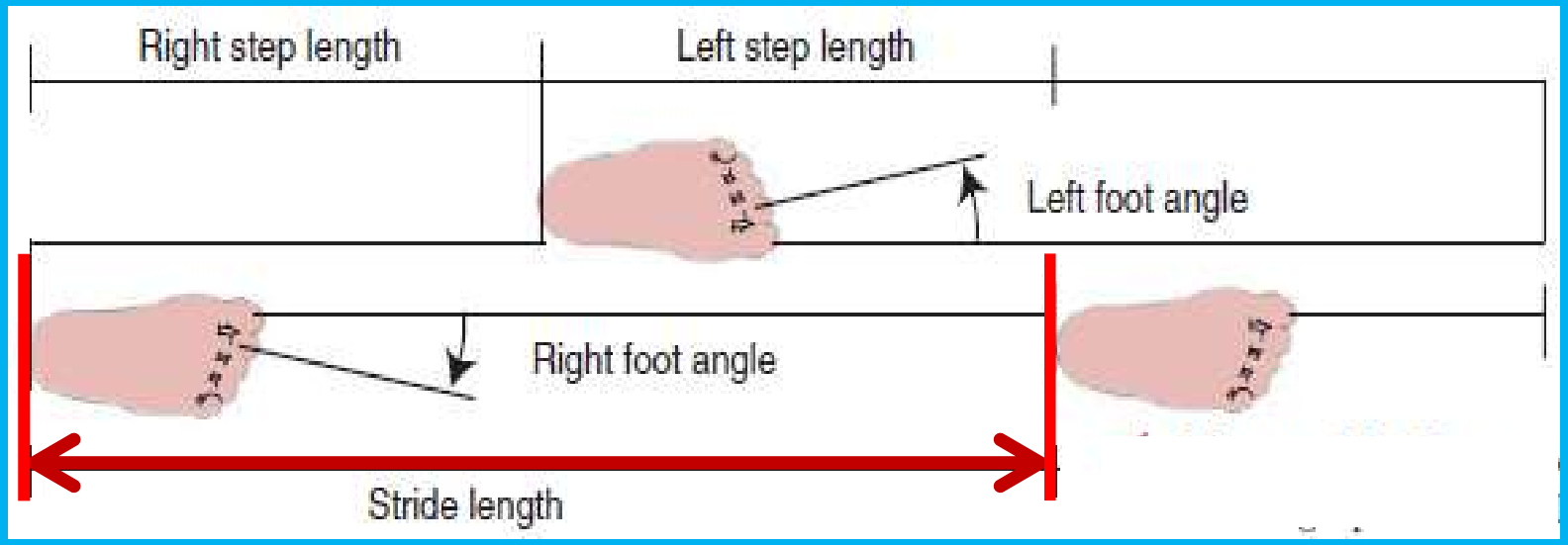
- Lower limb of one side of body is beginning its stance phase & the opposite side is ending its stance phase.
- During double support both the lower limb are in contact with the ground at the same time.
- It account approx 22% of gait cycle.
- This phase is absent in running

variables

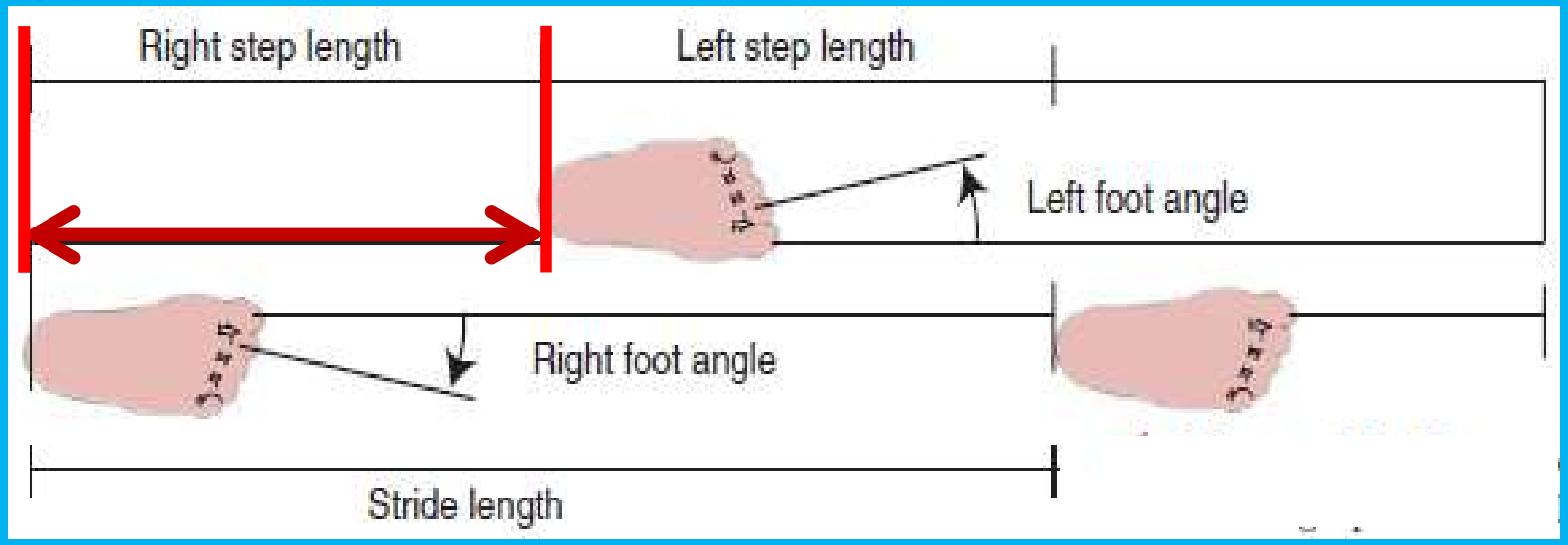
- Temporal variable –
  - Stance time
  - Single-limb & double-support time,
  - Swing time,
  - Stride and step time,
  - Cadence
  - Speed

- Distance variable –
  - Stride length
  - Step length and width
  - Degree of toe-out

- Stride length:
  - It is the linear distance from the heel strike of one lower limb to the next heel strike of the same limb.



- **Step length**:
  - It is the linear distance from the heel strike of one lower limb to the next heel strike of opposite limb.



- Stride duration:
  - It refers to amount of time taken to accomplish one stride.
  - Stride duration and gait cycle duration are synonymous.
  - One stride, for a normal adult, lasts approx 1 sec

- Step duration:
  - It refers to the amount of time spent during a single step.
  - Measurement usually is expressed as sec/step.
  - When weakness or pain in limb, step duration may be decreased on the affected side and increased on the unaffected side.

- Cadence:
  - It is the no of steps taken by a person per unit of time.
  - It is measured as the no of steps / sec or per minute.

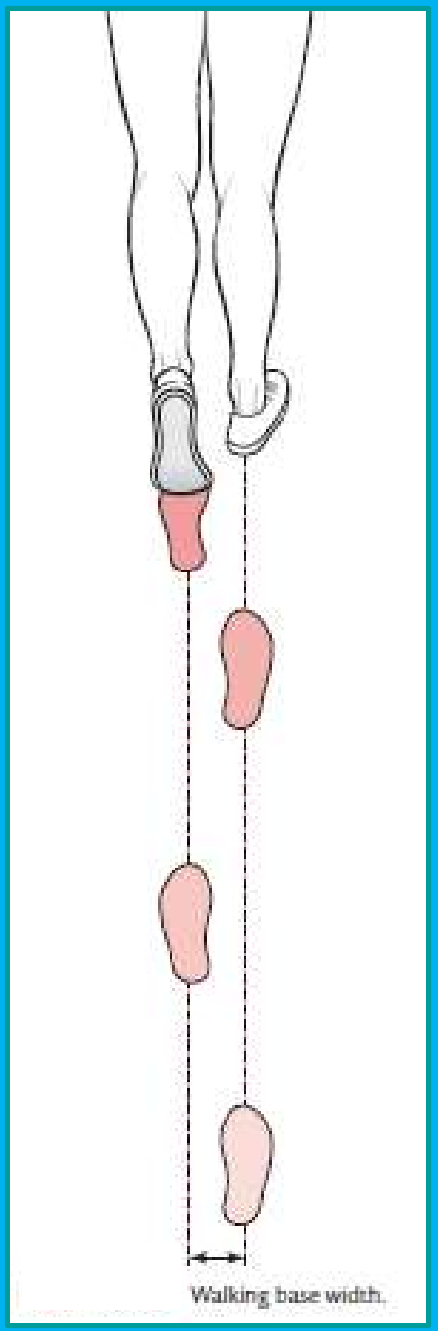
Cadence = Number of steps / Time

- Walking velocity:
  - It is the rate of linear forward motion of the body, which can be measured in meters or cm/second, meters/minute, or miles/hour.

Walking velocity (meters/sec)=Distance walked (meters)/time (sec)

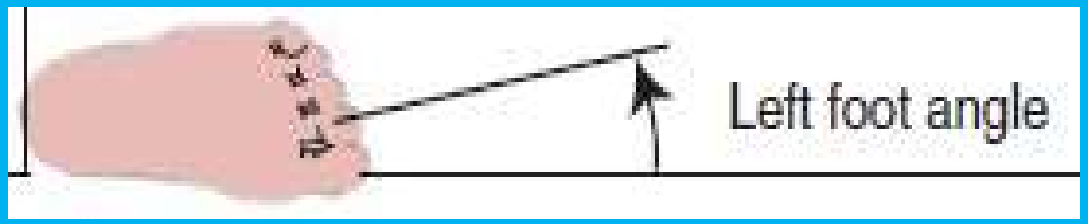
- Speed of gait:
  - It is referred to as slow, free, and fast.
    - Free speed of gait refers to a person's normal walking speed
    - Slow & fast speeds of gait refer to speeds slower or faster than the person's normal comfortable walking speed, designated in a variety of ways.

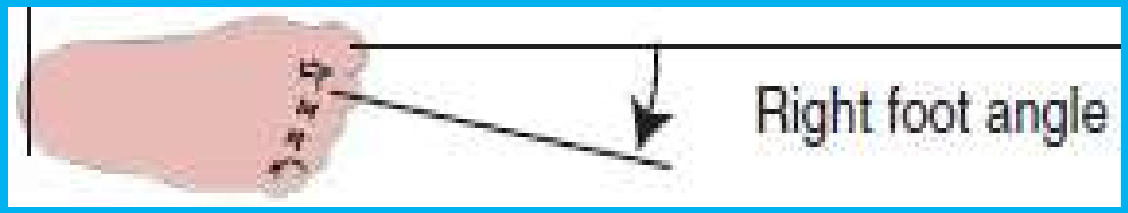
- Step width or width of the walking base:
  - It is the measure of linear distance between the midpoint of the heel of one foot and the same point on the other foot



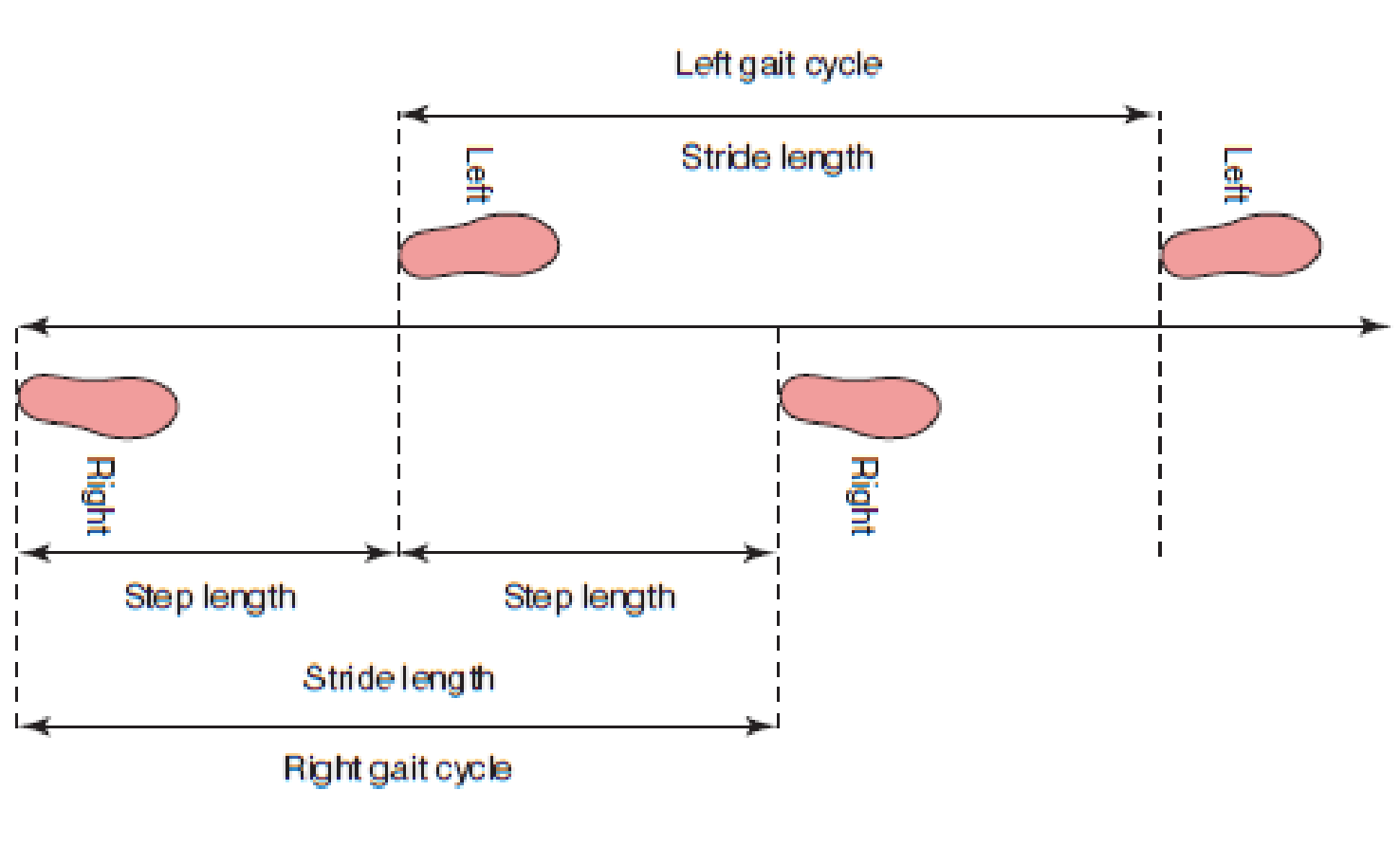
- Degree of toe-out (DTO):
  - It represents the angle of foot formed by each foot's line of progression and a line intersecting the centre of the heel and the second toe.
  - The angle for men is about 7^0 from the line of progression of each foot at free speed walking.
  - The DTO decreases as the speed of walking increases in normal men.

Degree of toe out



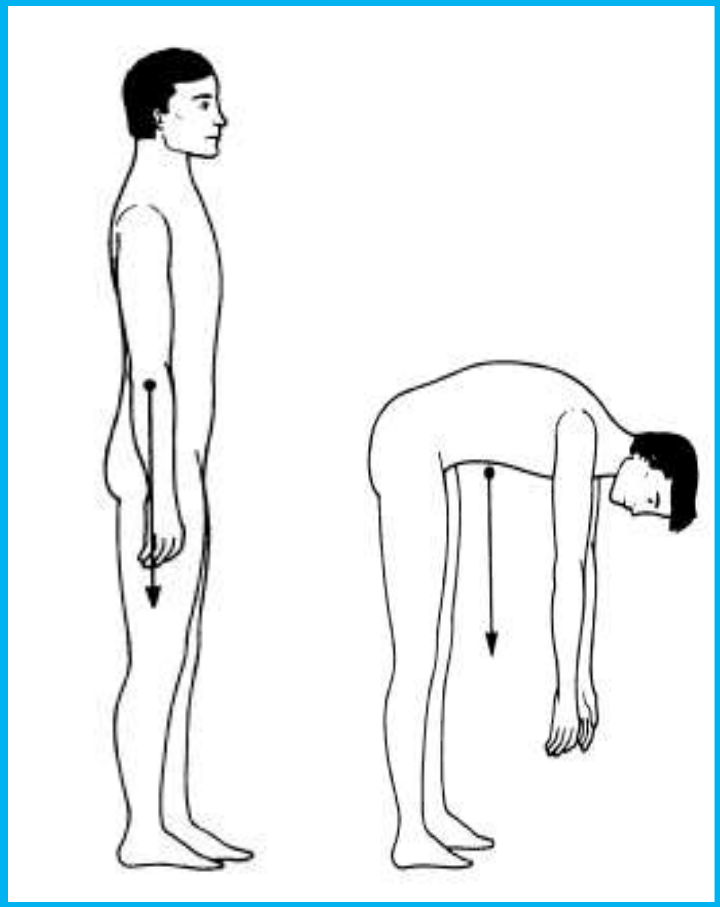


Variables of gait



Path of COG

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



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

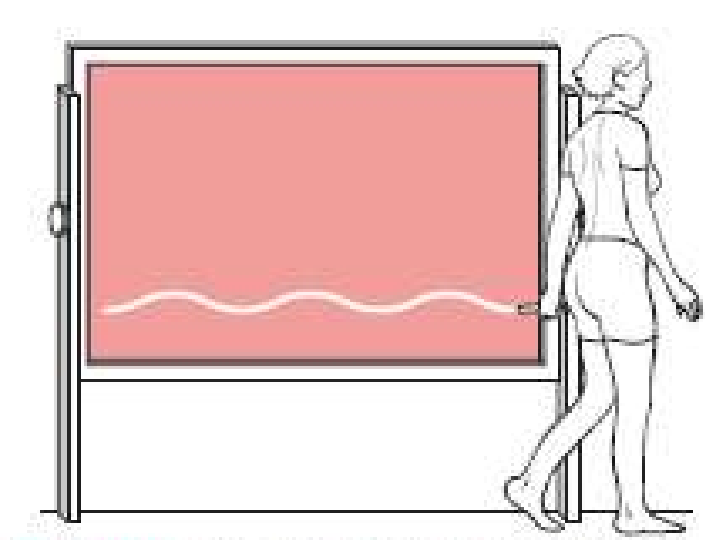
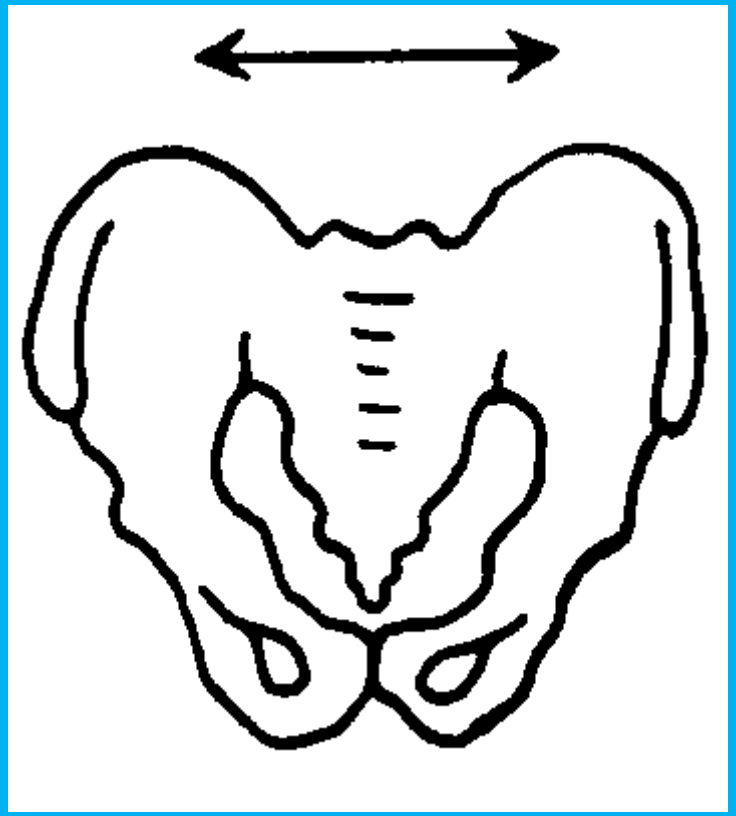
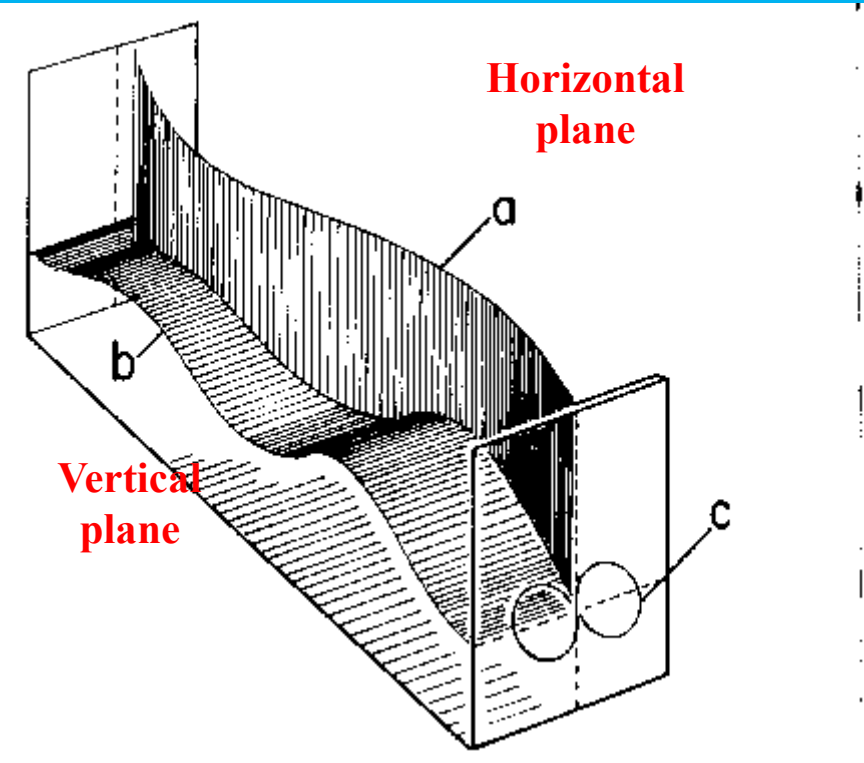


Figure 21-13. Vertical displacement of the body's center of gravity during the gait cycle.

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



- Overall displacement:
  - Sum of vertical & horizontal displacement
  - movement of CG as seen from AP view



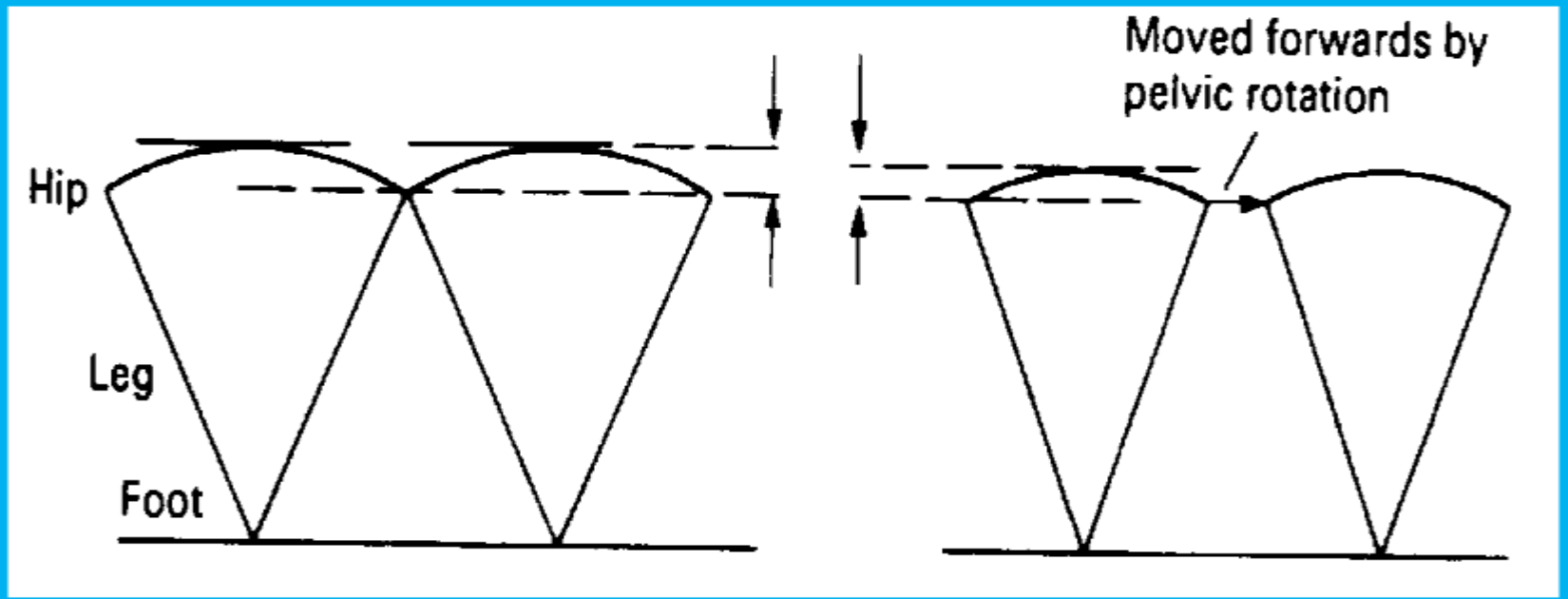
Saunders' Determinants of gait

- Gait "determinants" was first described by "Saunders & Coworkers" in 1953.
- Six optimizations used to minimize excursion of CG in vertical & horizontal planes.

DETERMINANTS OF GAIT

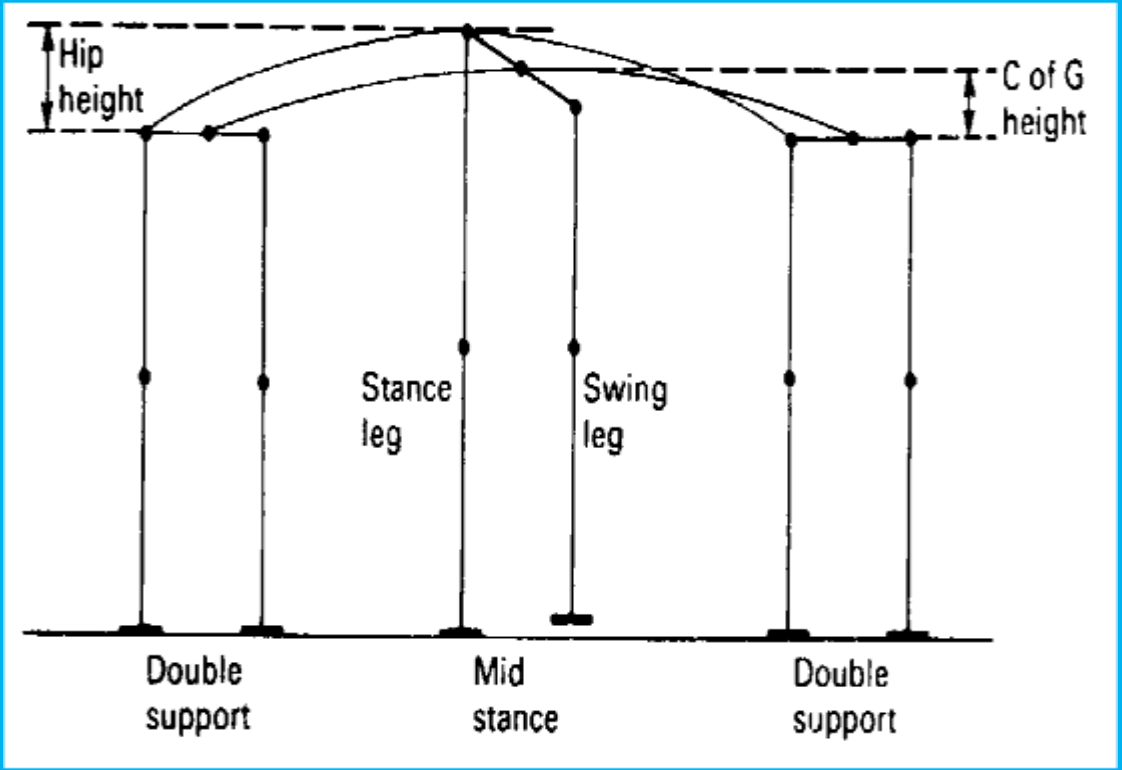
1) Pelvic rotation:

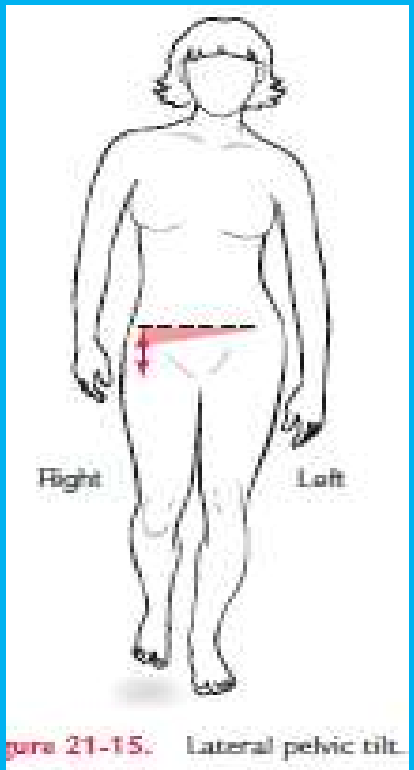
- Forward rotation of the pelvis in the horizontal plane approx. 8o on the swing-phase side
- Reduces the angle of hip flexion & extension
- Enables a slightly longer step-length w/o further lowering of CG



(2) Pelvic tilt:

- 5 degree 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

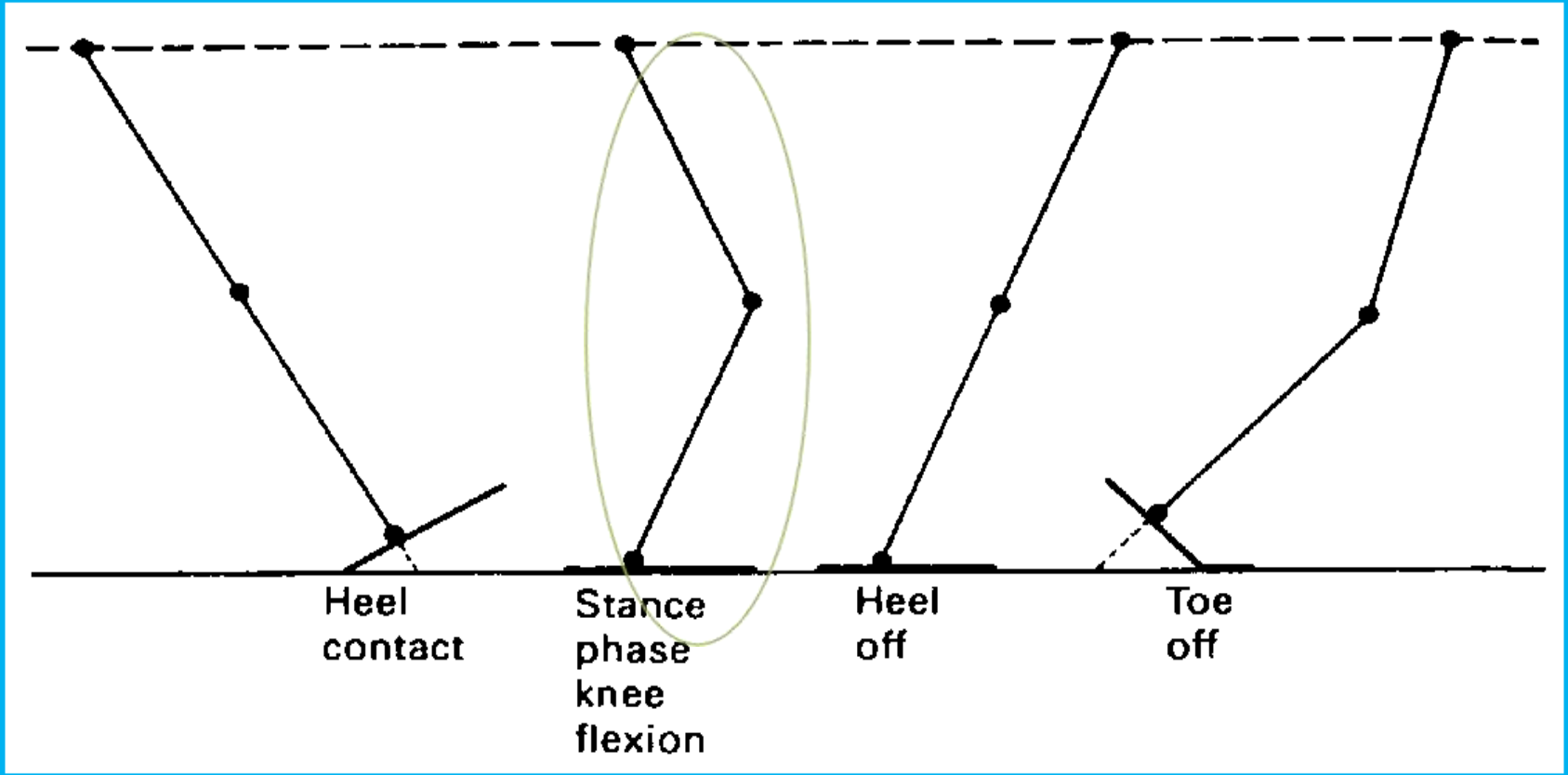




gure 21-15. Lateral pelvic tilt.

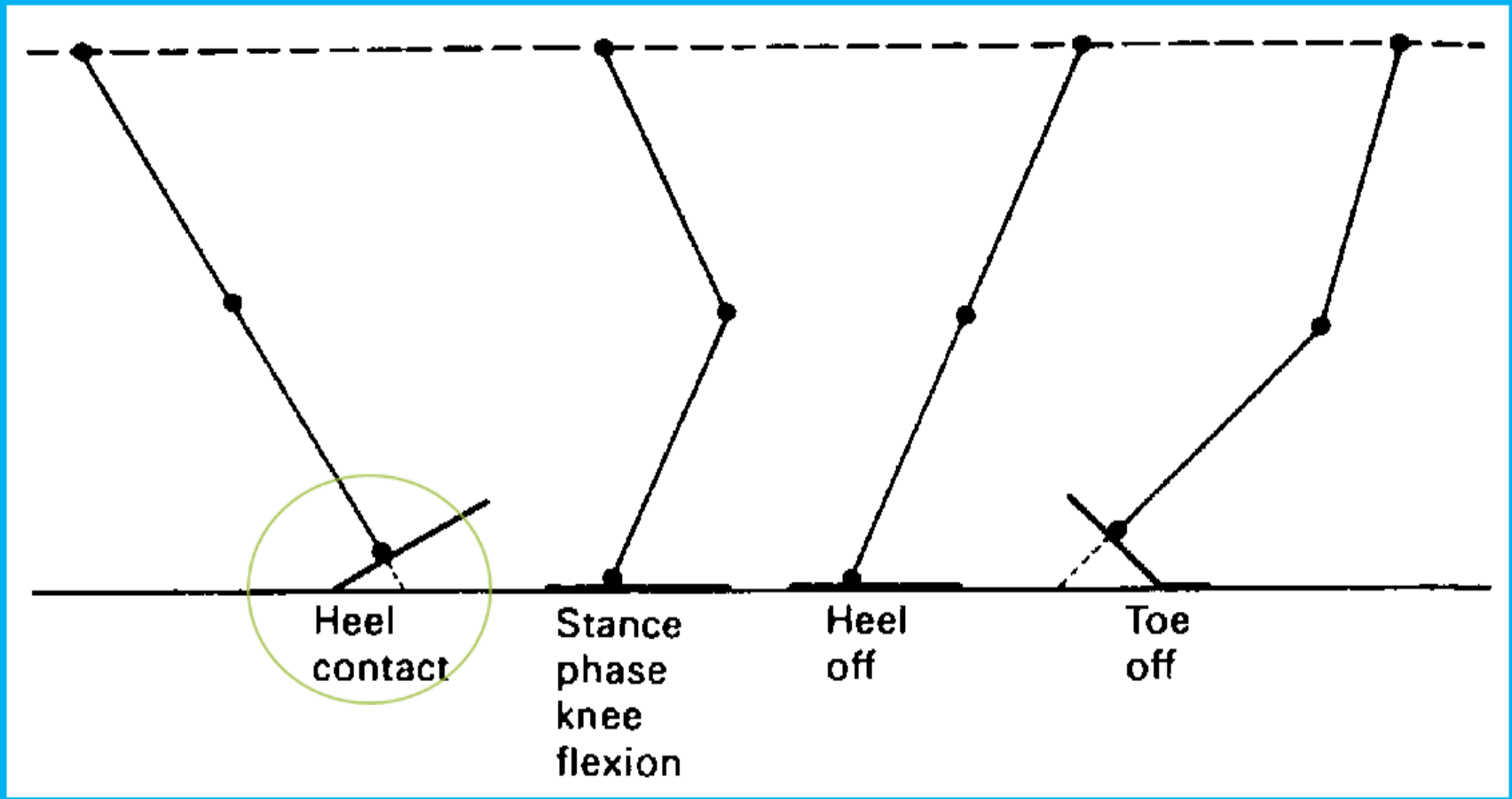
(3) Knee flexion in stance phase:

- Approx. 20o dip
- Shortens the leg in the middle of stance phase
- Reduces the height of the apex of the curve of CG



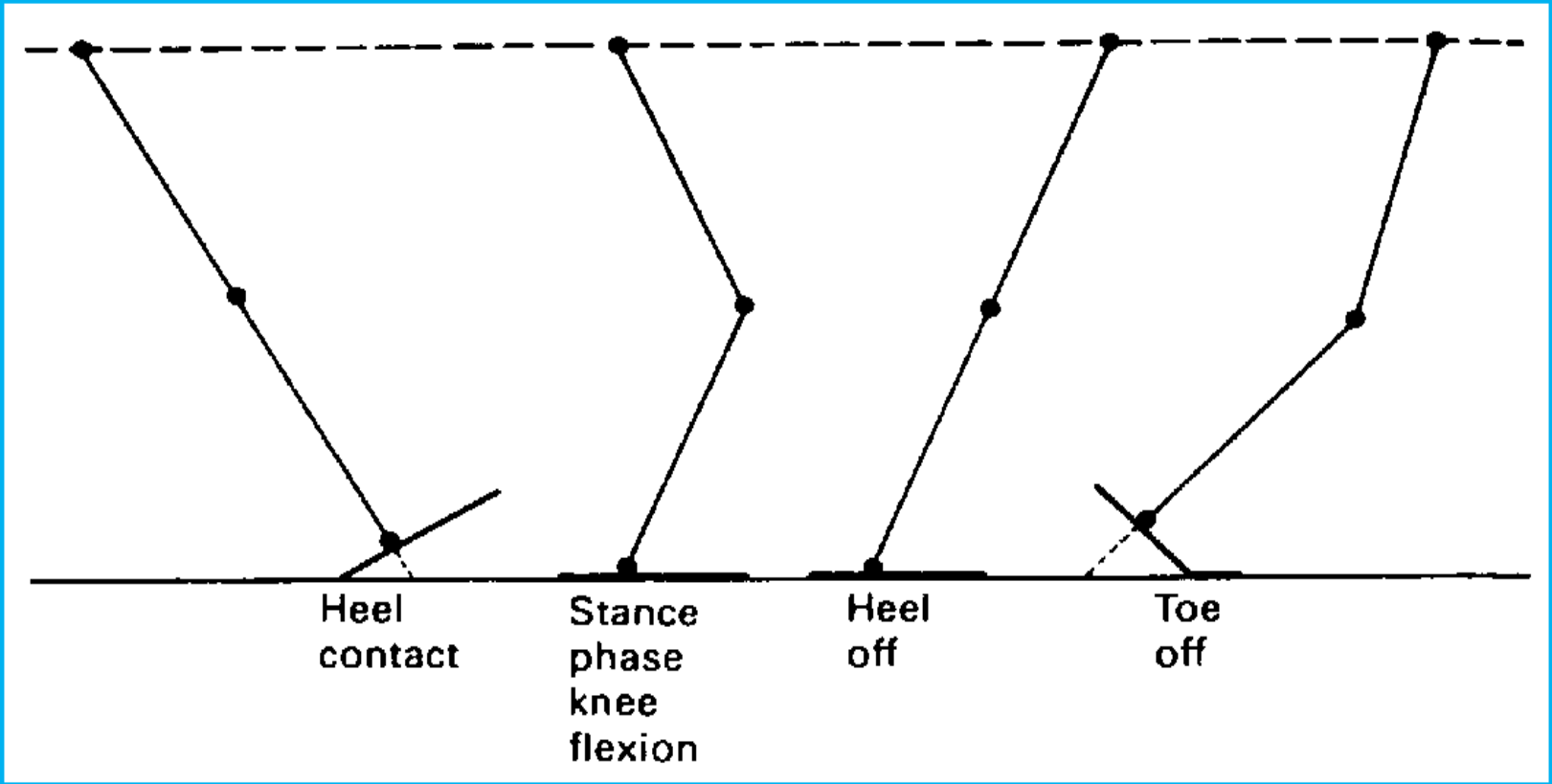
(4) Ankle mechanism:

- Lengthens the leg at heel contact
- Smoothens the curve of CG
- Reduces the lowering of CG



(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

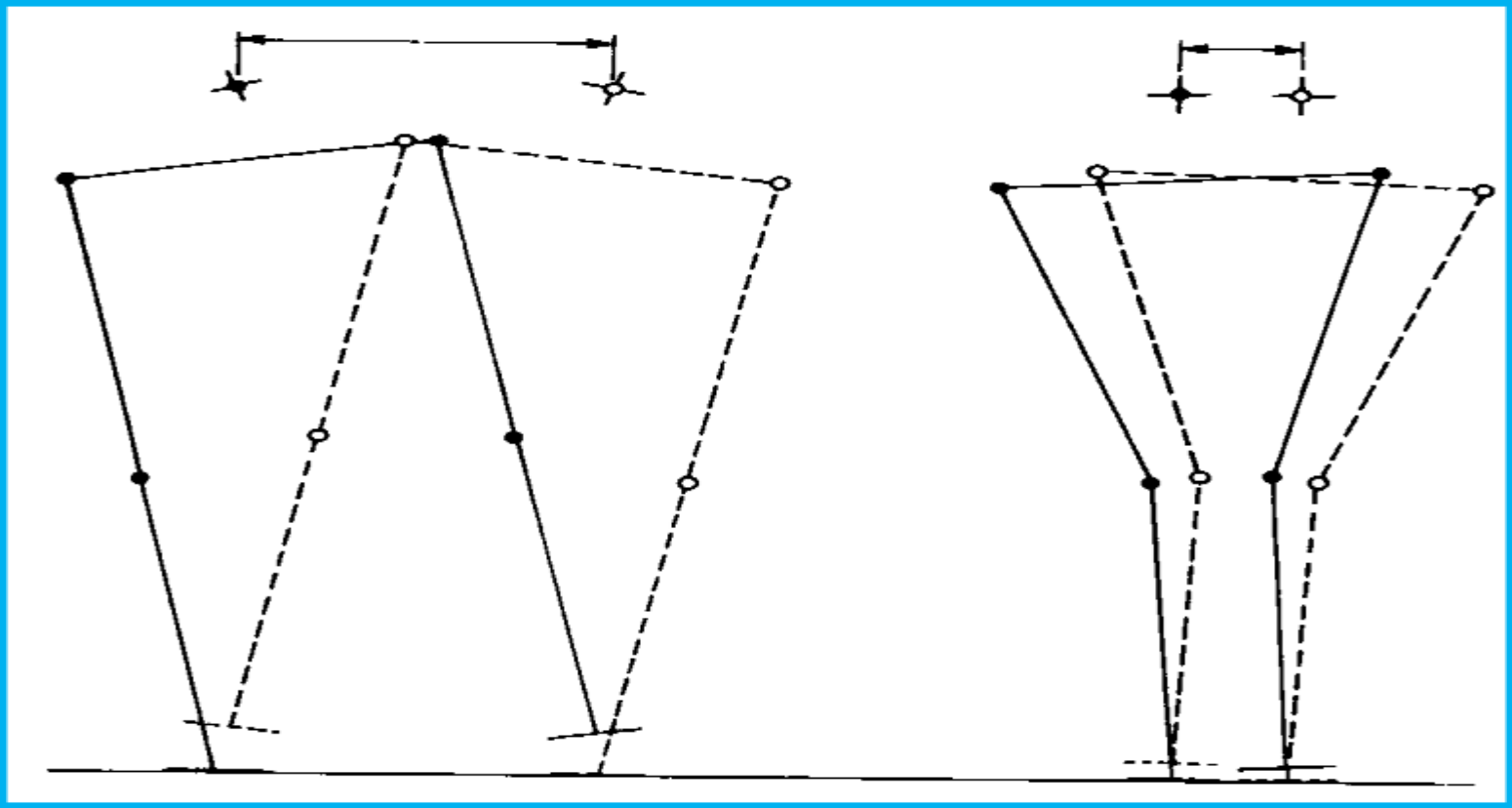


Lateral displacement of body

- Physiologic valgus of the knee reduce side-to-side movement of the COM in frontal plane.
- The normally narrow width of the walking base minimizes the lateral displacement of CG
- Reduced muscular energy consumption due to reduced lateral acceleration & deceleration

- Physiological valgus of knee

  Reduces the base of support, so only little lateral motion of pelvis is necessary.

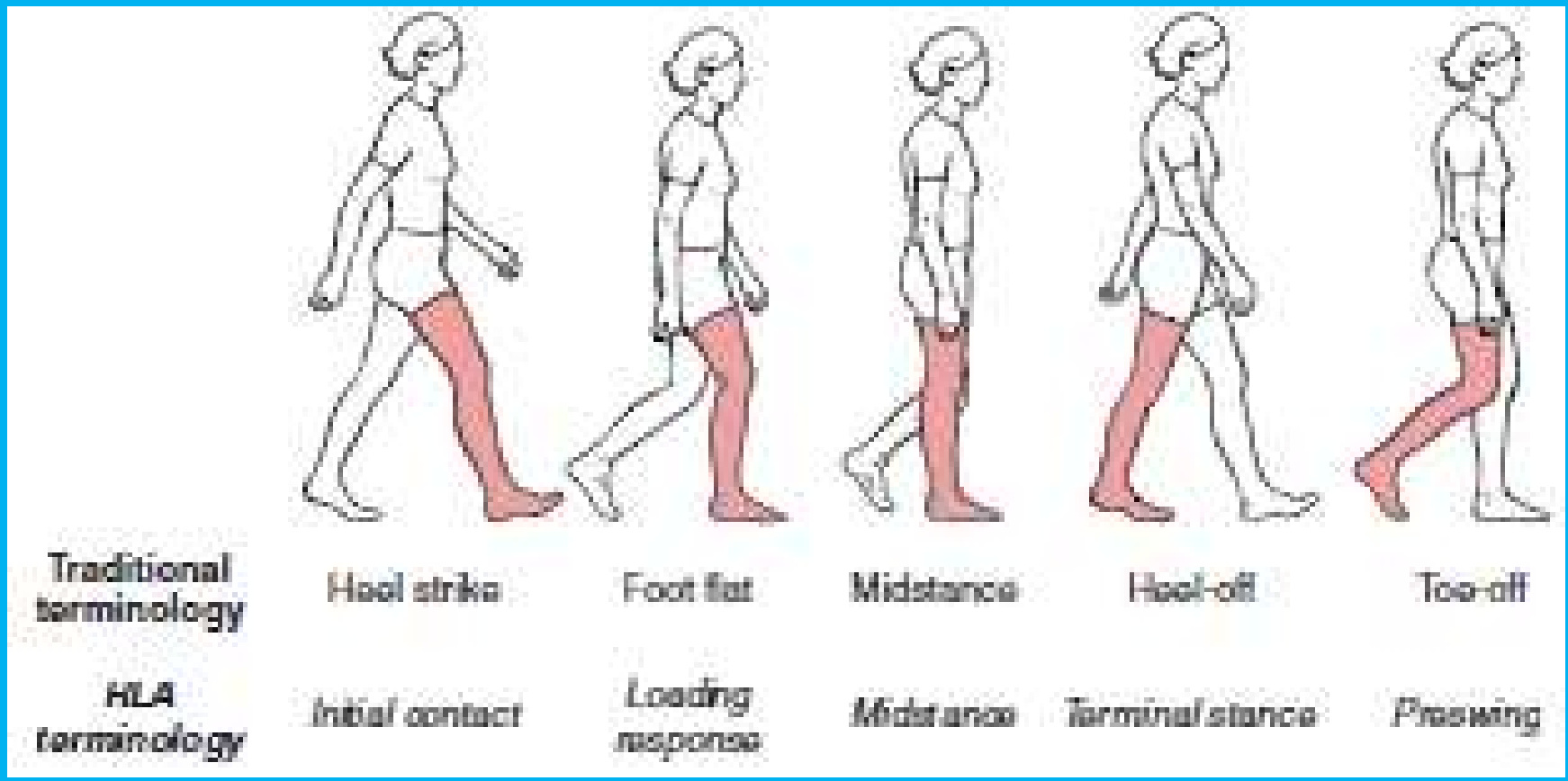


Comparison of gait terminology

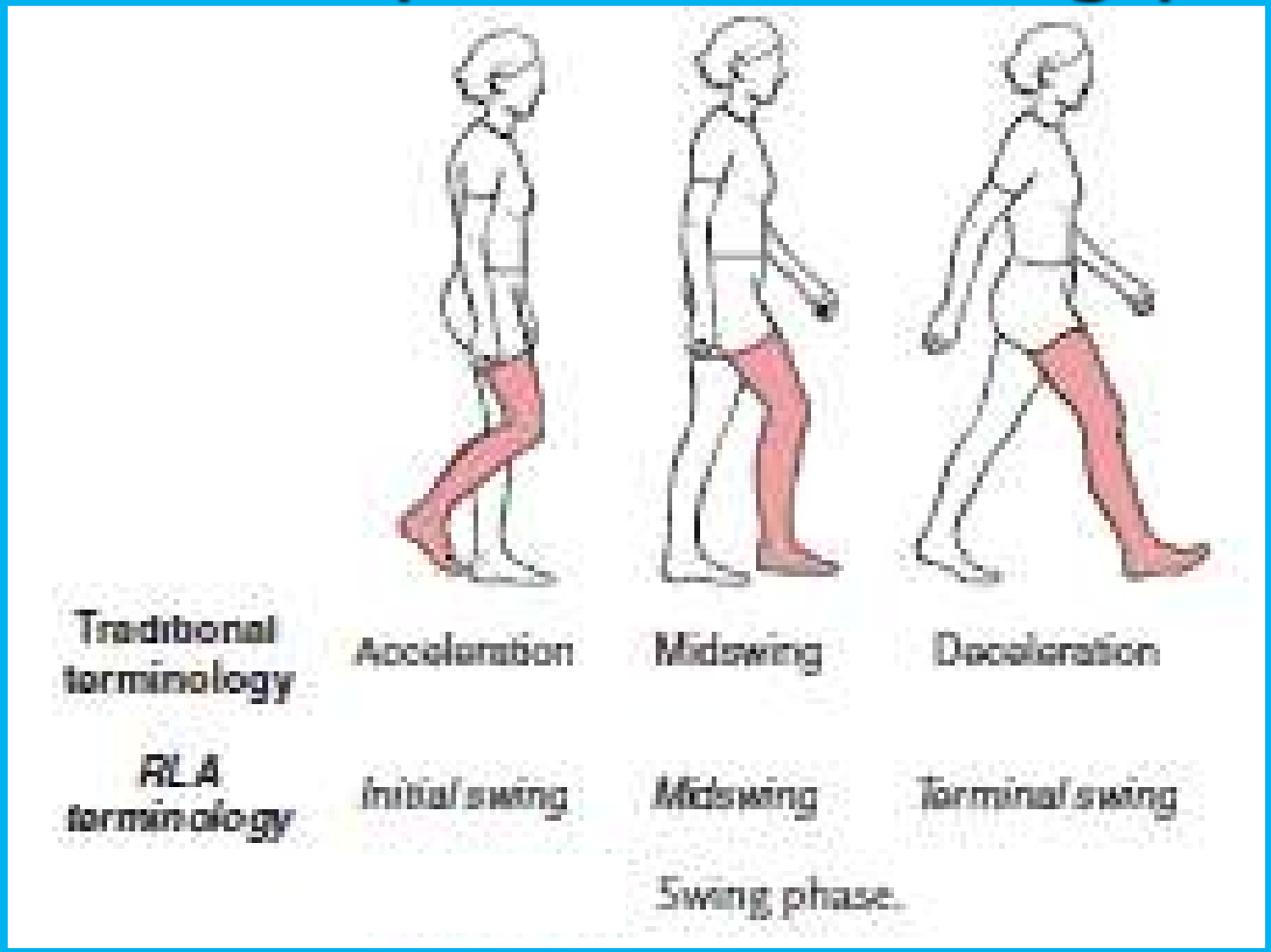
- Traditional –
  1) Heel strike
  2) Foot flat
  3) Mid-stance
  4) Heel off
  5) Toe off
  6) Acceleration
  7) Mid-swing
  8) Deceleration

- RLA –
  1) Initial contact
  2) Loading response
  3) Mid-stance
  4) Terminal stance
  5) Pre-swing
  6) Initial swing
  7) Mid-swing
  8) Terminal swing

Sub component of stance phase



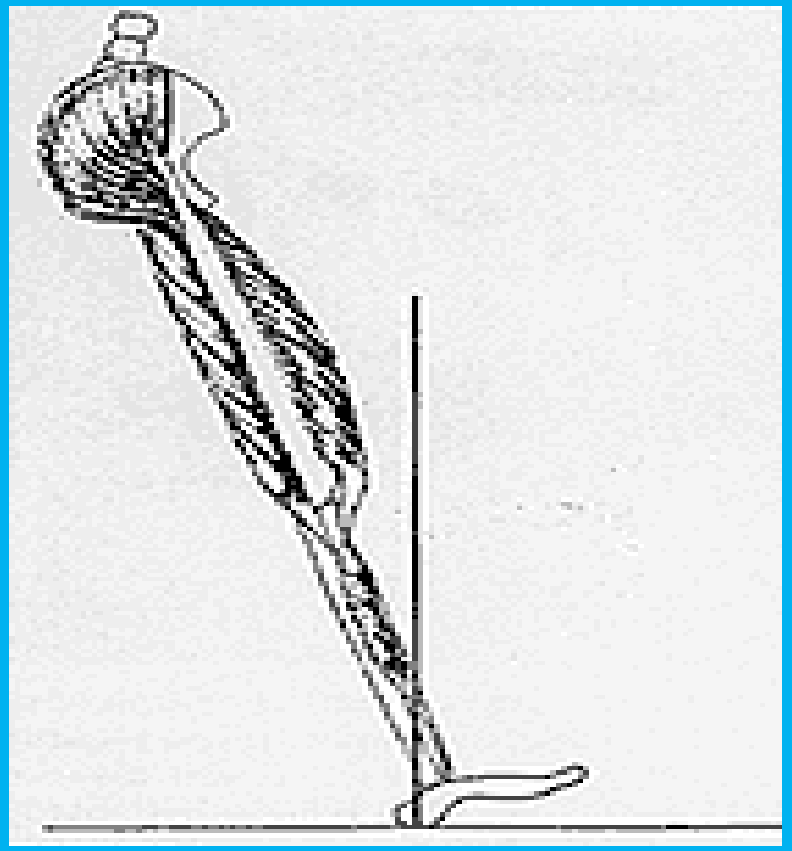
Sub component of swing phase



RLA phases of gait

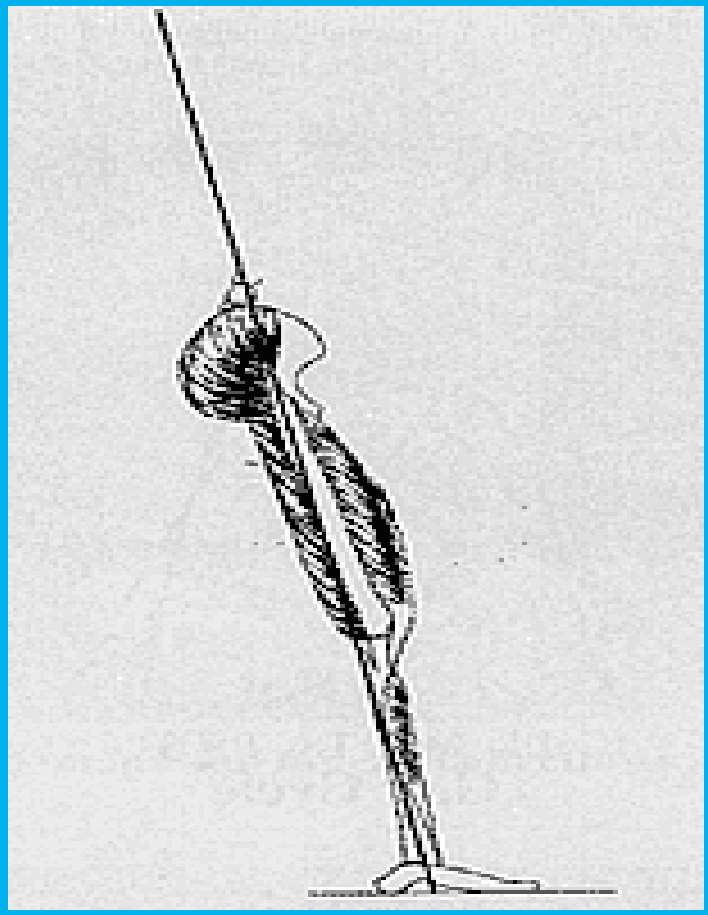
Initial contact

- It refer to the initial contact of the foot of leading lower limb.
- Normally the heel pointed first to contact.
- In abnormal gait it is possible to either whole foot or toes rather than the heel to strike.



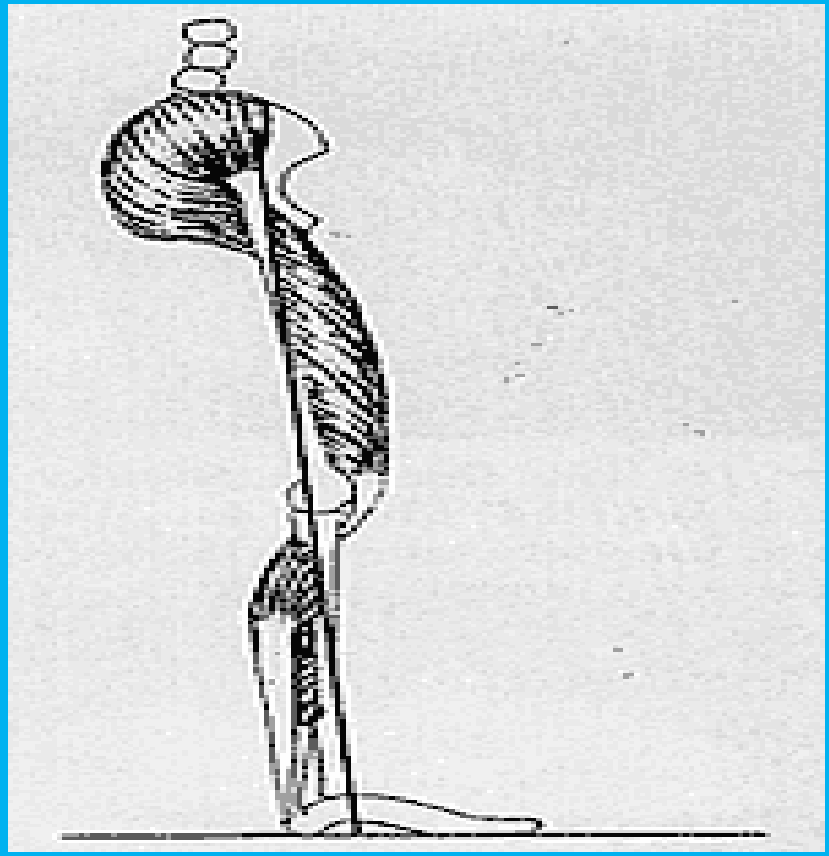
Loading response

- Begins at initial contact & ends when the contra lateral extremity lifts off the ground at the end of the double-support phase.
- It occupies about 10% of gait
- First rocker



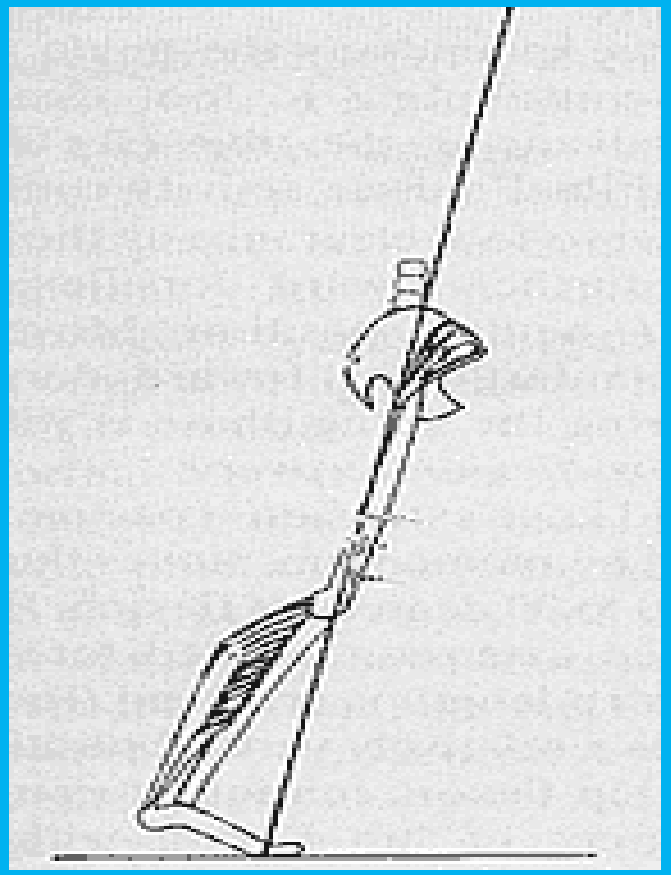
Mid-stance phase (RLA)

- Begins when the contra-lateral extremity lifts off the ground at about 11% of the gait cycle
- Ends when the body is directly over the supporting limb at about 30% of the gait cycle.
- 2nd rocker



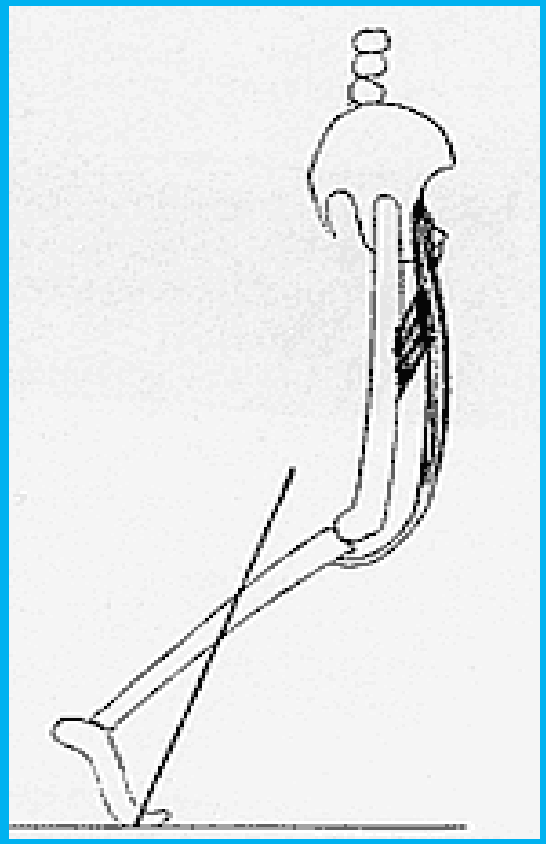
Terminal stance (RLA)

- Begins when the body is directly over the supporting limb at about 30% of the gait cycle
- Ends just before initial contact of the contra-lateral extremity at about 50% of the gait cycle.
- 3rd rocker.



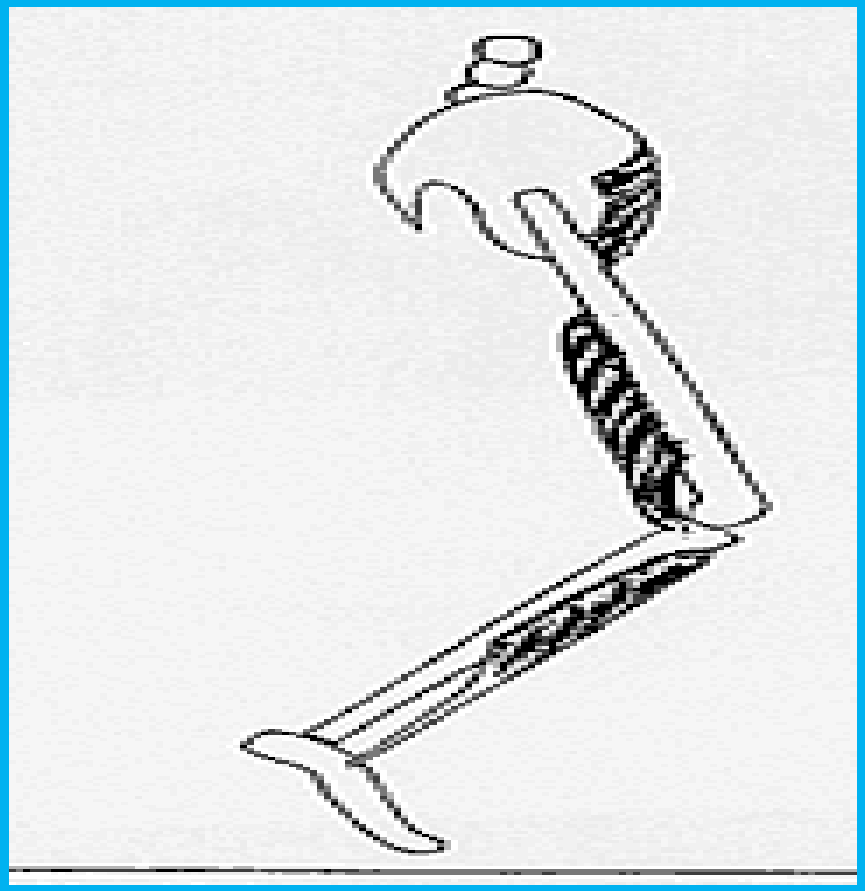
Pre-Swing (RLA)

- It is the last 10% of stance phase and begins with initial contact of the contra-lateral foot (at 50% of the gait cycle) and ends with toe-off (at 60%).



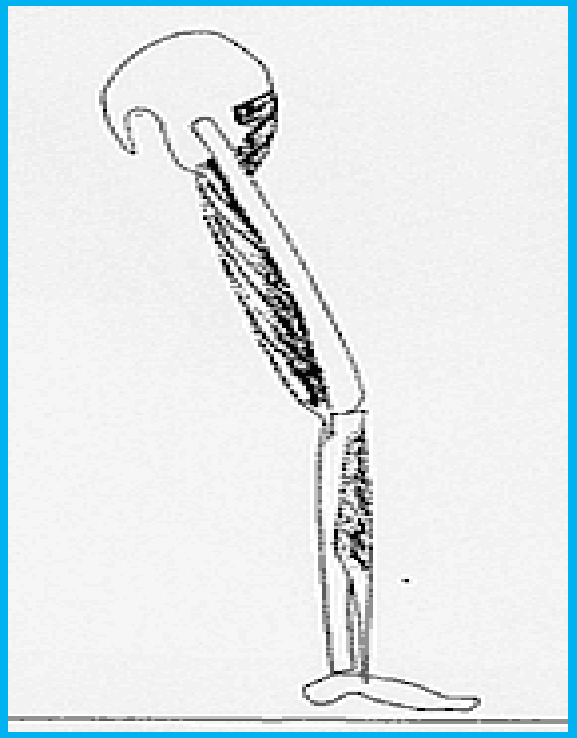
Initial swing (RLA)

- Begins when the toe leaves the ground & continues until max knee flexion occurs.
- Ankle 20 deg. Plantar flexion (max.)
- Knee 60 deg. Flexion.
- Hip 20 deg. Flexion.



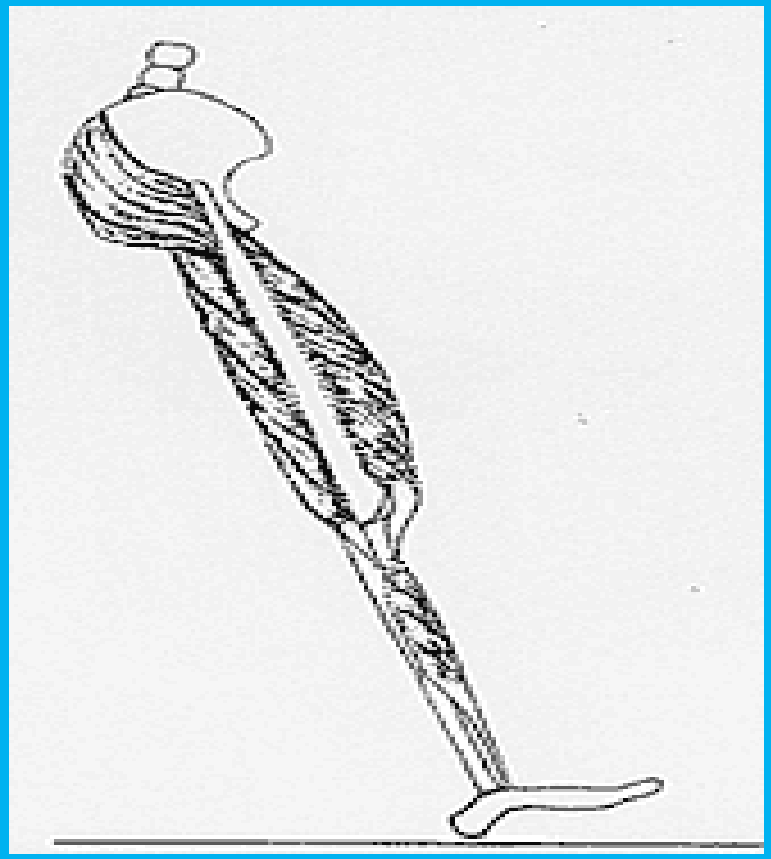
Mid-Swing (RLA)

- Encompasses the period from maximum knee flexion until the tibia is in a vertical position.
- Ankle dorsiflexes.
- Knee extends (60-30).
- Hip flexed 30.

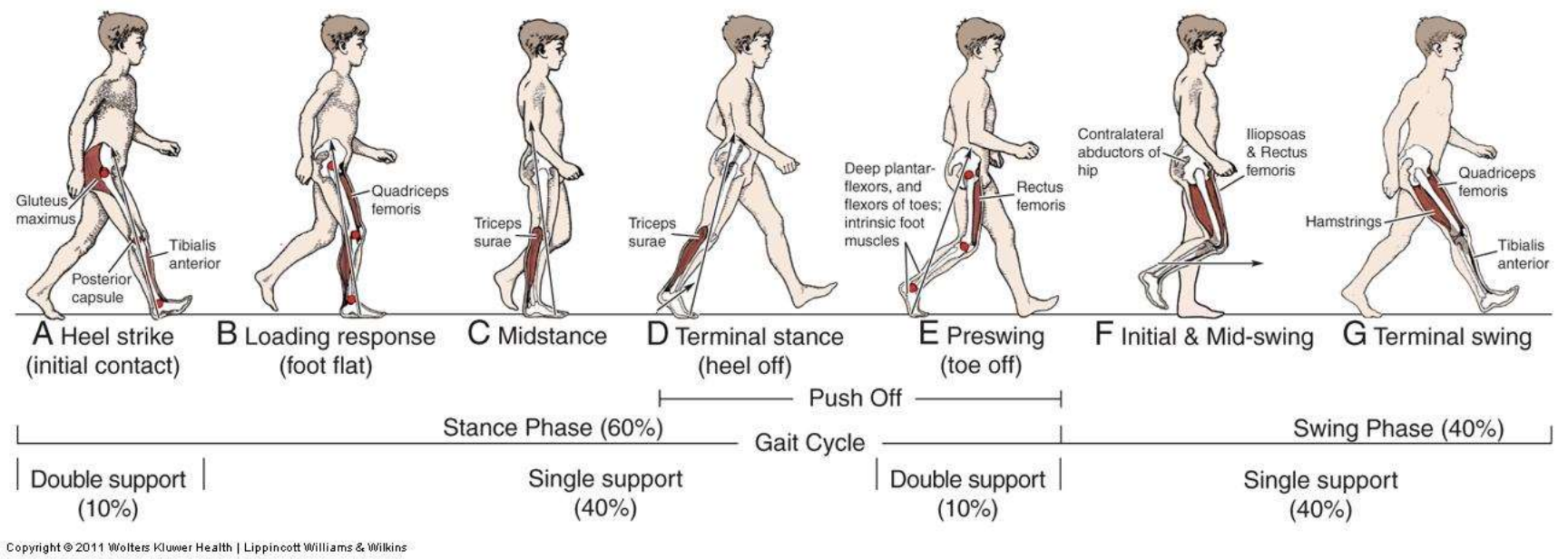


Terminal swing (RLA)

- Includes the period from the point at which the tibia is in the vertical position to a point just before initial contact.



Muscle activity



factors affecting variables

- Age,
- Gender,
- Height,
- Size & shape of bony components,
- Distribution of mass in body segments,
- Joint mobility,
- Muscle strength,
- Type of clothing & footwear,
- Habit,
- Psychological status.

Abnormal (Atypical) Gait

- There are numerous causes of abnormal gait.
- There can be great variation depending upon the severity of the problem.
  - If a muscle is weak, how weak is it?
  - If joint motion is limited, how limited is it?

Pathological gaits

- Abnormality in gait may be caused by –
  - Pain
  - Joint muscle range-of-motion (ROM) limitation
  - Muscular weakness/paralysis
  - Neurological involvement (UMNL/ LMNL)
  - Leg length discrepancy

Types of pathological gait

- Due to pain –
  - Antalgic or limping gait – *(Psoatic Gait)*
- Due to neurological disturbance –
  - Muscular paralysis – both
    - Spastic *(Circumductory Gait, Scissoring Gait, Dragging or Paralytic Gait, Robotic Gait[Quadriplegic])* and
    - Flaccid *(Lurching Gait, Waddaling Gait, Gluteus Maximus Gait, Quadriceps Gait, Foot Drop or Stapping Gait,)*
  - Cerebellar dysfunction *(Ataxic Gait)*
  - Loss of kinesthetic sensation *(Stamping Gait)*
  - Basal ganglia dysfunction *(FestinautGait)*

Types of pathological gait

- Due to abnormal deformities –
  - Equinus gait
  - Equinovarous gait
  - Calcaneal gait
  - Knock & bow knee gait
  - Genurecurvatum gait
- Due to Leg Length Discrepancy (LLD) –
  - Equinus gait

Antalgic gait

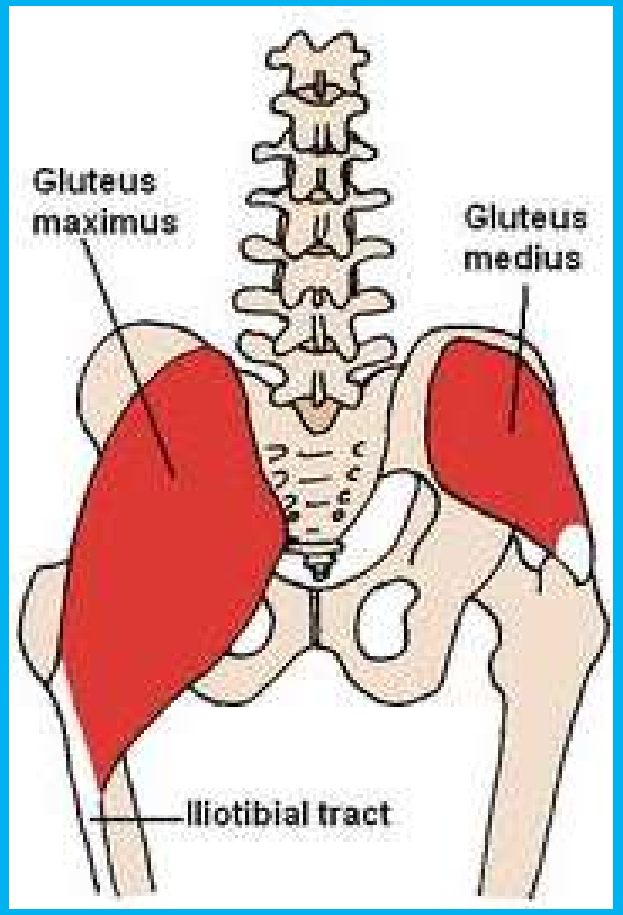
- This is a compensatory gait pattern adopted in order to remove or diminish the discomfort caused by pain in the LL or pelvis.
- Characteristic features:
  - Decrease in duration of stance phase of the affected limb (unable of weight bear due to pain)
  - There is a lack of weight shift laterally over the stance limb and also to keep weight off the involved limb
  - Decrease in stance phase in affected side will result in a decrease in swing phase of sound limb.

Psoatic gait

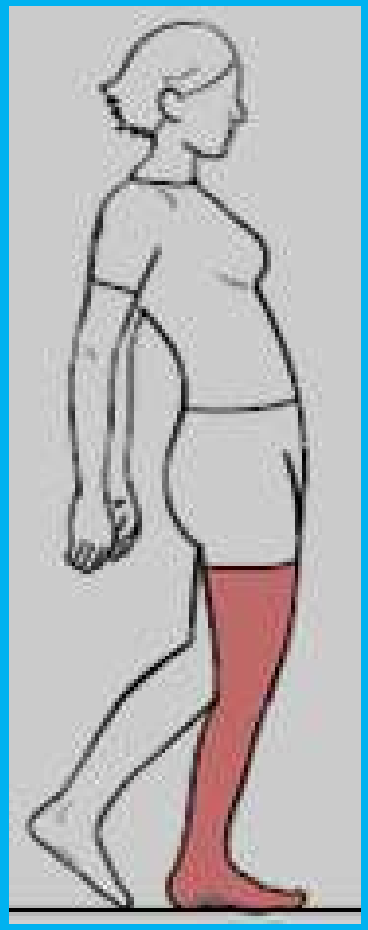
- Psoas bursa may be inflamed & edematous, which cause limitation of movement due to pain & produce a atypical gait.
  - Hip externally rotated
  - Hip adducted
  - Knee in slight flexion
- This process seems to relieve tension of the muscle & hence relieve the inflamed structures.

Gluteus maximus gait

- The gluteus maximus act as a restraint for forward progression.
- The trunk quickly shifts posteriorly at heel strike *(initial contact).*
- This will shift the body's COG posteriorly over the gluteus maximus, moving the line of force posterior to the hip joints.

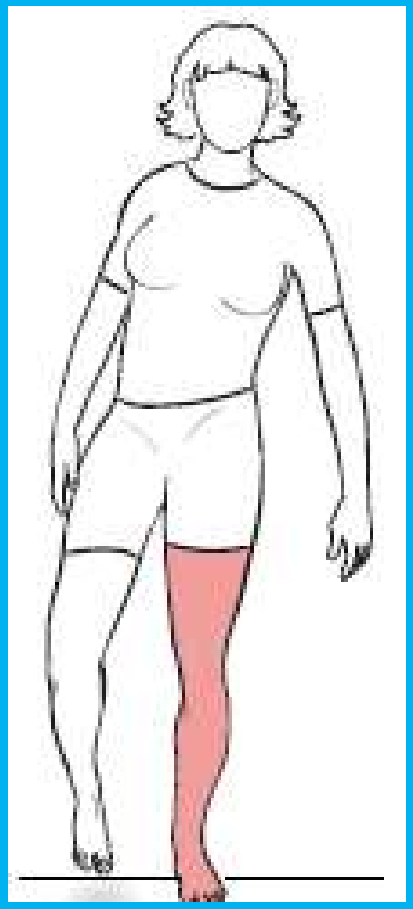


- With foot in contact with floor, this requires less muscle strength to maintain the hip in extension during stance phase.
- This shifting is referred to as a "Rocking Horse Gait" because of the extreme backward-forward movement of the trunk.



gluteus medius gait

- It is also known as "Trendelenberg gait" or "Lurching Gait" when one side affected.
- The individual shifts the trunk over the affected side during stance phase.
- When right gluteus medius or hip abductor is weak it cause two thing:
  1. The body leans over the left leg during stance phase of the left leg, and
  2. Right side of the pelvis will drop when the right leg leaves the ground & begins swing phase.



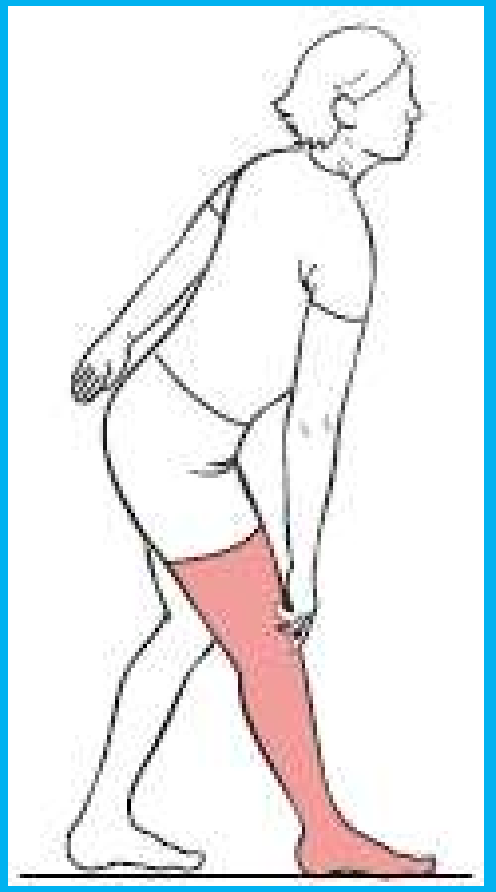
- Shifting the trunk over the affected side is an attempt to reduce the amount of strength required of the gluteus medius to stabilize the pelvis.
- Bilateral paralysis, waddling or duck gait.
- The patient lurch to both sides while walking.
- The body sways from side to side on a wide base with excessive shoulder swing.
  - E.g. Muscular dystrophy

Quadriceps gait

- Quadriceps action is needed during loading response and midstance when there is a flexion movement acting at the knee.
- Quadriceps weakness/ paralysis will lead to buckling of the knee during gait & thus loss of balance.
- Patient can compensate this if he has normal hip extensor & plantar flexors.

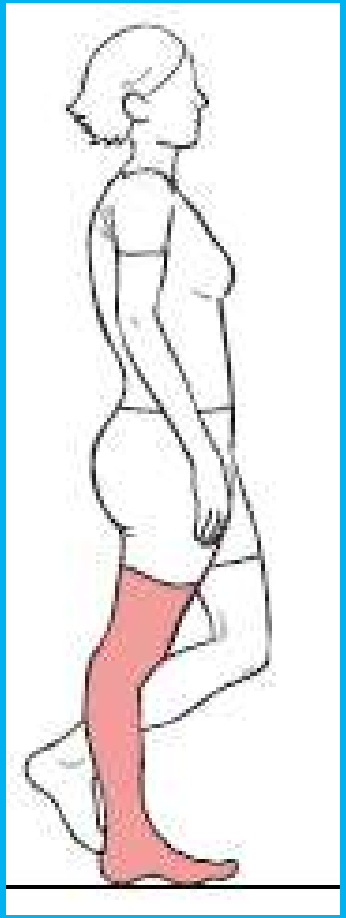
- Compensation:
  - With quadriceps weakness, the individual may lean forward over the quadriceps at the early part of stance phase, as weight is being shifted on to the stance leg.
  - Normally, the line of force falls behind the knee, requiring quadriceps action to keep the knee from buckling.
  - By leaning forward at the hip, the COG is shifted forward & the line of force now falls in front of the knee.
  - This will force the knee backward into extension.

- Another compensatory manoeuvre to use is the hip extensors & ankle plantar flexors in a closed chain action to pull the knee into extension at heel strike *(initial contact).*
- In addition, the person may physically push on the anterior thigh during stance phase, holding the knee in extension.



Genu recurvatum gait

- Hamstrings are weak, 2 things may happen
  - During stance phase, the knee will go into excessive hyperextension, referred to as "genu recurvatum" gait.
  - During the deceleration *(terminal swing)* part of swing phase, without the hamstrings to slow down the swing forward of the lower leg, the knee will snap into extension.



Foot drop or slapping gait

- This is due to dorsiflexor weakness caused by paralysis of common peroneal nerve.
- There won't be normal heel strike, instead the foot comes in contact with ground as a whole with a slapping sound.
- So it is also known as "Slapping gait".

- Due to plantarflexion of the ankle, there will be relatively lengthening at the leading extremity.
- So to clear the ground the patient lift the limb too high.
- Hence the gait get s its another name i.e. “High Stepping Gait”

Equinus gait

- Equinus = Horse
- Because of paralysis of dorsiflexor which result in plantar flexor contracture.
- The patients will walk on his toes (toe walking).
- Other cause may be compensation by plantar flexor for a short leg.

Calcaneal gait

- Result from paralysis plantar flexors causing dorsiflexor contracture.
- The patient will be walking on his heel (heel walking)
- It is characterized by greater amounts of ankle dorsiflexion & knee flexion during stance & a shorter step length on the affected side.
- Single-limb support duration is shortened because of the difficulty of stabilizing the tibia & the knee.

Unequal Leg Length

- We all have unequal leg length, usually a discrepancy of *approx 1/4 inch* between the right and left legs.
- Clinically, these smaller discrepancies are often corrected by inserting heel lifts of various thicknesses into the shoe.
- Leg length discrepancy (LLD) are divided in –
  - Minimal leg length discrepancy
  - Moderate leg length discrepancy
  - Severe leg length discrepancy

Minimal LLD

- Compensation occurs by dropping the pelvis on the affected side.
- The person may compensate by leaning over shorter leg.

Moderate LLD

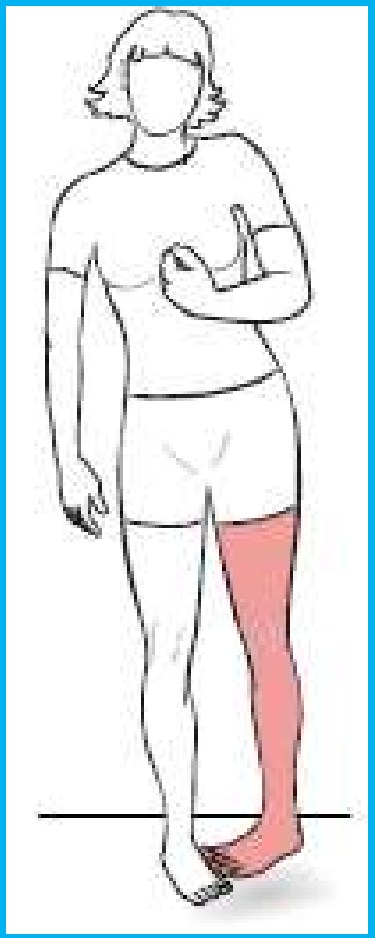
- Approx between *3 & 5 cm*, dropping the pelvis on the affected side will no longer be effective.
- A longer leg is needed, so the person usually walks on the ball of the foot on the involved (shorter) side.
- This is called an "Equinnus Gait".

Severe LLD

- It is usually discrepancy of *more than 5 cm*.
- The person may compensate in a variety of ways.
- Dropping the pelvis and walking in an equinnus gait plus flexing the knee on the uninvolved side is often used.

hemiplegic gait

- With spastic pattern of hemiplegic leg
  - Hip into extension, adduction & medial rotation
  - Knee in extension, though often unstable
  - Ankle in drop foot with ankle plantar flexion and inversion (equinovarus), which is present during both stance and swing phases.
- In order to clear the foot from the ground the hip & knee should flex.



- But the spastic muscles won't allow the hip & knee to flex for the floor clearance.
- So the patient hikes hip & bring the affected leg by making a half circle i.e. circumducting the leg.
- Hence the gait is known as "Circumductory Gait".
- Usually, there will be no reciprocal arm swing.
- Step length tends to be lengthened on the involved side & shortened on the uninvolved side.

Scissoring gait

- It results from spasticity of bilateral adductor muscle of hip.
- One leg crosses directly over the other with each step like crossing the blades of a scissor.
  - E.g. Cerebral Palsy

Dragging or paraplegic gait

- There is spasticity of both hip & knee extensors & ankle plantar flexors.
- In order to clear the ground the patient has to drag his both lower limb swings them & place it forward.

Cerebral Ataxic gait

- Abnormal function of cerebellum result in a disturbance of normal mechanism controlling balance & therefore patient walks with wider BOS.
- The wider BOS creates a larger side to side deviation of COG.
- This result in irregularly swinging sideways to a tendency to fall with each steps.
- Hence it is known as "Reeling Gait".

Sensory ataxic gait

- This is a typical gait pattern seen in patients affected by tabes dorsalis.
- It is a degenerative disease affecting the posterior horn cells & posterior column of the spinal cord.
- Because of lesion, the proprioceptive impulse won't reach the cerebellum.
- The patient will lose his joint sense & position for his limb on space.

- Because of loss of joint sense, the patient abnormally raises his leg (high step) jerks it forward to strike the ground with a stamp.
- So it is also called as "Stamping Gait".
- The patient compensated this loss of joint position sense by vision.
- So his head will be down while he is walking.

Short shuffling or festinate gait

- Because of rigidity, all the joint will go for a flexion position with spine stooping forward.
- This posture displaces the COG anteriorly.
- So in order to keep the COG within the BOS, the patient will no of small shuffling steps.
- Due to loss of voluntary control over the movement, they loses balance & walks faster as if he is chasing the COG.
- So it is called as "Festinate Gait".
- Since his shuffling steps, it is otherwise called as "Shuffling Gait".

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