Foot and Ankle Biomechanics

Anatomy

Tibiofibular Joint

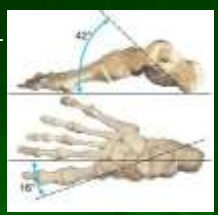
- Very stable joint structure
- Only true motion occurs in full DF due to anatomy of talus moving in mortise
- Maximum gapping is approximately 14mm
- Fibula moves in accordance to ankle

Talocrural Joint

- Normal available motion: DF=10-20°, PF=30-50°
- Required during walking - 20° PF and 10° DF
- Axis of inclination 20-30° posterior to frontal plane and 10° inferior
- Not cardinal plane

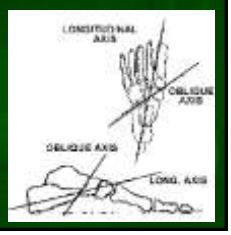
Subtalar Joint

- Normal available motion: inversion=30° eversion=10-20°
- Average axis of inclination: 42° superior from frontal plane and 16° medial from sagittal plane
- Triplanar motion



Midtarsal Joints

- Comprised of two separate joints: longitudinal midtarsal joint and oblique midtarsal joint
- Separate axes: longitudinal - talonavicular joint, oblique – calcaneocuboid joint



Midtarsal Joints

Longitudinal Midtarsal Joint

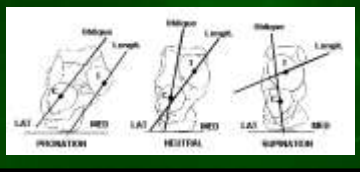
- Axis= 15° from transverse plane, 75° from frontal and 9° from sagittal planes
- Primary motion – inversion and eversion

Oblique Midtarsal Joint

- Axis= 52° from the transverse plane, 57° from the sagittal plane and 38° from the frontal plane
- Motion – DF and ABD; PF and ADD

Midtarsal Joints

- Alignment of midtarsal joint axes are a result of subtalar influence.
- Pronation of STJ causes MTJA to become more parallel allowing greater fore foot motion



First Ray

- Comprises the first metatarsal, medial cuneiform, navicular
- Axis of motion: posterior/dorsal/medial to anterior/plantar/lateral. 45° from the sagittal and frontal planes
- Motion occurs in 2 planes simultaneously:
  - Dorsiflexion and inversion
  - Plantarflexion and eversion

Plantar Fascia

- Attaches primarily from the medial calcaneal tuberosity to the base of the proximal phalanges
- Acts as a truss and beam system – windlass effect

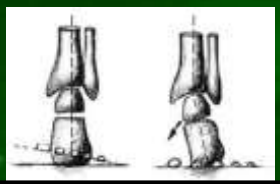
Other Support Structures

- 4 layers of intrinsic muscles
- 19 extrinsic muscles (long tendons)
- Approximately 107 ligaments

Biomechanics and Alignment

Normal Alignment

- Open chain: calcaneal bisection comparison to lower 1/3 of leg is 0-2° inverted
- Closed chain: both plantar condyles and metatarsal heads are in the same plane and positioned on support surface

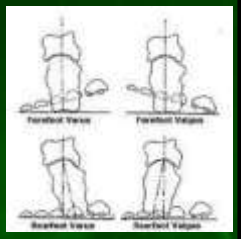


Normal Alignment

- Normal amounts of pronation occur (4-6°)
- From posterior view, calcaneus is either rectus or slightly everted
- Amount of normal pronation is different in children under age 7,
  = (7-age+ 4-6°)

Rearfoot Varus

- Calcaneus is inverted with respect to the lower leg
- Considered by some to be the most common osseus foot deformity
- 3 types: compensated, partially compensated and uncompensated



Rearfoot Valgus

- Hindfoot is everted when held in subtalar joint neutral
- Extremely rare – probably wrong – measure it again
- Assess for contributing pathology

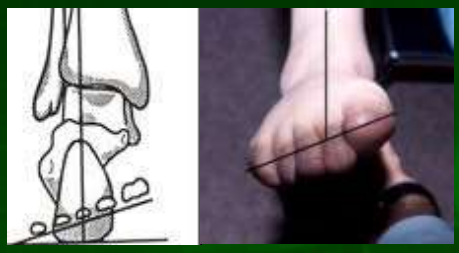
Tibial Varum

- Curvature or bowing of the tibia in the frontal plane places the hindfoot in an inverted position in relation to the supporting surface
- Up to 4° is considered normal. 4-7° is notable. 8° or more is pathological.

Forefoot Varus

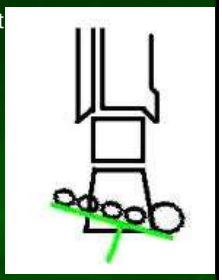
- Medial aspect of the forefoot is inverted in relation to the lateral aspect of the forefoot.
- Also inverted in relation to the rearfoot (at level of midtarsal joint)
- Some consider forefoot varus to be most common deformity of the foot.

Forefoot Varus



Forefoot Valgus

- Medial aspect of the forefoot is everted in relation to the lateral aspect of the forefoot
- Forefoot is everted in relation to plantar condyles of the calcaneus

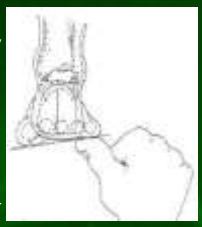


Forefoot Valgus

- Flexible forefoot valgus – the midtarsal joint has sufficient flexibility to allow the lateral column of the foot to reach the floor
- Calcaneus is vertical in weightbearing
- Rigid forefoot valgus – rigid midtarsal joint does not allow the lateral column to reach the ground subsequently the subtalar joint supinates to compensate.

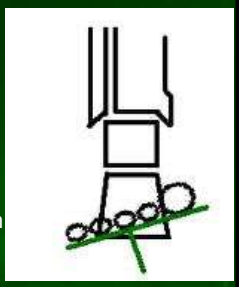
Plantarflexed First Ray

- First Ray = first metatarsal + first cuneiform + Navicular
- Plantar aspect of the first ray is inferior to the plane of 2nd – 5th metatarsals
- Similar appearance to forefoot valgus if rigid
- If flexible, functions similar to forefoot varus, looks like a neutral foot.



Forefoot Supinatus

- Soft tissue deformity of forefoot
- Same appearance as forefoot varus
- Consequence of long term over-pronation



Ankle Equinus

- Maximum dorsiflexion is less than 10°
- Produces requirements of over-pronation
- Motion is required of oblique midtarsal joint
- Creates early heel off
- Increased energy expenditure during ambulation

Forefoot Equinus

- Forefoot is in plantigrade with respect to the rearfoot

Hallux Limitus

- Great toe extension at the MTP joint is less than 70° in open chain and less than 30° in closed chain
- May be structural or functional limitation

Hallux Rigidus

- Great toe extension at first MTP joint is less than 30° in open chain or less than 10° in closed chain
- Typically a structural limitation

Hallux Primus Elevatus

- Dorsal first ray hypermobility
- In weight bearing, first ray is forced dorsally secondary to instability and ground reaction forces

Hallux Abductovalgus

- Medial deviation of the great toe at the level of the MTP
- Typically see widening of the space between the first and second metatarsal shafts
- One part of a bunion formation

Metatarsus Adductus

- Medial deviation of all five metatarsal shafts
- Produces the appearance of a curved shaped foot.

Biomechanical Evaluation Process

Evaluation Process

- Analyze gait, noting main abnormalities
- Gain an impression of lower extremity function as a whole through functional screening
- Measure/assess objective data
- Put the pieces of the puzzle together

Functional Evaluation

- Perform in order to maximize patient comfort
- Use information to formulate a functional hypothesis and compare to actual function
- Compare available motion vs motion utilized
- Carefully bisect the posterior calcaneus and distal limb first
- Don't split hairs – if all does not correlate then NOTHING IS

Prone Evaluation

- Passive inversion available
- Passive eversion available
- STNJ position (rearfoot and forefoot)
  - Talar head congruency
  - Passive DF from inversion to eversion
- Dorsiflexion (gross ROM and in STJN with knee flexed and extended)
- Assess extrinsic and intrinsic muscle strength (gross strength and isolated strength)
- All performed in 'Figure 4' position or in hip neutral

Prone Evaluation – Lab Activities

- Bisect distal leg and posterior heel
- Measure available inversion
- Measure available eversion
- Find subtalar joint neutral
- In STJN, measure leg rearfoot relationship
- In STJN, measure rearfoot to forefoot relationship
- Measure DF/PF with knee flexion and

Supine Evaluation

- Utilized to determine leg length inequalities
  - Measured from ASIS to medial malleolus and umbilicus to medial malleolus. Average over 3 trials. Recorded in cm.
  - Must first clear the pelvis to assess leg length differences.
- Measure malleolar torsion
  - With femoral condyles in neutral, palpate malleoli, measure the plane of the axis
    - Norms: 18-23° of external rotation

Supine Evaluation

- Measure midtarsal joint integrity
  - LMTJA: with rearfoot in supination, assess the flexibility of medial midfoot invert and evert
  - OMTJA: with rearfoot in supination, assess flexibility of lateral midfoot to dorsiflex/abduct and plantarflex and adduct
- Measure great toe ROM into extension

Supine Evaluation – Lab Activities

- Leg length assessment
  - Visual inspection in supine and sitting
    - Measure ASIS to medial malleolus
    - Measure umbilicus to medial malleolus
- Malleolar Torsion
  - Femoral condyles neutral
  - Measure axis
- Midtarsal joint integrity
  - LMTJ
  - OMTJ
- Great toe ROM

Standing Evaluation

- **Resting Calcaneal Stance Position** – provides information on self selected foot postures
- Patients frequent subtalar joint position

- **Half Squat** – provides information on maximum pronated position
- Mimics loading response and early midstnace positions during gait
- Gives information on foots effect on kinetic chain

Pronation/Supination Test

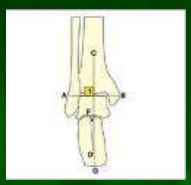
- Quick screen utilized to determine the flexibility of the subtalar joint
- Gait cycle requires pronation from ground up and supination from the hip down
- Grossly measured as excessive, adequate, inadequate

Heel Rise Test

- Used to demonstrate posterior tibial function
- Rated as normal inversion, partial inversion, unable to perform/eversion. Rate height of elevation as well.
- Must compare to noninvolved side if applicable.

Tibial Angle

- Measured posteriorly from bisection of distal limb and a known angle
- Provides information on contributions of proximal structures on foot function
- Greater than 4° is excessive, greater than 8° is pathological



Axis of Inclination

- Used to predict suspected amount of subtalar motion that is normal for the individual
- Measures frontal plane motion of calcaneus to transverse plane motion of talus
- High axis = 2-4° of suspected eversion at maximum pronation, average axis = 4-6° of eversion, low axis = 6-8° of eversion

Navicular Drop Test

- Measures magnitude the navicular tuberosity drops from a non-weight bearing position to a weight bearing position
- Average for normal is 7-8°

Standing Evaluation Lab Activities

- Measure RCSP
  - Resting calcaneal stance position – leg to rearfoot
- Measure ½ squat position
  - Leg to rearfoot
- Measure tibial angle
  - Leg to floor
- Assess axis of inclination
  - High, normal, low
- Assess
  - Pronation/supination test
    - Excessive motion, normal motion, insufficient motion
- Assess heel rise test
  - Full ROM?
  - Calcaneal inversion?
- Navicular Drop test
  - Seated height
  - Standing height