GAIT: NORMAL, ABNORMAL & ASSESSMENT

GAIT

- 1- Normal Walking
- 2- Gait cycle – phases, temporal parameters
- 3- Determinants of gait
- 4- Kinematic & kinetic analysis
- 5- Gait in young, elderly & women
- 6- Some abnormal gaits
- 7- Assessment – visual, video recording
- 8- Clinical Gait laboratory

Walking

- Walking

- complex interaction of different parts of body
- it's advancement in the desired line of progression.

- Muscle act - this motion and forces are controlled
- Normal walking –

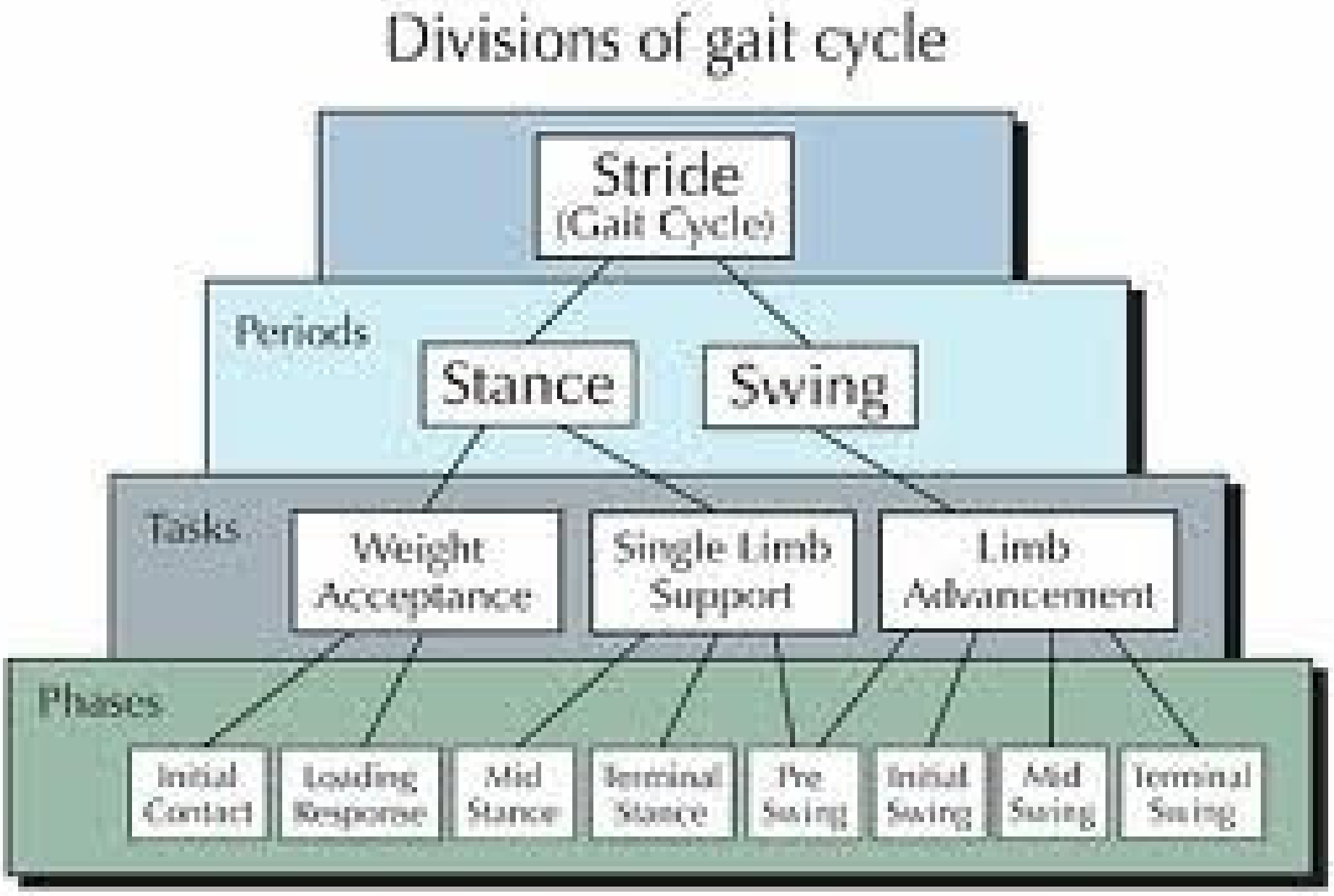
- weight bearing stability and
- progression over the supporting foot
- optimal conservation of physiologic energy.

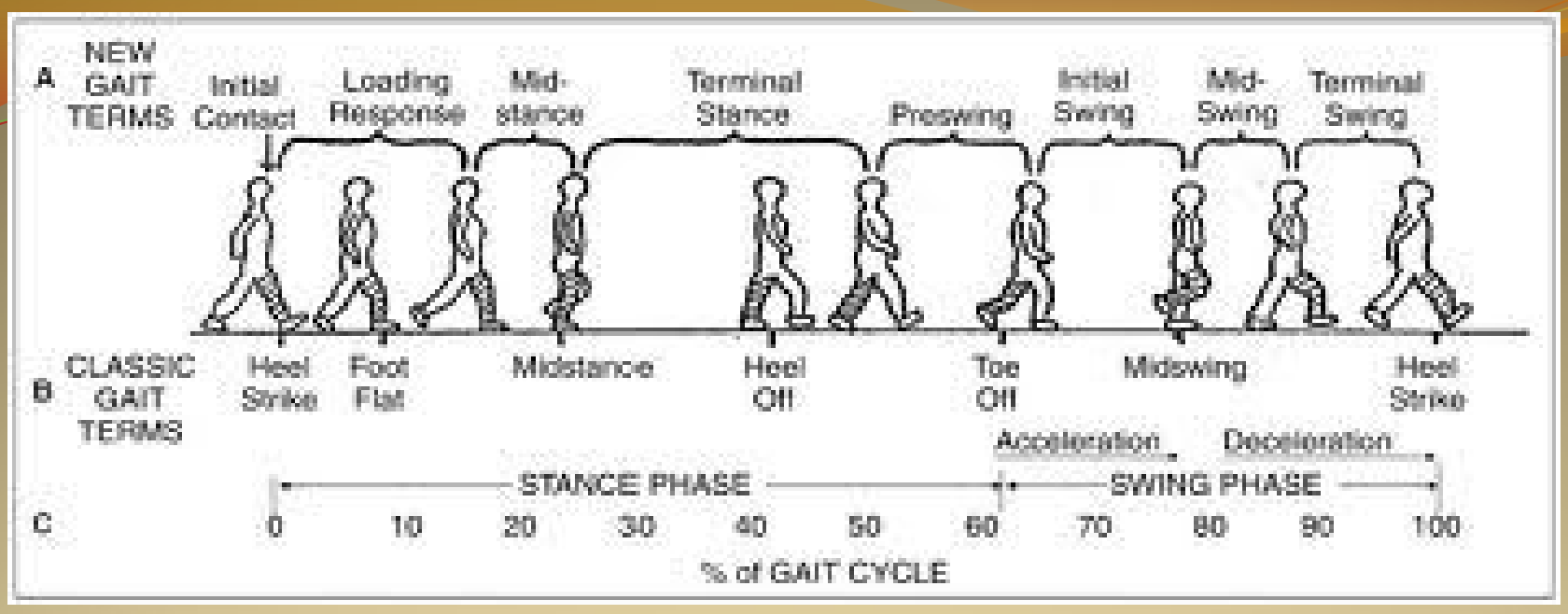
- GAIT CYCLE :- Activity that occurs between heel strike of one extremity and subsequent heel strike same side.

- STANCE PHASE :- Phase in which limb is in contact with the ground. (60%)
- SWING PHASE :- Phase in which the foot is in air for limb advancement. (40%)

- DOUBLE SUPPORT: When two extremities are in contact with the ground simultaneously

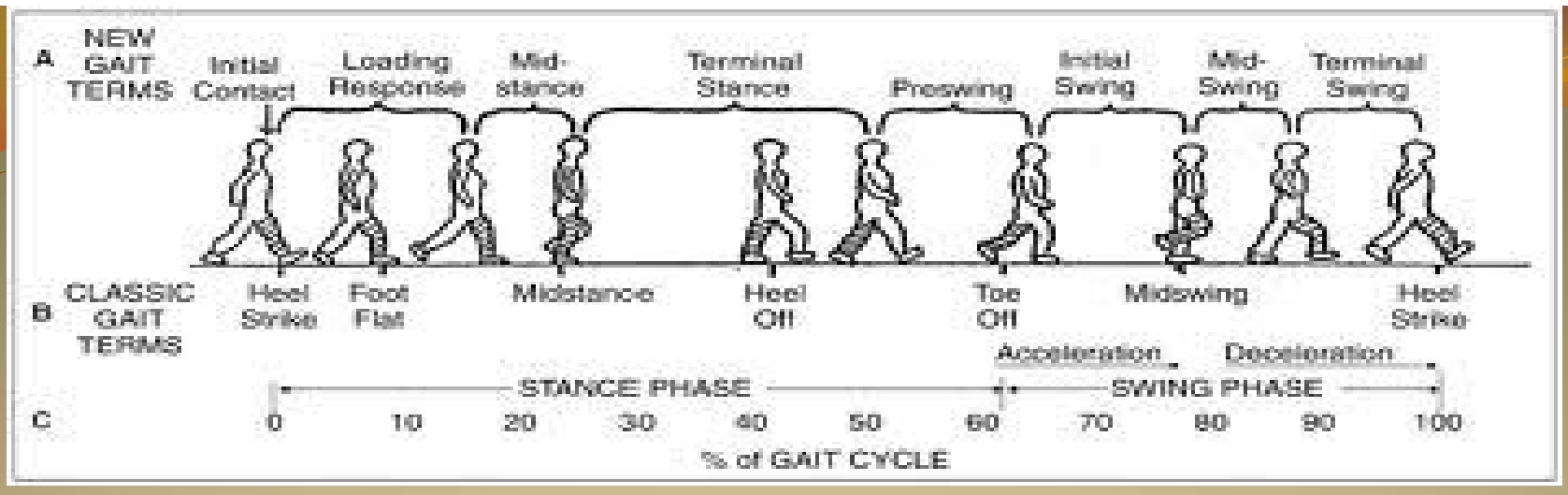
- cadence (speed of walking) - double support
- Absence of double support - running





- Initial contact: (0%) Instant the foot contacts the ground.
- Loading response: (0-11%)

- immediately following initial contact - lift of C/L extremity from ground
- weight shift occurs.



- Mid- stance: (11-30%)

- lift of C/L extremity from ground - ankles of both extremities are aligned in the frontal (coronal) plane.

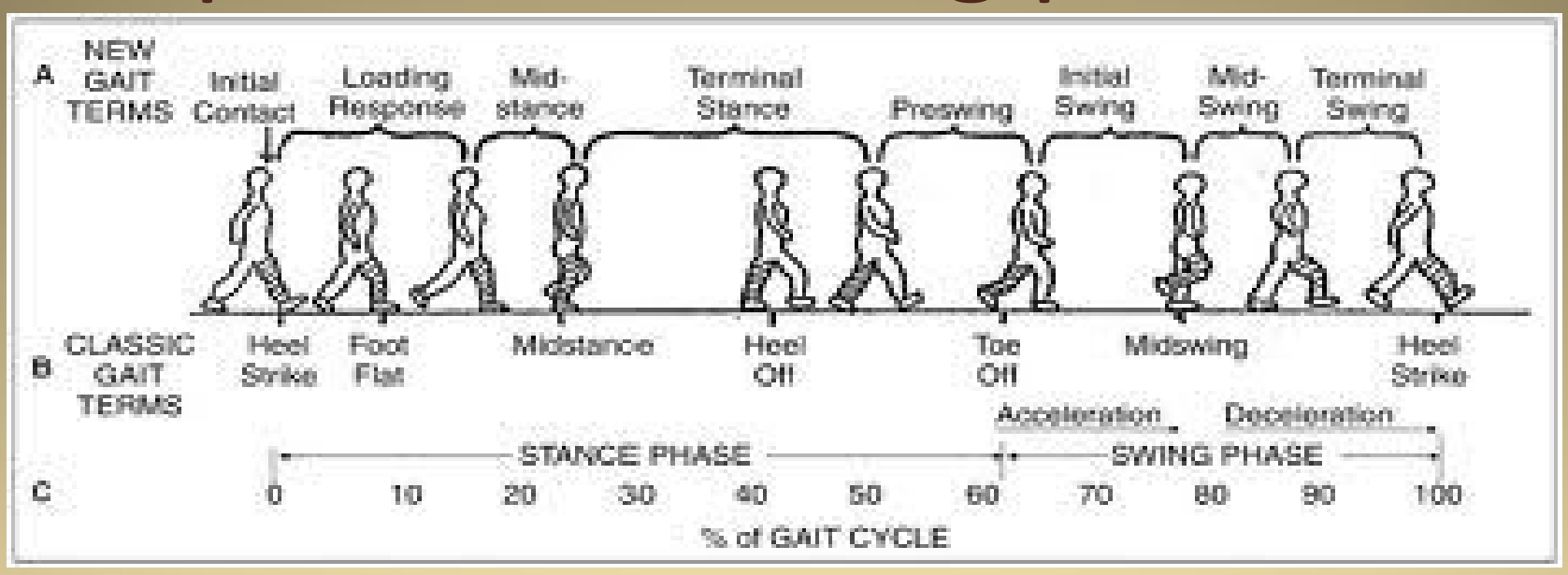
- Terminal stance: (30-50%)

- ankle alignment in frontal plane - just prior to initial contact of C/L extremity.

- Preswing: (50-60%)

- initial contact of C/L extremity - prior lift of Ipsilateral extremity from ground.

Sub phases of Swing phase



- Initial swing: (60-73%) Lift of the extremity from ground - position of maximum knee flexion.
- Mid swing: (73-87%) Immediately following knee flexion - vertical tibia position.
- Terminal swing: (87-100%) Following vertical tibia position - just prior to Initial contact.

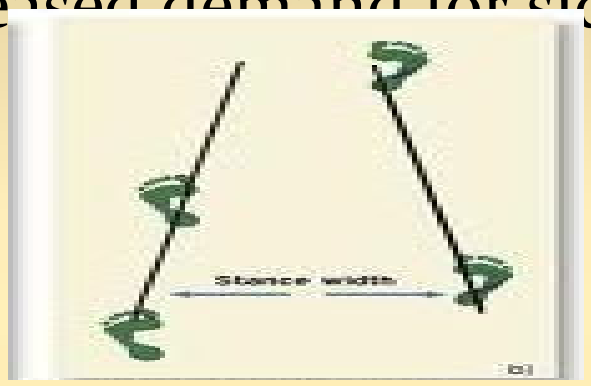
New terminology (Figure 6–2A)	Old (traditional) terminology (Figure 6–2 B)	
Initial contact	Heel (foot strike) strike	STANCE PHASE
Loading response	Foot flat	
Midstance	Midstance	
Terminal stance	Heel off	
Preswing	Toe off	
Initial swing	Acceleration	SWING PHASE
Midswing	Midswing	
Terminal swing	Deceleration	

Temporal Gait Parameters

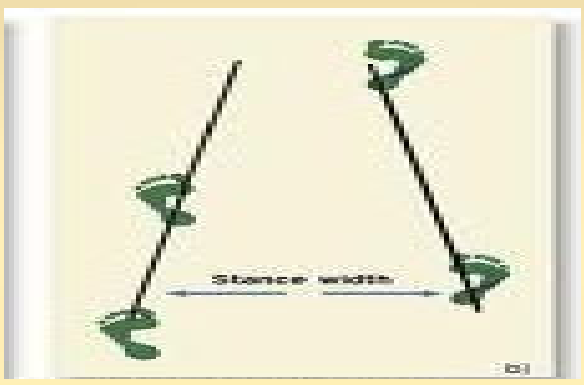
- Stride length: Linear distance between corresponding successive points of contact of the same foot
- Highly variable - normalized by dividing it by leg length or total body height
- increases as the speed increases.

- Step length: opposite foot
- gait symmetry.

- Cadence: No. of steps/minute
- Velocity (meters/minute): Distance covered in given time in the given direction.
- Step width (width of walking base):
- Distance between the midpoints of the heel of two feet
- increases - increased demand for side to side stability.



- Degree of toe-out:
- Represents the angle of foot placement
- Angle between the line of progression and the line intersecting the centre of heel and the second toe
- decreases as the speed increases



Temporal gait parameter	Average value
Velocity (m/s)	**0.9 – 1.5**
Cadence (steps/min)	**90 - 135**
Stride length (m)	**1 – 1.5**
Step length (cm)	**38**
Walking base (cm)	**6 - 10**
Degree of toe-out	**7º**
Stance phase	**60%**
Swing phase	**40%**
Double limb support	**20%**

Determinants of Gait (Saunders 1953)

- Optimizations to minimize excursion of centre of gravity (COG), hence reduction of energy consumption

1. Pelvic rotation
2. Pelvic tilt
3. Knee flexion in stance
4. Ankle PF
5. Foot supination
6. Lateral displacement of the pelvis

- Determinants 1 - 5 reduce displacement on the vertical plane (50%)
- determinant 6 - horizontal plane (40%).

- GROUND REACTION FORCE (GRF)- When a person takes a step, forces are applied to the ground by the foot and by the ground to the foot (GRF)
- equal but opposite
- GRFVector = sum of the force components in each direction (vertical, anteroposterior and mediolateral axes)
- typical pattern from initial contact to toe-off.
- MOMENTS (Torque/ turning force)-

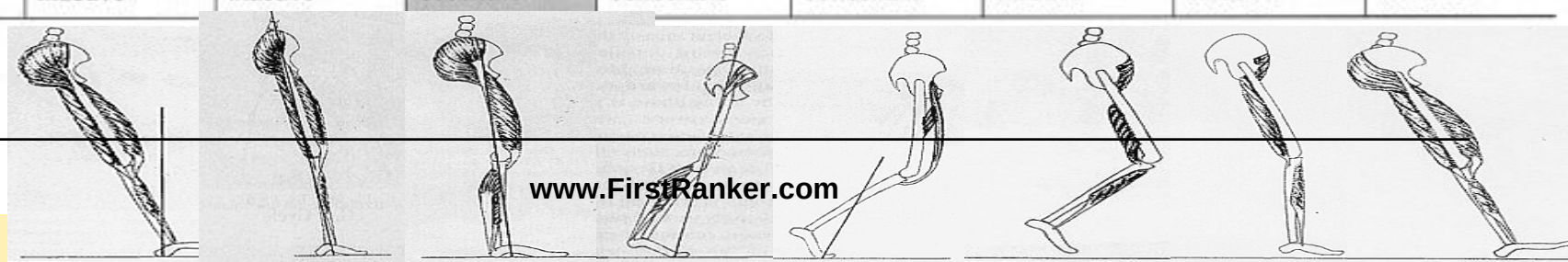
  External forces - GRF, gravity and inertia - external moments about the joints.

  Internal moments - moments generated by the muscles, joint capsules, and ligaments - countract the external forces

Muscle activity

CLASSIC GAIT TERMINOLOGY:	Heel Strike	Foot Flat	Midstance	Heel Off	Toe-Off	Acceleration	Midswing	Deceleration
Rancho Los Amigos Terms NEW TERMINOLOGY	INITIAL CONTACT	LOADING RESPONSE	MID STANCE	TERMINAL STANCE	PRE-SWING	INITIAL SWING	MID SWING	TERMINAL SWING
	STANCE PHASE 60%					SWING PHASE 40%		
% OF TOTAL PHASE	0-2%	0-10%	10-30%	30-50%	50-60%	60-73%	73-87%	87-100%
ILIOPSOAS	inactive	inactive	inactive	concentric	concentric	concentric	concentric	inactive
GLUTEUS MAXIMUS	eccentric	inactive	inactive	inactive	inactive	inactive	inactive	inactive
GLUTEUS MEDIUS	eccentric	eccentric	eccentric	eccentric	inactive	inactive	inactive	inactive
HAMSTRINGS	eccentric	eccentric	inactive	inactive	inactive	eccentric	eccentric	eccentric
QUADRICEPS	eccentric	eccentric	inactive	inactive	eccentric	eccentric	inactive	inactive
PRETIBIAL MUSCLES	eccentric	eccentric	inactive	inactive	inactive	concentric	concentric	concentric
CALF MUSCLES	inactive	inactive	eccentric	concentric	concentric	inactive	inactive	inactive

KEY:



Kinetics and Kinematics

- Kinetics : Study of forces, moments, masses and accelerations, but without any detailed knowledge of the position or orientation of objects involved.
- Kinematics : Describes motion, but without reference to forces involved.

Trunk and Shoulder

- Trunk along with shoulder girdle twists in opposite direction of pelvic twist
- Total excursion of trunk is 7° and pelvic girdle 12°.
- Total ROM of shoulder is 30° (24° of extension and 6° of flexion)
- Center of gravity (COG) is located 5 cm anterior to second sacral vertebra
- It is displaced 5 cm horizontally and 5 cm vertically during a gait cycle.

Gait in children

- Children have no heel strike, initial contact being made by flatfoot (2 yr)
- Very little stance phase knee flexion (2 yr)
- Whole leg is externally rotated during swing phase (2 yr)
- Walking base is wider (4 yr)
- Absence of reciprocal arm swing (4 yr)
- Stride length and velocity are lower and cadence higher (15 yr)

GAIT IN ELDERLY

- Decreased stride length and cadence
- Increase in walking base
- Reduction in total range of flexion and extension of joints

GAIT IN WOMEN

- Gait speed is slower
- Step length is smaller
- Increased cadence

ABNORMAL GAIT

- Any deviation from normal pattern of walking

- Caused
- motor system
- skeletal supports
- neural control
- combination of the above.

PAINFUL/ANTALGIC GAIT

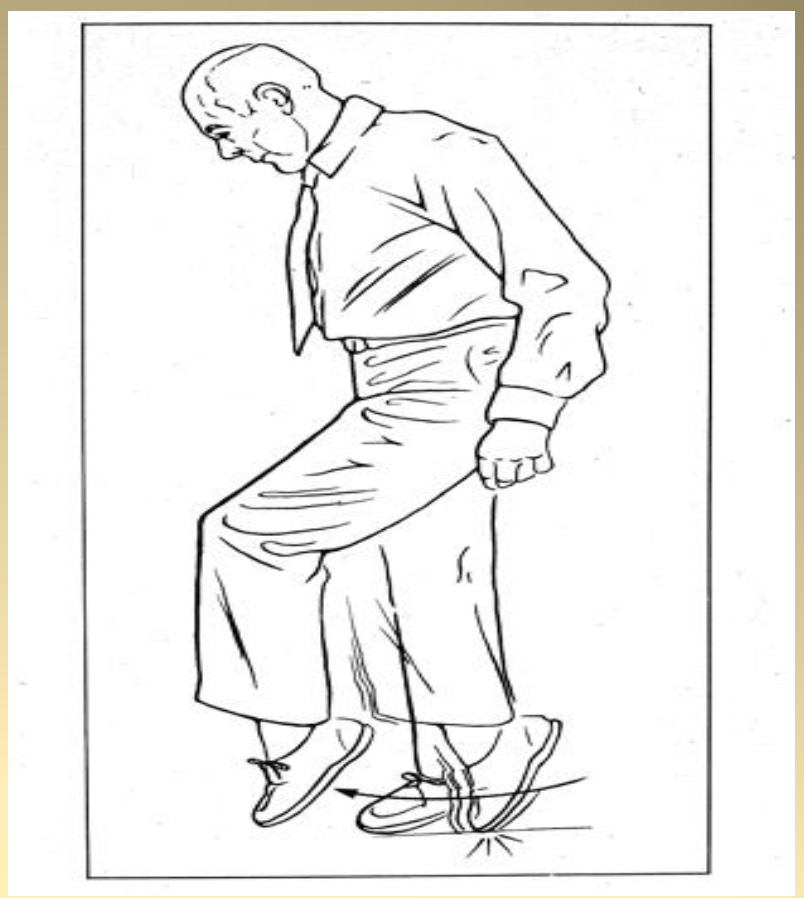
- Avoidance of weight bearing on the affected limb
- shortening of stance phase in that limb

HIGH STEPPAGE GAIT

- weakness of ankle dorsiflexors
- excessive knee and hip flexion with toes pointing downwards in the swing phase

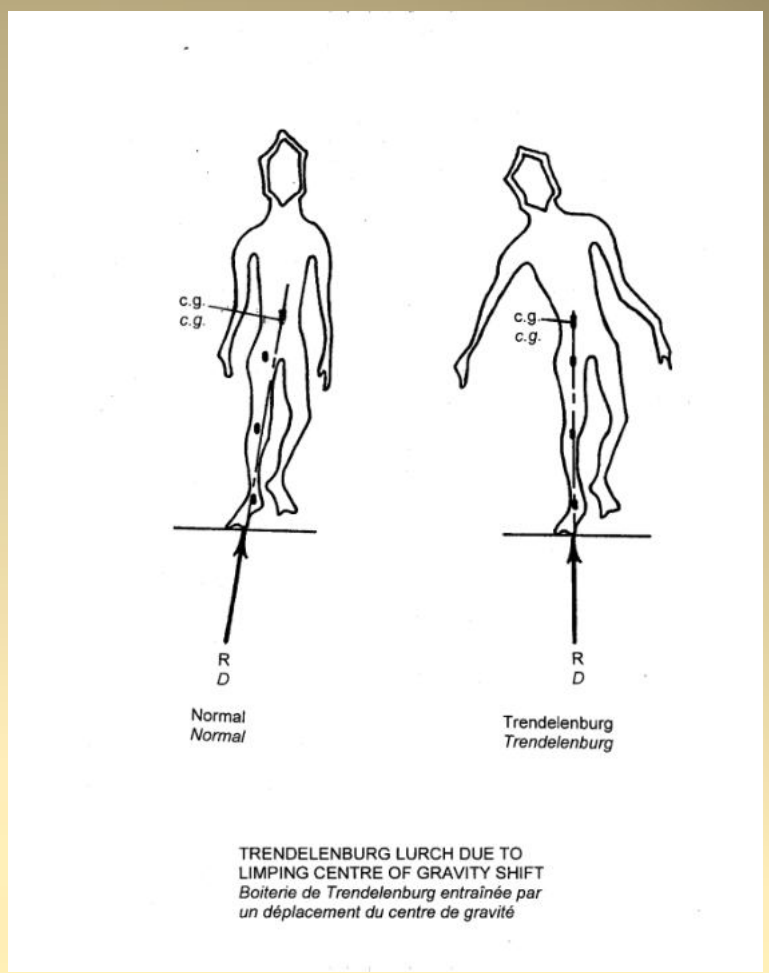
VAULTING

- Seen in limb length discrepancy, hamstring weakness or extension contractures of the knee
- The knee is hyper-extended and locked at end of stance phase and entire swing phase.
- So to clear the leg the patient goes up on the toes of the other leg to clear the affected limb.



TRENDELENBURG GAIT

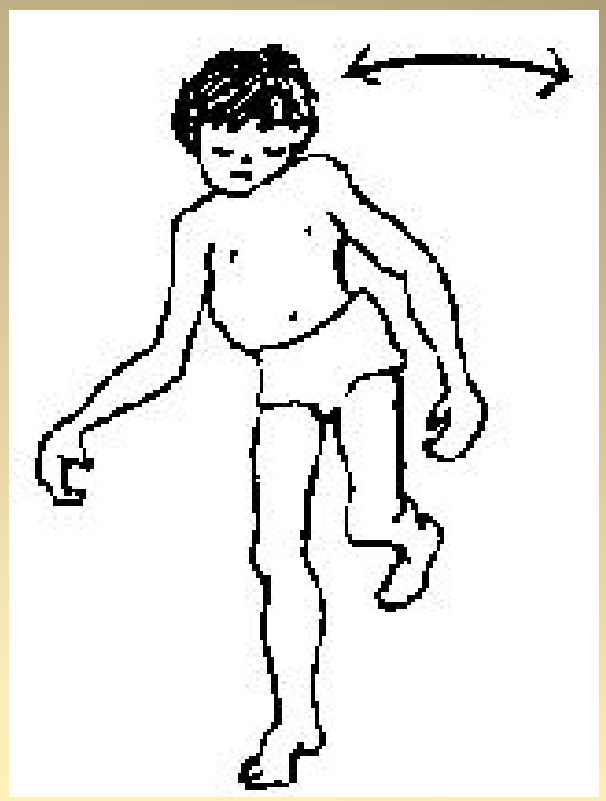
- The gluteus medius during the stance phase, pulls the stance side pelvis over the supporting limb to prevent excessive pelvic drop in the opposite swing limb.
- If the hip abductors are weakened, the opposite limb pelvis may drop excessively during swing phase.
- To avoid this, the entire trunk shifts to the stance side to bring the stance pelvis on to the supporting limb.
- This is known as gluteus medius lurch or trendelenburg gait.



TRENDELENBURG LURCH DUE TO LIMPING CENTRE OF GRAVITY SHIFT
Boiterie de Trendelenburg entraînée par un déplacement du centre de gravité

MYOPATHIC GAIT

- If both hip abductors are weak, the trunk sways from side to side during the stance phase to bring the pelvis level on the supporting limb.
- waddling gait.
- muscular dystrophies
- accompanied by excess lumbar lordosis to compensate for hip extensor weakness.



HEMIPLEGIC GAIT

- In extensor synergy -

→heel strike is missing and patient lands on forefoot

→Since hip and knee are kept extended throughout the gait cycle, there is relative limb lengthening and hence circumduction or hip hiking is used for clearance

→Toe drag may be present in swing phase

→Swing phase is longer on the affected limb

→Decreased arm swing on the affected side.

- If flaccid paralysis or flexor synergy is present

→knee buckling and instability

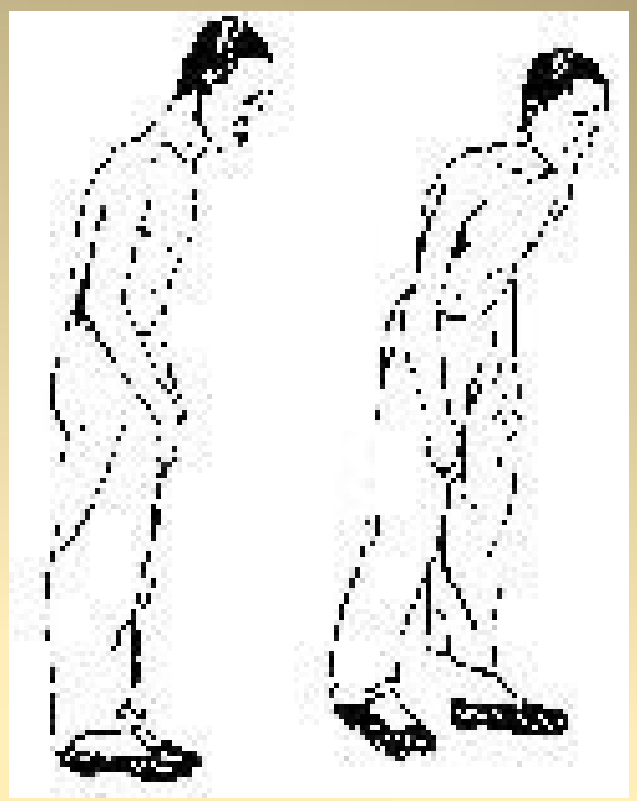
FESTINATING/PROPULSIVE GAIT

- Lack of arm swing
- Short, quick steps with increasing speed
- Cannot stop abruptly or change directions
- Stooped posture

Seen in

Parkinsonism

Carbon monoxide poisoning



ATAXIC GAIT

- Seen in cerebellar lesions
- Dysmetria and inco-ordination
- Staggering and lack of smooth movements (reeling or drunken gait)
- Falls to the side of lesion
- Compensated by wide-based gait to increase base of stability

STOMPING GAIT

- Seen in sensory ataxia
- Gait with heavy heel strikes, forceful knee extension and improper foot placement as well as a postural instability
- Usually worsened when the lack of proprioceptive input cannot be compensated for by visual input, such as in poorly lit environments.
- Friedreich's ataxia, pernicious anemia, tabes dorsalis, spinal cord pathologies

CEREBRAL PALSY GAIT

Crouch gait

→Hip and knee increased flexion throughout stance with ankle dorsiflexion

→Due to hamstring tightness

Jump knee gait

→Flexion at hip and knee and ankle equinus is characteristic of this gait

GAIT IN CEREBRAL PALSY

Stiff knee gait

→excess knee extension throughout swing

→Has to use circumduction or vaulting

→Due to increased rectus femoris activity in swing phase

Recurvatum knee

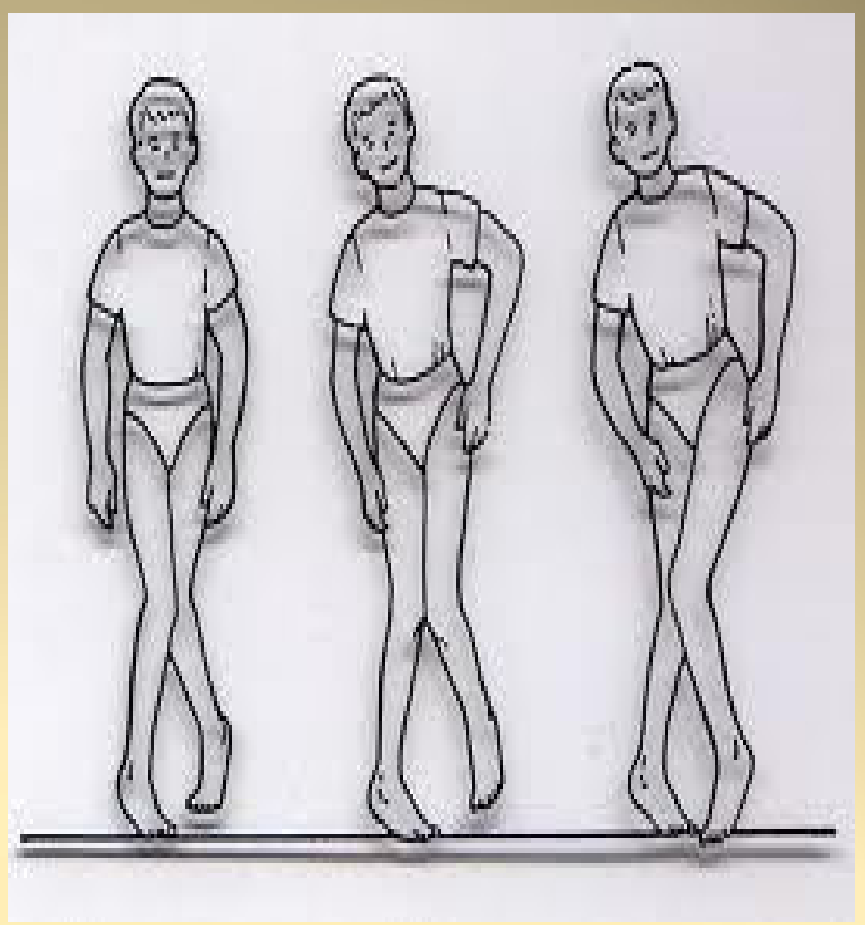
→Due to triceps spasticity or hamstrings transfer

→Leads to increased knee extension in mid & late stance

SCISSORING GAIT

Spasticity of the hip adductors with relative weakness of hip abductors and secondary changes in the hip gives rise to

- rigidity and excessive adduction of the leg in swing
- plantar flexion of the ankle
- increased flexion at the knee
- adduction and internal rotation at the hip



Diplegic CP, Spinal cord pathologies

METHODS OF GAIT ANALYSIS

VISUAL GAIT ANALYSIS

- The simplest form of gait analysis.
- Look for:

Symmetry and smoothness of movements

Balance

Degree of effort

Motion of specific segments

Gait parameters

- Gait should be observed from at least 3 angles (side, front & back)

- Limitations-
- gives no permanent record
- eyes cannot observe high-speed events
- only possible to observe movements not forces
- depends entirely on the skill of the individual observer.

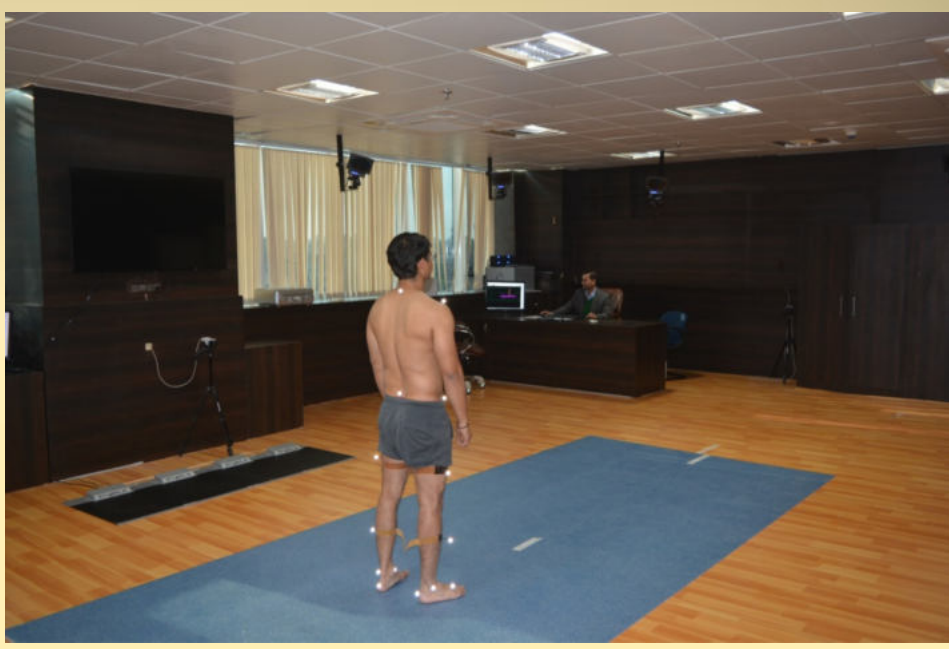
- Gait analysis walkway
- Length – 10-12 m
- Width - visual - 3 m
  video recording - 4 m
  kinematic system - at least 6 m.

ANALYSIS BY VIDEO RECORDING

- Advantages-
- gives permanent record
- can observe high speed events
- reduces the number of walks a subject needs to do
- makes it possible to show the subject exactly how they are walking
- makes it easier to teach visual gait analysis to someone else.
- The majority of today's domestic cameras are perfectly suitable for use in gait analysis

Clinical Gait laboratory

- A fully equipped clinical gait laboratory can be expected to posses a combined kinetic/kinematic systems, with ambulatory EMG, as well as facilities for making videotapes.
- Equipment may also be available for measuring oxygen uptake or pressure beneath the feet

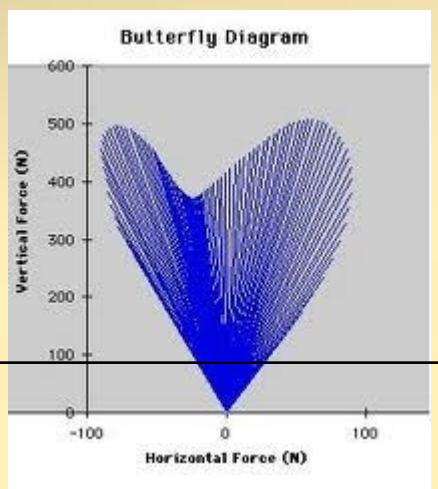


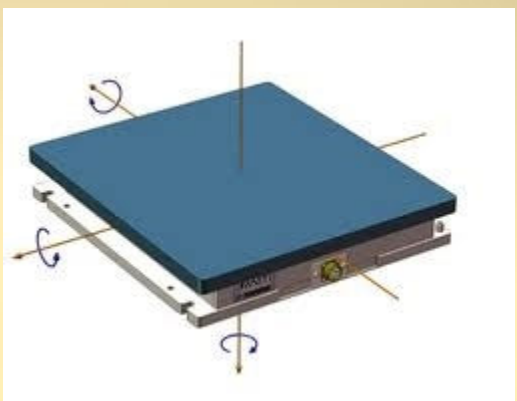
- KINEMATICS –

- Camera by using infrared radiations measures the position of the markers

- FORCE PLATFORM / FORCEPLATE

- Usual methods of displaying force platform data is the butterfly diagram





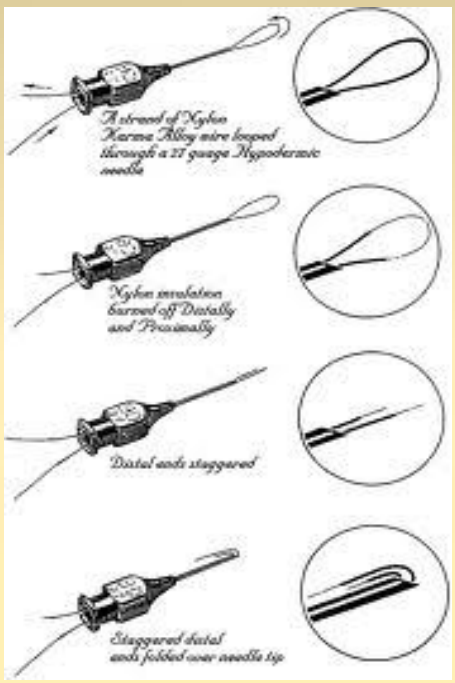
ELECTROMYOGRAPHY (EMG)

- EMG measures the electrical activity of a contracting muscle during different phases of gait cycle

1- Surface electrodes- Not suitable for deep muscles like iliopsoas.

2- Fine wire electrodes-

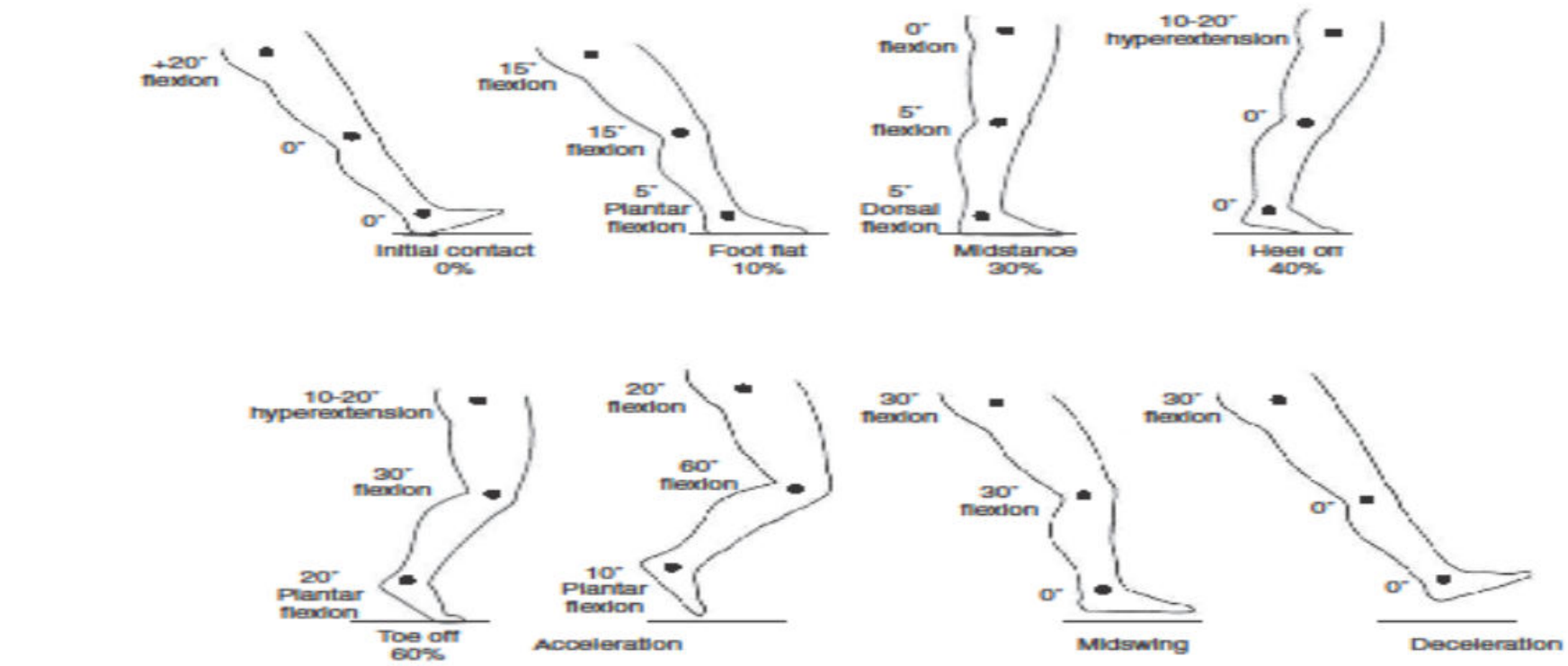
3- Needle electrodes-



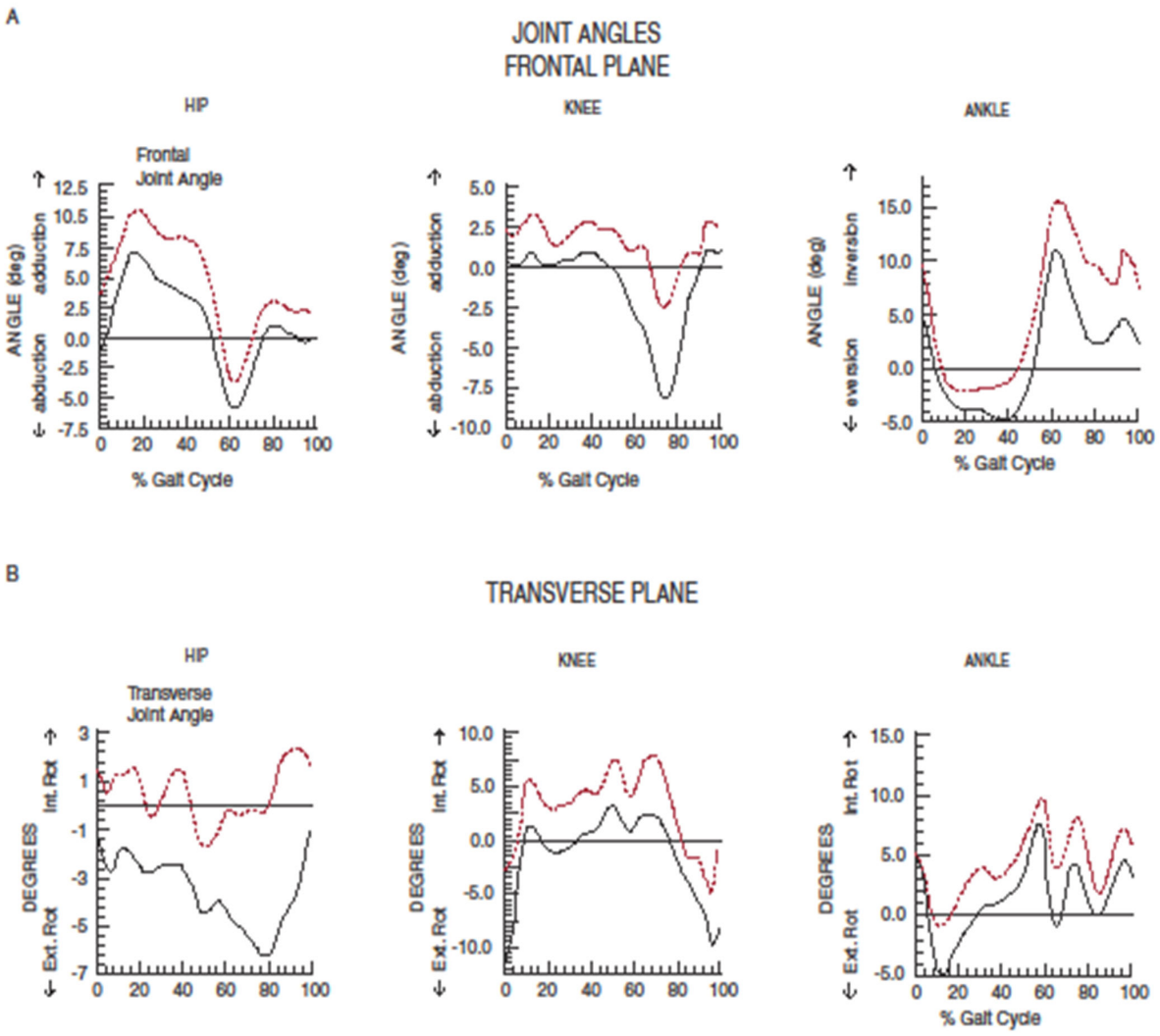
MEASURING ENERGY CONSUMPTION

- Oxygen consumption-
- measurements of oxygen uptake
- while not particularly pleasant for the subject (who has to wear face mask or mouth piece)
- Practical
- Whole body calorimetry-
- most accurate way but quite impractical
- subject is kept in an insulated chamber for measuring the heat output of the body
- Physiological Cost Index: less accurate

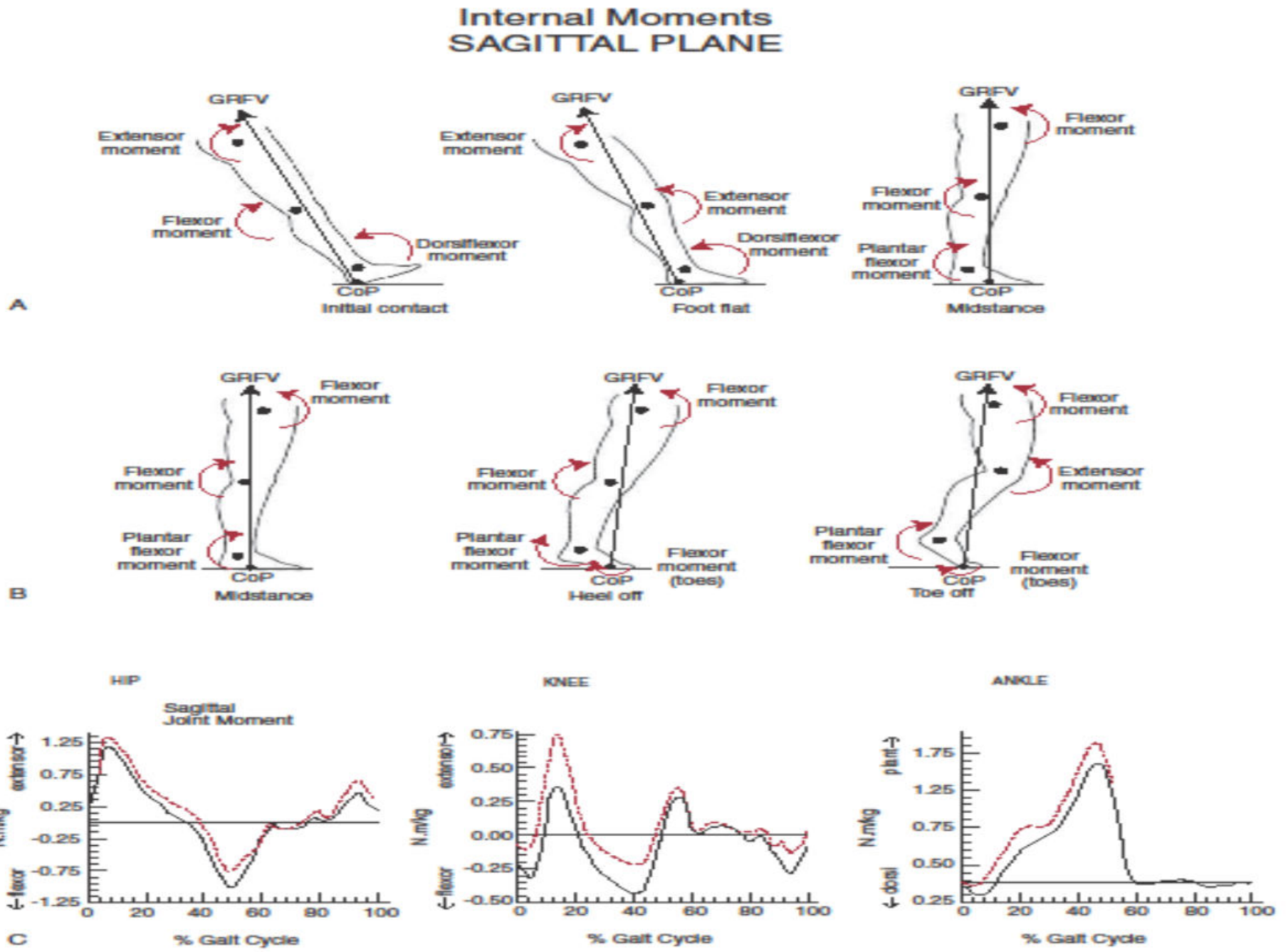
$$PCI = \frac{(\text{Walking HR} - \text{Resting HR})}{\text{Walking Speed in m/min}}$$



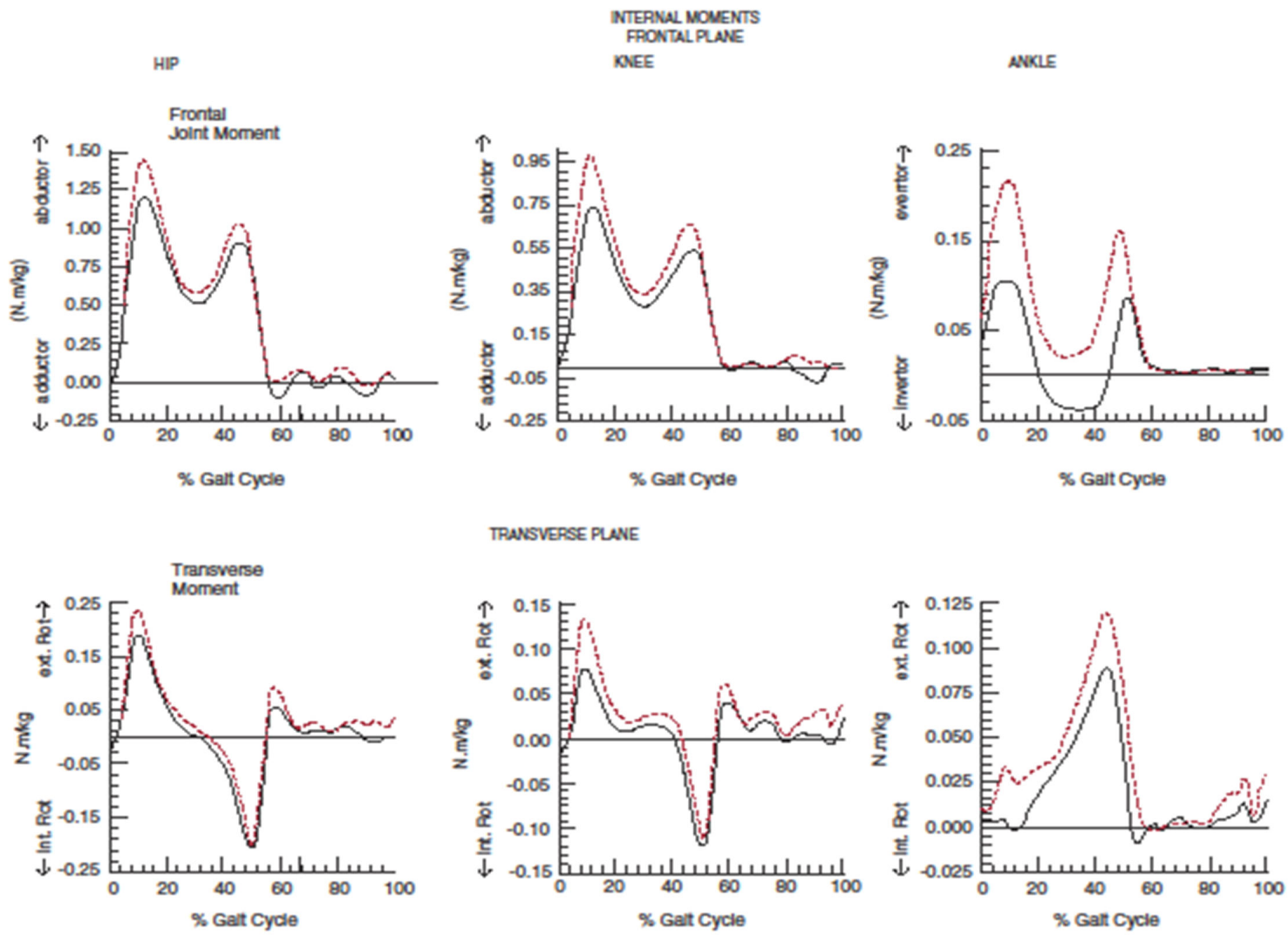
▲ **Figure 14–11** ■ Joint angles in degrees at the hip, knee, and ankle angles in the sagital plane. The doued lines in the angle diagrams represent the standard deviation values, and the solid lines represent the mean values. (Joint angle diagrams redrawn from Winter DA, Eng JJ, Ishac MG: A review of kinetic parameters in human walking. In Craik RL, Otis CA [eds]: Gait Analysis: Theory and Application, pp 263-265. St. Louis, Mosby-Year Book, 1994, with permission from Elsevier.)



▲ **Figure 14–12** ■ A. Joint angles in degrees in the frontal plane at the hip, knee, and ankle. B. Transverse plane hip knee and ankle motion in degrees. (Joint angle diagrams for the frontal and transverse planes redrawn from Winter DA, Eng JJ, Ishac MG: A review of kinetic parameters in human walking. In Craik RL, Otis CA [eds]: Gait Analysis: Theory and Application, pp 263-265. St. Louis, Mosby-Year Book, 1994, with permission from Elsevier.)



▲ **Figure 14–16** ■ Patterns of internal moments in the sagittal plane at the hip, knee, and ankle with center of pressure (CoP) and ground reaction force vectors (GRFVs). The dotted lines represent the standard deviations, and the solid lines represent the mean values. (Diagrams of internal moments redrawn from Winter DA, Eng JJ, Ishac MG: A review of kinetic parameters in human walking. In Craik RL, Otis CA [eds]: Gait Analysis: Theory and Application, pp 263-265. St. Louis, Mosby–Year Book, 1994, with permission from Elsevier.)



▲ **Figure 14–18** ■ Patterns of internal moments in the frontal plane at the hip, knee, and ankle. The dotted lines represent the standard deviation, and the solid lines indicate the mean values. (Redrawn from Winter DA, Eng JJ, Ishac MG: A review of kinetic parameters in human walking. In Craik RL, Otis CA [eds]: Gait Analysis: Theory and Application, pp 263-265. St. Louis, Mosby–Year Book, 1994, with permission from Elsevier.)

Thank You.