PLEASE CLICK ON THE FOLLOWING LINK TO WATCH THE LECTURE ONLINE:-

https://www.youtube.com/watch?v=0C7YNuKuQto&list=PLuBRb5B7fa_cjuGL06zhWXRxCDRoGpJlh&index=4

GAIT BIOMECHANICS

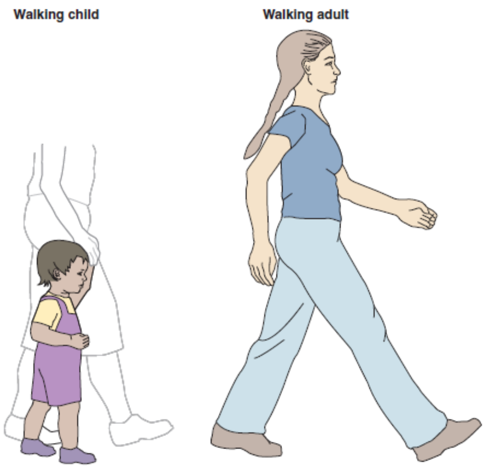
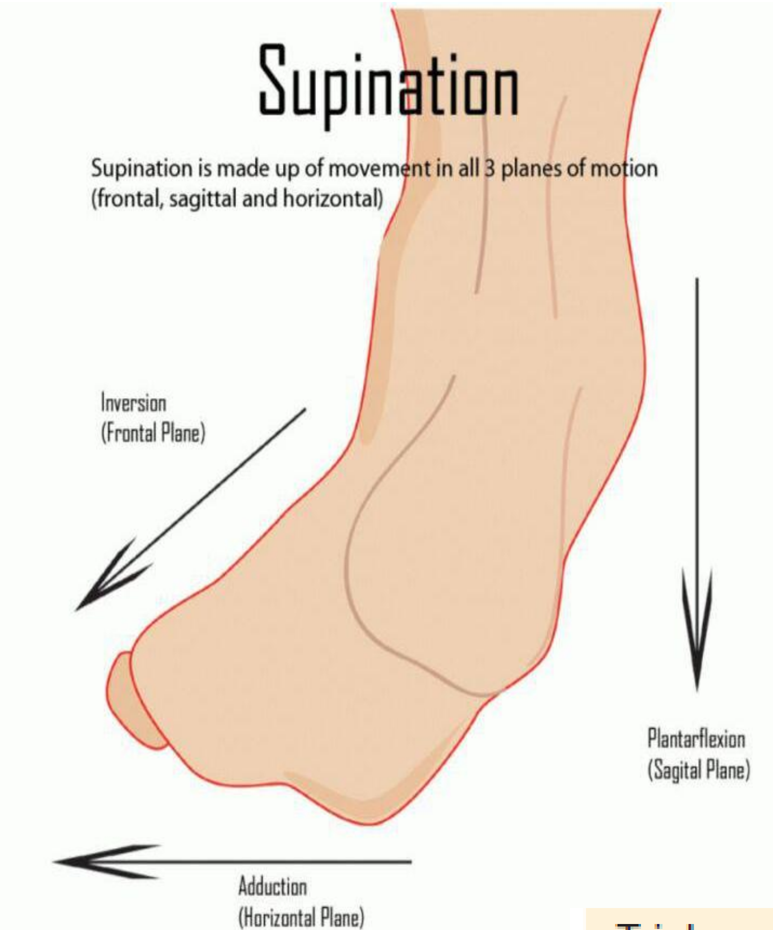
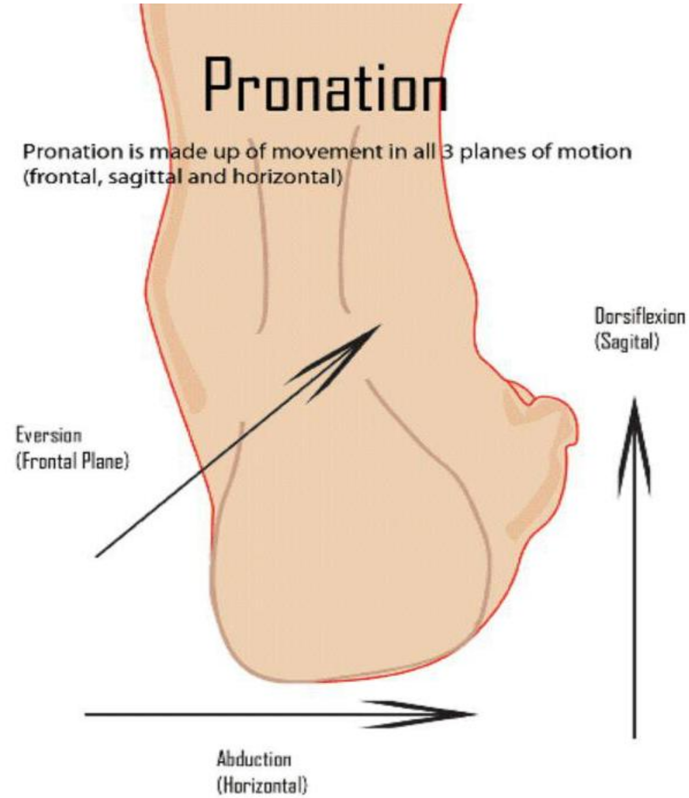


FIGURE 15-1. Walking at various stages in life.

Abdullah Alkhawaldah MD, FACS
RMS Jordan. Foot And Ankle surgery

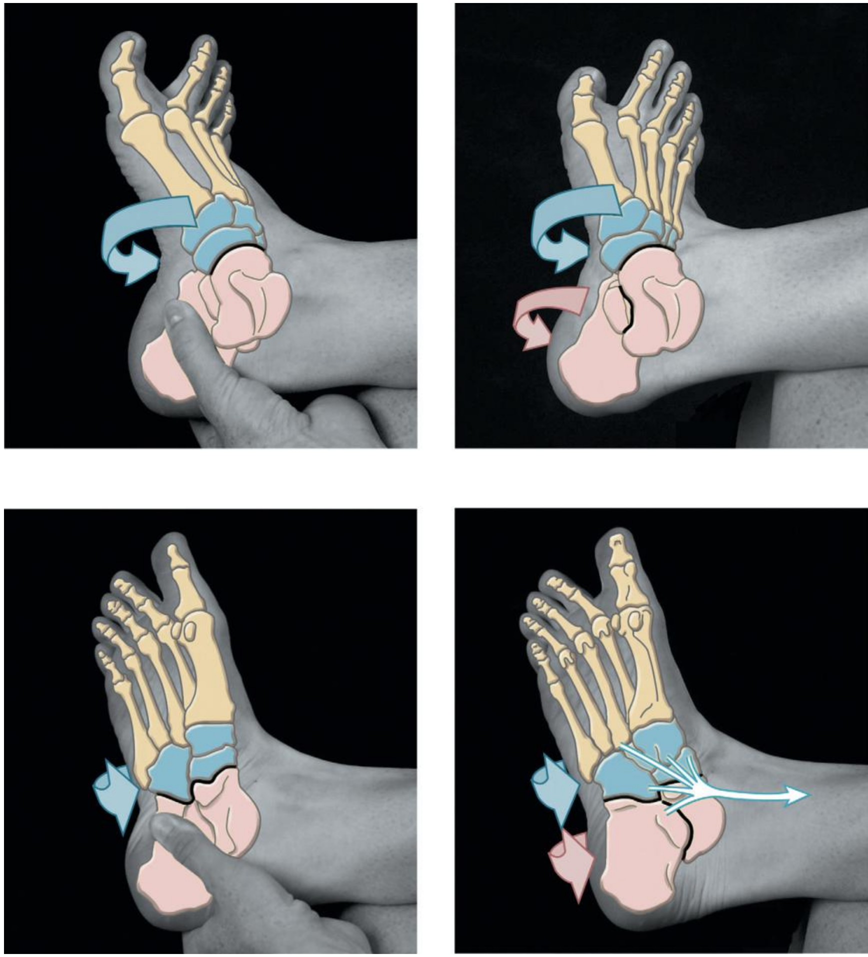
Review





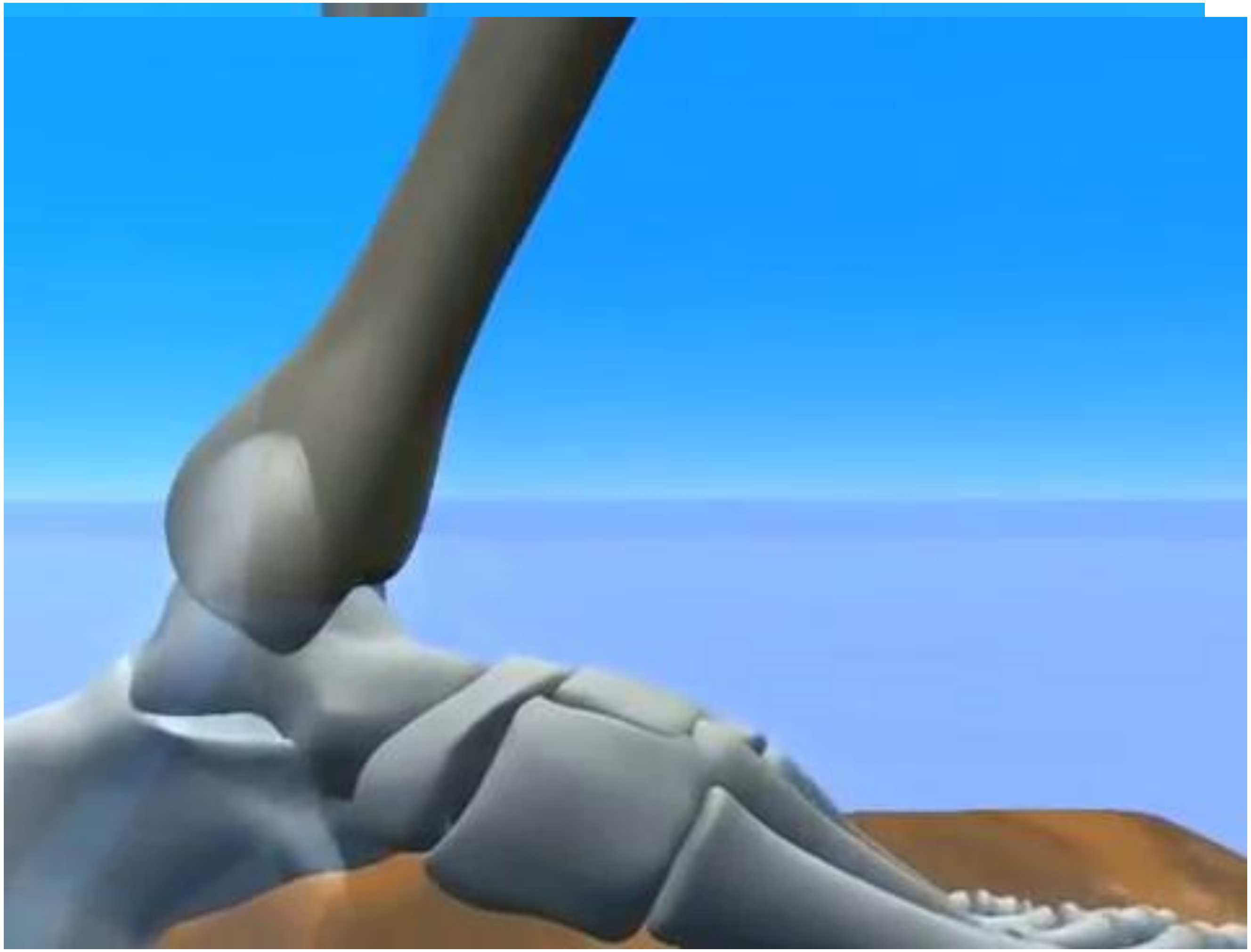
Triplanar motion	Supination Adduction Inversion Plantar flexion Pronation Abduction Eversion Dorsiflexion

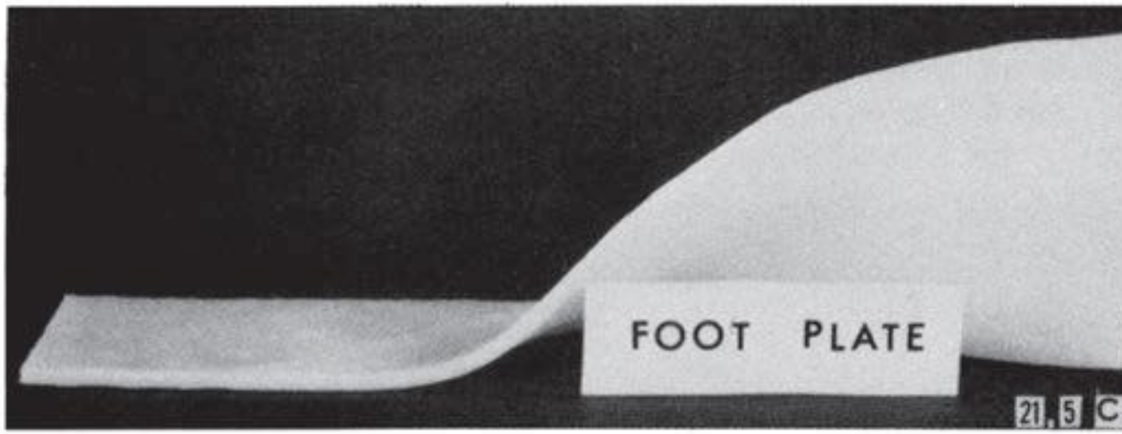
Pronation and supination of the unloaded right foot demonstrates the interplay of the subtalar and transverse tarsal joints. With the calcaneus held fixed, pronation and supination occur primarily at the midfoot (**A and C). When the calcaneus is free, pronation and supination occur as a summation across both** the rearfoot and midfoot (**B and D). Rearfoot movement is indicated by pink arrows; midfoot movement is** indicated by blue arrows. The pull of the tibialis posterior muscle is shown in **D as it directs active supination** over both the rearfoot and midfoot



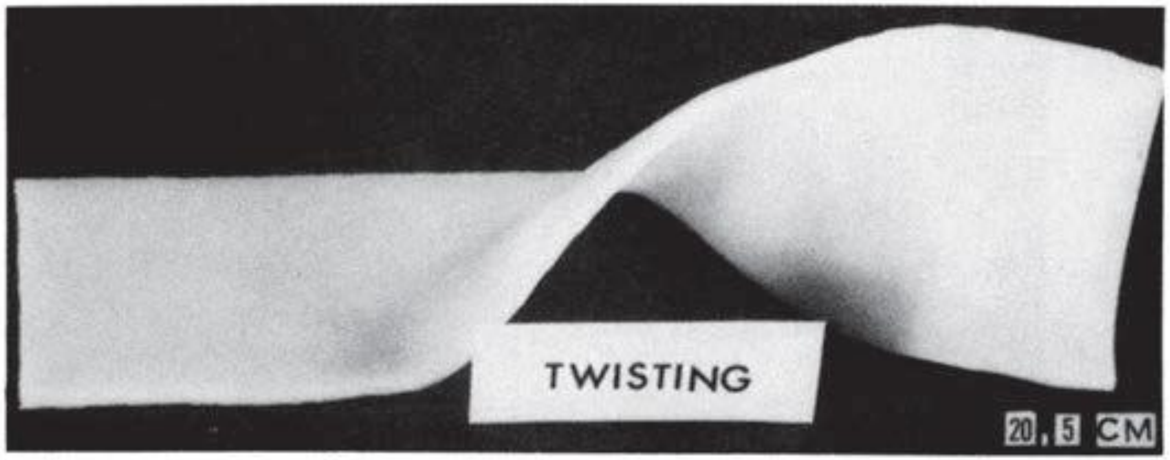
Open kinematic chain

Closed kinematic chain





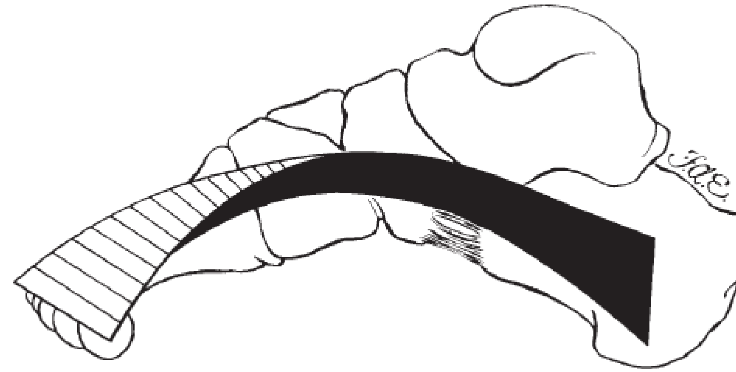
A

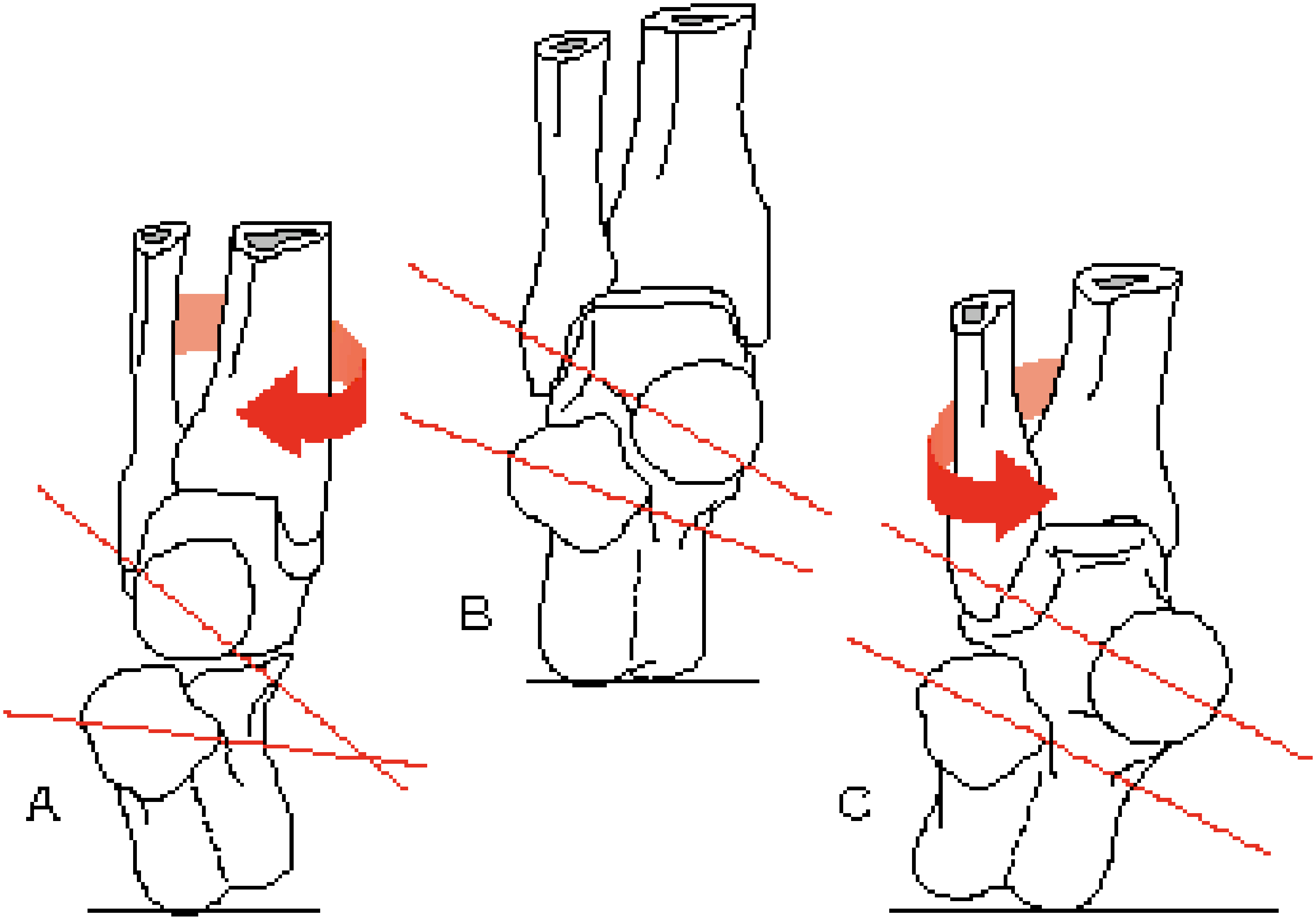


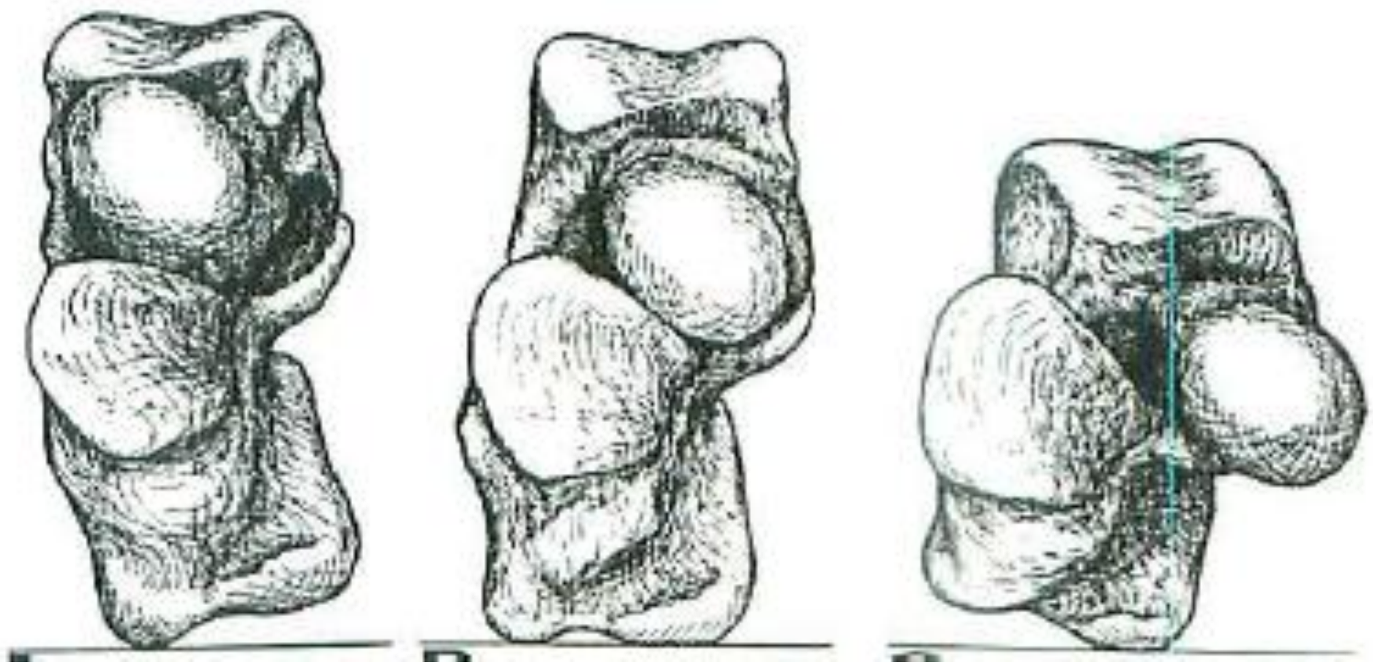
B

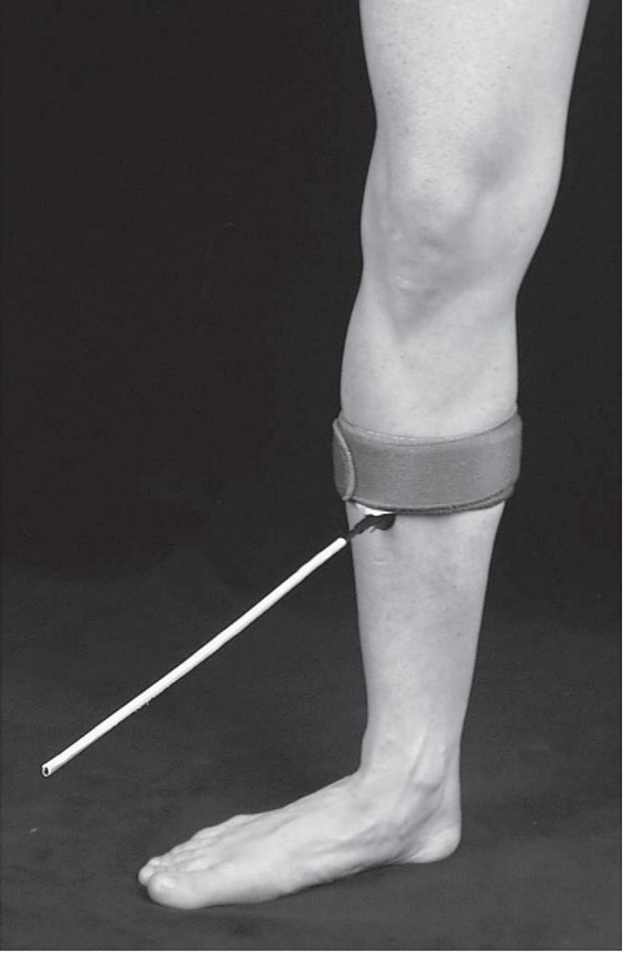
C

MS,




A
B
C





With the foot fixed, full internal rotation of the lower limb is mechanically associated with rearfoot pronation (eversion), lowering of the medial longitudinal arch, and valgus stress at the knee. Note that as the rearfoot pronates, the floor “pushes” the forefoot and midfoot into a relatively supinated position.

With the foot fixed to the
ground, full *external rotation of the lower limb*
is mechanically associated with: rearfoot supination
(inversion) and raising of the medial
longitudinal arch. Note that as the rearfoot
supinates, the forefoot and midfoot pronate to
maintain contact with the ground

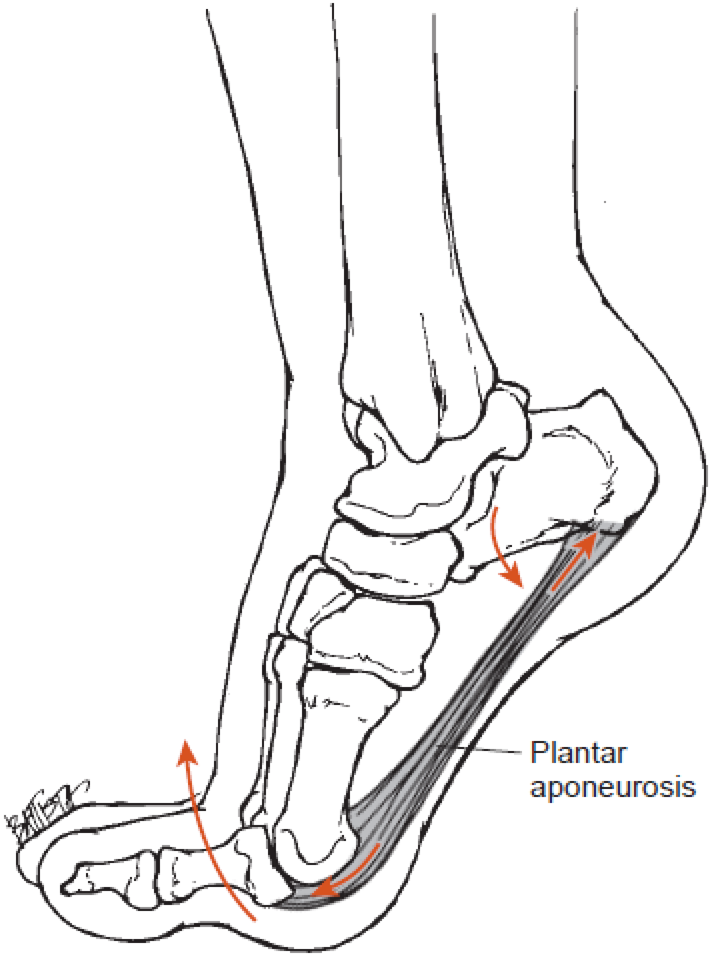
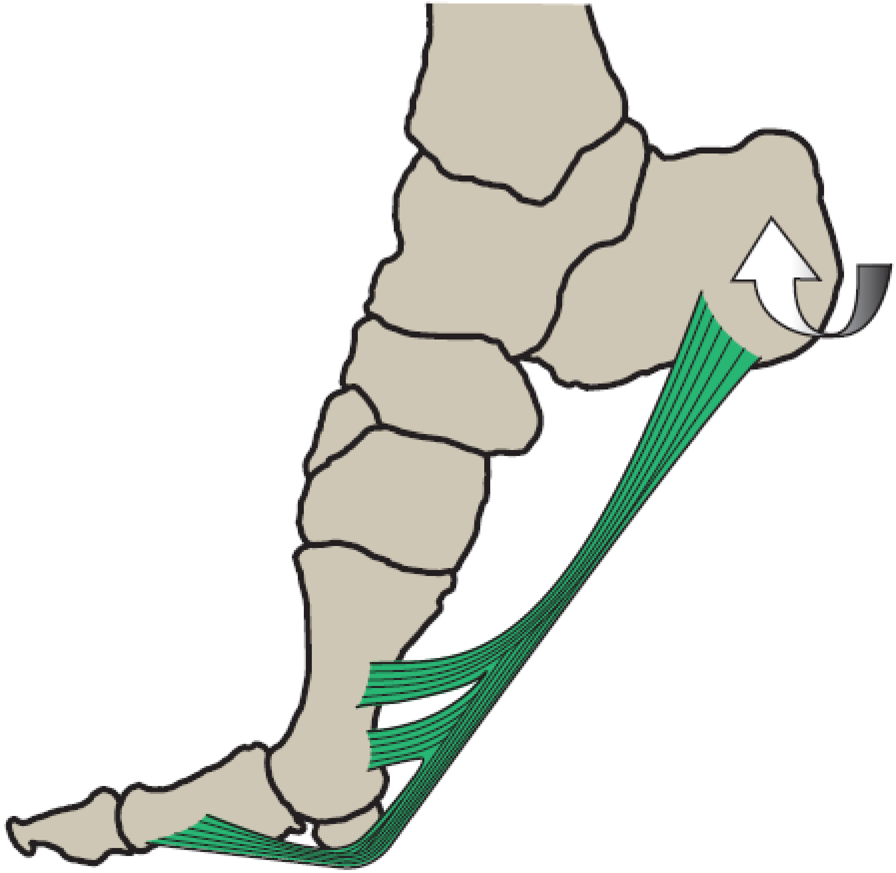
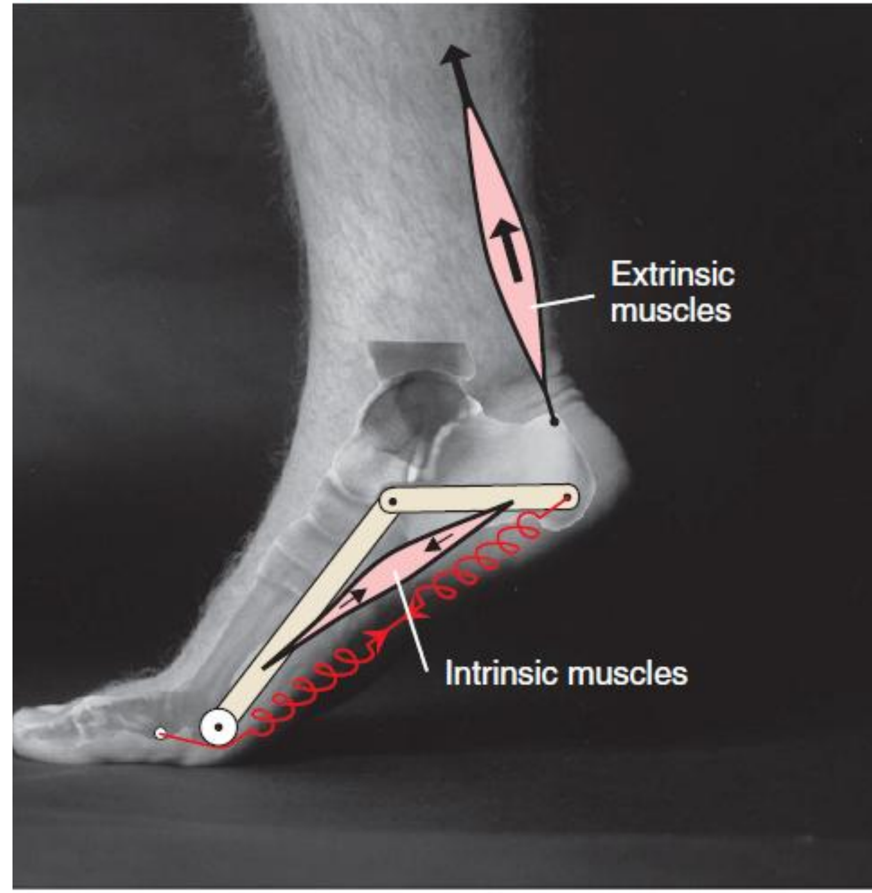


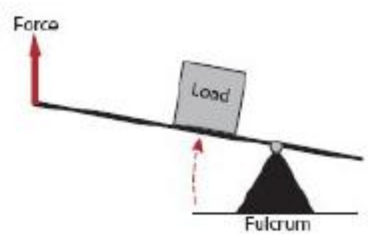
Figure 44.33: The plantar aponeurosis is stretched by plantarflexion of the calcaneus and by hyperextension of the toes.

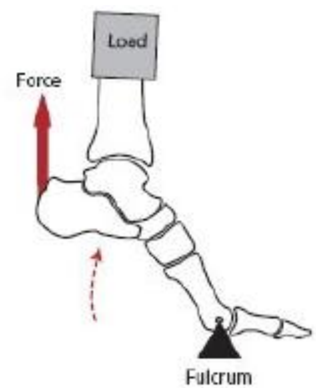
Normal foot





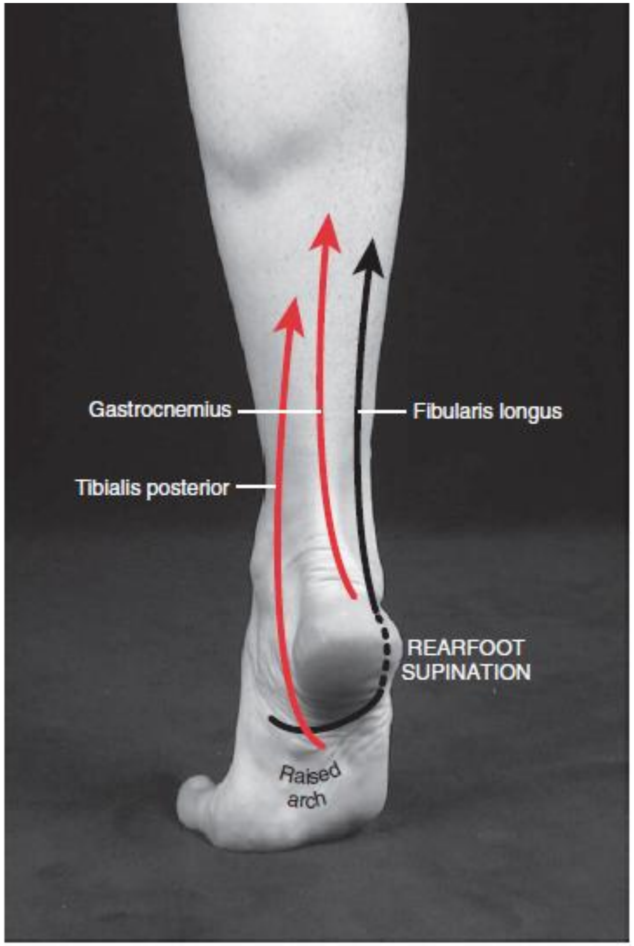
2nd class:





3rd class:

The line of force of several plantar flexor muscles while a subject rises on tiptoes. Note that the fibularis longus and tibialis posterior form a sling that supports the transverse and medial longitudinal arches. The pull of the gastrocnemius and tibialis posterior muscles causes a slight supination of the rearfoot, which adds further stability to the foot. (Invertor muscles are indicated by the red arrows; evertor muscle by the black arrow.)



- The axes of rotation and osteokinematics at the transverse tarsal joint. The *longitudinal axis of*
- rotation is shown in red from the side (**A and C) and from above (B). (The component axes and associated**
- osteokinematics are also depicted in **A and B.) Movements that occur around the longitudinal axis are (D)**
- *pronation (with the main component of eversion) and* ***(E) supination (with the main component of inversion).***
- The *oblique axis of rotation is shown in red from the side (****F and H) and from above (G). (The component***
- axes and associated osteokinematics are also depicted in **F and G.) Movements that occur around the oblique**
- axis are **(I)** ***pronation (with main components of abduction and dorsiflexion) and (J) supination (with main***
- components of adduction and plantar flexion). In **I and J, blue arrows indicate abduction and adduction, and**
- green arrows indicate dorsiflexion and plantar flexion.

Gait

- Review Terminology
- Define Gait, tasks and initiation
- Outline (gait cycle)
- Gait cycle components and subdivisions
- Explain Determinants of Gait

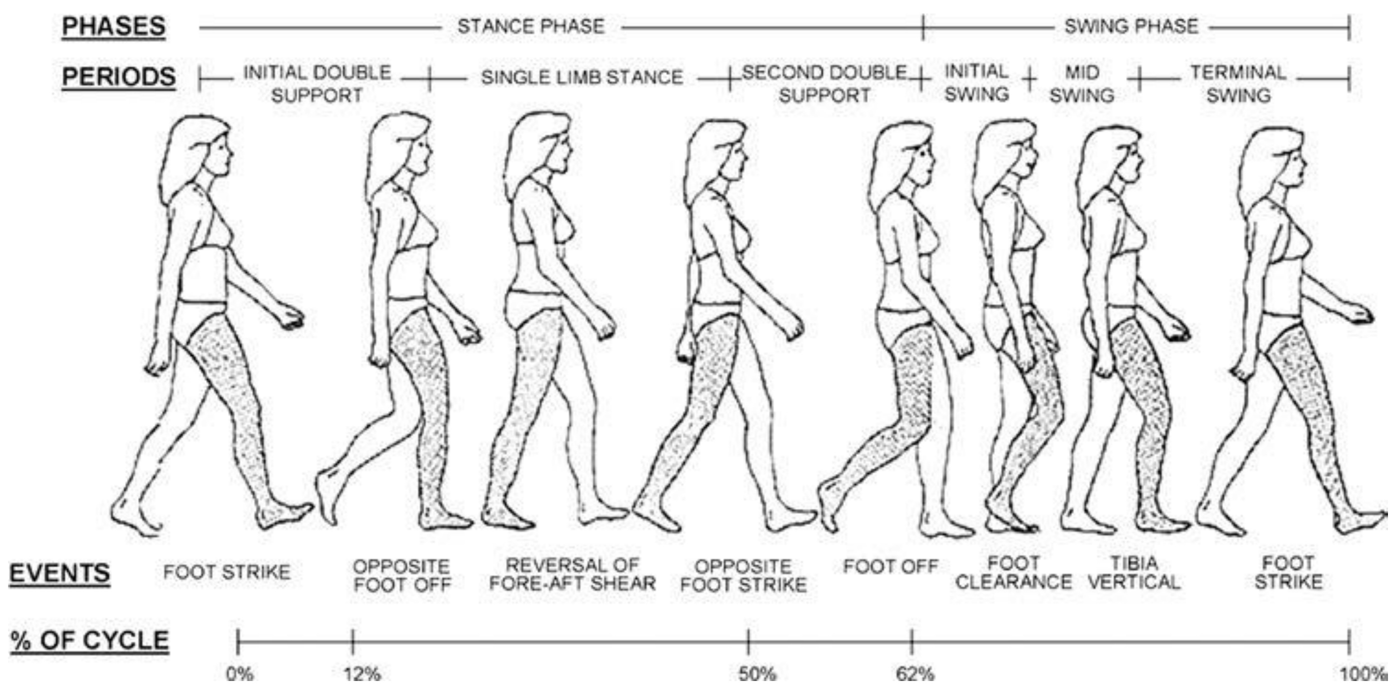
Gait

Gait is a cyclical movement that, once begun, possesses very repeatable events that continue repetitively until the individual

begins to stop the motion

Normal Gait

Series of rhythmical , alternating movements of the trunk & limbs which result in the forward progression of the center of gravity…Energy-efficient activity



Gait

Definition :

Gait

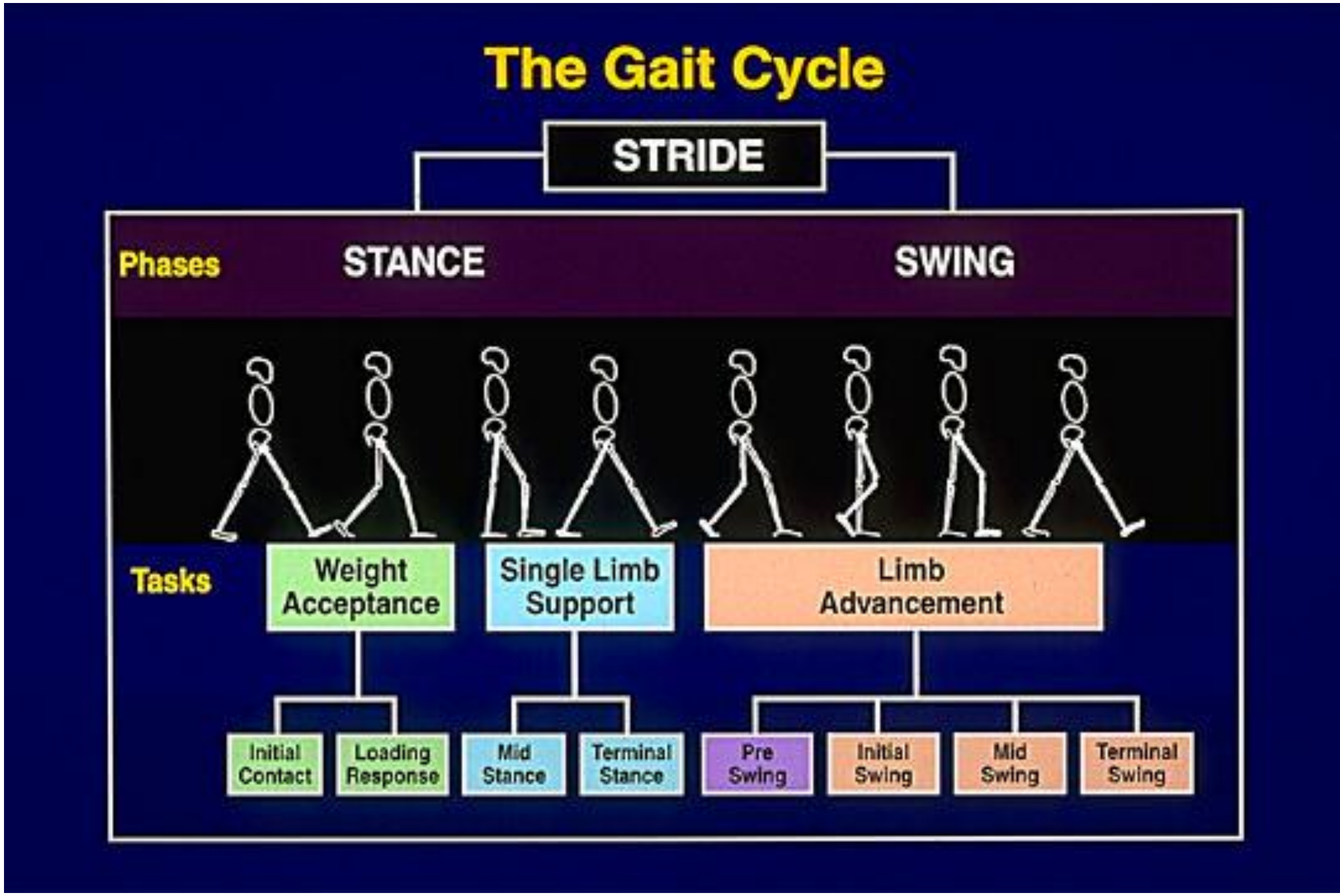
- Defined as translatory progression of the body as a whole produce by coordinated, rotatory movement of the body segment

Normal Gait

- Energy-efficient activity
- Repetitive process of sequential / Series of rhythmical , alternating movements of the lower limbs
- Move the body from one location to another while maintaining upright stability (Arms and Trunk provides stability and balance)
- Result in the forward progression of the center of gravity
- Series of ‘controlled falls’
- Alternating propulsion and retropulsive motion f LL

Gait Cycle

period of time from one heel strike to the next heel strike of the same limb



gait cycle can be described as the series of movements of the lower extremities between foot initial impact with the surface until it reconnects with the surface at the end of the cycle

Gait Cycle =

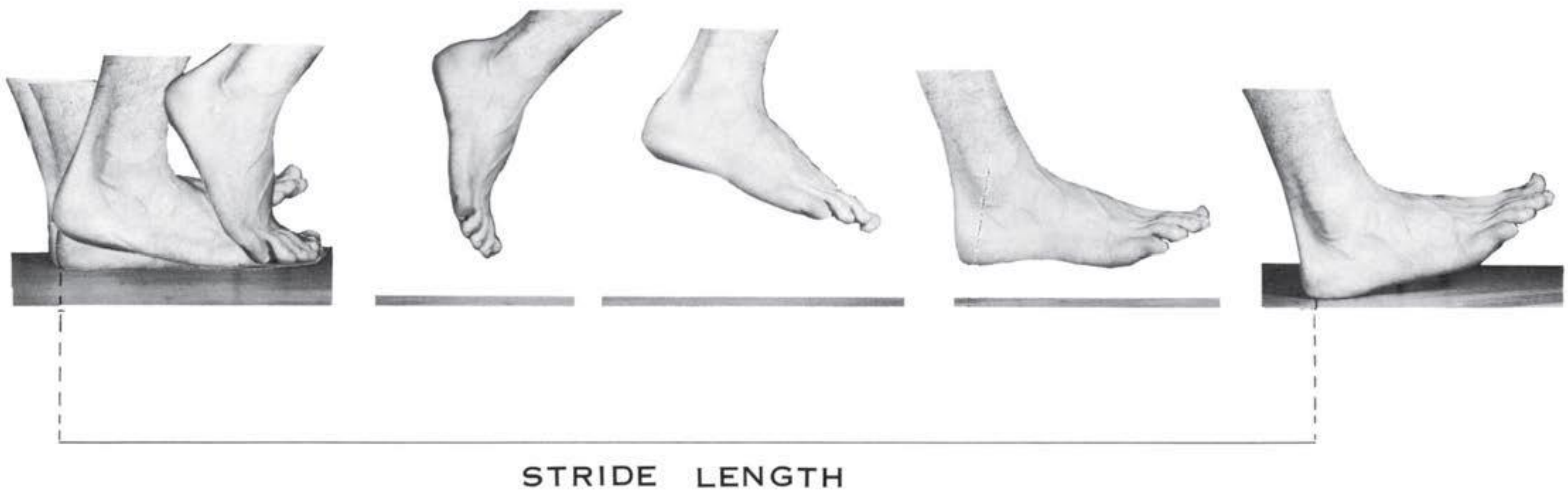
Single sequence of functions by **one limb**

Begins when reference foot contacts the ground

Ends with subsequent floor contact of the same foot

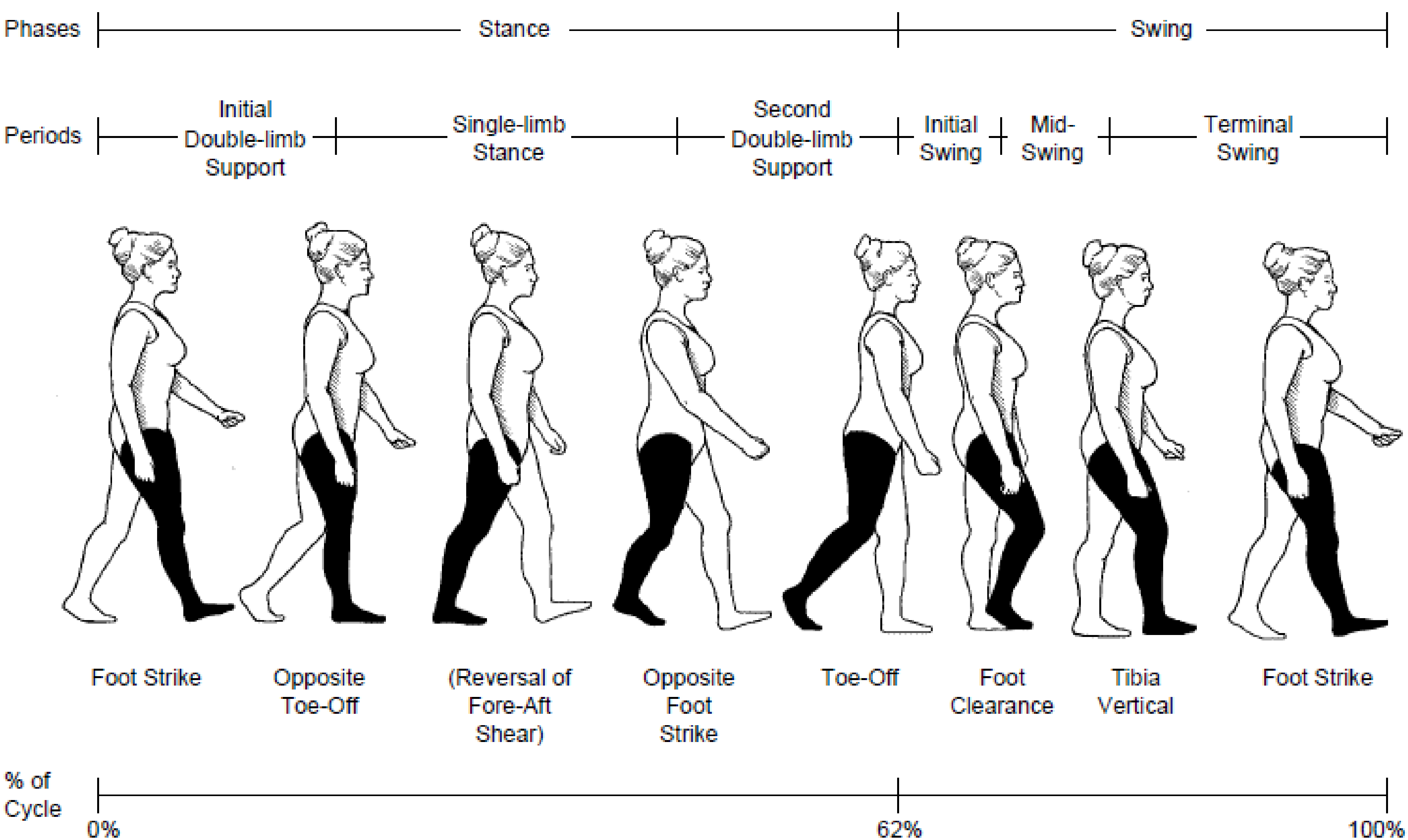
- Gait Cycle =
  - Repetitive patterns of **steps** and **strides**

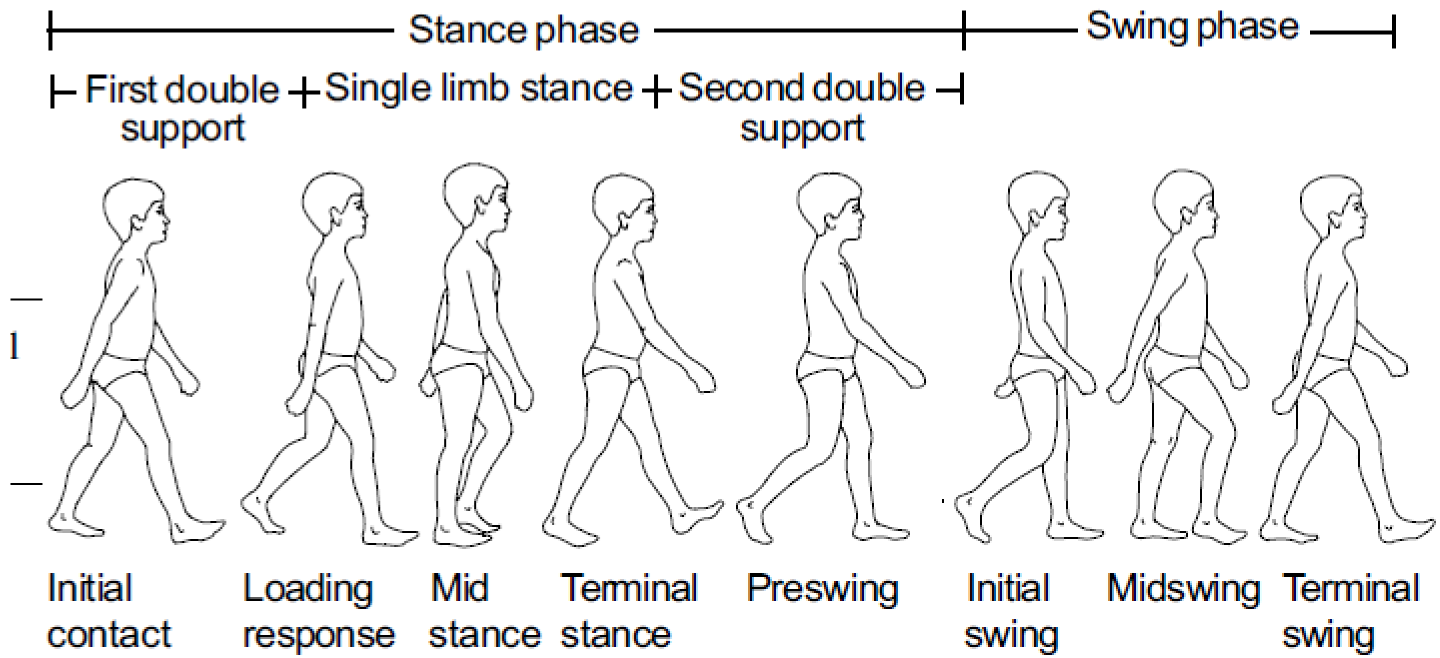
Gait Cycle Components



- <u>Two phases</u>:
  (1) <u>Stance phase</u>
    - Period of time that the foot is on the ground
    - **60% of cycle** spent in this period
    - leg accept body weight

  (2) <u>Swing phase</u>
    - period of time that the foot is off the ground moving forward
    - **40 % of cycle** spent in this period
    - Limb advancement


Phases
Stance
Swing
Periods
Initial Double-limb Support
Single-limb Stance
Second Double-limb Support
Initial Swing
Mid-Swing
Terminal Swing
Foot Strike
Opposite Toe-Off
(Reversal of Fore-Aft Shear)
Opposite Foot Strike
Toe-Off
Foot Clearance
Tibia Vertical
Foot Strike
% of Cycle
0%
62%
100%

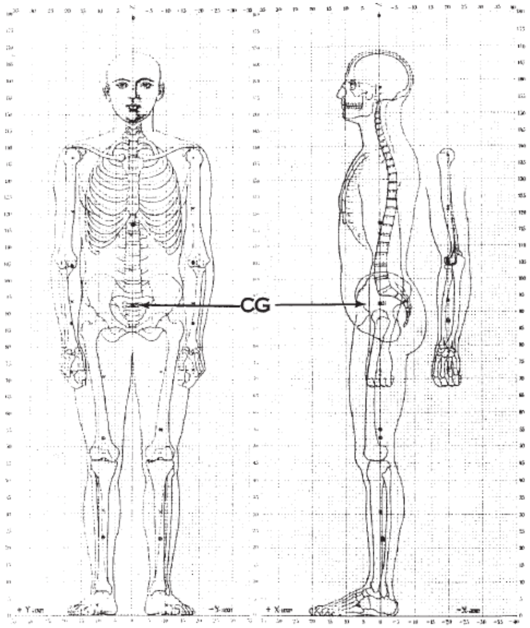

Stance phase
Swing phase
First double support
Single limb stance
Second double support
Initial contact
Loading response
Mid stance
Terminal stance
Preswing
Initial swing
Midswing
Terminal swing

Terminology

- **Kinematics** :

  Description of motion (i.e.: time, displacement, velocity, and acceleration, etc.)

- **Kinetics** :
  – Study of forces associated with motion of a body
- **Center of Gravity (COG):**
  – The balance point of body at which torque on all sides is equal (sum of all vectors equal zero).
  – Its also the point at which the planes of the body i



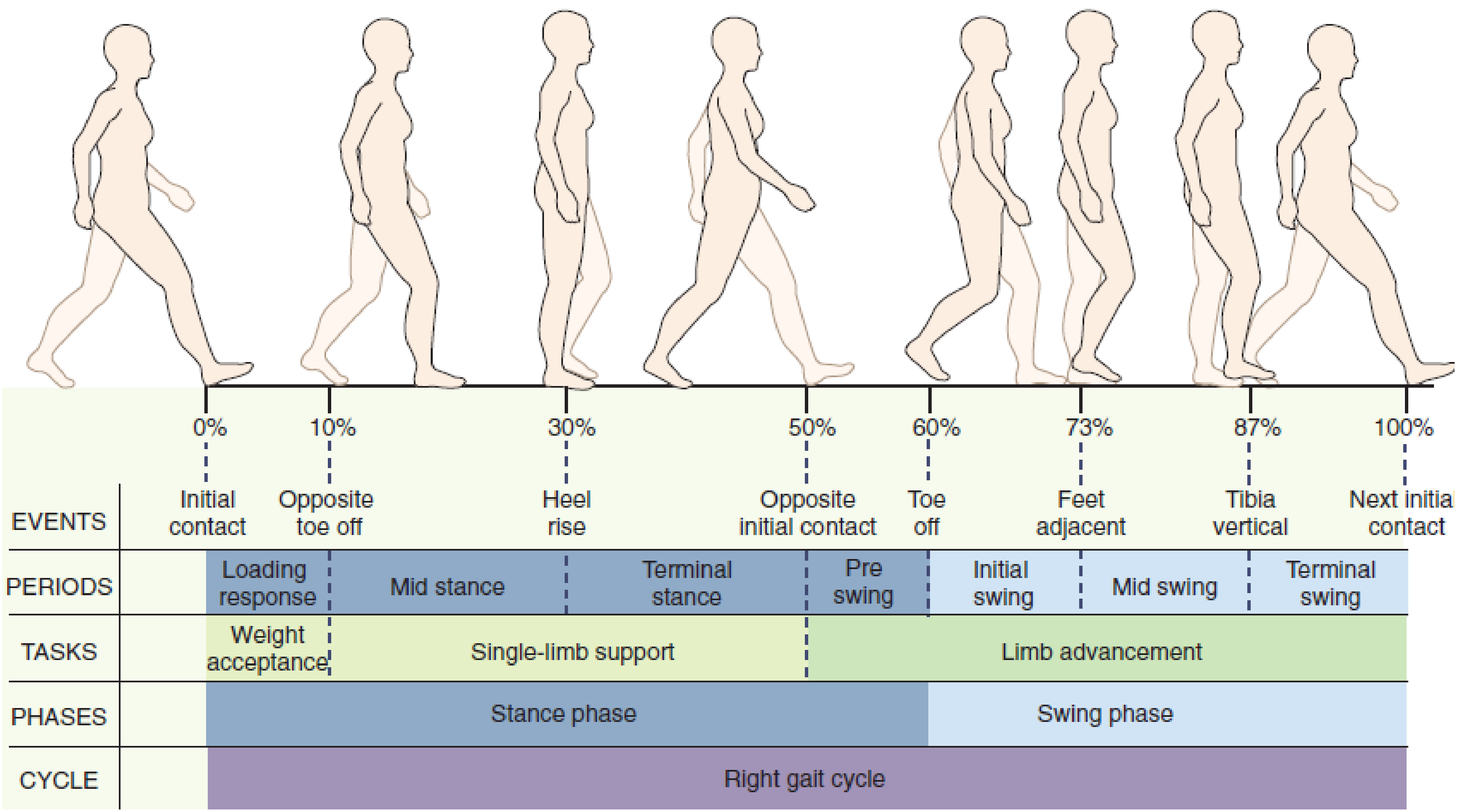

0%
10%
30%
50%
60%
73%
87%
100%
EVENTS
Initial contact
Opposite toe off
Heel rise
Opposite initial contact
Toe off
Feet adjacent
Tibia vertical
Next initial contact
PERIODS
Loading response
Mid stance
Terminal stance
Pre swing
Initial swing
Mid swing
Terminal swing
TASKS
Weight acceptance
Single-limb support
Limb advancement
PHASES
Stance phase
Swing phase
CYCLE
Right gait cycle

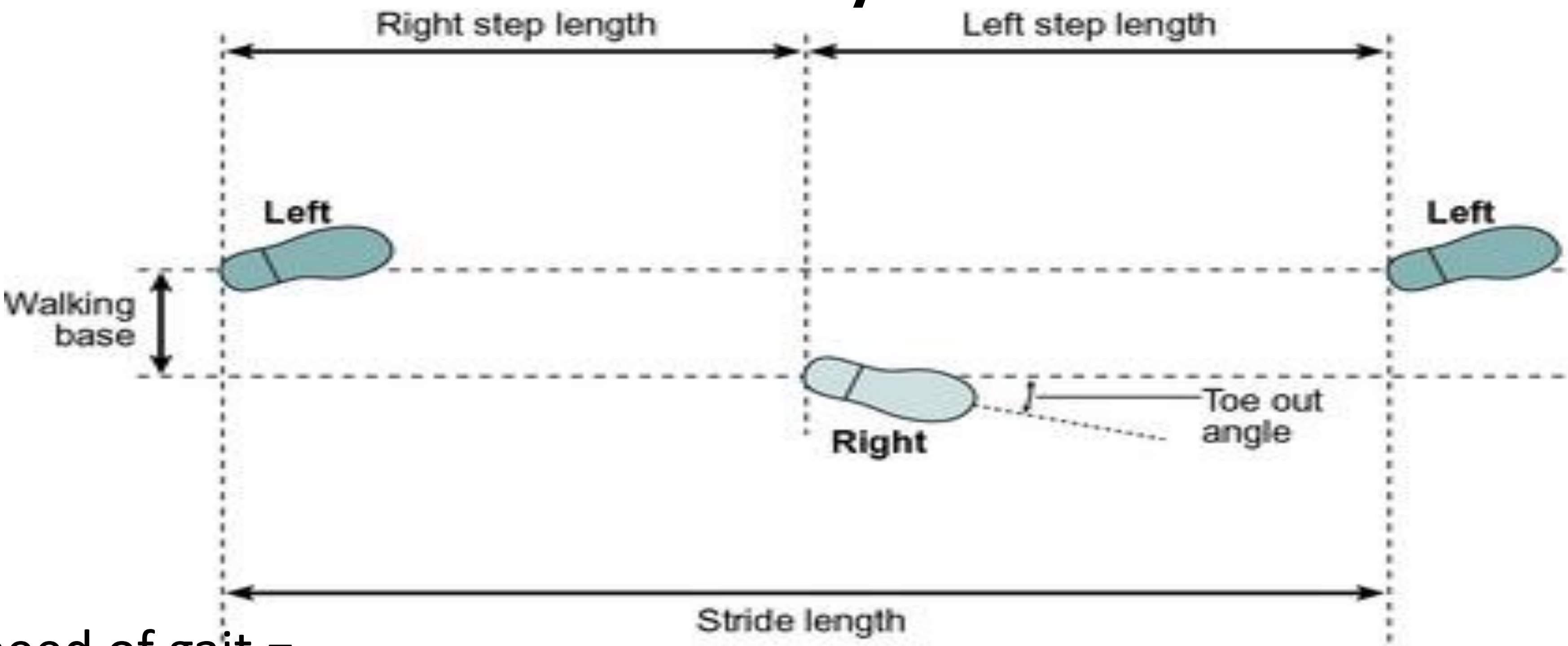
FIGURE 15-12. Terminology to describe the events of the gait cycle. *Initial contact corresponds to the beginning* of stance when the foot first contacts the ground at 0% of gait cycle. *Opposite toe off occurs when the contralateral* foot leaves the ground at 10% of gait cycle. *Heel rise corresponds to the heel lifting from the ground* and occurs at approximately 30% of gait cycle. *Opposite initial contact corresponds to the foot contact of the* opposite limb, typically at 50% of gait cycle. *Toe off occurs when the foot leaves the ground at 60% of gait* cycle. *Feet adjacent takes place when the foot of the swing limb is next to the foot of the stance limb at 73%* of gait cycle. *Tibia vertical corresponds to the tibia of the swing limb being oriented in the vertical direction* at 87% of gait cycle. The final event is, again, initial contact, which in fact is the start of the next gait cycle. These eight events divide the gait cycle into seven periods. *Loading response, between initial contact and* opposite toe off, corresponds to the time when the weight is accepted by the lower extremity initiating contact with the ground. *Mid stance is from opposite toe off to heel rise (10% to 30% of gait cycle). Terminal stance begins* when the heel rises and ends when the contralateral lower extremity touches the ground, from 30% to 50% of gait cycle. *Pre-swing takes place from foot contact of the contralateral limb to toe off of the ipsilateral foot, which* is the time corresponding to the second double-limb support of the gait cycle (50% to 60% of gait cycle). *Initial swing is from toe off to feet adjacent, when the foot of the swing limb is next to the foot of the stance limb (60%* to 73% of gait cycle). *Mid swing is from feet adjacent to when the tibia of the swing limb is vertical (73% to 87%* of gait cycle). *Terminal swing is from a vertical position of the tibia to immediately before heel contact (87% to* 100% of gait cycle). The first 10% of the gait cycle corresponds to a task of weight acceptance—when body mass is transferred from one lower extremity to the other. Single-limb support, from 10% to 50% of the gait cycle, serves to support the weight of the body as the opposite limb swings forward. The last 10% of stance phase and the entire swing phase serve to advance the limb forward to a new location.

Gait cycle

Gait Cycle: Events, Periods, and Phases

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

Gait Cycle



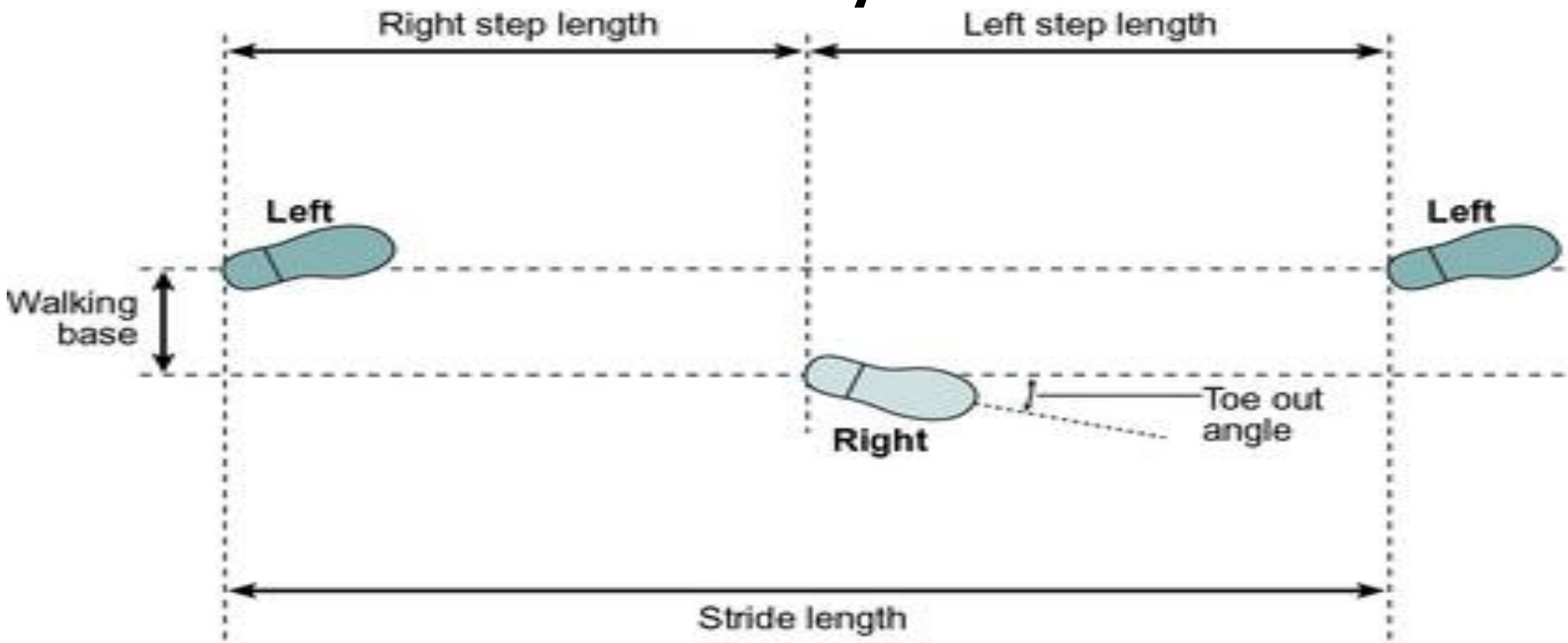
<u>Speed of gait =</u>

Described as **free, slow and fast**

Free speed …normal walking speed of person

Slow and fast … slower or faster than comfortable walking speed of person

Gait Cycle



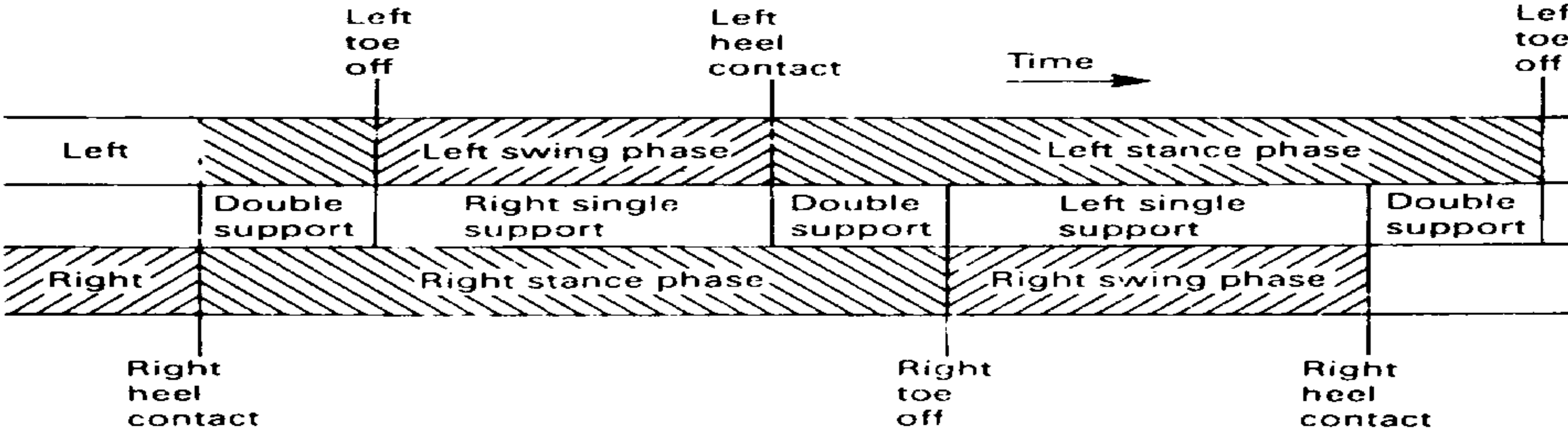
<u>Fast walking speed</u> =

- Increase gait cadence
- Increase stride length
- Decrease toe out angle

<u>Toe out angle =</u>

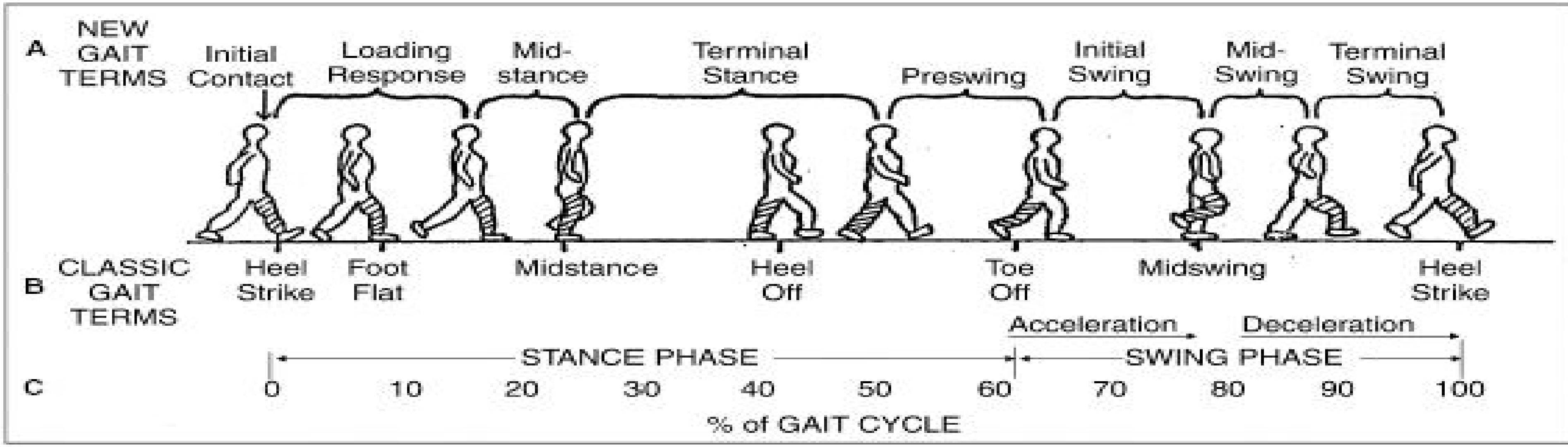
- Intersecting angle between line of foot progression and line that pass from center of heel toward second toe
- Average 7 degree in men
- Decreases as the speed of walking is increased in normal men

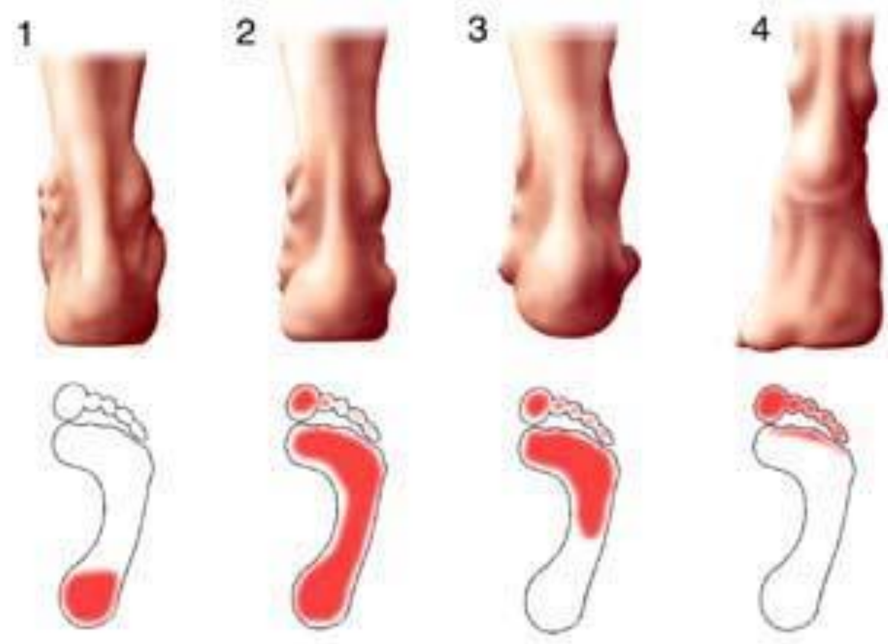
Gait Cycle Components



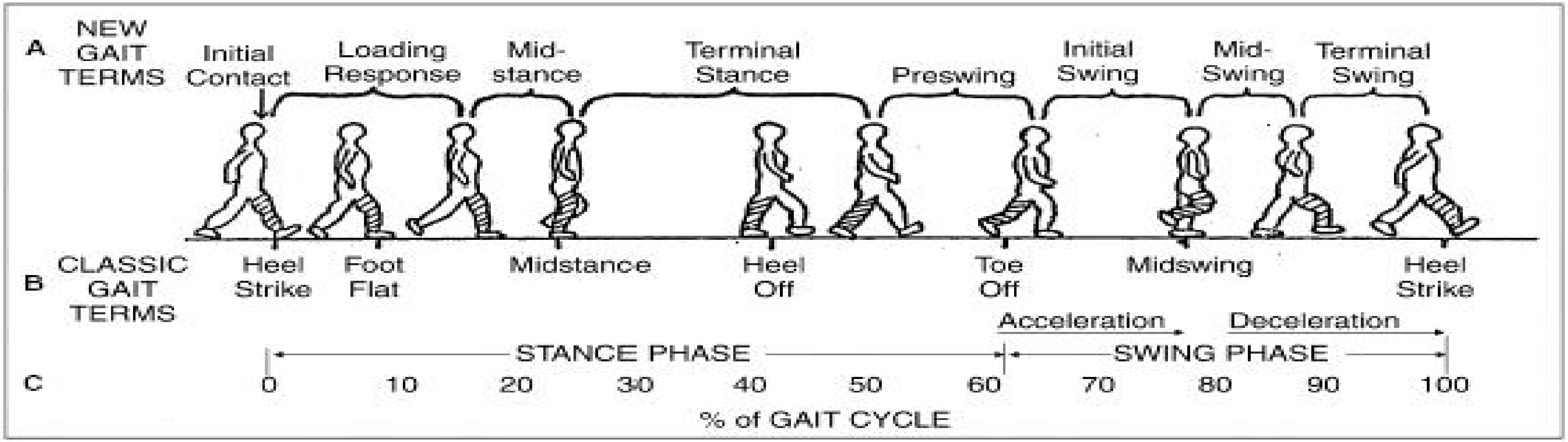
- **<u>Stance Support</u>:**
  - **(1) <u>Single Support</u>**:
    - only one foot in contact with the floor
    - **During midstance phase**
    - **40 % of gait cycle**
  - (2**) <u>Double Support</u>**:
    - both feet in contact with floor.
    - **During loading response phase and toe off phase**
    - **20% of gait cycle**

Gait Cycle Components



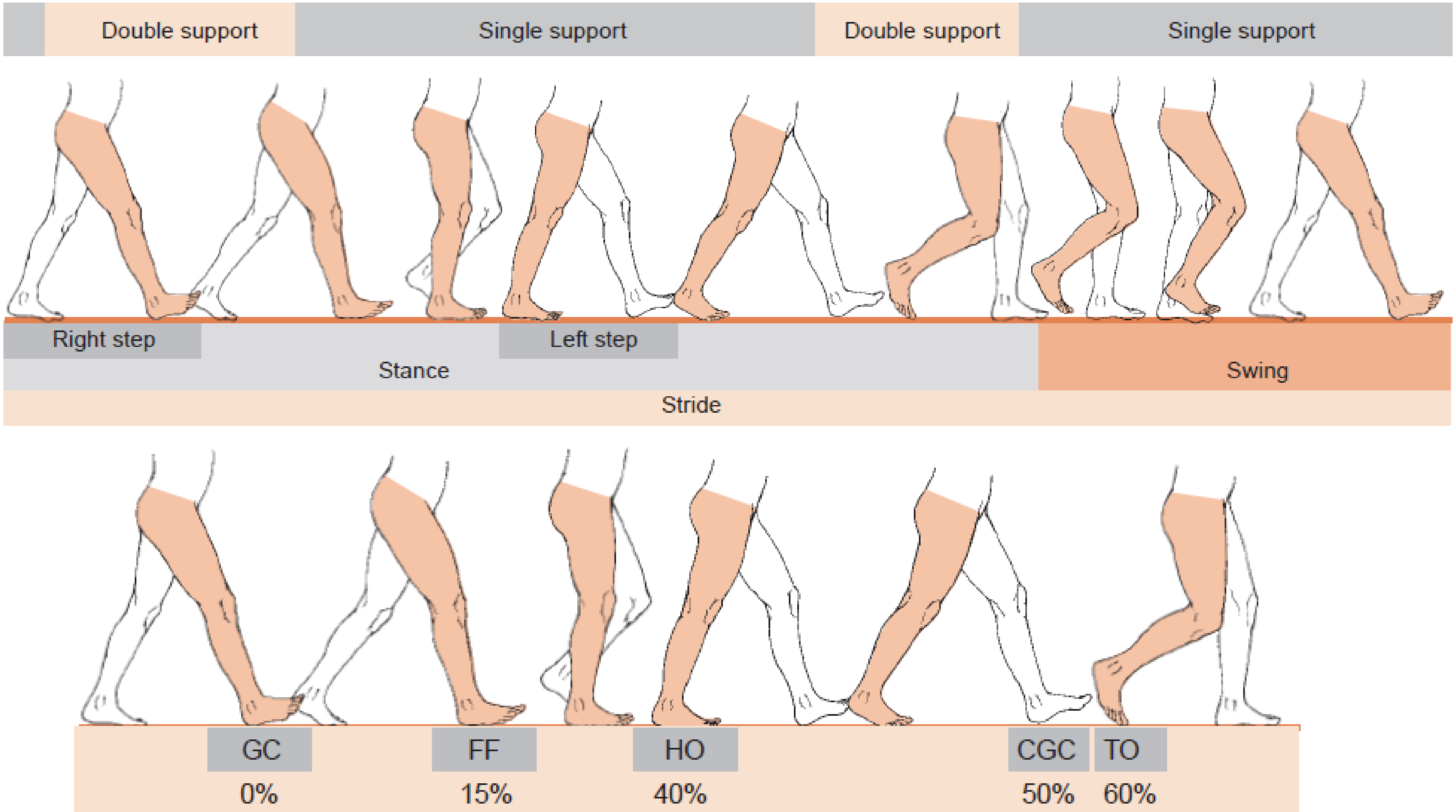


Gait Cycle Components



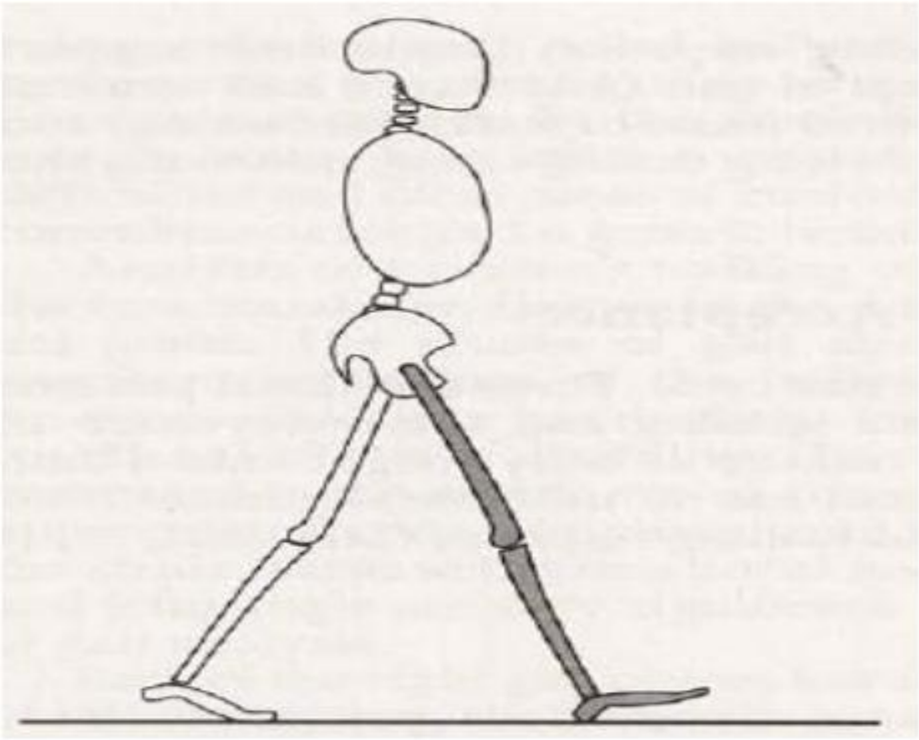
. <u>Swing phase:</u>

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



The stance phase is divided into smaller phases that are demarcated by specific events. *GC, ground contact; FF, foot flat; HO, heel off; CGC, contralateral ground contact, TO, toe off.*

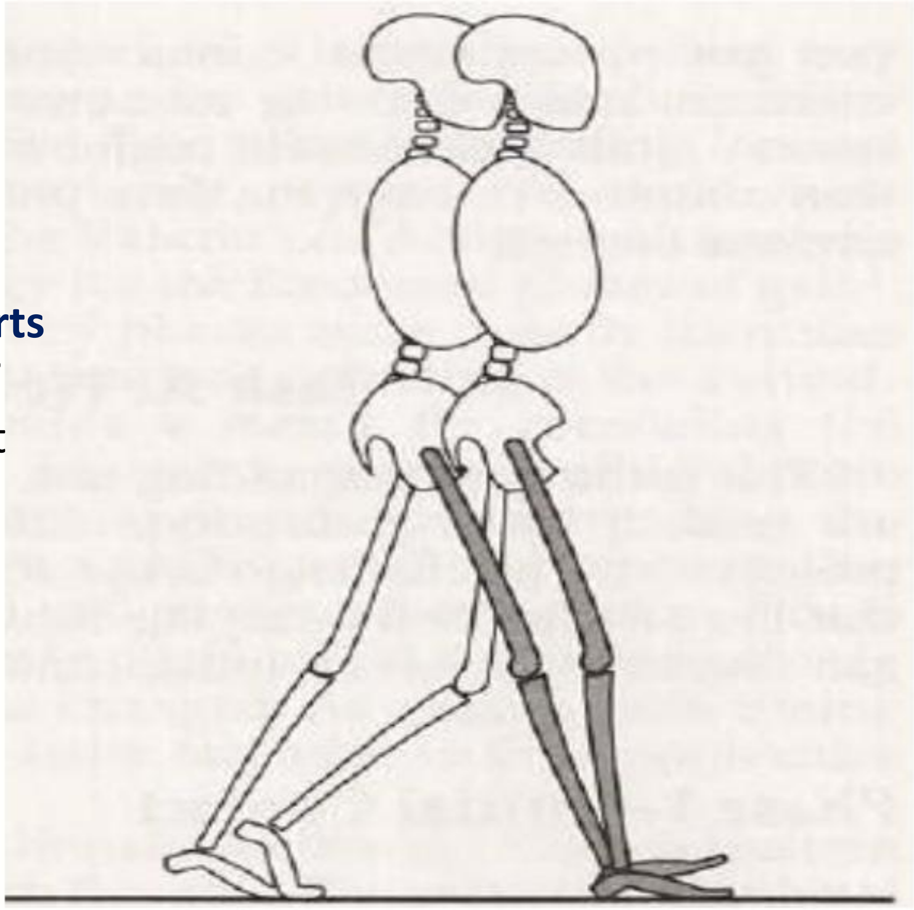
Phase I-Initial Contact



Shading indicates the reference limb

the hip is flexed, the knee is extended; the ankle is dorsiflexed to neutral.

Phase 2-Loading Response
initial double stance period.



Loading response starts **with initial contact of** reference (swing) foot

ends with toe-off of contralateral foot.

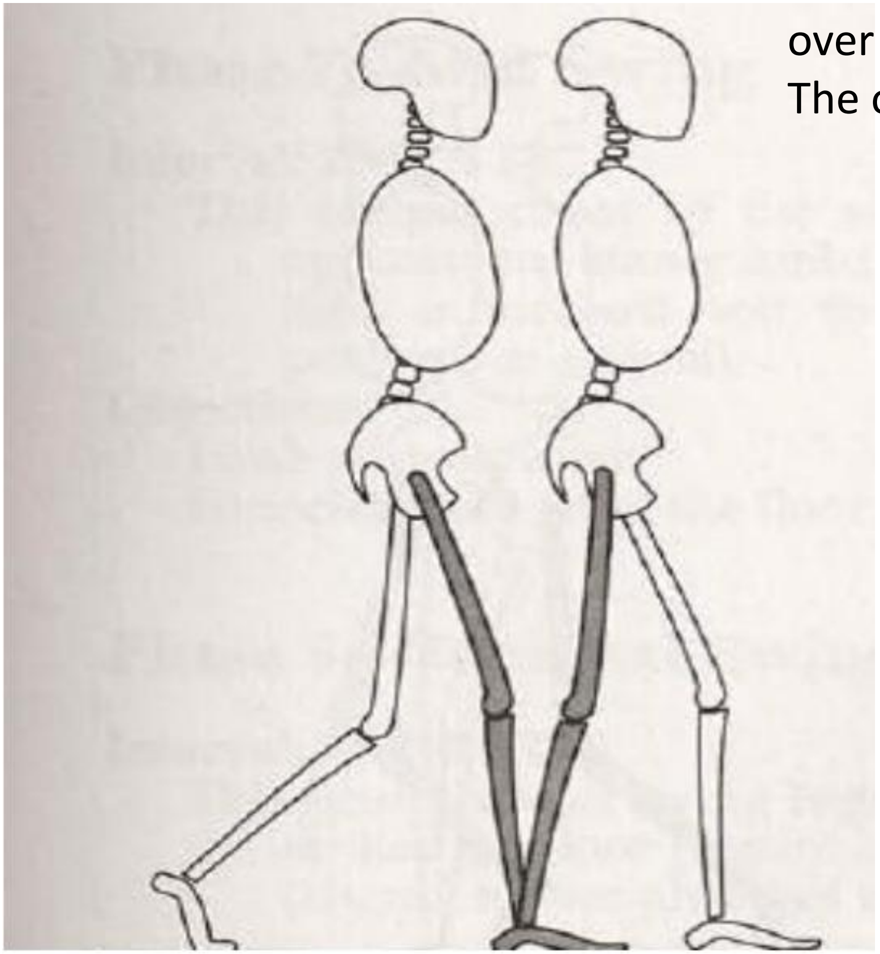
the knee is flexed
for shock absorption.
Ankle

Double Limb Support period beginning
body weight is transferred into the leg in this phase
Important for **shock absorption, weight bearing and forward progression**
Other leg in the **pre-swing phase**

Single Limb Support
-Mid Stance

the other foot is lifted a

until body weight is aligned over the forefoot
The other leg vertical



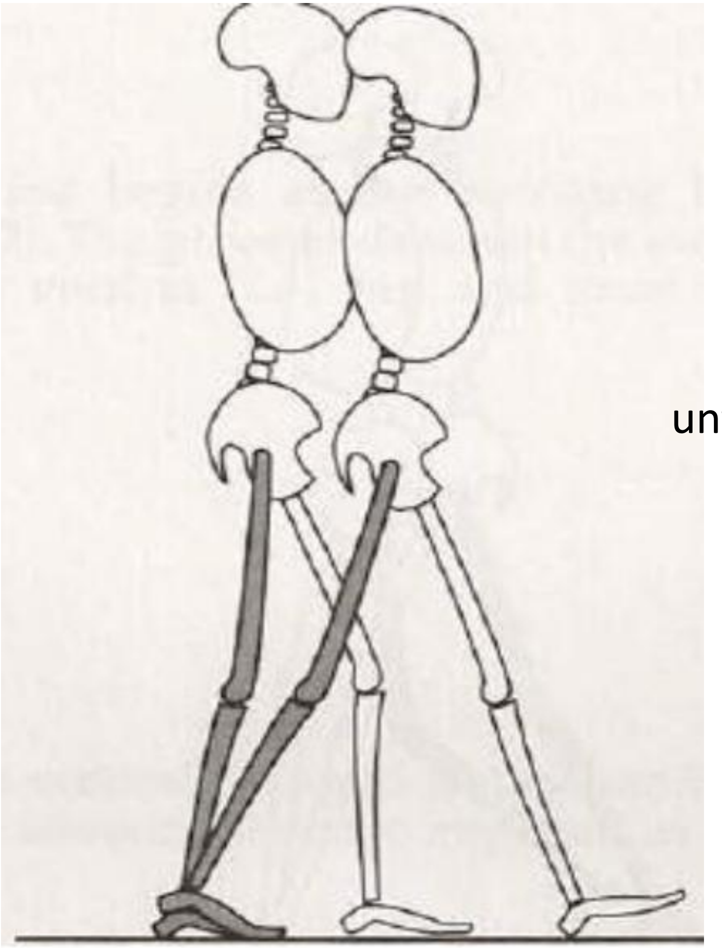
begins with toe-off of swing foot and ends when center of gravity is directly over reference foot now in support phase.

until the **body weight is aligned over the same (supporting) foot**

The other leg in the **mid-swing phase**

Phase 4- Terminal Stance

Terminal stance starts when the same heel rises and continues until
the **heel of the other foot hits the floor**



until the other foot strikes

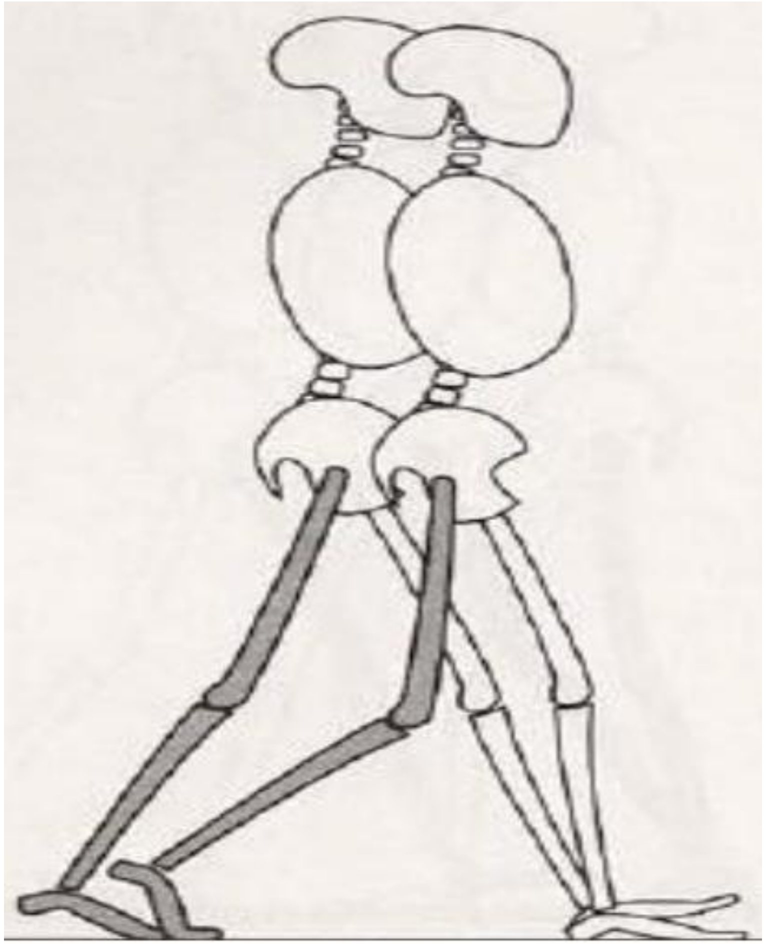
Throughout this phase body weight moves ahead of the forefoot

the heel rises and the limb advances over the forefoot rocker

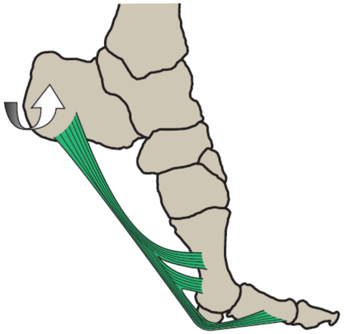
Increased hip extension puts the limb in a more trailing position

Phase 5-Pre-Swing
terminal double support.

begins with initial contact of the opposite limb



ends with ipsilateral toe-off



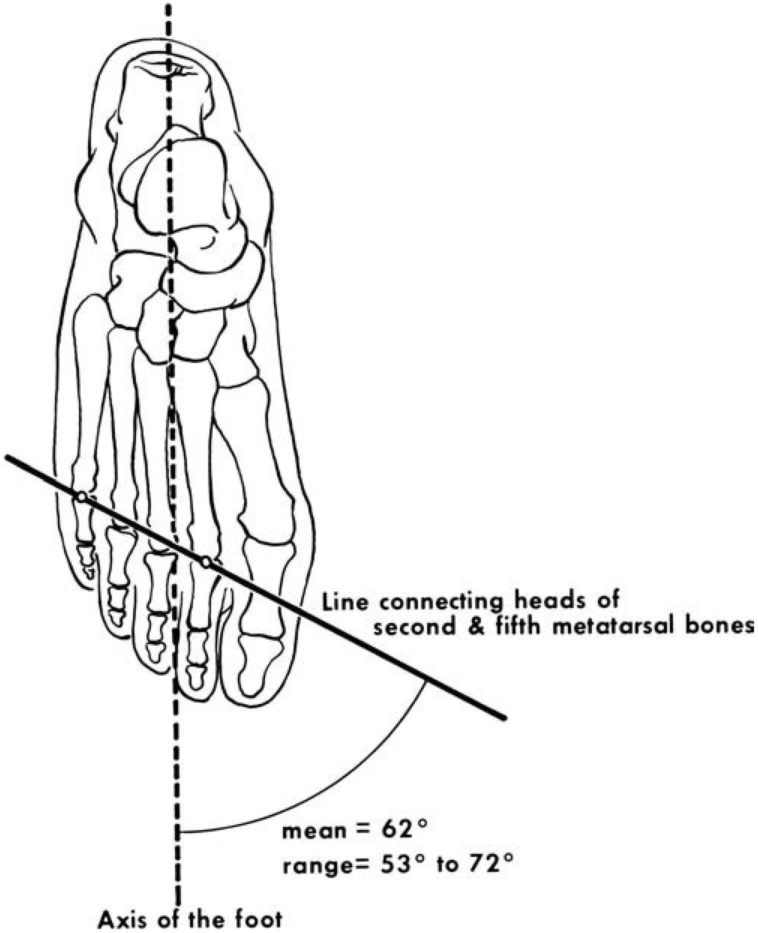
increased ankle plantar flexion. Greater knee flexion and loss of hip extension.

unloads the limb

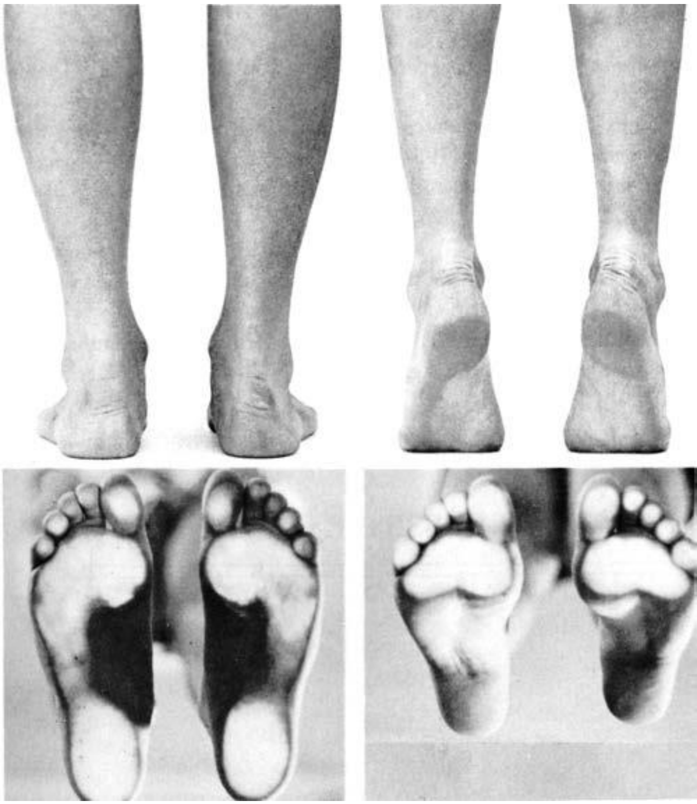
The metatarsal break

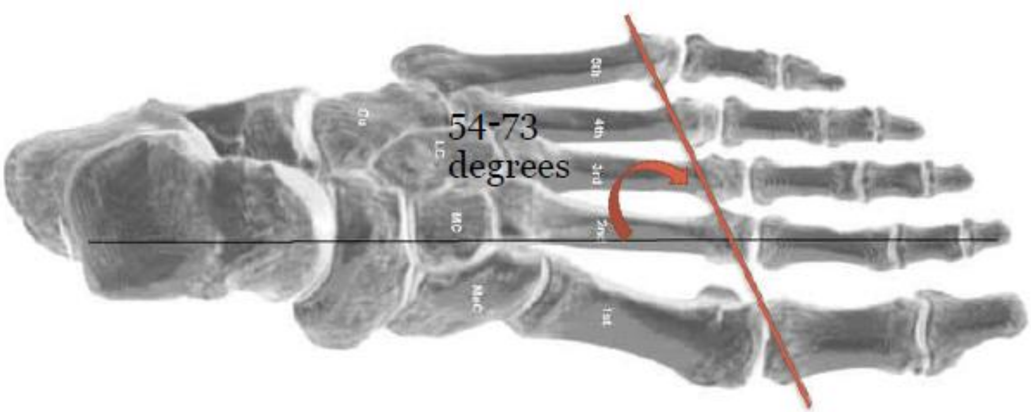
heel rises and the metatarsal heads and toes remain weight bearing.

- The metatarsal break occurs as metatarsophalangeal extension around a single oblique axis that lies through the second to fifth metatarsal heads.



Angle of metatarsal heads: the angle between the long axis of the foot and a line connecting the heads of the second and fifth metatarsals, Rising on toes. Note that as the body weight is transferred to the forefoot, the heels invert, the legs rotate externally, and the longitudinal arches rise.





Axis of metatarsal break

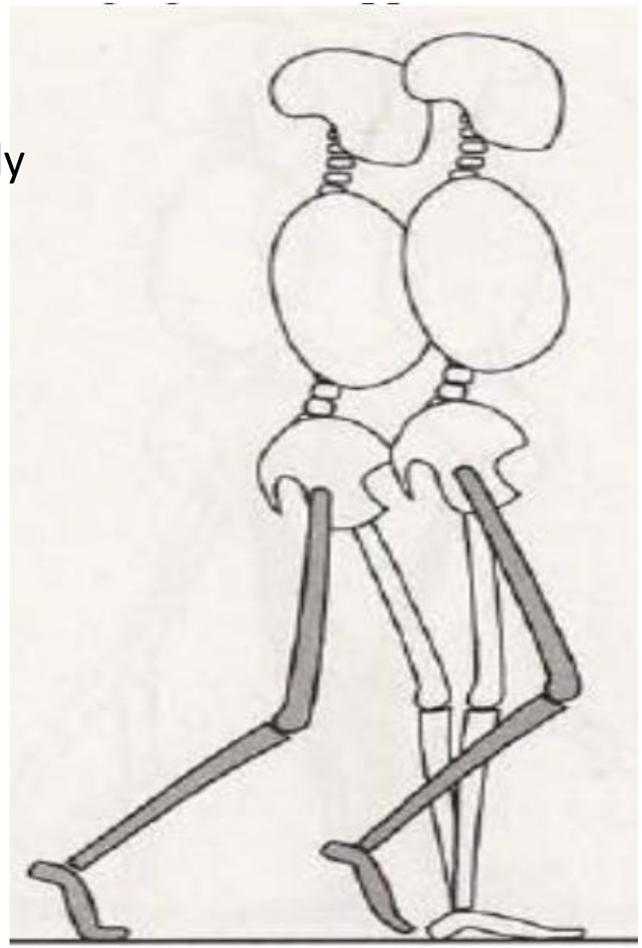
The swing phase

The swing phase is divided into initial swing, midswing, and terminal swing

Phase 6-Initial Swing

Initial swing begins at toe-off, ending when knee is maximally flexed (60 degrees)

1. **Acceleration: 'Initial swing'**

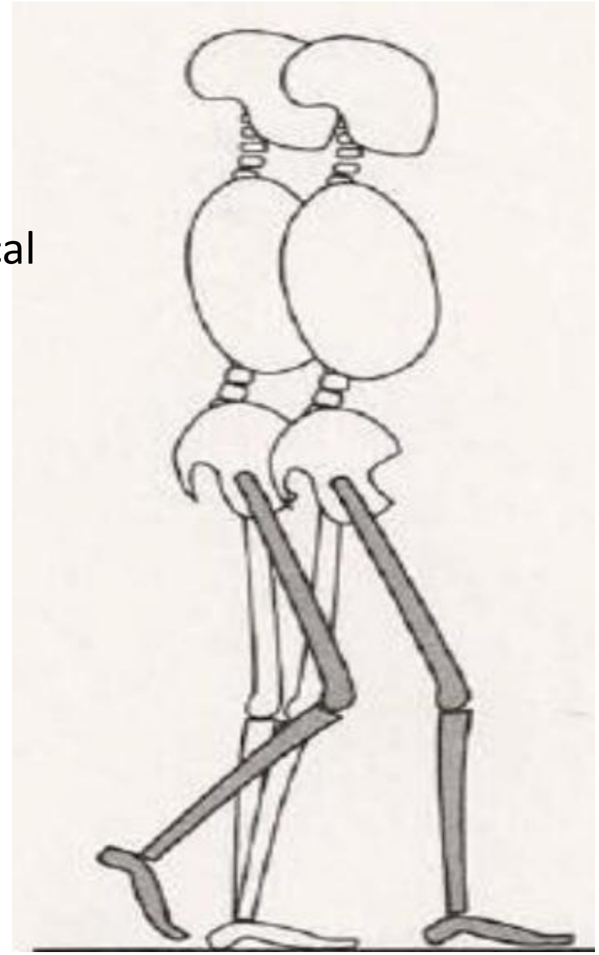


ends when the swinging foot is opposite the stance foot

foot is lifted and limb advanced by hip flexion and increased knee flexion. The ankle only partially dorsiflexes.

Phase 7-Mid Swing

from maximum knee flexion until tibia perpendicular/vertical to ground



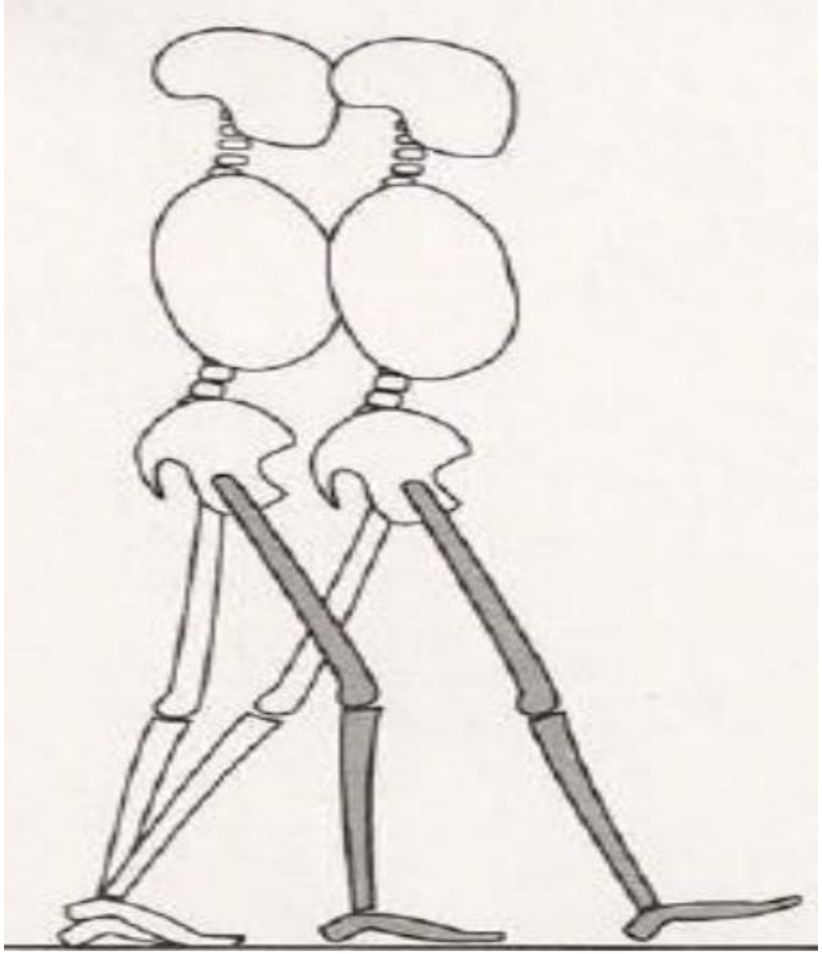
begins as the swinging limb is opposite the stance limb.

The phase ends when the swinging limb is forward and the tibia is vertical

Advancement of the limb anterior to the body weight line is gained by further hip flexion.

Phase 8- Terminal Swing

begins with a vertical tibia

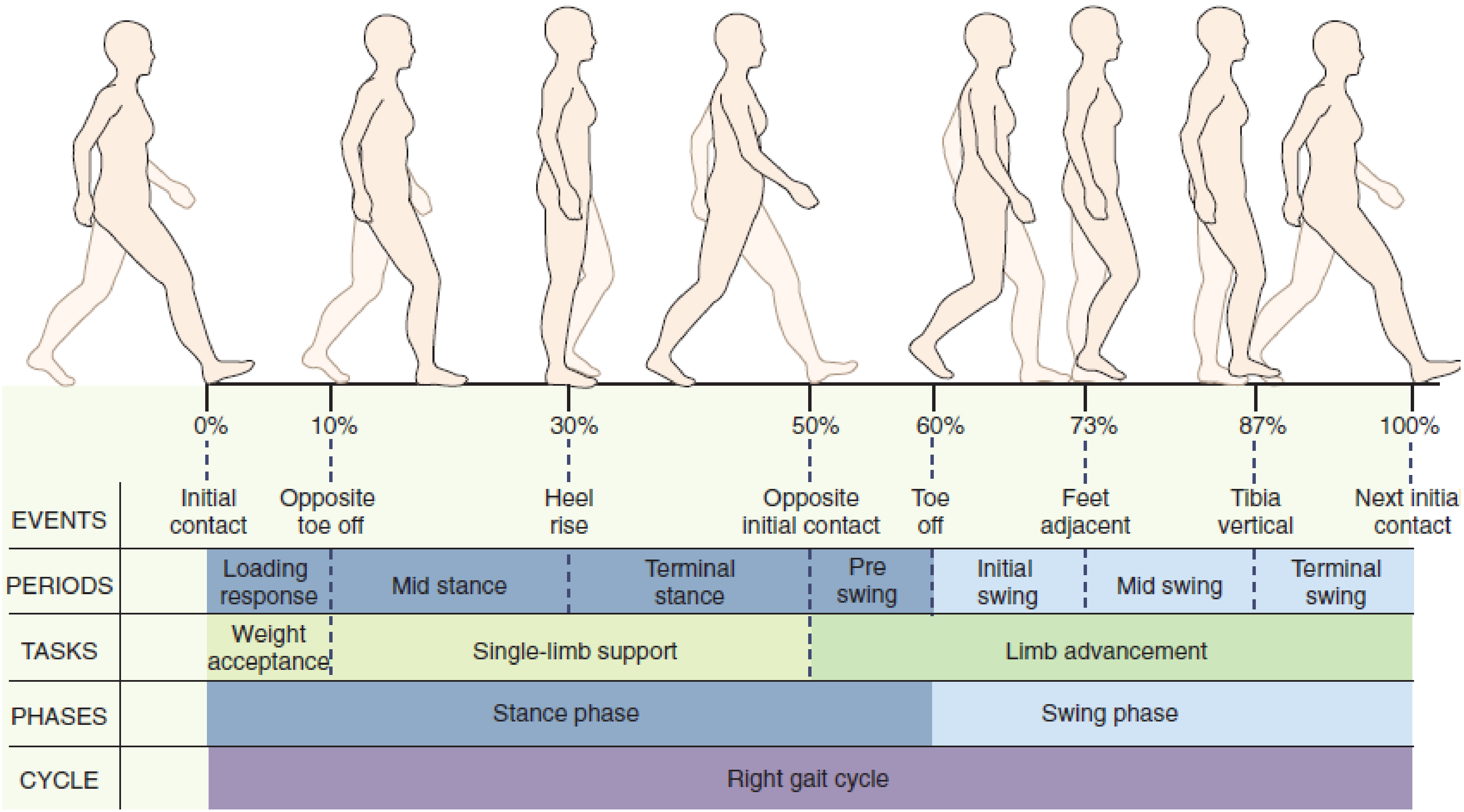


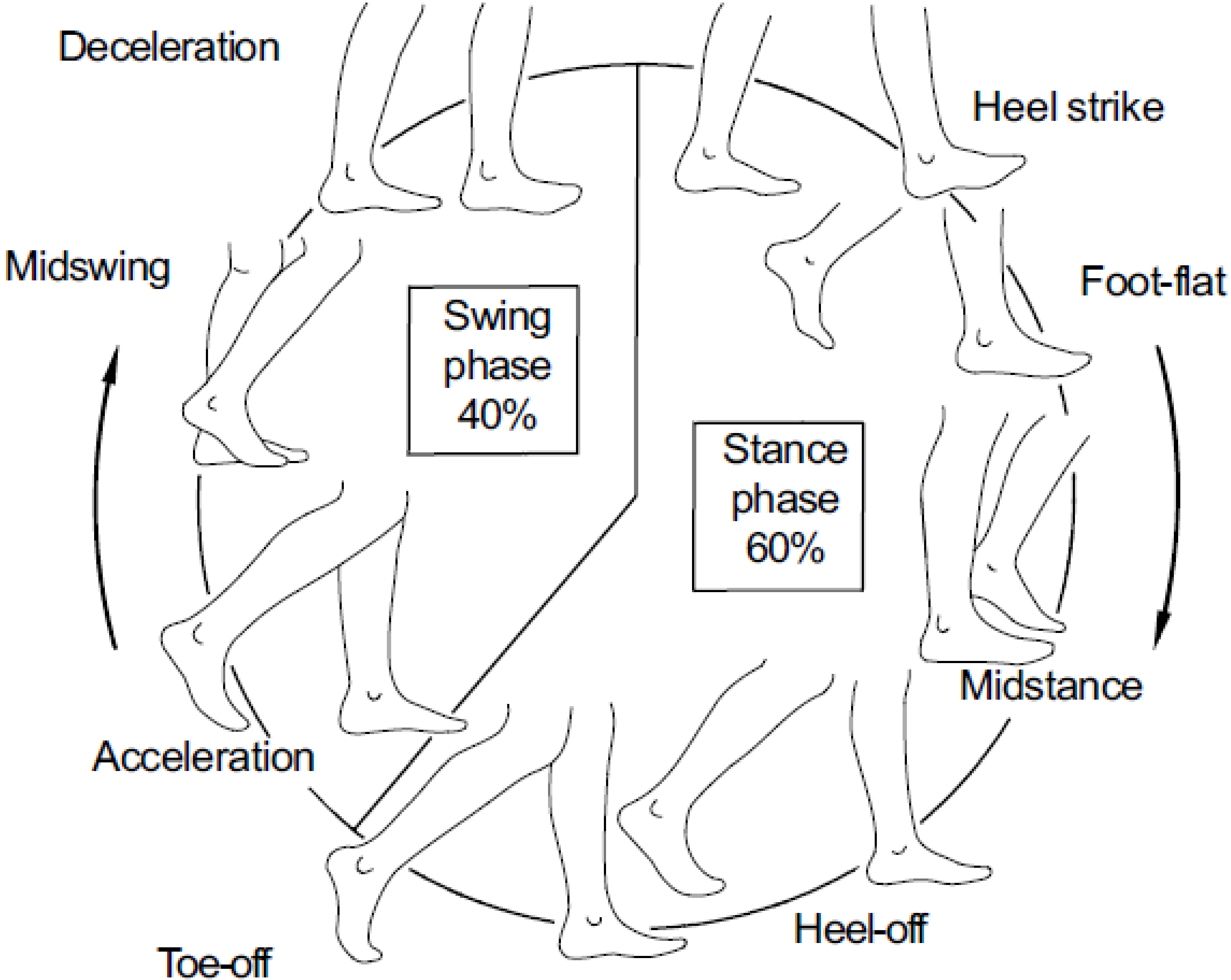
ends when the foot strikes the floor

deceleration

Gait Cycle: Periods and Functions

Period	% Cycle	Function	Contralateral Limb
Initial double-limb support	0-12	Loading, weight transfer	Unloading and preparing for swing (preswing)
Single-limb stance	12-50	Support of entire body weight; center of mass moving forward	Swing
Second double-limb support	50-62	Unloading and preparing for swing (preswing)	Loading, weight transfer
Initial swing	62-75	Foot clearance	Single-limb stance
Midswing	75-85	Limb advances in front of body	Single-limb stance
Terminal swing	85-100	Limb deceleration, preparation for weight transfer	Single-limb stance


0%
10%
30%
50%
60%
73%
87%
100%
EVENTS
Initial contact
Opposite toe off
Heel rise
Opposite initial contact
Toe off
Feet adjacent
Tibia vertical
Next initial contact
PERIODS
Loading response
Mid stance
Terminal stance
Pre swing
Initial swing
Mid swing
Terminal swing
TASKS
Weight acceptance
Single-limb support
Limb advancement
PHASES
Stance phase
Swing phase
CYCLE
Right gait cycle


Deceleration
Heel strike
Midswing
Foot-flat
Swing phase 40%
Stance phase 60%
Midstance
Acceleration
Toe-off
Heel-off

Temporal (Time) variables
Distance (Spatial) variables

Spatial Descriptors of Gait

- Stride length
- Step length
- Step width
- Foot angle

Temporal Descriptors of Gait

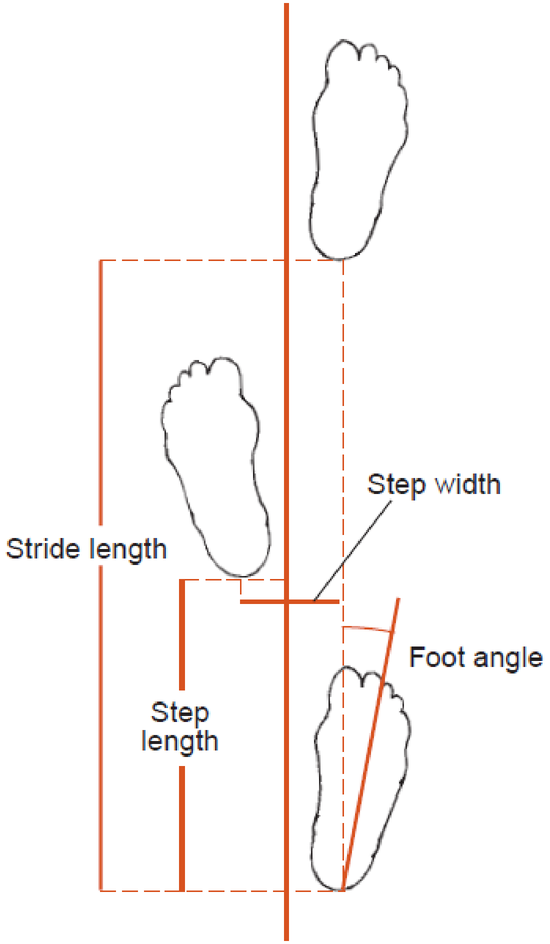
- Cadence
- Stride time
- Step time

Spatial-Temporal Descriptor

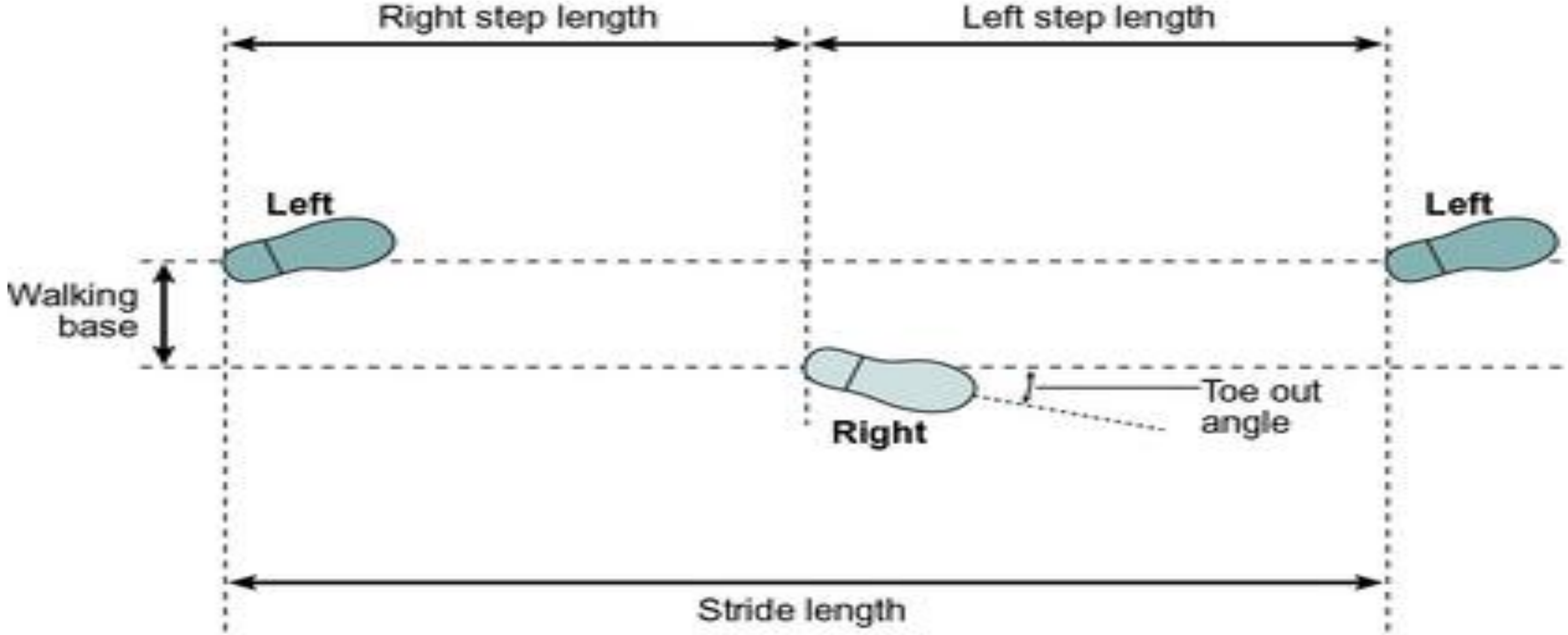
- Walking speed

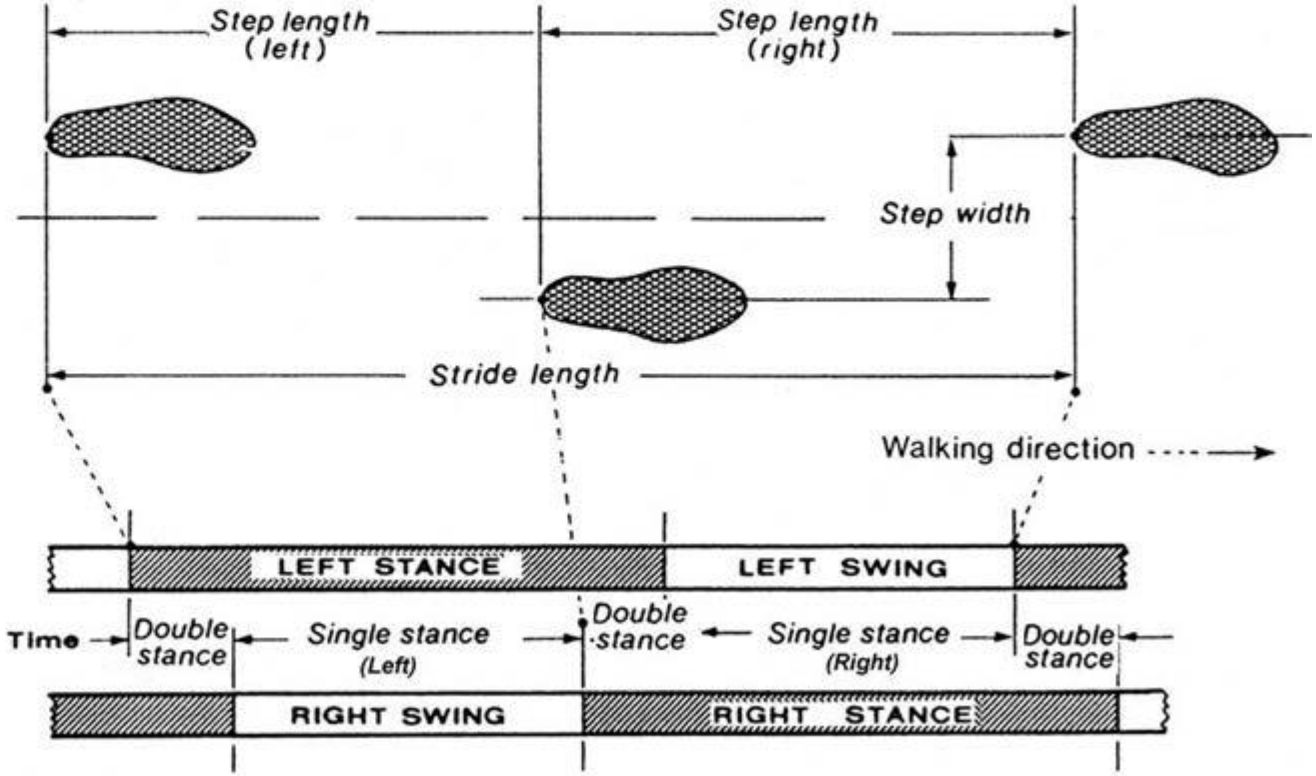
Step Length

Distance between corresponding successive points of heel contact : of the opposite feet.



A *stride (synonymous with a gait cycle) is the sequence of* events taking place between successive heel contacts of the same foot

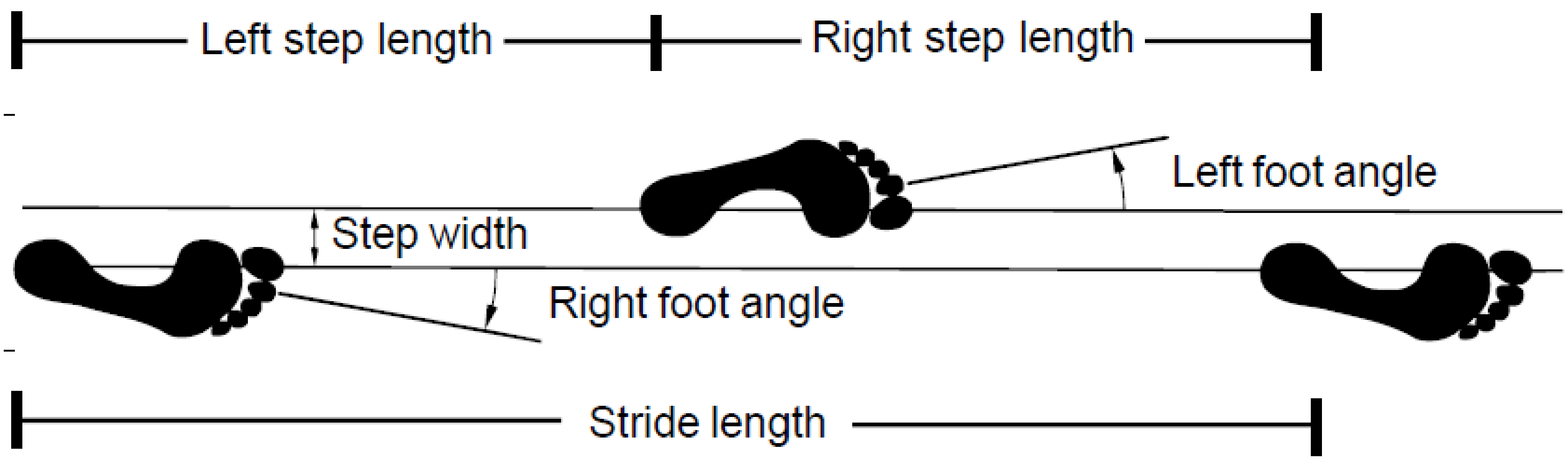




Step width

is the lateral distance between the heel centers of two consecutive foot contacts and is on average around 8 to 10 cm

- **Base of Support (BOS):**
  - That part of the body that is in contact with the supporting surface
  - Width of base of support = 1-5 " inch (on Avg)



Foot angle, the amount of "toe-out,"

is the angle between the line of progression of the body and the long axis of the foot.

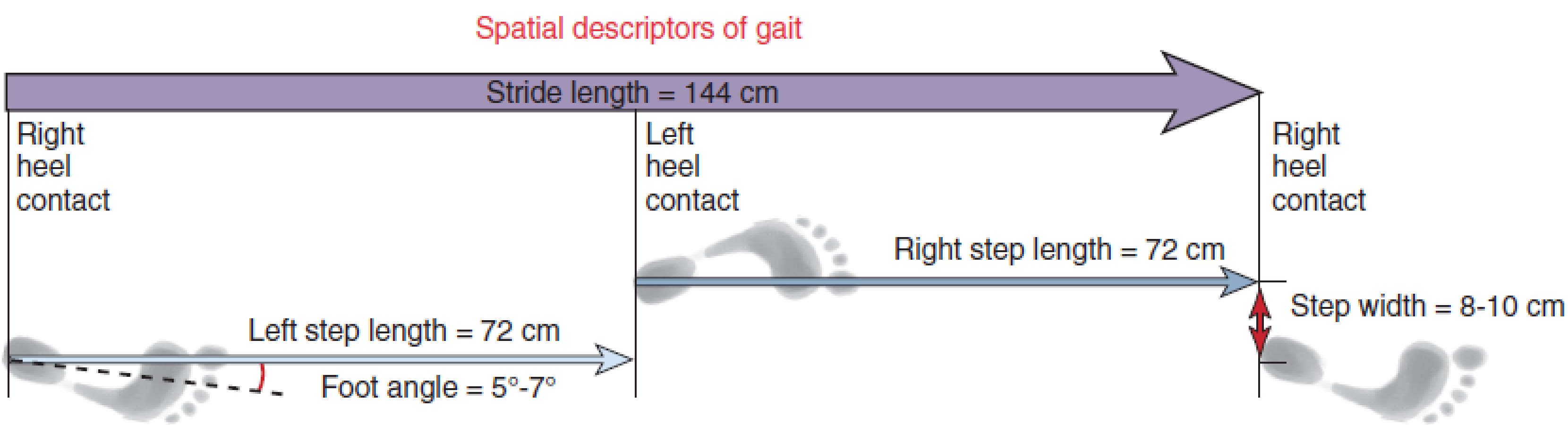
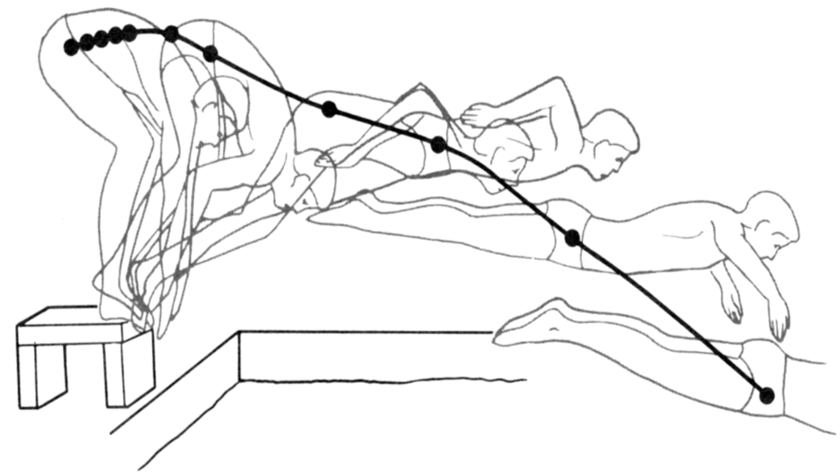


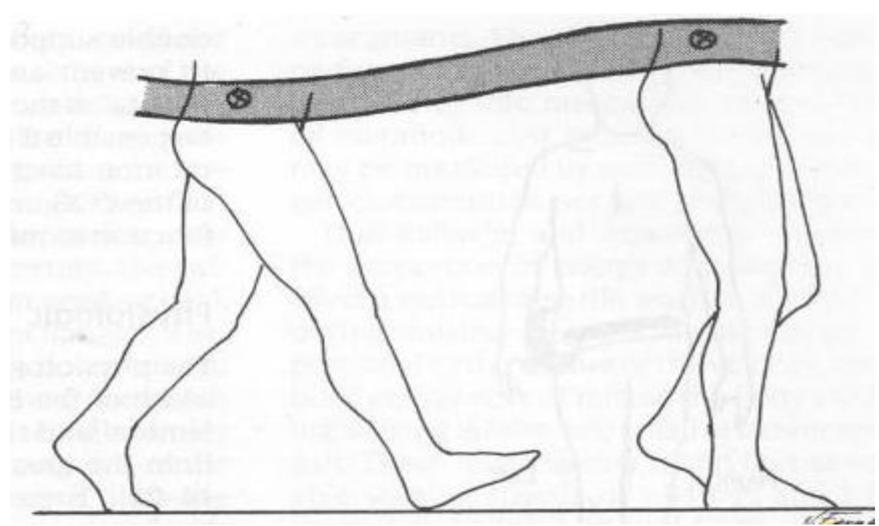
FIGURE 15-7. Spatial descriptors of gait and their typical values for a right gait cycle.

Movement of COG

- Since human beings do not remain fixed in the anatomical position, **the precise location of the COG changes constantly with every new position of the body and limbs**.
- When the line of gravity falls outside the Base of support (BOS), then a reaction is needed in order to stay balanced. Since person is said to be **unstable**
- **The highest point of COG occur in the mid stance phase**
- **The lowest point of COG occur in the double limb support**

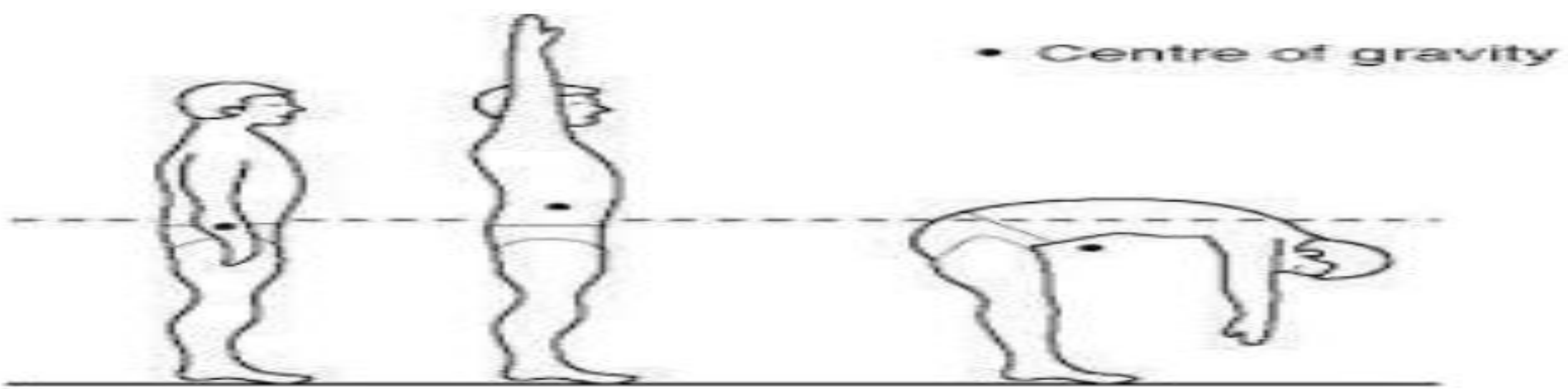


● = Location of estimate of center of gravity marked at every fifth frame



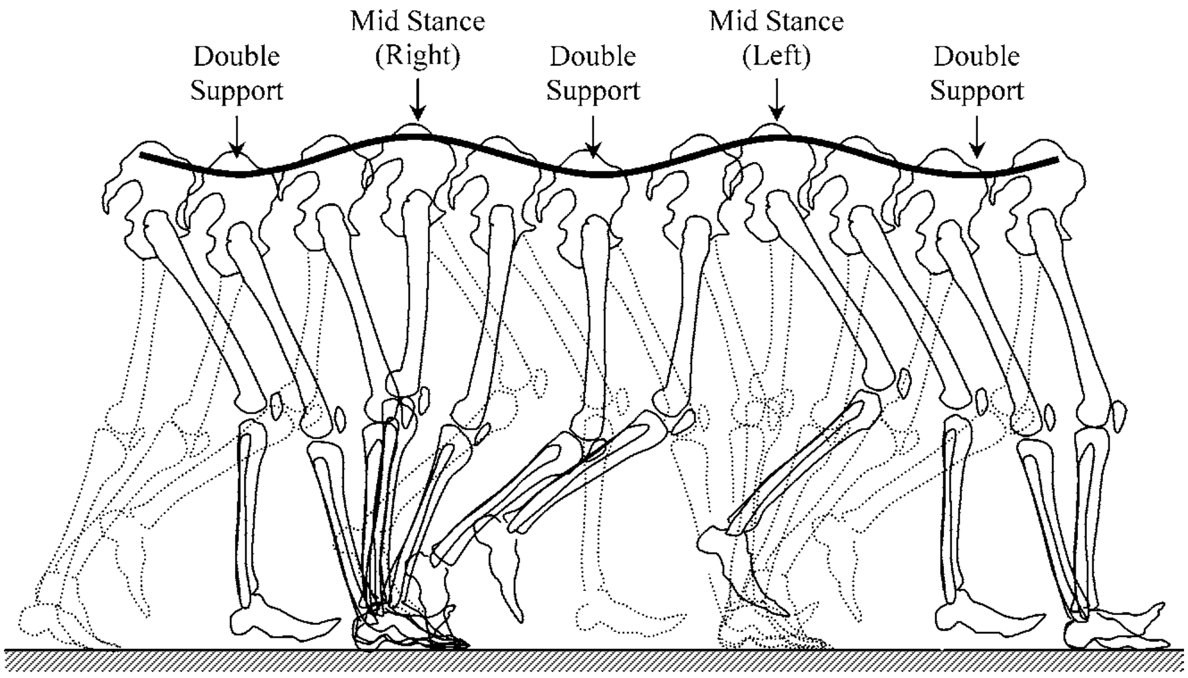
Movement of COG

- Factors affecting COG in the Body
  - **Sex ,,,,female (Lower COG)…Male (higher COG)**
  - **Position of any segment in relation to body total segment**
    - Crouching , kneeling or setting position will lower COG and increase stability
    - A wrestler or defensive lineman will lower COG to increase stability
    - COG will move toward heavy mass … flexion COG move forward, extension backward . Upward , rt or left



COM

The **body's line of gravity is anterior to s2 and provides a** reference for the moment arm to the center of joint under consideration. the resulting gait pattern resembles a sinusoidal curve



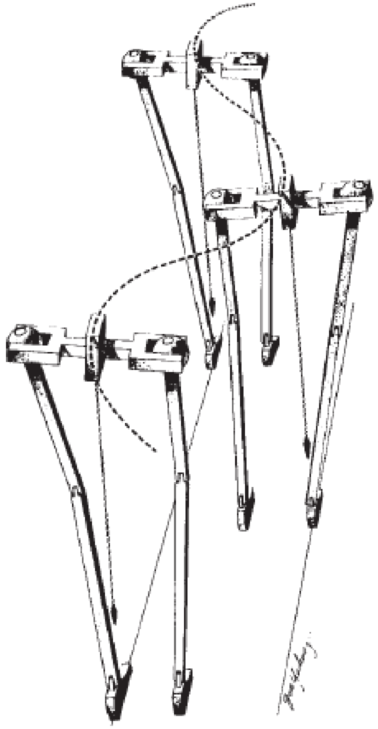
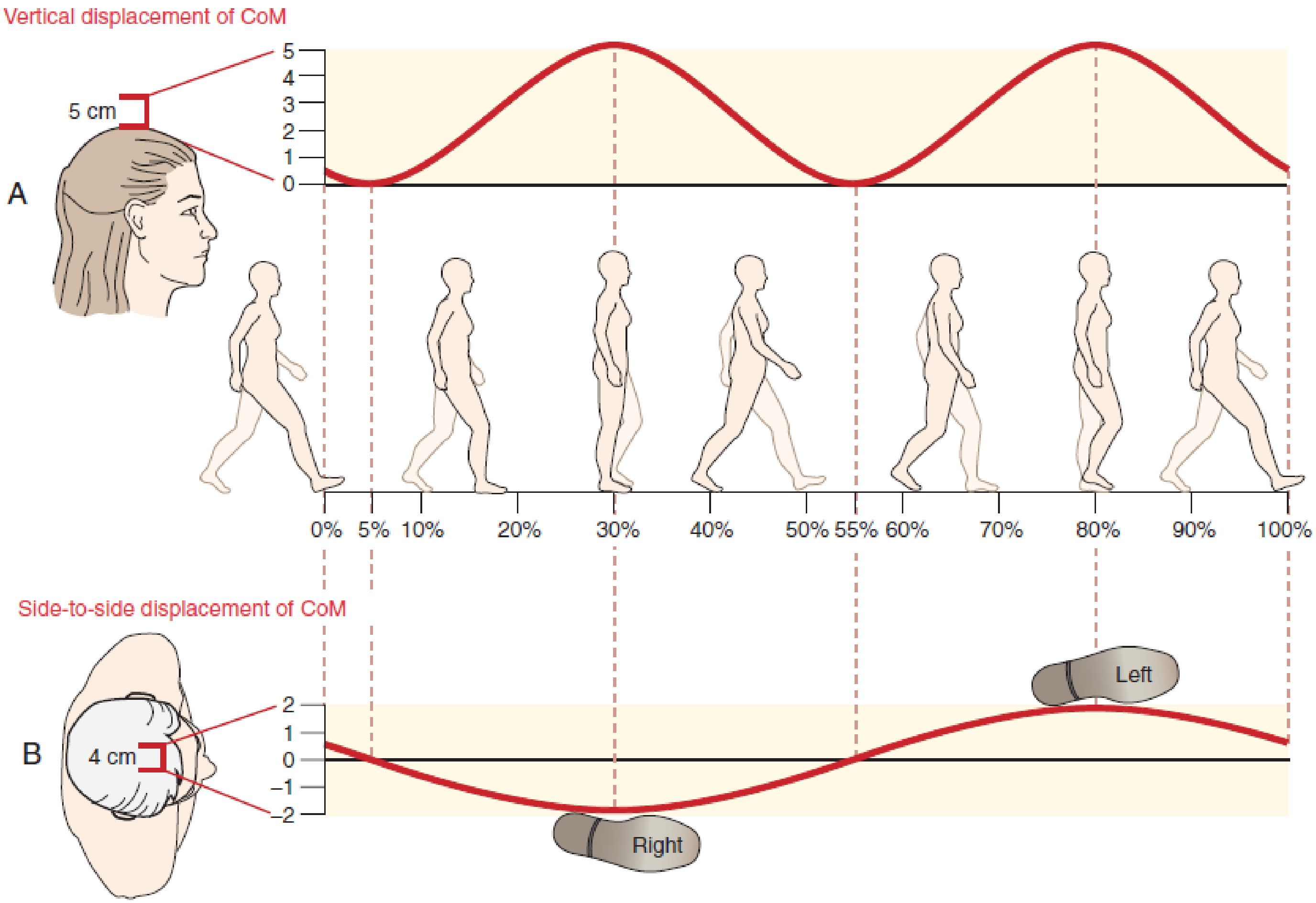


Figure 10.175 Pathway of the center of gravity in the transverse plane during the walking cycle. The pathway is sinusoidal. During each step, the body is displaced over the weight-bearing leg. With a wide walking phase (stride width) the amplitude is large. (Saunders JB, Dec M, Inman VT, et al. The major determinants in normal and pathological gait. *J Bone Joint Surg Am.* 1953;35[3]:552. Reproduced in Inman VT, Ralston HJ, Todd F. *Human Walking*. Baltimore: Williams & Wilkins; 1981:14.)



Center of mass (CoM) displacement during gait. The vertical and the side-to-side displacements of the CoM are illustrated in **A and B, respectively. The CoM is at its lowest and most central position, in** the side-to-side direction, in the middle of double-limb support (5% and 55% of the gait cycle)—a position of relative stability with both feet on the ground. Conversely, the CoM is at its highest and most lateral position at mid stance (30% and 80% of the gait cycle)—a position of relative instability. During single-limb support, the trajectory of the CoM is never directly over the base of support. This fact is illustrated in **B, with the vertical** projection of the CoM always located between the footprints

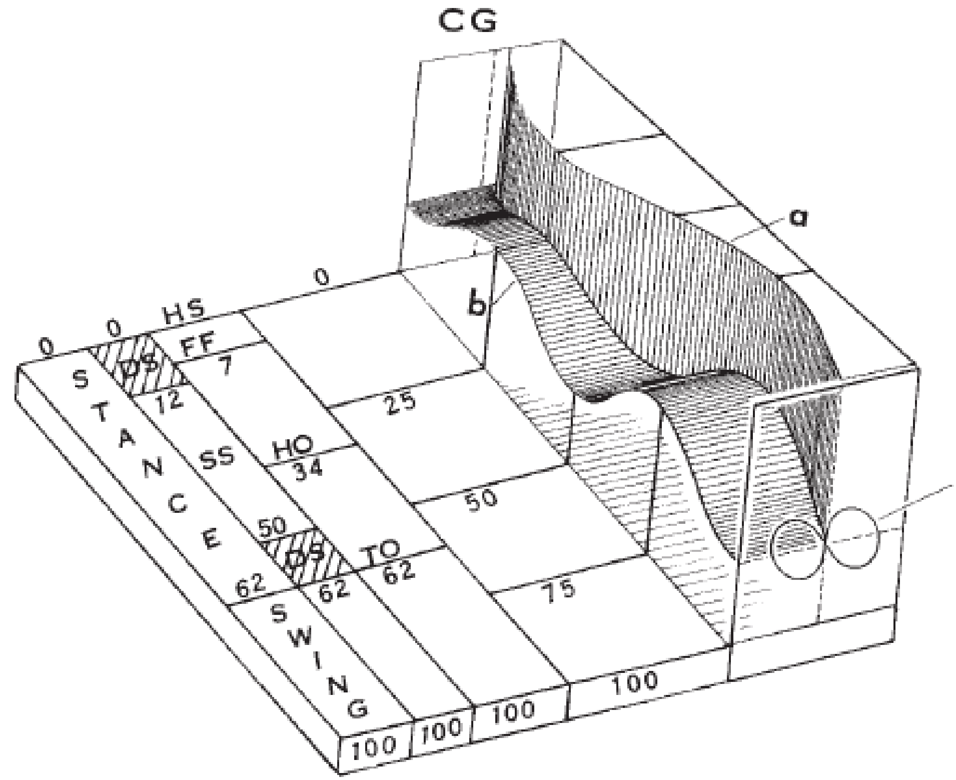
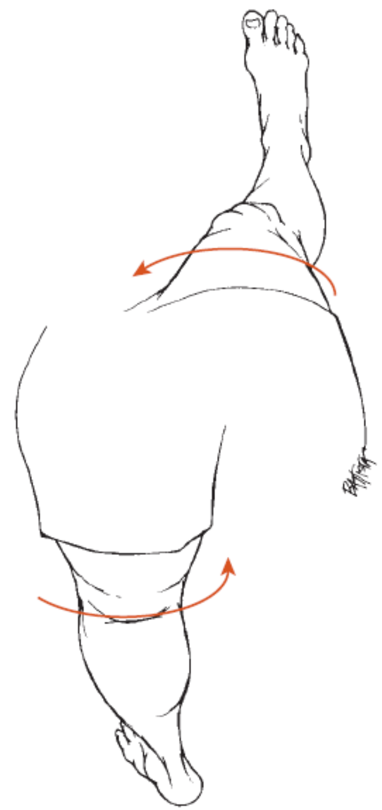


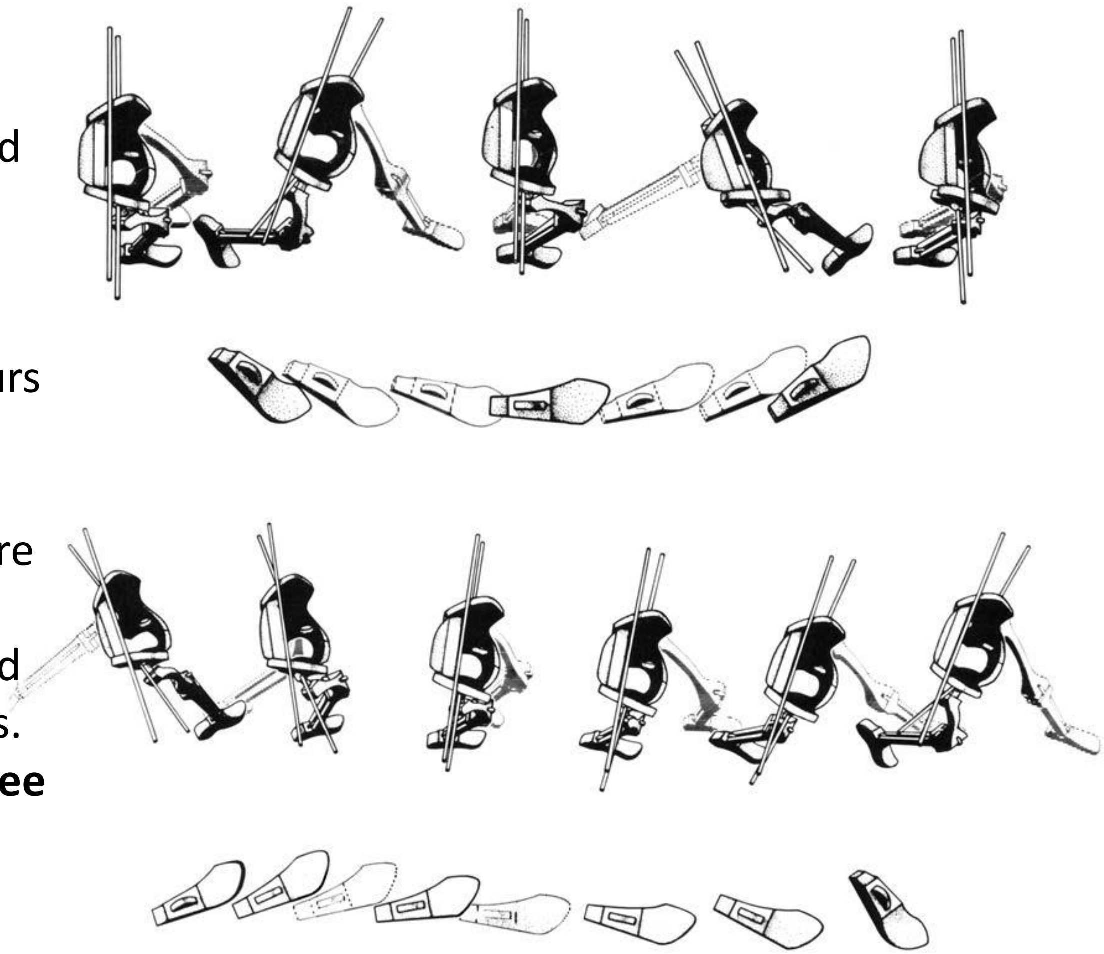
Figure 10.174 The motion of the center of gravity (*CG*) during the gait cycle. The displacement of the *CG* traces a sinusoidal curve *b* in the sagittal plane and a sinusoidal curve *a* in the transverse plane with a resultant curve *c*. In the sagittal plane the maximum displacement of the *CG* occurs at 25% and 75% of the walking cycle, and the lowest point of the *CG* occurs at 50% of the cycle. (*HS*, heel-strike; *HO*, heel-off; *TO*, toe off; *DS*, double support; *SS*, single support.) The numbers indicate the percentage of the walking cycle. (Composite made with the sinusoidal displacement curve segments adapted from Inman VT, Ralston HJ, Todd F. *Human Walking*. Baltimore: Williams & Wilkins; 1981:4.)

Pelvic rotation, the first determinant, may be used to increase step length, especially at faster walking speeds, but it reportedly has little effect on the vertical displacement of the body's center of mass

The pelvic position in the transverse plane and the femoral rotation in the transverse plane both contribute to the transverse plane hip joint position during the gait cycle. At ground contact the femur is medially rotating, but the forward alignment of the pelvis contributes to lateral rotation of the hip. At heel off the opposite is true.



Transverse rotations of pelvis, leg, and foot. A model of the pelvis and lower limb is viewed from above. Small sticks have been attached to the pelvis and femurs to reveal more clearly that the leg rotates through a greater range than the pelvis. The transverse rotations are readily seen. The actual angular displacements have been exaggerated approximately threefold for emphasis. Note that in (**A) the swinging leg is free to rotate internally from toe-off to heel strike. In (B) the leg is in stance** phase and must rotate externally through the same amount. On a slippery surface, the foot would have to slip as shown in the figure



The Human Foot - A Companion to Clinical Studies

The foot by itself works as a small segment of a wheel, whereas the lower leg and the thigh behave together like spokes as in a wheel rolling on the ground, successive points on the wheel always come into contact with successive points on the ground, so that the wheel progresses without need of displacement or rubbing. The same process occurs for the plantar sole during walking. Rolling of the plantar sole thus consists of a successive shifting of pushing against the ground from the heel to the tip of the toes. As in a wheel, rolling avoids friction which would occur in displacement by sliding. Besides this advantage, rolling of the plantar sole on the ground during walking also provides the advantage that it considerably increases the step. . . . This rolling thus increases the step by the length of a foot. The forward foot strikes the ground with its heel and finally leaves the ground from its toes, after having rolled on the ground its whole length. Rolling of the plantar sole is a way of making steps longer and consequently, of using fewer steps in a given time for a consistent velocity of gait. This contributes to the comfort of walking. We would lack this advantage if our legs were built like stilts, which when striking and leaving the ground always rest with their tip at the same point and are provided with no surface for rolling.

Weber and Weber

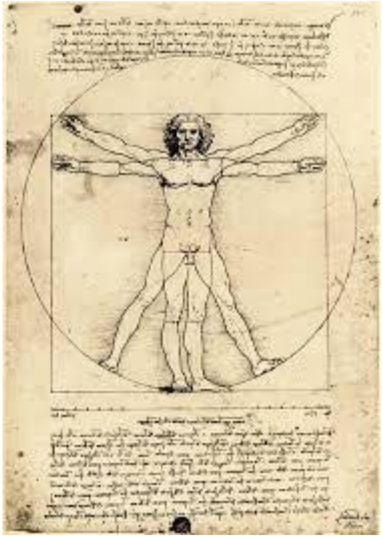
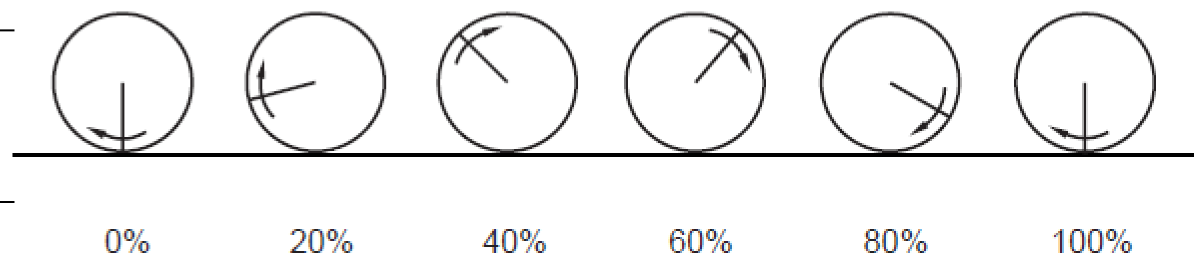
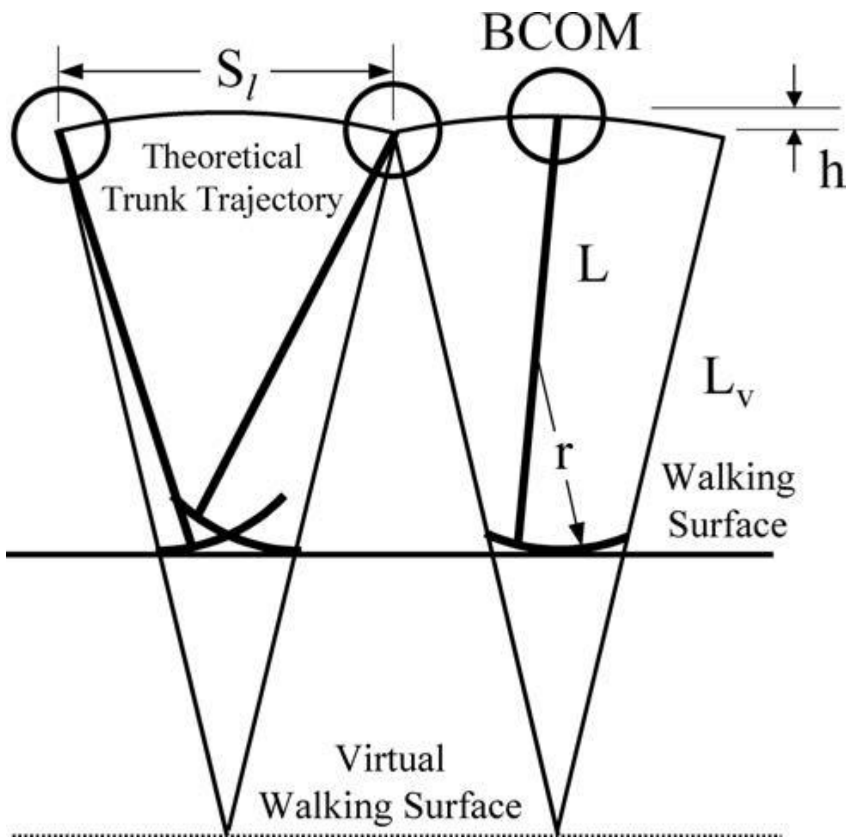


Figure 2.4 A rotating wheel demonstrates the cyclic nature of forward progression.

Gait Cycle



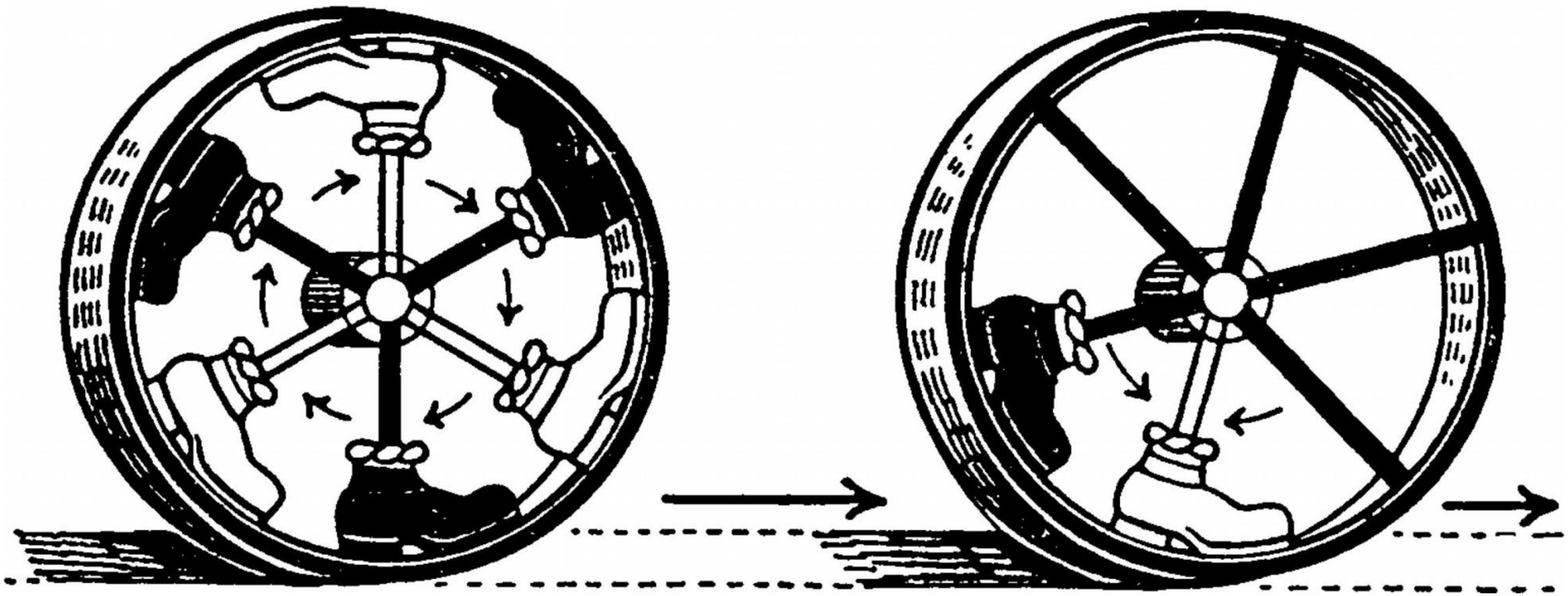
This analogy of a wheel can be applied to human gait. When we think of someone walking these three foot rocker mechanisms are integrated during walking to create a single, smooth "rollover shape" for the foot/ankle system that facilitates progression of the center of pressure (COP) distally along the plantar surface of the foot; this effectively lengthens the leg and flattens the trajectory of the body center of mass (14

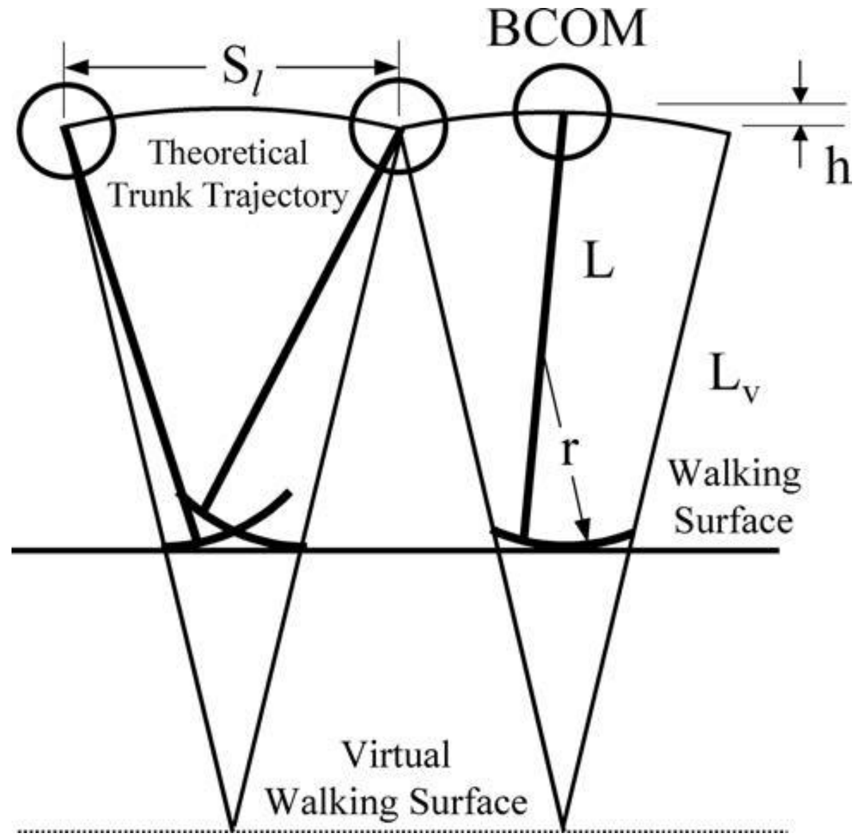


during single support the body appears to move along the arc of a circle that has a radius about 2.2 times longer than the length of the leg.

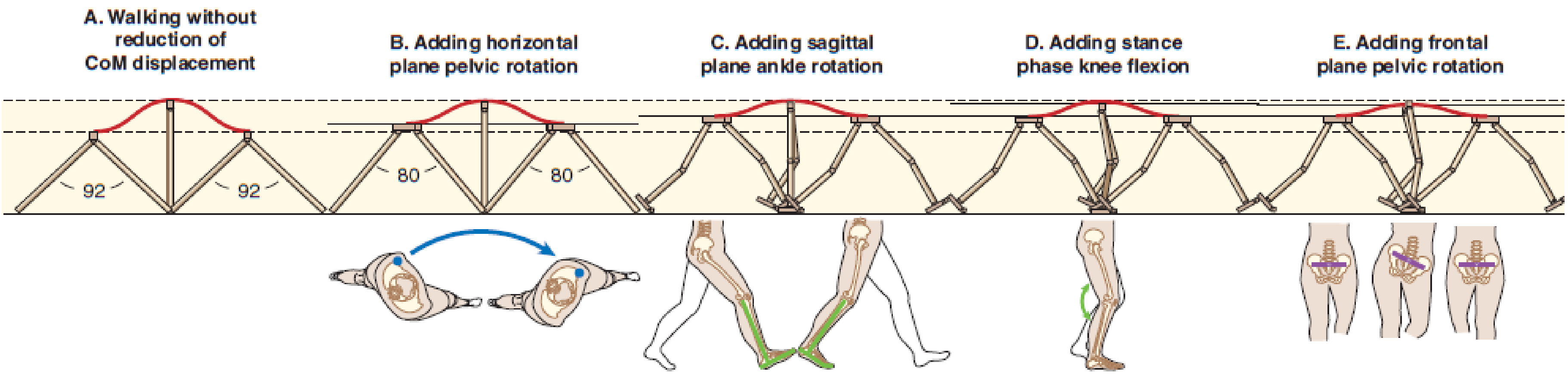
In a rocker-based inverted pendulum model, the foot rocker (with radius r) effectively lengthens the anatomical leg (L) to create an effective leg length (Lv) that flattens the vertical displacement of the body (h) for a given step length (S*l*).

The foot as part of a wheel. (From James Gray How Animals Move (1953) Cambridge University
Press, page 19, with permission




BCOM
S_l
h
Theoretical
Trunk Trajectory
L
L_v
r
Walking
Surface
Virtual
Walking Surface

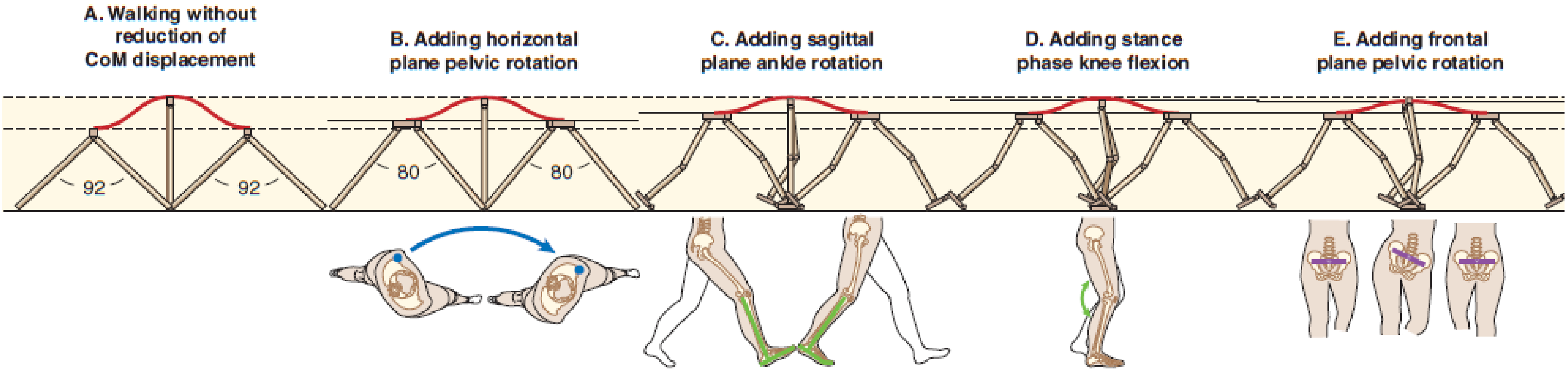
Vertical motion of the body's center of mass appears to be reduced by foot and ankle rocker mechanisms



the large vertical oscillation of the CoM while a persor walks *without the strategies*

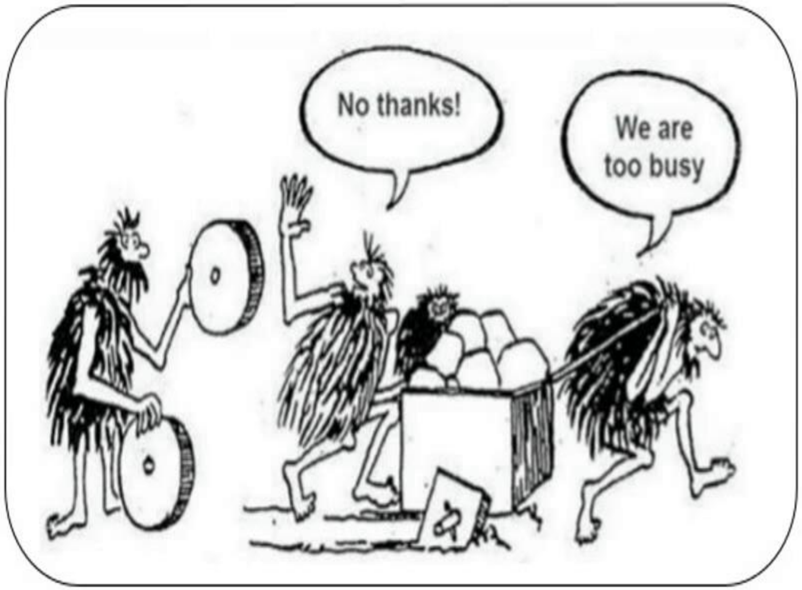
B illustrates that rotation of the pelvis in the horizontal plane functionally lengthens the lower extremities and reduces the magnitude of the hip flexion-extension angle required for a given step length, thereby reducing the downward displacement of the CoM.

This series illustrates the individual and additive effects of four kinematic strategies to reduce vertical center of mass (CoM) excursion.



C illustrates that further reduction of the downward displacement of the CoM is achieved by rotation of the ankle in the sagittal plane. D illustrates that the small amount of knee flexion present during stance reduces the functional length of the lower extremity and therefore the upward displacement of the CoM

. **E shows that the contralateral**
pelvic drop during stance also reduces the net overall elevation of the CoM. The angle values in **A and B are for illustrative purposes only and do not represent the actual** hip angles during walking


No thanks!
We are too busy


WAY BETTER!
Should have done this long time ago!

DETERMINANTS OF GAIT (MOTION PATTERNS)

The basic concept proposed was that the first three

determinants—pelvic rotation [first],

pelvic list [second]

and knee flexion in stance phase [third]—

all presumably act to flatten the trajectory of the body center of mass (BCOM) and thereby reduce the vertical translation of the body during able-bodied walking

Determinants of gait

- **Definition:** Determinant is a various movement occurs in the body including pelvis, knee and ankle to maintain center of gravity of the body in a horizontal plane, ensure the smoothing pathway of gait and keep movement of the COG to minimum

I. **Displacement of center of gravity (COG).**

II. **Factors responsible for minimizing displacement of center of gravity.**

- Major factors
  1. Lateral pelvic tilt (frontal plane)
  2. Knee flexion in stance
  3. Knee, Ankle and foot interactions

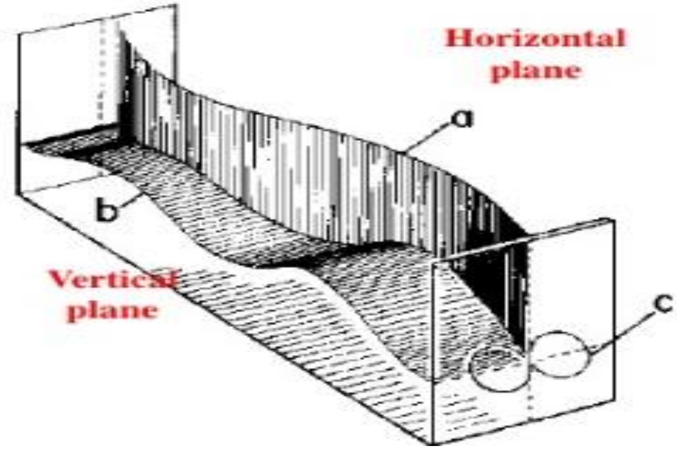
  (items 1–3: Keep the vertical height of COG)

  4. Pelvic rotation (transverse plane) prevent drop
  5. Lateral displacement of body
- Minor factors
  1. Neck movements
  2. Swinging of arms

Determinants of gait

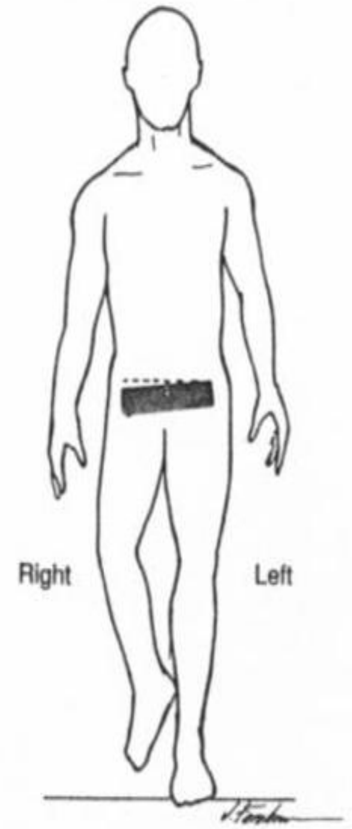
- **Displacement of COG**
  - During normal pattern of gait within each gait cycle, the center of gravity is displaced:
    - **Twice in vertical direction, in sagittal Plane.**
      - Movement of the lowest displacement occurs at heel strike and double support.
      - Movement of the highest displacement occurs at mid-stance.
      - Average: 1.8 inch.
      - Pathway: sinusoidal curve (up and down).
    - **Twice in lateral direction, in horizontal Plane.**
      - The displacement occurs over the right then over the left leg during walking.
      - The maximum displacement is at mid-stance
      - Average: one and 3/4 inches.
      - Pathway: sinusoidal curve.
  - That occurs relative to plane of progression.

Determinants of gait



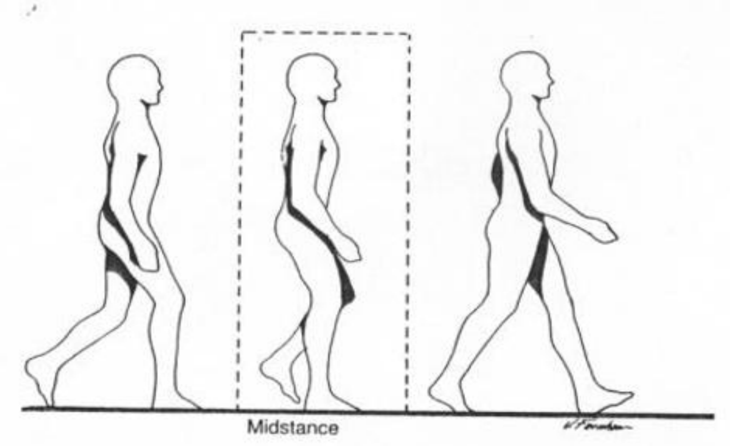
- **The combination of displacement**
  - When the vertical and lateral displacement of center of gravity of body are combined and projected on the coronal plane: They will describe as figure of(8).
  - It occupies approximately "2" inches square.
  - The importance of displacement pattern of center of gravity is helping in translation of body from one point to another tical displacement during walking
  - **N.B.** At the maximum vertical displacement of center of gravity, it still lies slightly below the level of same COG when the subject is standing. that means **the person is slightly shorter when he is walking than in standing**.

Determinants of gait



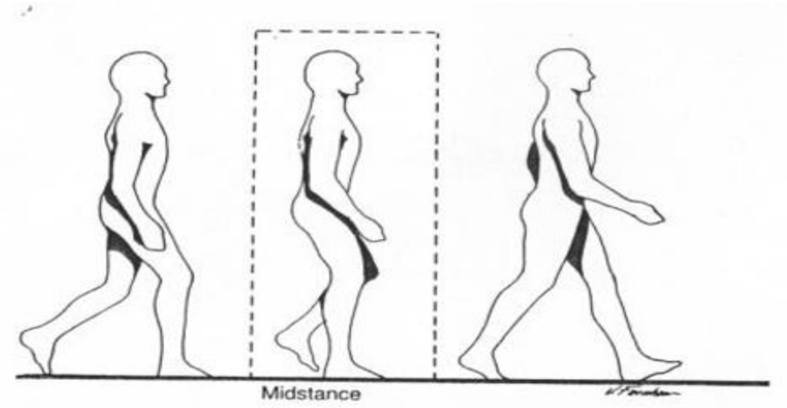
- **Lateral pelvic tilt** :
  - In normal pattern of walking:
  - The pelvis tilts downward on swing leg (on the side which is opposite to that of weight bearing leg) along the frontal plane around sagittal axis. The **maximum tilting is at mid-swing**.
  - **The average magnitude:** The average of the angular displacement is (5°) five degrees.
- **Associated hip movement:** There are relative hip adduction in stance phase and hip abduction in the swing phase.
- **Function:** Pelvic tilting helps to decrease vertical displacement of center of gravity 1/8 inch.

Determinants of gait



- **Knee flexion in stance phase**
  - In normal pattern of walking:
  - **At initial contact**, the knee is almost (0 ±5^{o}).
  - **At loading response**, the knee begins the first excursion of flexion after the heel strike (= 15^{o} – 20^{o})
  - It has 3 functions:
    1) Shock absorption.
    2) Minimize displacement of COG. Smoothen the pathway of COG from lowest COG to highest COG point (from double stance to mid stance(single stance)).
    3) Decrease energy expenditure.
  - **At mid- stance**, the extension of knee reaches (5^{o}) in flexion.
  - **At terminal stance**, the knee joint reaches 0^{o} of extension to start the first excursion of knee extension.
  - **At pre-swing**, the knee joint flexes up to 10^{o} flexion to start the second excursion of knee flexion.

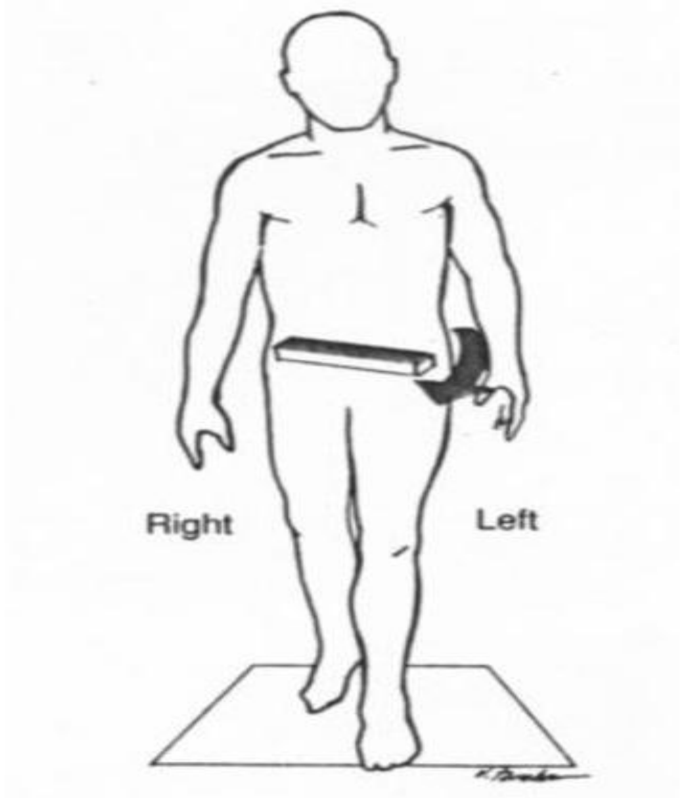
Determinants of gait

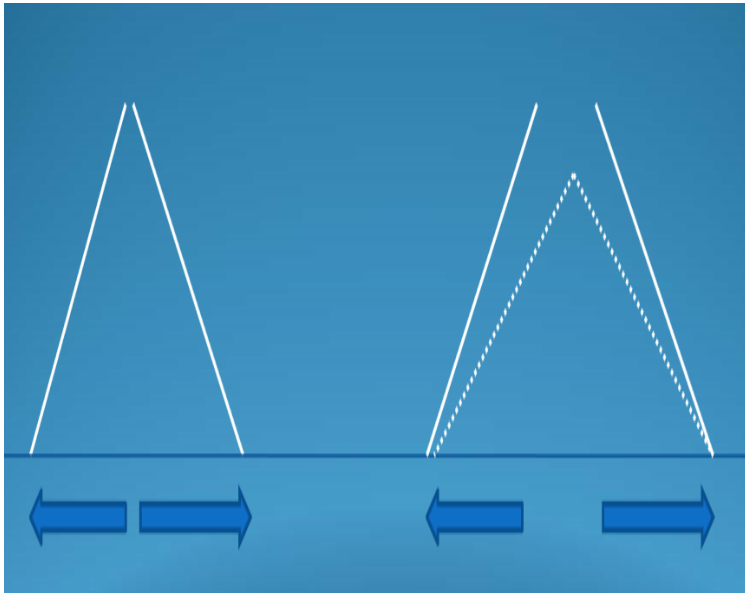


- **Knee, ankle and foot interaction**
  - In normal pattern of walking:
    - **Early in the stance phase**:
      - The foot is dorsiflexed while the knee is almost fully extended. So, the extremity is at its maximum length and the center of gravity reaches its lowest point in a downward displacement.
    - **Late in the stance phase:**
      - The foot is plantar flexed while the knee is in the beginning of flexion. That will maintain the center of gravity in its beginning of progression with minimum displacement.(COG raises again)

Determinants of gait

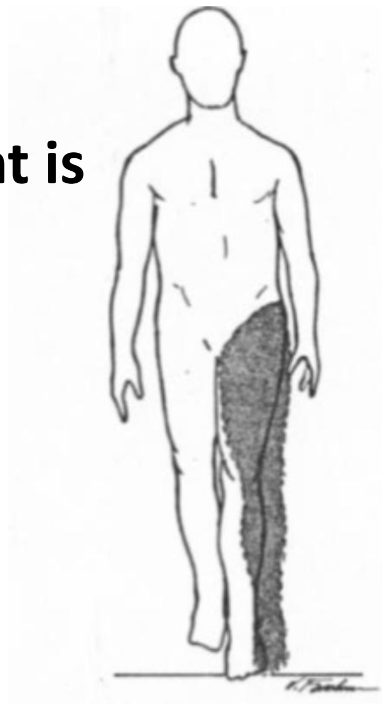
- **Pelvic rotation**
  - In normal pattern of walking:
  - The pelvis rotates alternatively to right and to left in relation to the line of progression in transverse plane about the vertical axis forward.
  - **The average magnitude** of this rotation is approximately four degrees (4^{o}) on either side of the central axis **(in the transverse plane 4 degrees forward on the swing limb and 4 degrees backward on the stance limb)**. The total equal "8" degrees.
  - **Associated hip movement**: Internal and external rotation during stance phase.
  - **Function:** Pelvic rotation during normal gait decreases the vertical displacement of COG 3/8 inches and cause apparent lengthening of the limb **(stride is lengthened without excessive drop of COG)**



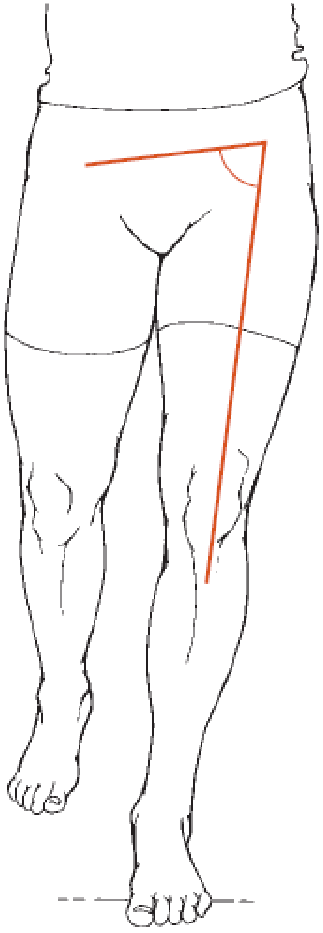


Determinants of gait

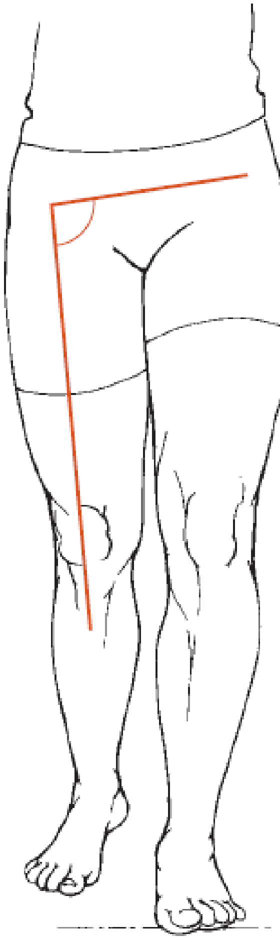
- **Lateral displacement of body and COG:**
  - In normal pattern of walking:
    - The center of gravity is displaced laterally over the weight – bearing extremity twice during the cycle of motion in the horizontal plane.
    - The motion is produced by the **horizontal shift of pelvis, physiological knee valgus and relative adduction of hip**.
    - Magnitude: **The maximum lateral displacement is lateral at mid-stance on the side of weight bearing leg (4.5 cm each stride).**



At weight acceptance, the individual shifts laterally to b keep the center of mass close to the stance foot, and the pelvis drops on the unsupported side. The stance hip is in adduction.



During weight acceptance, the hip drops on the
unsupported side, which is abducted.



Prerequisites of normal gait

Perry (1985) described five prerequisites of normal gait, a concept subsequently popularized

by Gage:

1. Stability in stance: this requires a stable foot position and good control of body segments above the lower limbs whilst still achieving clearance and forward propulsion.

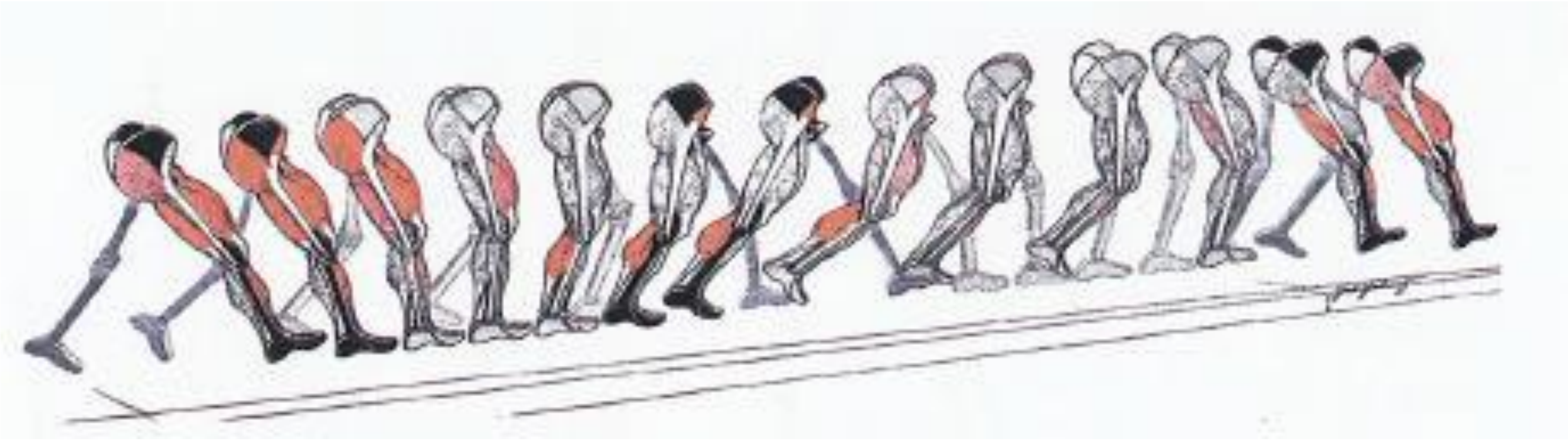
2. Adequate foot clearance in swing: this requires appropriate positioning of hip, knee and ankle in the stance limb with adequate flexion at the hip and knee and adequate ankle dorsiflexion in the swing limb.

3. Adequate step length: this follows from good balance and stability on the stance side with appropriate flexion on the swing side.

4. Appropriate pre-positioning of the foot in terminal swing: this follows from all

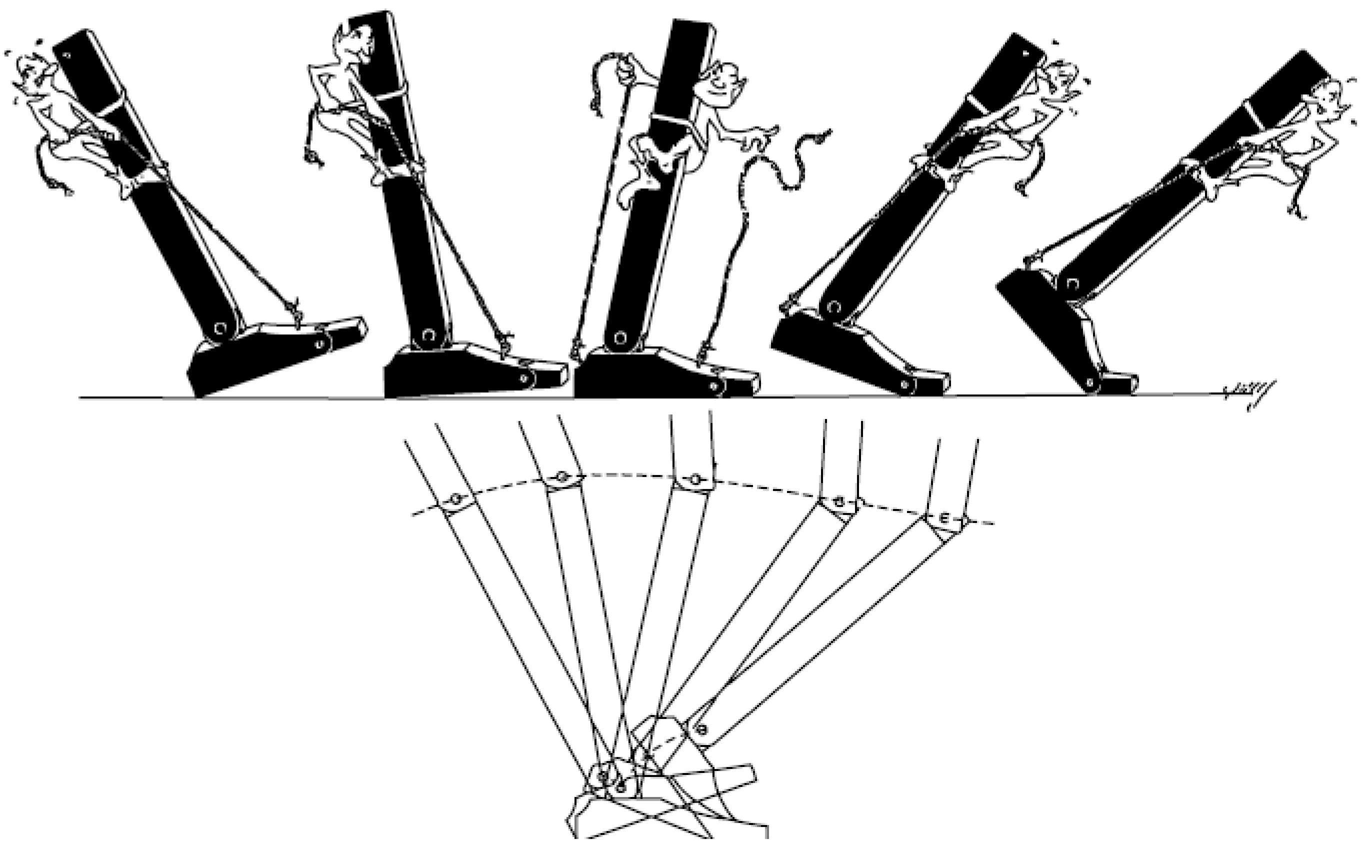
the above

Muscle Activity During Gait



Muscle activities

- Agonist and antagonist muscle groups work in concert during
- the gait cycle to effectively advance the limb through space.



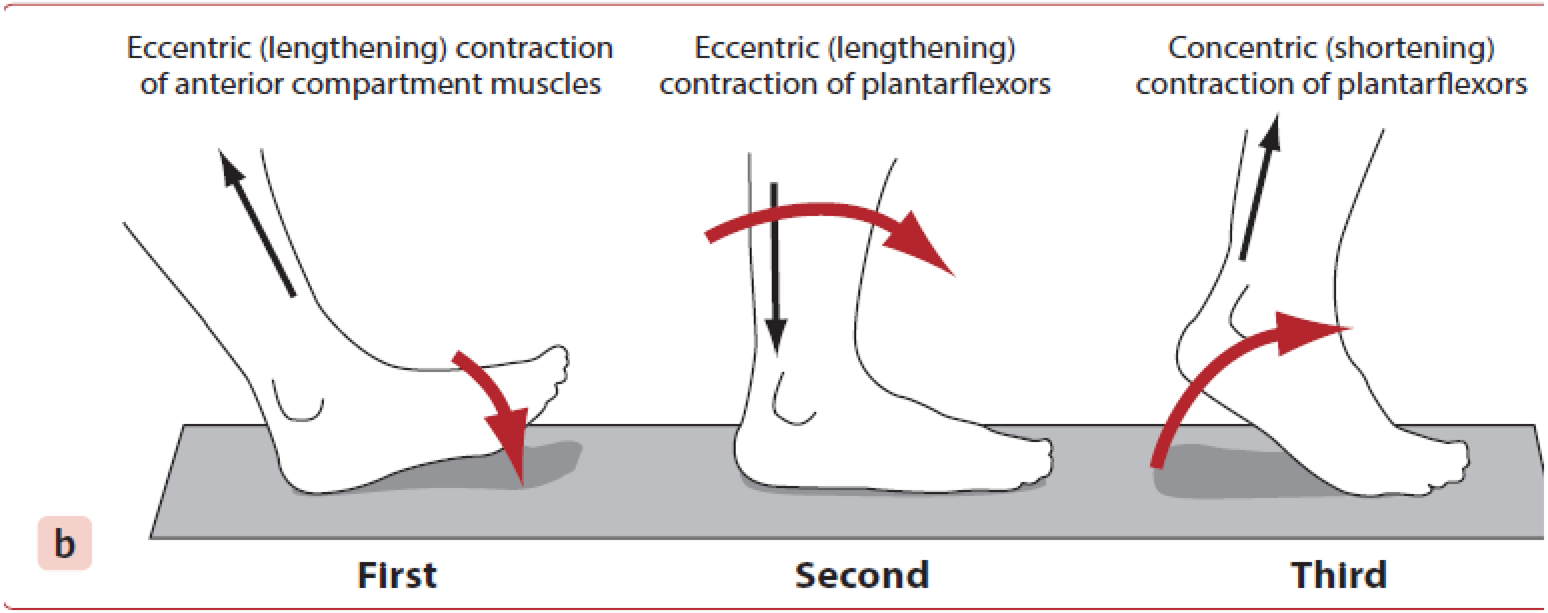
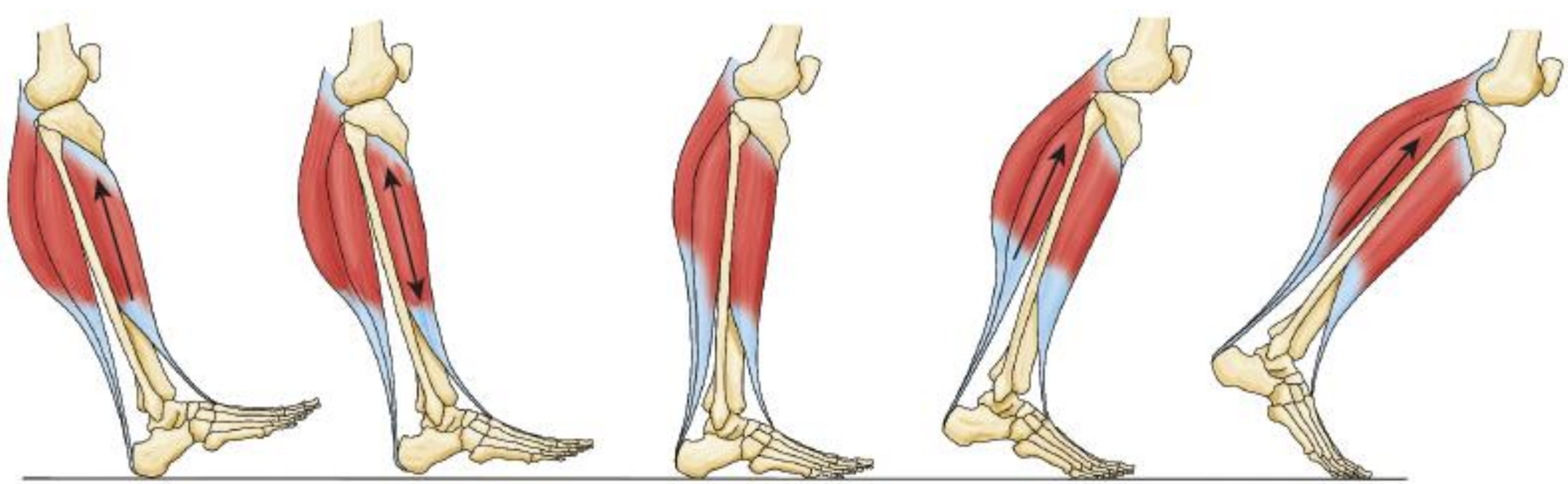
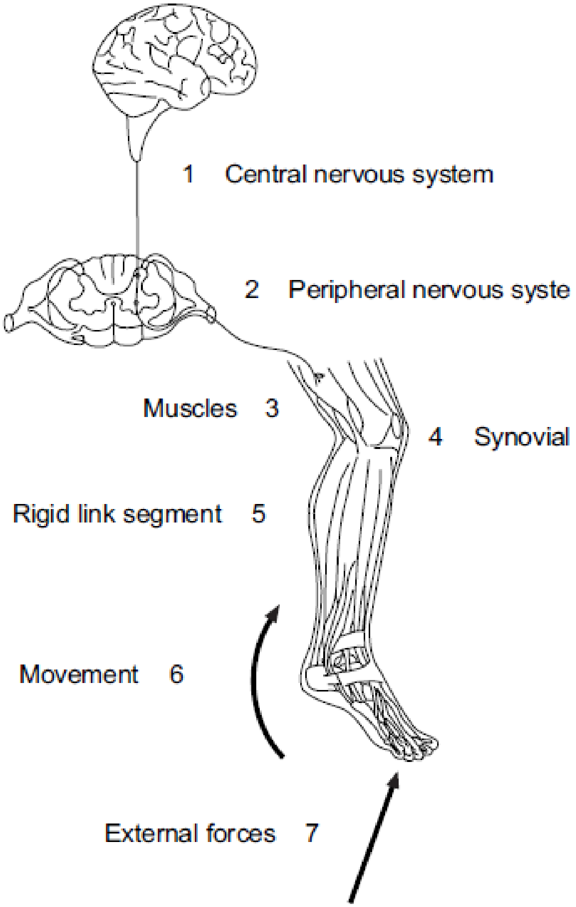


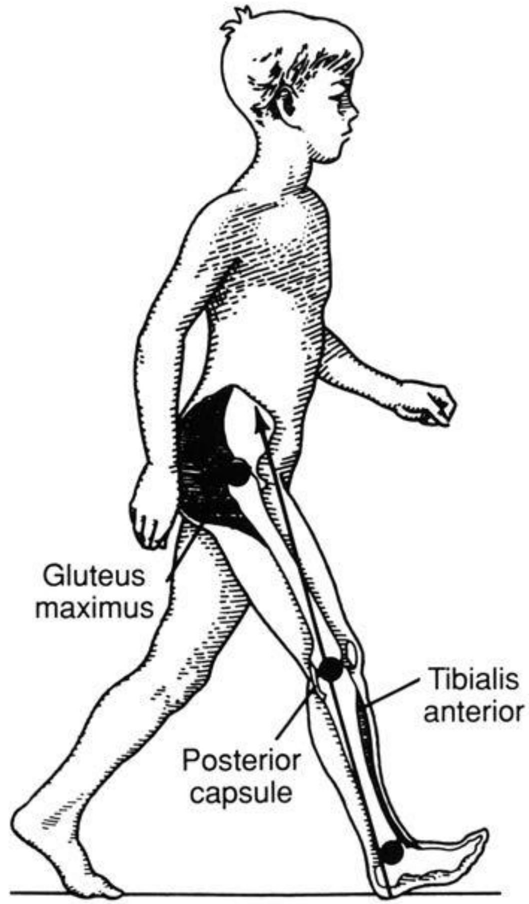
Figure 26.2 a: Gait rockers and the ground reaction force; b: the three ankle rockers.



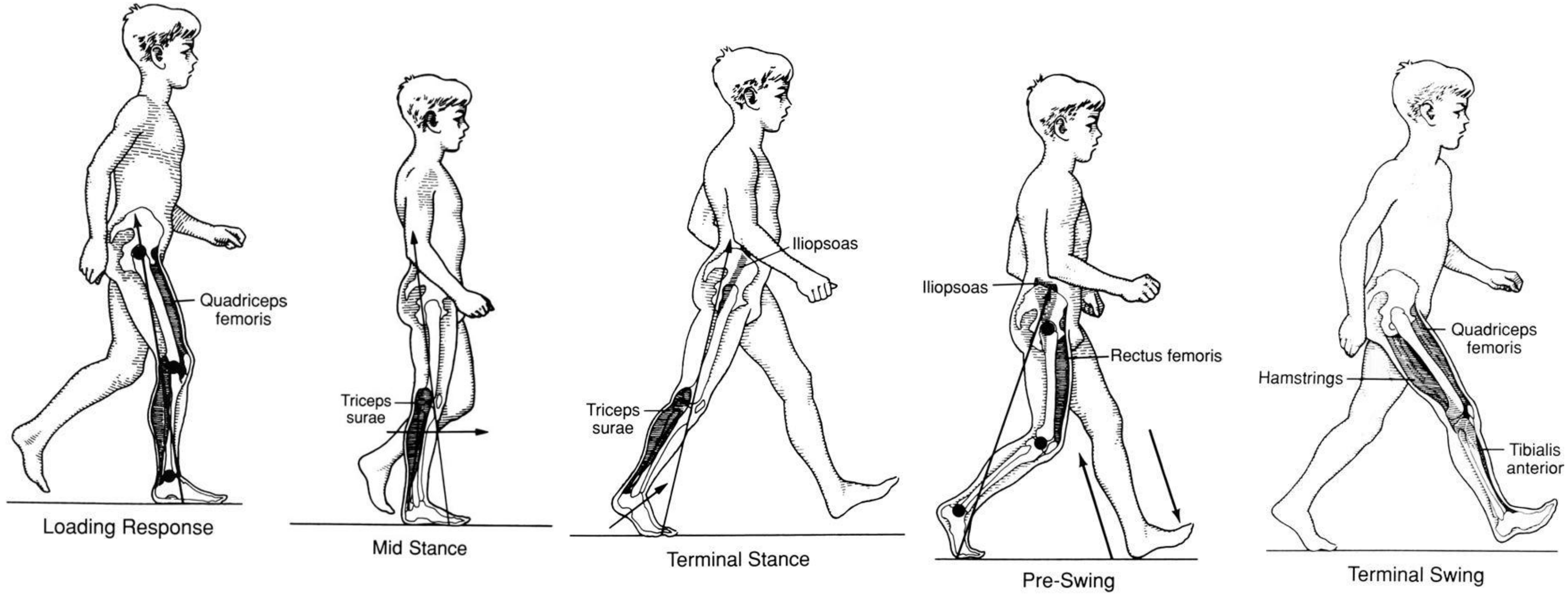
- **Tibialis anterior has both eccentric (heel strike) and**
- **concentric (swing) muscle actions during normal gait**

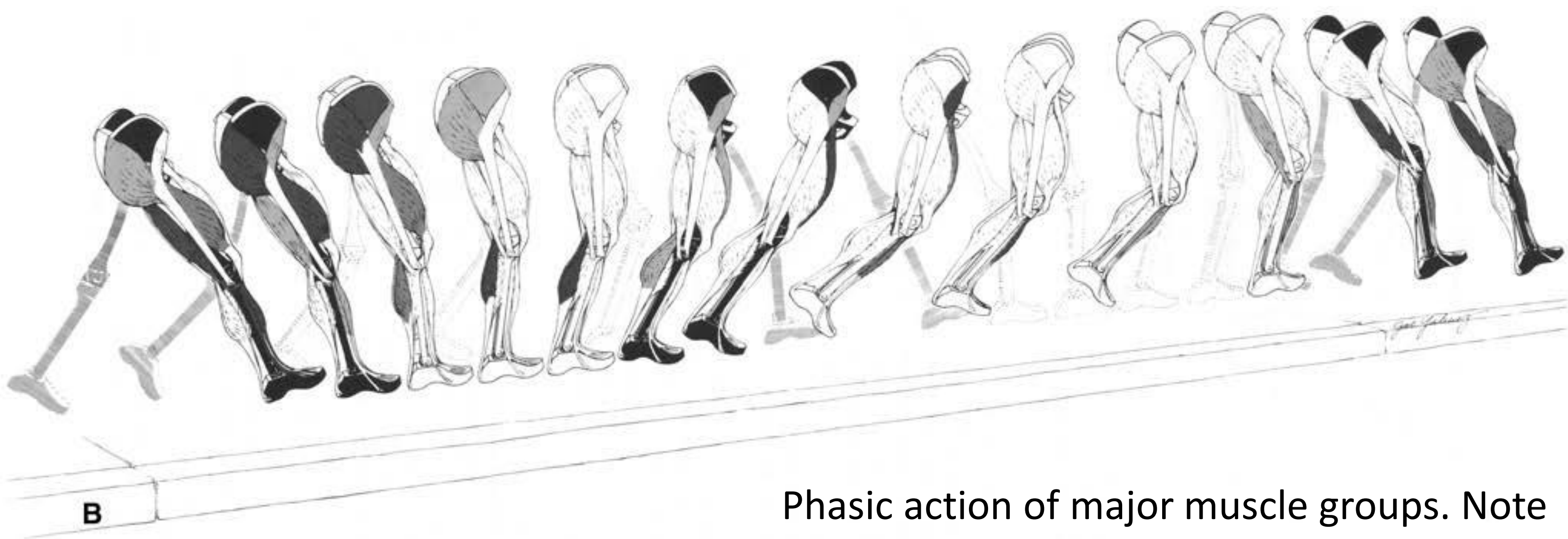
The seven components that form the functional basis for the way in which we walk. This top-down approach constitutes a cause-and-effect model





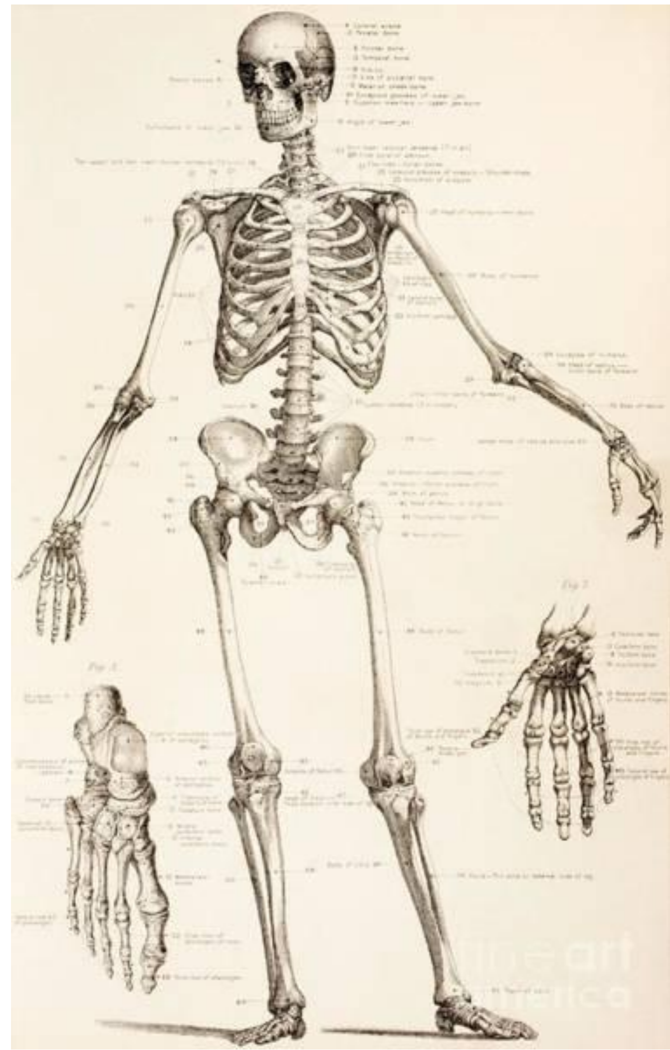
Initial Contact


Quadriceps femoris
Loading Response
Triceps surae
Mid Stance
Iliopsoas
Triceps surae
Terminal Stance
Iliopsoas
Rectus femoris
Pre-Swing
Quadriceps femoris
Hamstrings
Tibialis anterior
Terminal Swing

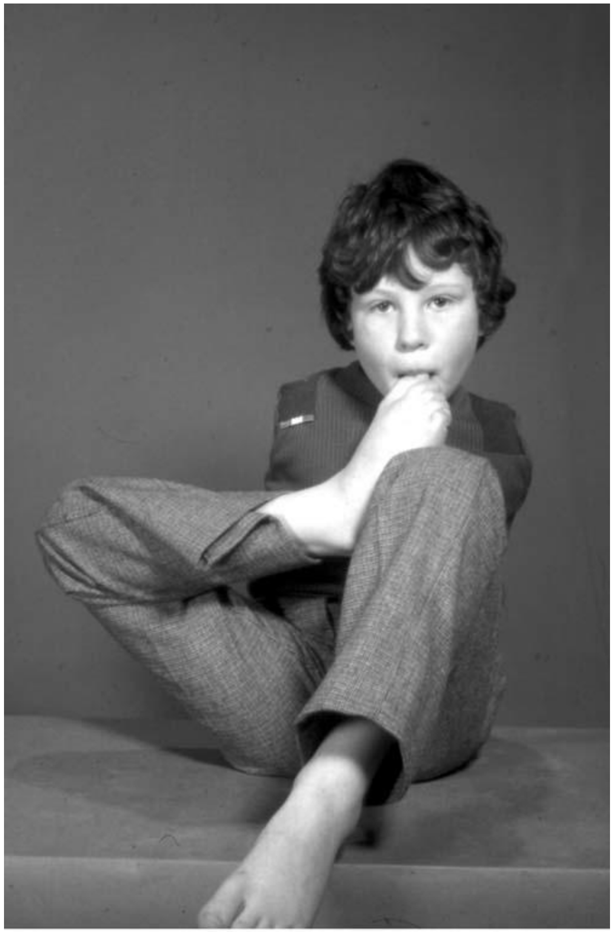


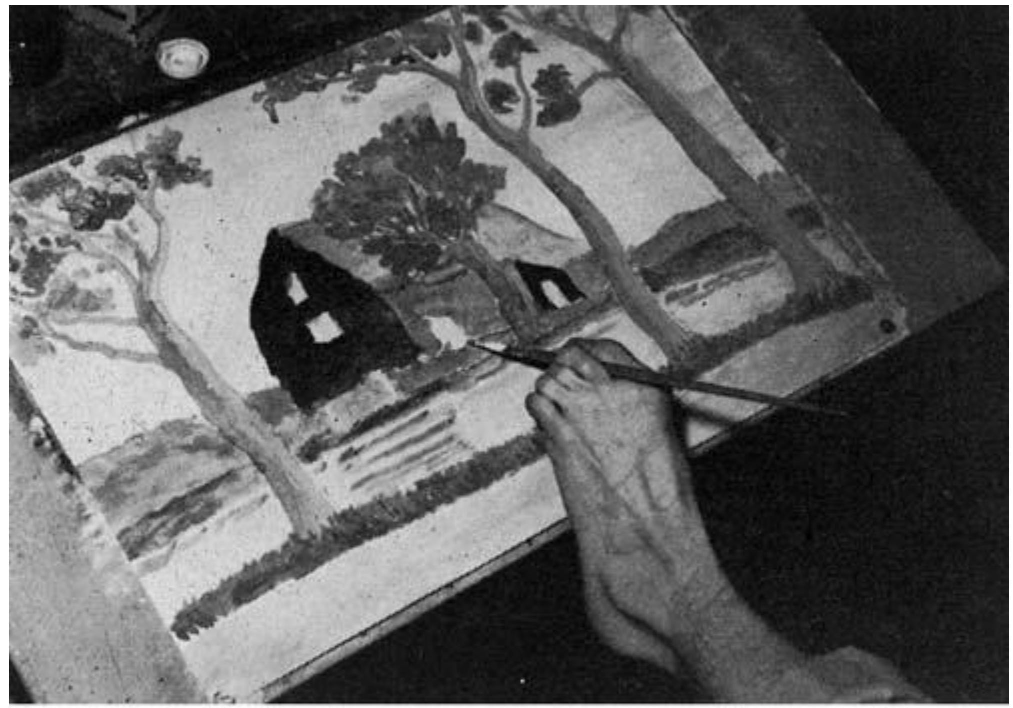
Phasic action of major muscle groups. Note that most muscles are active at the beginning and end of swing phase. During midstance, there is minimal muscle activity. This suggests that the
main function of muscle is to accelerate and decelerate the limbs and that after weight acceptance, the
metabolic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

The human foot is a meracle



armless

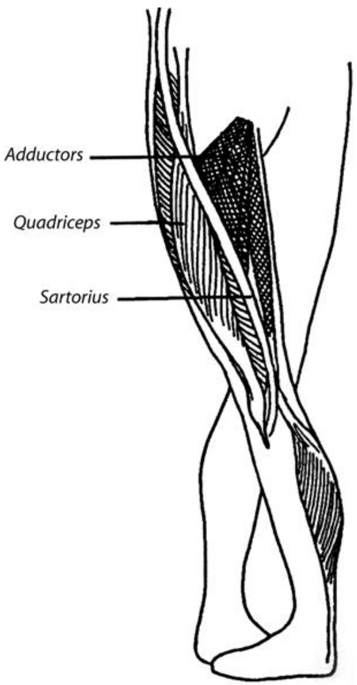

C


E

Ballet Dancing

en pointe

total of external rotation of the entire leg
involving the
hip, knee, ankle, and foot



A

Proper turnout must come
from the hip down not from the feet up.

B

equinus and is in line with the shin

THE PENNY ILLUSTRATED PAPER

WITH ALL THE NEWS OF THE WEEK.

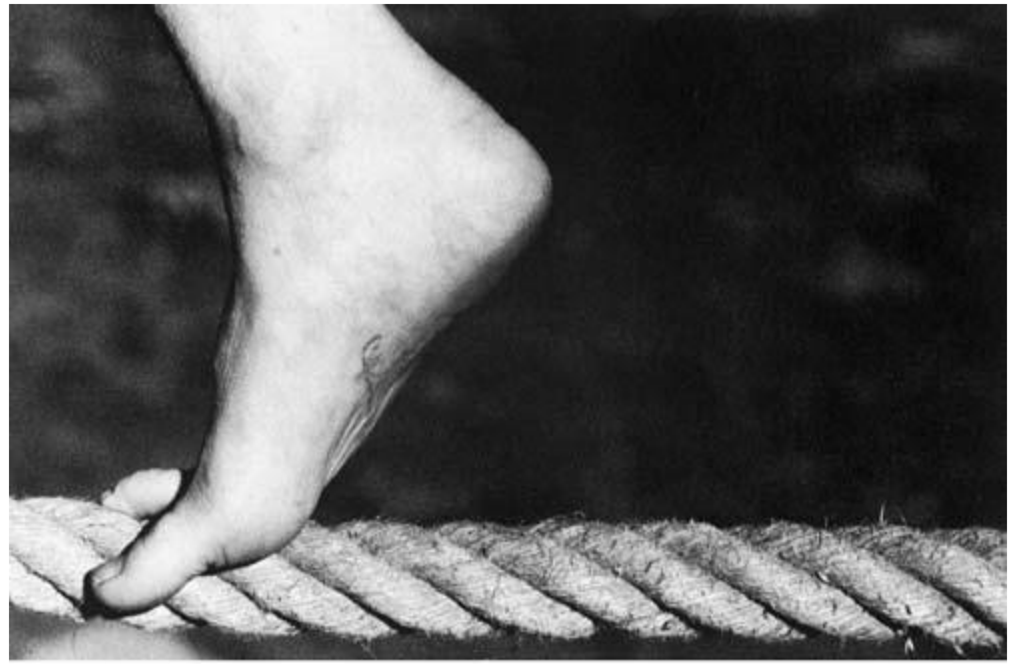
No. 1.] LONDON, SATURDAY, OCTOBER 12, 1861. [Vol. 1.

Topics of the Week.

. new era opens upon the people. In producing an lustrated Paper for the million, let us plainly say, we ant to be esteemed the friend of the million. Not to atter it: that is the part of an enemy; nor to gloss er its errors and prejudices, for such friendship is as eak as it is contemptible. No; we wish to study the asses, to understand them, to sympathise with them, to co-operate in a labour of love in whatever may interest them in the wide domains of Literature and Art. We put these professions to a fitting test when we say to the reader, "Judge for yourself of the value of what is given in the ensuing pages, and of the price you are charged for it."

We have said that a new era is opened to us by the Repeal of the Paper Duties. It is one that none of us can yet hope rightly to estimate. But these things are sure:—The measure will give new intellectual life, tend wonderfully to the dissemination of knowledge, and help to create through society a greater equality of tastes, habits, and modes of thought. But these are amongst the least of its blessings. Consider the effect upon the poor. When we see how large a portion of our daily records are given up to details of criminal atrocities — when we are reminded, by such a case as that of Mrs. Guinness Hill's child, of the state in which our labouring poor habitually live in the very heart of our civi-

B



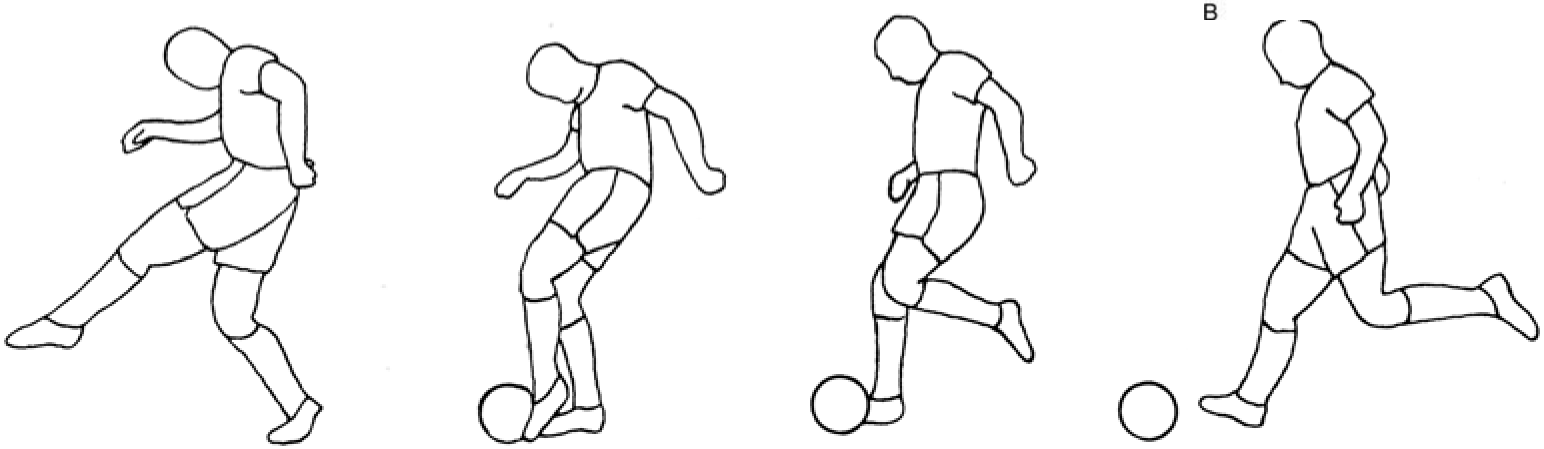
A

Grasping the
tightrope between the great and
second toes to obtain a good hold.

firewalker

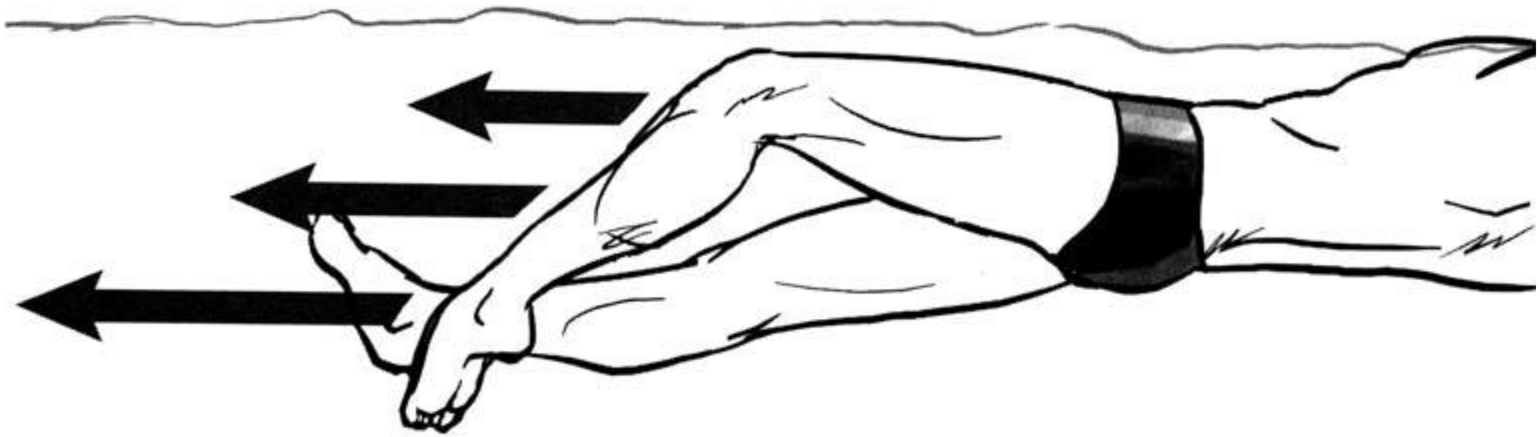
Kicking

B



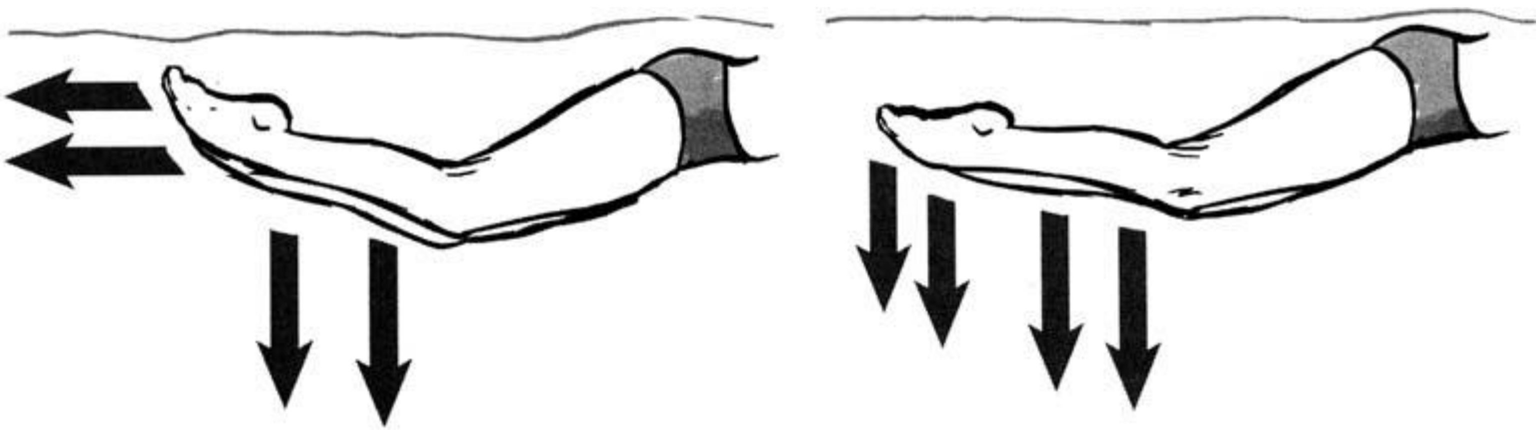
A

SWIMMING



Propulsion during the upbeat of the backstroke flutter kick.

A



B

Take Home Message

- **Normal Gait** is energy efficient activity, series of control falls and alternating propulsive and retropulsive activity
- **Gait cycle kinematics** : stance phase and swing phase subdivisions
- **Gait determinants** :
  - pelvic tilt downward 5 degree on average swing limb
  - pelvic rotation 4 degree swing limb forward and 4 degree backward stance limb