BASIC PRINCIPLES OF BIOMECHANICS

FICS™ INTERNATIONAL FEDERATION OF SPORTS CHIROPRACTIC

Lower Limb

A simple guide to pick up on Normal and Abnormal biomechanical limb behaviour:

PRESENTED BY:

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M-Tech Chiropractic (UJ) 2010

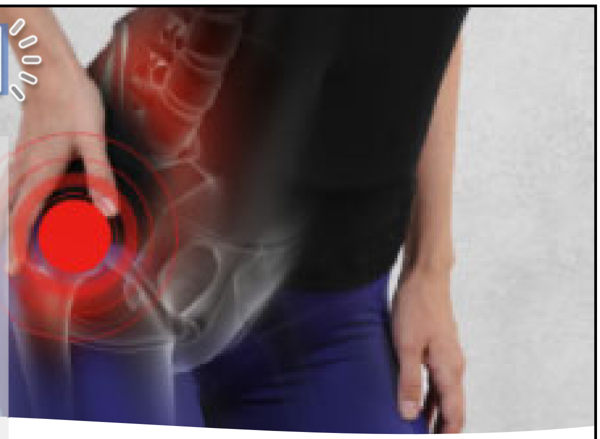
ICCSP (T 201602222193)

*Main source of referencing acquired from:
- Hyde, T. E. and Gengenbach, M. S. (2007), Conservative Management of Sports Injuries, 2nd ed, Massechusetts, Jones and Bartlett.
- Levangie, P.K. and Norkin, C. C. (2005) Joint Structure a& Function: A Comprehensive Analysis, 4th ed, Philadelphia, F. A. Davis Company.

Unit Content

- Hip
- Knee
- Ankle and Foot
- Injuries
- Gait Analysis

Hip Complex



Content:

Anatomy, Structure and Function overview

Coxafemoral Joint

Anatomy

- Angles of importance
  - Centre Edge Angle of Acetabulum (CEA)
  - Angle of Acetabular Anteversion (AAA)
  - Angle of Femoral Inclination (AI)
  - Angle of Femoral Torsion (AT)

Hip Joint Pathology in the Young Athlete

Hip joint degeneration in the Senior Athlete

Rehab

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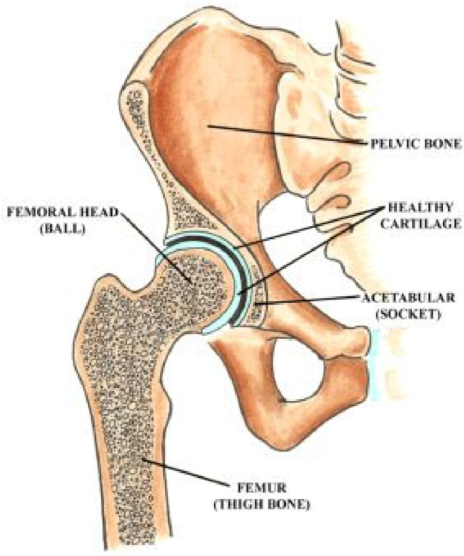
Anatomy of the Hip

The Hip joint (coxafemoral joint) is a diarthrodial ball and socket joint with 3^0 of freedom, allowing:

- Flexion / extension in the sagittal plane
- Abduction / adduction in the frontal plane
- Medial (internal) / Lateral (external) rotation in the transverse plane



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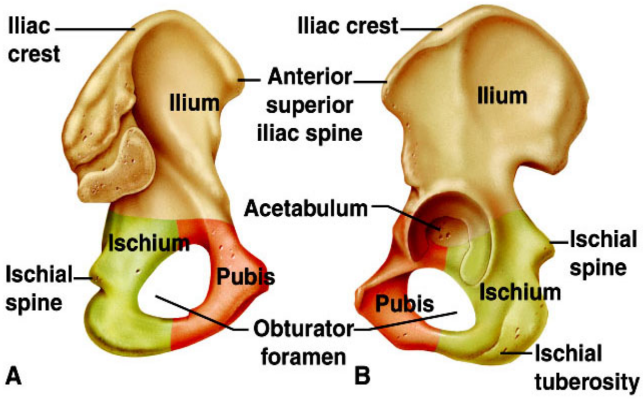
Anatomy of the Hip

- Three bones form the pelvis: ilium, ischium and pubis, contribute to the structure of the acetabulum.
- The cup like girdle is referred to as the innominate or Os Coxa.
- Ossification of pelvis occurs at approximately 20-25 years of age.
- Lunate surface of acetabulum covered with hyaline cartilage. The base of the horse-shoe (lunate surface) interrupted by the acetabular notch.
- Acetabular fossa is a non-articular portion and the femoral head does not contact this area.



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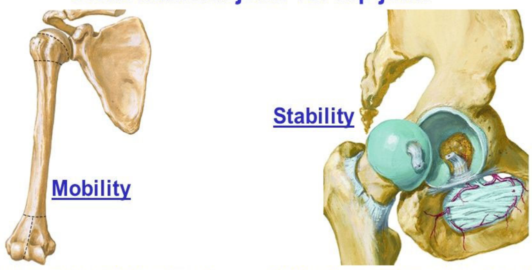
Comparison of the Hip to the Shoulder joint

- Similarities and differences between shoulder and hip joints:
- Shoulder provides stable base for hand mobility against gravity- precedence for open chain functions. And has a relatively weak capsule.
- Hip primary function is to support weight of the head, arms and trunk (HAT). Capsule is strong and dense and contributes to joint stability.

Comparison of Lower Limb with Upper Limb

Glenohumeral joint vs. Hip joint



Glenohumeral joint	Hip joint
~33% humeral head fits in glenoid cavity	>50% of head of femur fits with socket; highly congruent
Relatively lax fibrous layer of joint capsule	Fibrous layer of joint capsule has stout ligamentous specializations
Tonus of rotator cuff critical to stability	Extensive supporting muscles but w/o required ‘rotator cuff’ mechanism

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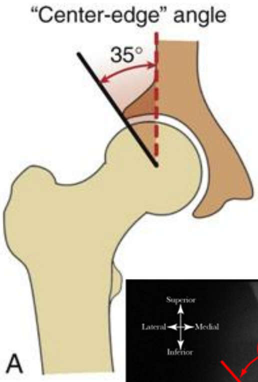
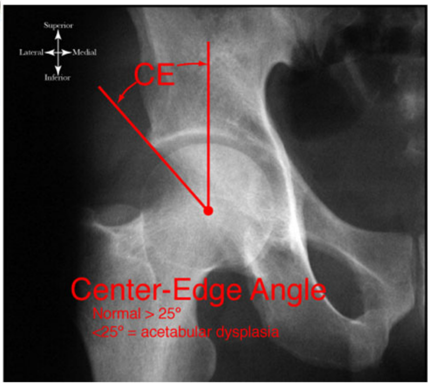
Centre Edge Angle of Acetabulum (CEA)

- Centre Edge Angle of the Acetabulum is the measurement of inferior angulation of the acetabulum.
- It is measured by the line connecting the lateral rim of the acetabulum and the centre of the femoral head. This line forms an angle with true vertical.
- Average measurements:
- 38^0 in males
- 35^0 in females
- A smaller CE angle makes the acetabulum more vertically orientated and results in less coverage of the femoral head resulting in less joint stability.





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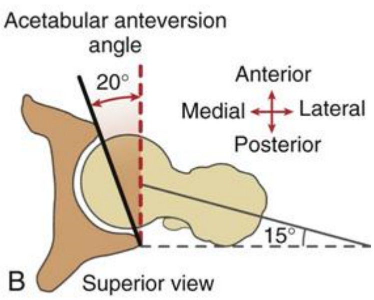
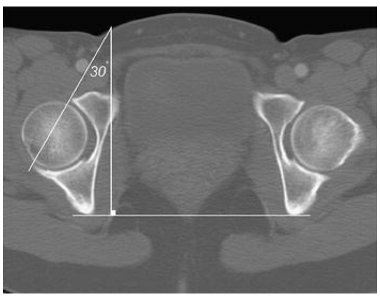
Angle of Acetabular Anteversion (AAA)





- Acetabulum faces laterally, inferiorly and anteriorly.
- The magnitude of the anterior orientation is called the angle of acetabular anteversion.
- Pathological increase in angle of anteversion causes decreased joint stability and an increased tendency for anterior dislocation of head of femur.

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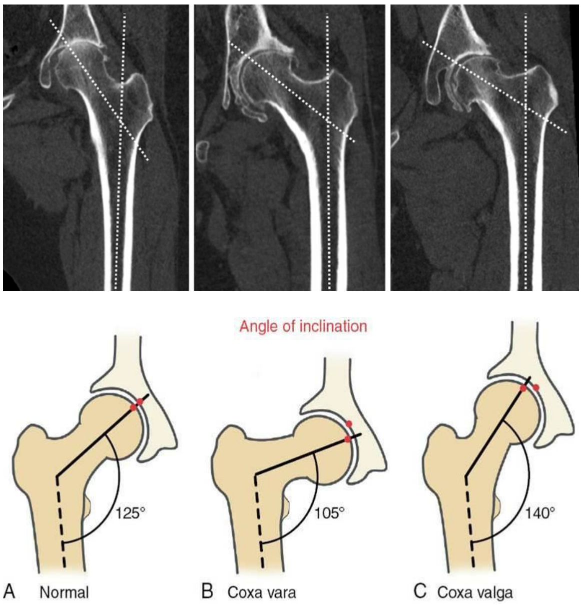
Angle of Femoral Inclination (AFI)



- *Angle of inclination*: occurs in the frontal plane between an axis through the femoral head and neck and the longitudinal axis of femoral shaft.
- In early infancy is approximately 150^0 and decreases to avg. of 125^0 in the normal adult and to approximately 120^0 in the elderly.
- Normally, the greater trochanter lies at the level of the center of the femoral head.
- Pathological increase in the angle is called coxa valga; and a pathological decrease is called coxa vara.

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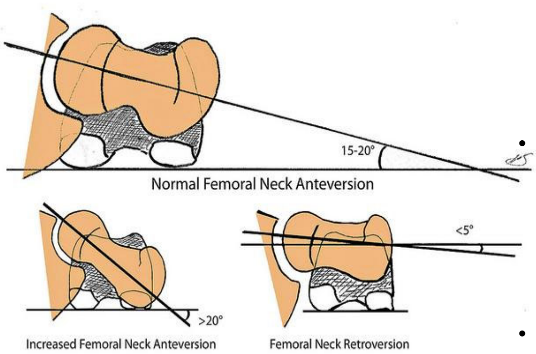
Angle of Femoral Torsion/Anteversion (AFT)



- *Angle of torsion* (aka angle of anteversion): occurs in the transverse plane between an axis through the femoral head and neck and the axis through the distal femoral condyles which creates a twist in the femoral shaft.
- The angle decreases with age: in the newborn it is approx. 40^0 and decreases to approximately 10^0-15^0 in adults (with a range between 7^0-30^0).
- A pathological increase in the angle is called femoral anteversion; and a pathological decrease is called femoral retroversion.

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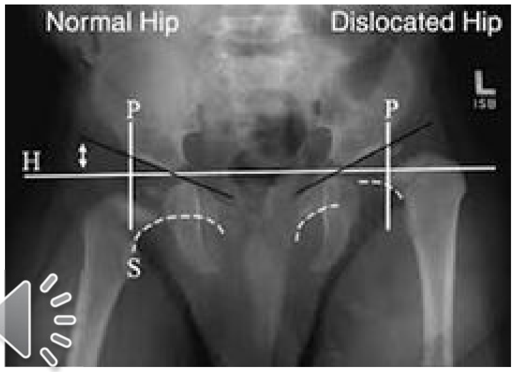
Hip Joint Pathologies in the young athlete

- Age is an important factor in the diagnosis of athletic injuries.
- Athletes are more susceptible to certain problems at certain ages:
- Young athletes with hip pain must be checked for:
  - (LCP) Legg-Calve-Perthe's Disease
  - (SFCE) Slipped Femoral Capital Epiphysis (SH type II)
  - Dysplasia (CHD)
  - Juvenile RA



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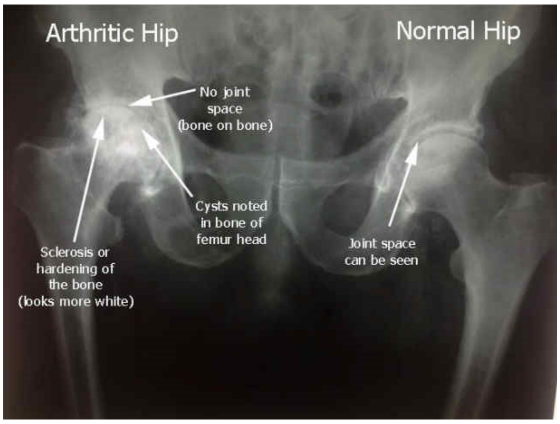
Hip Joint Pathologies in the senior athlete

- Extraspinal (DJD) degenerative joint disease is most commonly found at the hip joint in the seasoned or senior athlete.
- Most common symptoms include Groin pain on activity or chronic gluteal pain and spasm.
- Usually picked up on PROM assessment with the patient experiencing pain or crepitus.
- Most commonly found in Runners and lunging sports (i.e. squash).



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Rehab Techniques

Refer to Conservative Management of Sports Injuries Text book for all methods and indications for rehabilitation techniques:

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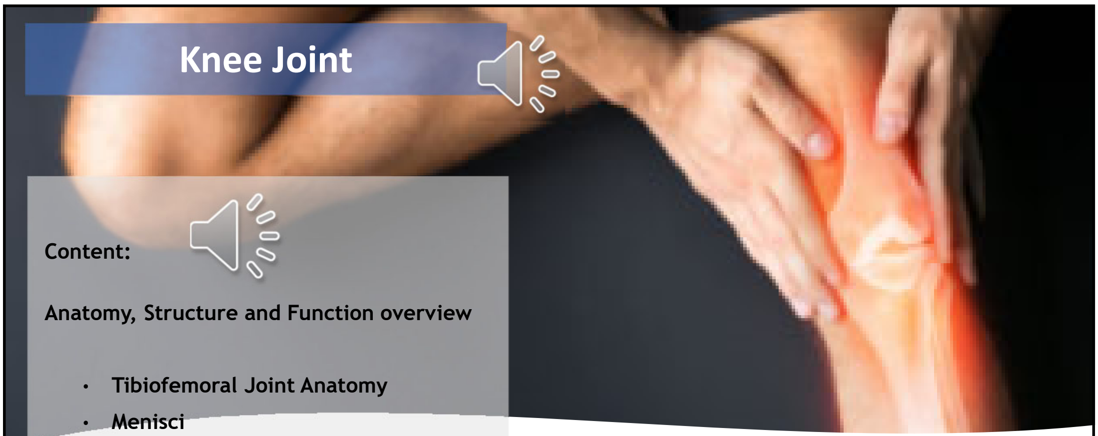

Knee Joint

Content:

Anatomy, Structure and Function overview

- **Tibiofemoral Joint Anatomy**
- **Menisci**
- **Ligaments of the knee**
  - Important Mechanisms of the knee
    - Tib-Fem Alignment
    - Q-angle
    - Screw Home Mechanism
- **Patellofemoral Joint**
- **Rehab**

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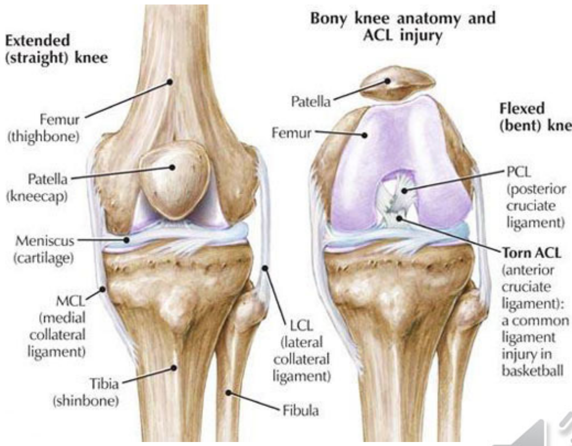
Anatomy of the Knee

One of largest joints in body, and the most complex.

Double condyloid joint, with 2^0 of freedom, allowing:

- flexion and extension in the saggital plane around a transverse axis.
- medial and lateral rotation in the transverse plane, around a vertical axis.



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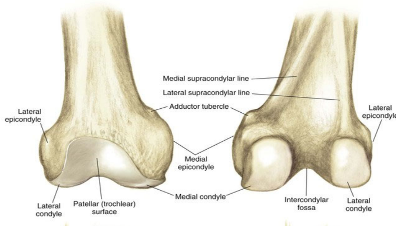
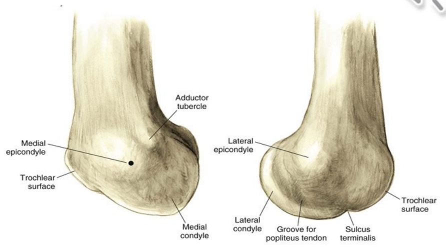
Anatomy of the Knee: Distal Femur

- Medial and lateral condyles on distal femur form the proximal part of the articulation.
- Large and obvious curvature antero-posteriorly and convex in the frontal plane.
- Condyles are separated by the intercondylar notch or fossa and joined anteriorly by the patellar groove.





- Femoral shaft is not aligned in a true vertical position, it is angled so that the femoral head is medial to femoral condyles.
- The lateral articular surface is not as large as the medial surface. The medial condyle extends further distally (⅔ of an inch) than the lateral so that the distal end of the femur is essentially level in anatomical position.

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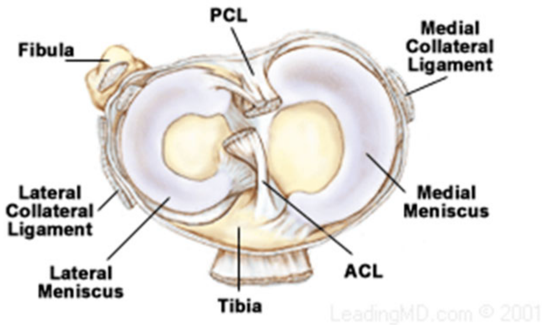
Anatomy of the Knee: Tibia

- Two concave, assymetrical medial and lateral tibial condyles.
- Articular surface of medial condyle is 50% larger than the lateral to correspond to the femoral condyles.
- Articular cartilage of medial tibial condyle is 3x thicker than the lateral condyle.
- The two articular condyles separated by intercondylar tubercles.



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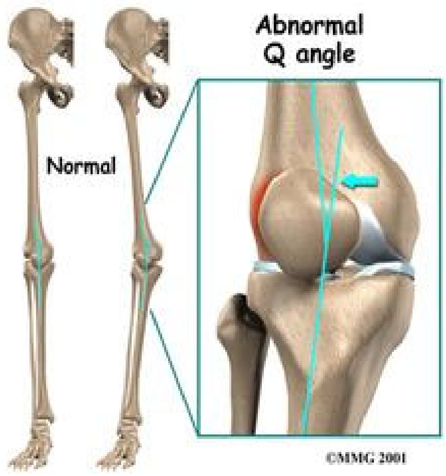
Function of the Knee

- In a closed kinematic chain, the knee works with hip and ankle to support body weight in static erect posture.
- It works dynamically to move and support body in sitting and squatting, as well as when supporting the transfer of weight during ambulation.
- In an open kinematic chain, the knee provides mobility for foot in space.
- Incongruence in the knee joint structure is accompanied by an accessory joint structure that enhances congruence and assists in the balance between mobility and stability.



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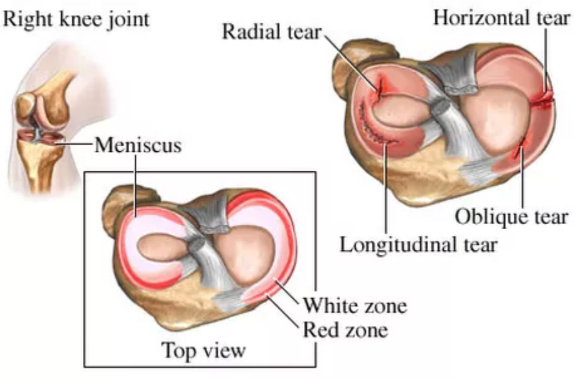
Menisci



- Two assymetrical fibrocartilagenous joint discs located between the condyles.
- Medial meniscus: semicirclular
- Lat meniscus: 4/5ths of a ring
- Both are wedge shaped. Thick peripherally and thin centrally. They open towards the intercondylar area.
  - Increase the radius of curvature of the tib condyles and therefore congruence.
  - Distribute weight bearing forces
  - Reduce friction between joint segments
  - Shock absorbers

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Ligaments of the Knee

ACL

- ACL runs from anterior tibia, superiorly and posteriorly to attach to the posterior inner aspect of lateral femoral condyle.
- Comprised of two subdivisions of the ligament:
  - Anterior Medial Band (AMB)
  - Posterior Lateral Band (PMB)
- With valgus loading, both ACL bands increase tautness with increased flexion.
- ACL is the primary restraint to anterior displacement of the tibia on the femoral condyles.
- It has a minor role to play in restraining medial and lateral forces to the knee.

Injury to ACL can result in

- increased anterior tibial translation, especially between 0º-90º of flexion
- increase in valgus tibial rotation, between 30º-90º
- increase in lateral tilt of patella with flexion
- increase in lateral shift of patella with flexion

- The Quadriceps is antagonistic to ACL. But if hamstrings are co-contracting it will reduce the forces through ACL.
- Therefore the hamstring complex decreases anterolateral tibial translation independent of the ACL.

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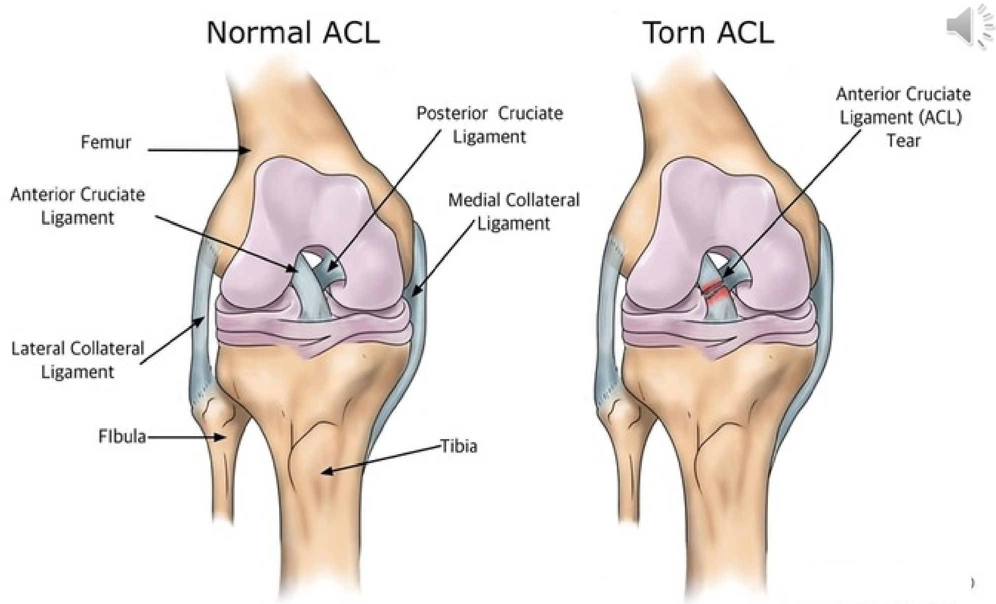

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Ligaments of the Knee

PCL

- The PCL runs superiorly and anteriorly to inner aspect of medial femoral condyle.
- It is the primary restraint to posterior displacement of tibia beneath the femur.
  - If a posterior directed force is applied, the tibia will also rotate laterally (ie: the PCL plays a role in locking of the knee which is critical for stabilization).
- Maximum loading occurs with knee fully extended and a posterior translatory force applied to the tibia.
- Also restrains varus and valgus forces.
- The hamstrings and gastrocnemius muscles are antagonistic whereas the quadriceps and popliteus muscles are synergistic to the actions of the PCL.

- The restraining system for knee extension includes:
  - PCL
  - Posterior joint capsule
  - LCL
  - Posterior oblique ligament
  - MCL, with meniscus attached
  - Posterior medial and posterior lateral menisco-tibial bands
  - Posterior menisco-fibular ligament

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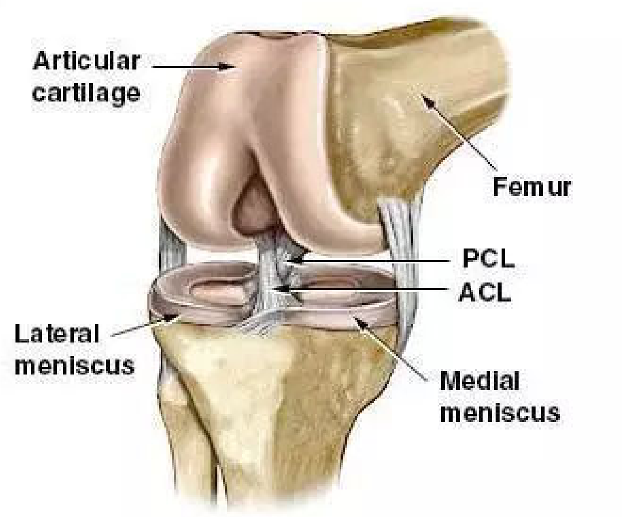

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Ligaments of the Knee

LCL

- Attaches between the lateral femoral epicondyle and posteriorly to the head of the fibula.
- It resists varus forces / adduction stresses on the knee.
- Also limits lateral rotation of the tibia (most substantial contribution at 35º of flexion) in conjunction with the posterolateral capsule and popliteus muscle.

MCL

- Attaches between medial femoral epicondyle and inserts into medial aspect of tibial condyle.
- It slants slightly anteriorly.
- Resists valgus forces / stresses on the knee; especially when knee is slightly flexed and other structures make a lesser contribution to resistance of valgus stress.
- The MCL checks lateral rotation of tibia.
- Acts as a backup restraint to pure anterior displacement of tibia when ACL is absent.

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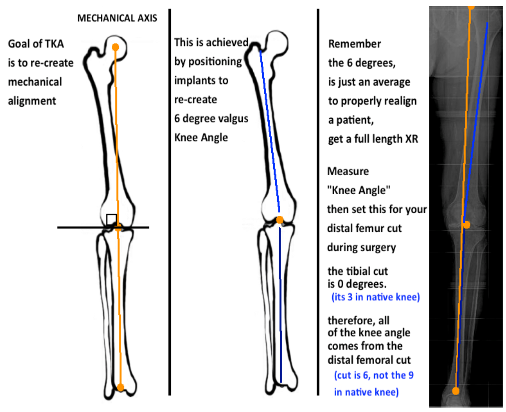
Important Mechanisms of the Knee

Tib-Fem alignment

- The long axis of the femur is oblique, directed inferiorly and medially ie: it is angled off vertical 5^0 to 10^0.
- The axis of the tibia is almost vertical. This creates an angle at knee (medially) between 185^0 and 190^0 and creates a normal / physiological valgus at the knee.
- Therefore, there is a balance of weight distribution on lateral and medial condyles as might be expected in bilateral static stance.



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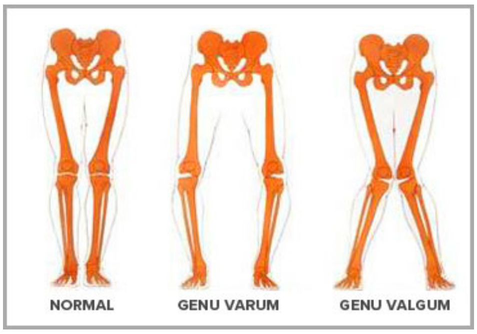
Important Mechanisms of the Knee

Genu Valgus / Genu Varus

- If the tib-fem angle is greater than 195^0, it is called genu valgum / knock knees.
  - This will increase compressive forces laterally and increase tensile forces medially.
- If the tib-fem angle is less than 180^0 it is called genu varum / bow legs.
  - This increases compressive forces medially and tensile forces laterally.
  - Even a mild genu varum can increase compression on medial meniscus by 25%.



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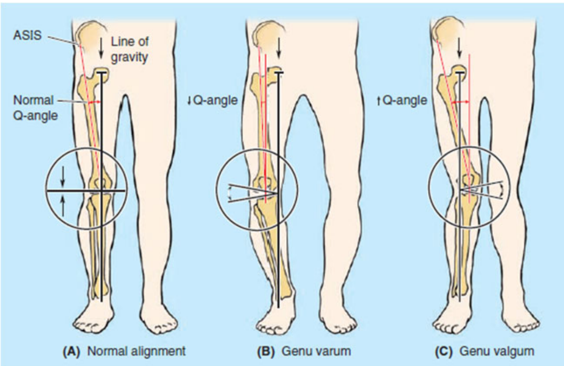
Important Mechanisms of the Knee

Q-Angle

- The Net effect of pull of quads and patellar ligament is measured using the **Q – angle**.
- This is the angle formed between a line connecting the ASIS to the midpoint of the patella and a line connecting tibial tuberosity and midpoint of patella. It usually measures 10^0-15^0 with the leg in extension.
- Females may have a greater angle (due to wider pelvic anatomy)
- A Q-angle of 20^0 or more is considered abnormal and creates excessive lateral forces on pat which can lead to pathological changes and suggests patellar instability.



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Anatomy of the Knee: Patellofemoral joint

- The Patella is the largest sesamoid bone in body
- Least congruent joint in the body
- Posterior surface of patella divided into 2 – medial and lateral articular facets.
- The med facet may be further divided into a larger medial and much smaller and most medial odd facet.

- The Patella slides distally on femur during knee flexion.
- Slides proximal on femur during knee extension.
- Patellar tilt – rotates around a vertical axis
- Patella rotation – rotation around an AP axis –
    - Apex of patella attached to tibial tuberosity via patellar tendon
    - therefore medial rotation of patella causes the inferior pole of patella to follow medial tib rotation.
    - Lateral rotation of patella causes inf pole of patella to remain lateral with the tibia.

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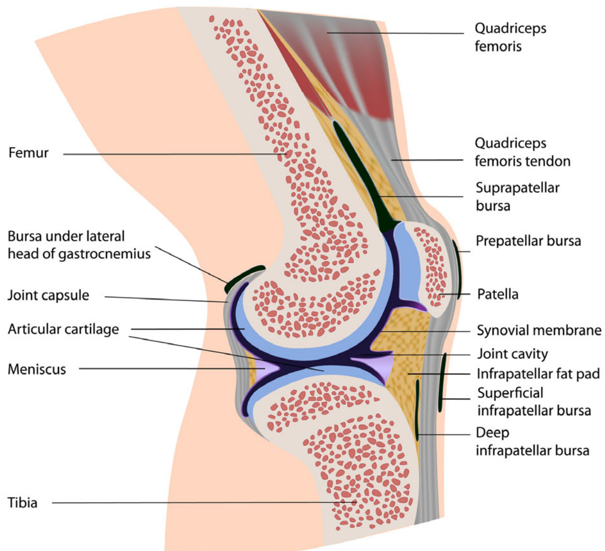
Anatomy of the Knee Joint



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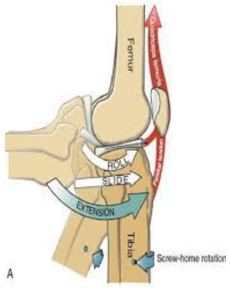
Important Mechanisms of the Knee

Screw Home Mechanism

- When the femur extends from full flexion back to approximately 30^0 of flexion, the smaller lateral femoral condyle is at complete range of motion.
- Extension continues in order to return the knee to 0^0. The larger medial condyle continues to roll/glide posteriorly although the lateral side has halted.
- This results in lateral rotation of the tibia on the femur (when non weight bearing) and medial rotation of the femur on the tibia in weight bearing.
- This pivots the femur about the fixed lateral condyle of the tibia when weight bearing. This is most evident in the last 5^0 of ext.



- The Mechanism may be assisted by increased tension in the ligaments as knee reaches full extension. This medial rotation is not voluntary and not produced by muscle action.
- It is this rotation that accompanies the end of extension and brings the knee joint into the close packed position.
- It is also known as the **locking mechanism** or **screw home mechanism**.

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Rehab Techniques

Refer to Conservative Management of Sports Injuries Text book for all methods and indications for rehabilitation techniques:

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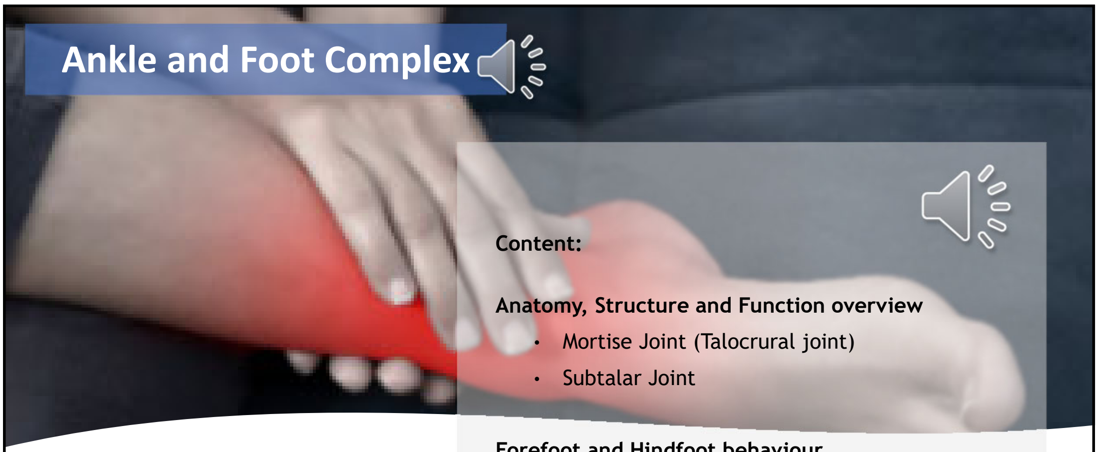

Ankle and Foot Complex

Content:

Anatomy, Structure and Function overview

- Mortise Joint (Talocrural joint)
- Subtalar Joint

Forefoot and Hindfoot behaviour

- Pronation/Supination of the foot
- Pronation and Supination twist

Plantar Fascia

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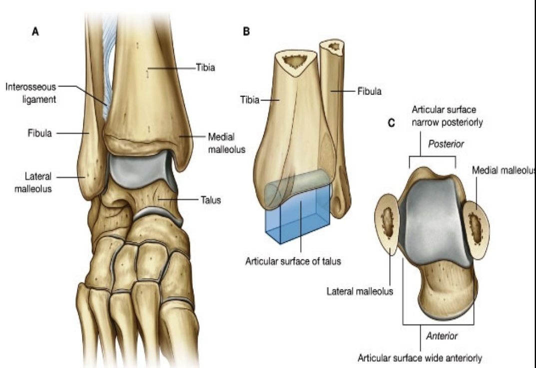
Anatomy of the Mortise Joint (Talocrural Joint)

- The Ankle is the most congruent joint in the body and therefore can withstand compression forces during gait up to 450% of body weight with little incidence of primary (non-traumatic) degenerative arthritis.
- The Mortise or talocrural joint is made up of tibiotalar and talofibular surfaces / joints.
- It is a synovial hinge joint with capsule and associated ligaments.
- Has a single oblique axis with 1˚ of freedom - dorsiflexion and plantarflexion



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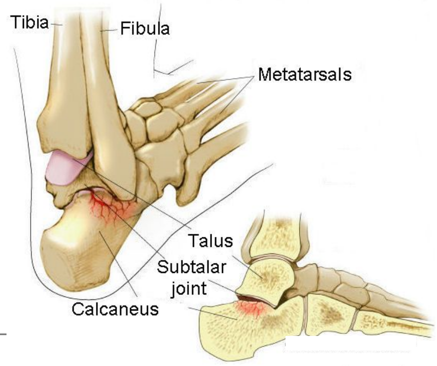
Anatomy of the Subtalar Joint

- The Subtalar joint or talocalcaneal Composite joint formed by three separate plane articulations between the talus superiorly and the calcaneus inferiorly.
- Also provides triplanar movement around a single joint axis in the form of pronation or supination.
- Function: to balance between (1) dampening rotational forces imposed by body weight and (2) maintaining contact of the foot with the supporting surface.
- 3 articulations on superior surface of the talus:
  - The posterior talocalcaneal articulation is largest
  - The medial & anterior articulations are smaller
- Between the posterior, medial and anterior articulations is a bony tunnel formed by a sulcus (concave groove) called the tarsal canal.



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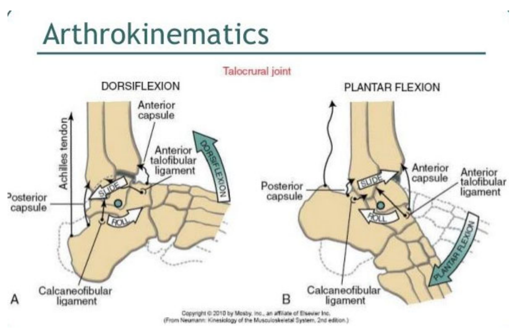
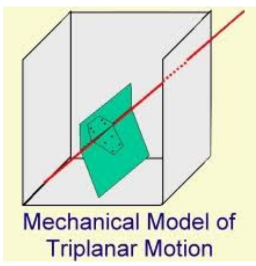
Forefoot and Hindfoot behaviour

How do you get triplanar movement at the subtalar joint?

- When the talus moves on the posterior facet of the calcaneus, the articular surface of the talus moves in the same direction as the bone moves.
- But at the medial & anterior facets, the talar surface moves opposite to the movement of the bone, therefore motion of talus is a complex twisting (screw-like motion).
- Triplanar movement of the talus is then considered to be around a single oblique joint axis.
- Therefore the subtalar joint is essentially a uniaxial joint with 1º of freedom – supination / pronation.





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Forefoot and Hindfoot behaviour

Pronation

- **Non-Weight Bearing**
  - Pronation is composed of: the component calcaneal motions of abduction (vert axis), eversion (AP/long axis), dorsiflexion (coronal).
- **Weight Bearing**
  - Pronation consists of: calcaneal eversion, talar adduction and plantarflexion (NOT calcaneal abduction and dorsiflexion).

Supination

- **Non-Weight Bearing**
  - Supination is composed of: the component calcaneal motions of adduction (vert axis), inversion (long axis), plantarflexion (coronal axis).
- **Weight Bearing**
  - Supination consists of: calcaneal inversion, talar abduction and dorsiflexion (NOT calcaneal adduction and plantarflexion).

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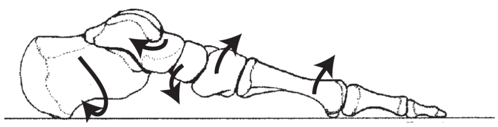
Forefoot and Hindfoot behaviour

Pronation Twist

- This is a mechanism to compensate for hindfoot supination in weight-bearing and maintaining contact of foot with ground.
- The hindfoot and Transverse Tarsal Joints are both locked into supination (CLOSED PACKED POSITION), adjustment of forefoot position must be left entirely to Tarso-Metatarsal joints (TMTs).
- The forefoot tends to lift medially and press into ground laterally.
  - 1st and 2nd rays will plantarflex and 4th and 5th will dorsiflex.

THIS RESULTS IN FOREFOOT EVERSION. The forefoot as a whole undergoes PRONATION TWIST of TMT joints.



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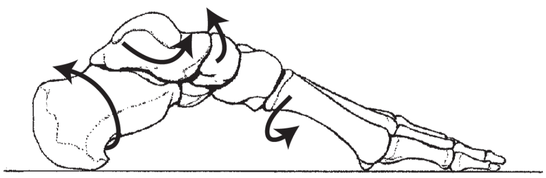
Forefoot and Hindfoot behaviour

Supination Twist

- Occurs as compensation for substantial hindfoot pronation in weight-bearing and thus to maintain contact of the foot with the ground.
- The Transverse Tarsal Joint (TTJ) will generally supinate to counter-rotate the forefoot, but it can only supinate to a limited degree.
- If range of TTJ supination not sufficient to meet demands of pronating force, the medial forefoot will press into ground and lateral side will tend to lift.
- 1st and 2nd rays are pushed into dorsiflexion, while 4th and 5th rays will plantarflex in order to keep contact with the ground THIS RESULTS IN FOREFOOT INVERSION.

The whole foot undergoes an inversion rotation around a hypothetical axis at the 2nd ray as a SUPINATION TWIST of TMT joints.



Rehab Techniques

Refer to Conservative Management of Sports Injuries Text book for all methods and indications for rehabilitation techniques:

Hyde, T. E. and Gengenbach, M. S. (2007), Conservative Management of Sports Injuries, 2nd ed, Massechusetts, Jones and Bartlett.

GAIT ANALYSIS SIMPLE UNDERSTANDING OF GAIT

Content:

- Normal Gait
- Gait Initiation
- Determinant Factors of Gait
- Gait Diagrams
- Running Gait

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GAIT

- Normal gait is rhythmic and characterized by alternating propulsive and retropulsive motions of the lower extremities.
- The lower extremities essentially support and carry the head arms and trunk (HAT) ie: 75% of body weight.
- In gait, the HAT must not only be balanced over one extremity but must also be transferred from one extremity to the other.
- These activities require co-ordination, balance, intact kinesthetic and proprioceptive senses and integrity of the joints and muscles.

Three main tasks are involved in walking:

- Weight acceptance
- Single-limb support; and
- Swing limb advancement

It is needed to support the weight of the body on one lower extremity and to swing one extremity forward in order to progress.

These tasks thus include the following tasks:

- Maintenance of support of HAT against gravity
- Maintenance of upright posture and balance; and
- Control of the foot trajectory to achieve safe ground clearance and a gentle heel contact.

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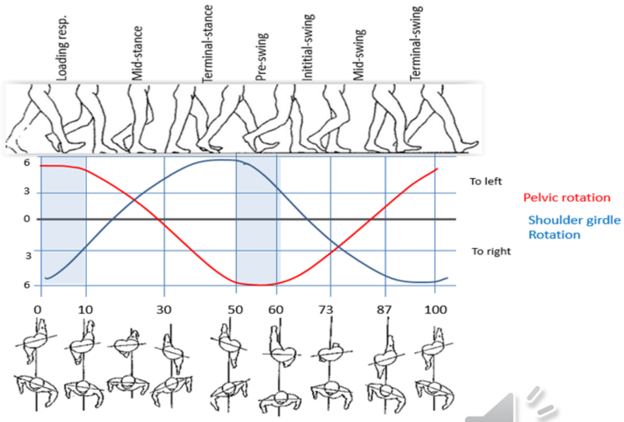
GAIT

Stance phase consists of:

- Heel strike / Initial contact
- Foot flat / Loading response
- Midstance
- Terminal stance
- Toe off / Pre-swing

Swing phase consists of:

- Acceleration / Initial Swing
- Midswing
- Deceleration / Terminal Swing



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GAIT INITIATION

- Begins in the erect standing posture with an activation of the tibialis anterior muscle and the vastus lateralis muscle, in conjunction with an inhibition of the gastrocnemius.
- Bilateral concentric contractions of the tibialis anterior (pulling the tibia anteriorly) results in a sagittal torque that inclines the body anteriorly from the ankles.
- The centre of pressure (COP) is now described as shifting either posteriorly and laterally towards the swing foot or posteriorly and medially towards the supporting limb.
- Abduction of the swing hip occurs simultaneously with contractions by the tibialis anterior and vastus lateralis and produces a coronal torque that propels the body towards the support limb.
- The support limb hip and knee flex a few degrees (3^0 - 10^0). The COP moves anteriorly and medially towards the support limb. This anterior and medial shift of the COP frees the swing limb so that it can leave the ground.
- The end of the gait initiation activity ends when either the stepping or swing extremity lifts off the ground or when the heel strikes the ground.

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DETERMINANT FACTORS OF GAIT

Distance and Time Variables

- **Stance time:** amount of time that elapses during the stance phase of one extremity in a gait cycle.
- **Single-support time:** time that elapses during the period when only one extremity is on the supporting surface in a gait cycle.
- **Double-limb support time:** amount of time that a person spends with both feet on the ground during one gait cycle.
- **Stride time / duration:** The amount of time it takes to accomplish one stride.

- **Step time / duration:** The amount of time spent during a single step. Measured in seconds per step.
- **Cadence:** Number of steps taken by a person per unit of time. Measured as no. of steps per second or per minute.
- **Speed / Walking Velocity:** The rate of linear forward motion of the body.
- **Acceleration** is the rate of change of velocity with respect to time.
- **Speed** is usually referred to as slow or fast.

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DETERMINANT FACTORS OF GAIT

Distance Variables:

- **Stride length:** The linear distance between two successive events that are accomplished by the same lower extremity during gait. Measured from the point of heel strike of one lower extremity to the next heel strike of the same extremity.
- **Step length:** The linear distance between two successive points of contact of opposite extremities. Measured from heel strike of one extremity to heel strike of the opposite extremity.

- **Width of walking base:** found by measuring the linear distance between the midpoint of the heel of one foot and the same point on the on the other foot.
- **Degree of toe out:** represents the angle of foot placement and may be found by measuring the angle formed by each foot's line of progression and a line intersecting the centre of the heel and the second toe. The angle measured is approximately 7^0.

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GAIT CYCLE

Phases of the Gait Cycle

- Gait cycle includes the activities that occur from the point of initial contact of one lower extremity to the point at which the same extremity contacts the ground again.
- During one gait cycle, each extremity passes through two phases: (1) a single stance phase; and (2) a single swing phase.

The stance phase begins at the instant that one extremity contacts the ground (heel strike) and continues only as long as some portion of the foot is in contact with the ground (toe off).

- Makes up 60% of the gait cycle.

- The swing phase begins as soon as the toe of one extremity leaves the ground and ceases just before heel strike or contact of the same extremity.
  - Makes up 40% of the gait cycle.

A period of double-limb support occurs when the lower extremity of one side of the body is beginning its stance phase and the lower extremity on the opposite side is ending its stance phase.

There are two periods of double support in a single gait cycle. During double support, both lower extremities are in contact with the ground at the same time.

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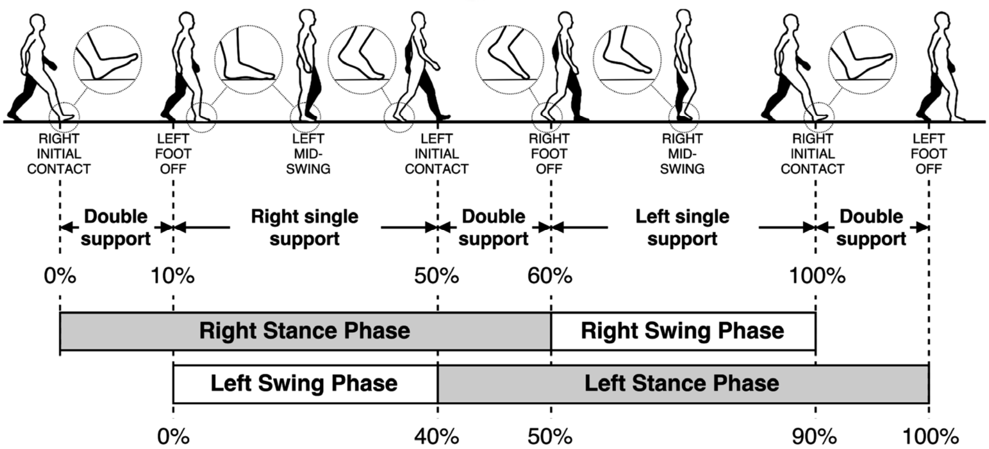
GAIT DIAGRAMS



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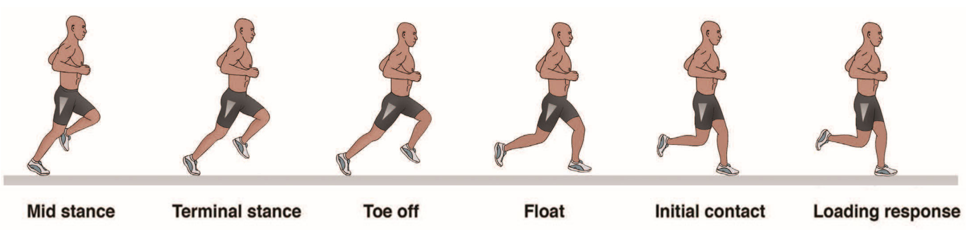
RUNNING GAIT

- In the running gait cycle, Maximum power is achieved with minimum contact and resistance from the ground.
- This is achieved by explosive contractions from the hamstrings and triceps suri muscle groups, and the quadriceps, glutei and ankle dorsiflexors alternating between the roles of synergists and antagonists, in order to 'spring load' the lower limbs for propulsion.
- Minimum resistance is achieved by bringing both limbs into the air as a 'double float' phase in stead of the double stance phase as seen in conventional walking gait cycle.



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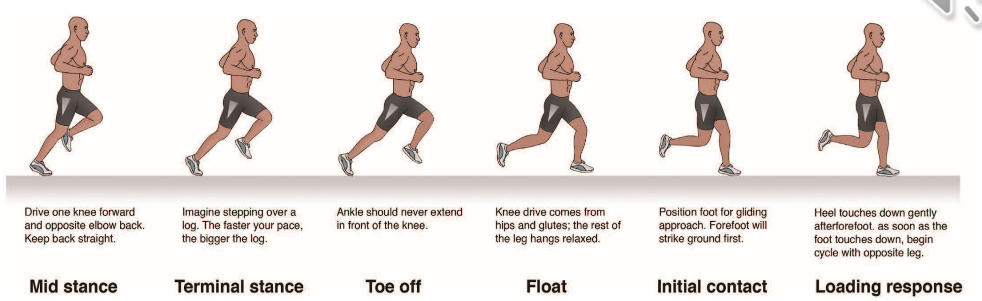
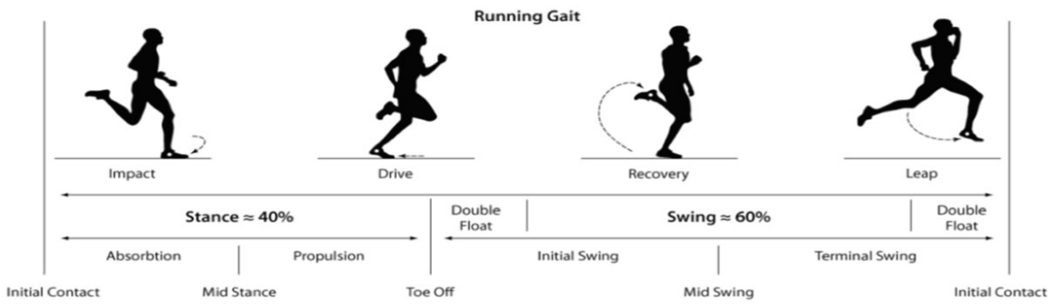
RUNNING GAIT





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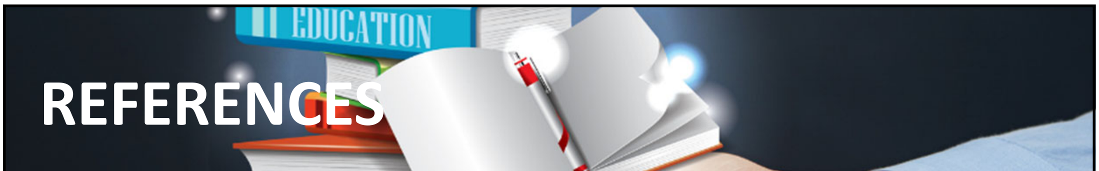

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