Anatomy, Biomechanics and Gait of the Foot and Ankle

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Disclaimer Slide

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J. W. Thomas Byrd, M.D.

• Nashville, Tennessee

• . . . a friend, a pioneer in indications for techniques and instrumentation in hip arthroscopy, a mentor.

• A gentleman, a caring sports medicine physician, and a friend.

Acknowledgement content of talk
Ankle: Modified Hinge Joint

- **Bony configuration**
  - Mortise
  - Circular Pretzel

- **Ligamentous stability**
  - ATF and CF laterally
  - Deltoid superficial and deep medially
  - Syndesmosis superiorly
Figure 4.10. A posterior view of the distal end of the tibia. Note the grooves for the tendons of flexor hallucis longus and tibialis posterior.
Figure 4.33. (A) The distal tibiofibular joint as seen anteriorly. Note the anterior tibiofibular ligament. (B) The distal tibiofibular joint as seen posteriorly. Note the posterior tibiofibular ligament.
Bones & Joints

- 14 phalanges
- 5 metatarsals
- 3 cuneiforms
- Cuboid
- Navicular
- Talus
- Calcaneus
- Tibia and fibula
Mid & Hindfoot Joints

- Lis Franc
  - Tarsal/metatarsal
- Chopart
  - Inter-tarsal
- Subtalar
- Highly complex
  - Flexibility for motion
  - Rigidity for weightbearing
Mid & Hindfoot Joints

- Lis Franc
- Tarsal metatarsal jt
- 2nd metatarsal is keystone
- Medial ligament attaches to medial cuneiform not 1st metatarsal
Lateral Ligaments

- Anterior Talofibular Ligament
- Calcaneofibular Ligament
- Posterior Talofibular Ligament
Lateral Ligaments

- Anterior talofibular ligament
  - Thickening of the anterior capsule
  - Anterior/oblique course from anterolateral malleolus to anterior lateral talus
  - Tight in plantar flexion (position of most ankle sprains)
  - Most frequently injured
  - Resists anterior drawer test
Video courtesy JW Thomas Byrd M.D, Nashville
Lateral Ligaments

- ATFL
- Calcaneofibular ligament
  - Discrete ligament
  - Traverses apex of lateral malleolus to prominence on calcaneus
- Usually injured after ATF with mechanism of plantarflexion / inversion (supination)
- Isolated injury with pure inversion or varus stress
- Major restraint to inversion (talar tilt test)
  - Combined restraint with the ATF when foot is plantarflexed
• Video courtesy JW Thomas Byrd M.D, Nashville
Lateral Ligaments

- ATFL
- CFL
- Posterior talofibular ligament
  - Intraarticular structure
  - Short course from posteromedial the lateral malleolus to posterior talus
  - Restraint only when ATF & CF are disrupted (rarely significant in management of lateral ankle sprains)
  - Strongest ligament; rarely injured except with ankle dislocation
Medial (Deltoid) Ligament

- Superficial & deep component; functions as single structure
- Primary resistance to eversion
Medial (Deltoid) Ligament

- Superficial deltoid fans out from the medial malleolus to insert on the:
  - Talus posteriorly
  - Calcaneus medially
  - Navicular anteriorly

- Deep deltoid ligament
  - Anterior fibers insert on the neck of the talus
  - Posterior fibers insert on the posterior medial tubercle of the talus
Tibiofibular Ligament

- Dense fibrous structure maintaining ankle mortise (tibiofibular articulation)
- Source of “high ankle sprain”
- Prolonged morbidity!
- Injury occurs from eversion, especially with the foot dorsiflexed
- 1 mm lateral shift of talus within mortise reduces contact area 42%
Transverse Tarsal Articulation

• Comprised of Calcaneocuboid & Talonavicular articulations
• Functions as one joint
Plantar Aponeurosis

Arises from the calcaneus, passing distally to insert into the base of the proximal phalanx.
Dorsiflexion of the proximal phalanges pulls the plantar aponeurosis over the metatarsal heads, resulting in depression of the metatarsal head and elevation of the longitudinal arch.
Plantar Aponeurosis
Windlass Mechanism

Also causes inversion of the calcaneus and resultant external rotation of the tibia
Transverse Tarsal Articulation

Allows motion within the subtalar joint while the foot is fixed on the ground
Transverse Tarsal Articulation

Allows motion within the subtalar joint while the foot is fixed on the ground
When the heel is elevated, the weight bearing forces are evenly distributed across the metatarsal heads.
The oblique orientation metatarsophalangeal crease causes the foot to supinate & laterally deviate as heel rises.

Compensatory supination of subtalar joint allows leg to remain vertical.
Muscles and Tendons

- Achilles, Gastroc/Soleus, Plantaris
- Peroneus longus, brevis, tertius
- Ant tibialis, EHL, EDC
- Posterior tibialis, FHL, FDC
- Foot intrinsics
Function

- Propulsion
- Support
- Flexibility
- Rigidity
- Gait mechanics: ankle and foot motions
Walking Cycle

- Stance phase (60%); Swing phase (40%)
- Double limb support (10%): both feet on ground
Events of Walking Cycle

• First Interval
  • Deceleration, heel-strike to foot-flat
    • Ankle rapid plantarflexion
    • Foot loaded in pronation – subtalar joint eversion
    • Lower leg internally rotates
    • Eversion unlocks transverse tarsal joint
  • Main thrust force absorption and dissipation
Events of Walking Cycle

• **Second Interval**
  • Foot-flat to heel-lift
    • Ankle dorsiflexes
    • Subtalar joint inverts
  • Lower limb external rotation
  • Inversion due to ankle oblique axis and plantar aponeurosis and metatarsal break
  • Stability of transverse tarsal joint increased by inversion
  • Mid-foot goes from flexible to rigid
Events of Walking Cycle

• **Third Interval**
  • Heel-lift to Toe-off
    • Ankle rapid plantarflexion
    • Windlass effect of plantar aponeurosis stabilizes longitudinal arch
    • Subtalar joint inverts to maximize rigidity of transverse tarsal joint
  • Body propelled forward
Ankle Axis

- Thus, with leg fixed and foot free
  - Dorsiflexion results in outward deviation of the foot
  - Plantarflexion results in inward deviation
Ankle Axis: Opposite with foot fixed

- With **foot fixed**, dorsiflexion / Plantarflexion results in rotation of the leg
  - Dorsiflexion results in **internal rotation**
  - Plantarflexion results in **external rotation**
Eversion and inversion of the subtalar joint are directly tied to internal and external rotation of the tibia.
During gait: coupled motion between ankle and subtalar joints

- **First**
  - Tibial internal rotation
  - Talar eversion
  - Foot pronation

- **Third**
  - Tibial external rotation
  - Talar inversion
  - Foot supination
Mechanics of Running

- **Added phase: Float**
  - Both feet are off the ground
- Shortened stance phase and gait cycle
- Basic kinematics of foot and ankle unchanged from walking
- Vertical ground reaction forces increased to 3X body weight during stance phase
- Range of motion of joints increased 50%
- Lower extremity muscle activity altered
Ankle Axis

• Thus, **with leg fixed and foot free**
  • Dorsiflexion results in outward deviation of the foot
  • Plantarflexion results in inward deviation
Third Interval: create rigid lever for push-off

- Ankle undergoes plantarflexion
- Longitudinal arch stabilized by windlass effect of the plantar aponeurosis as toes are brought into dorsiflexion
- Subtalar joint continues to invert (enhanced by obliquity of the ankle joint) maximizing rigidity of the transverse tarsal joint at toe off
Mechanics of Running

- Basic kinematics of the foot and ankle not significantly altered
- Gait cycle shortened
- Stance phase shortened
- Vertical forces during stance phase increase to 2.5 - 3 times body weight
- ROM of joints is increased 50%
- Phasic activity of the lower extremity muscles altered
Fig. 1-14. Simple mechanism demonstrating functional relationships. A, Action of mitered hinge. B, Addition of pivot between two segments of mechanism.
Fig. 1-9. Diagrammatic representation of “windlass action.”
A, Foot flat. B, Increased tension of plantar aponeurosis caused by dorsiflexion of the toes with resultant elevation of longitudinal arch.
Fig. 1-5. Composite of events of first interval of walking or period that extends from heel strike to foot flat.

Fig. 1-6. Composite of events of second interval of walking or period of foot flat.
Fig. 1-8. Composite of all events of third interval of walking or period extending from foot flat to toe-off.
Assessment of spinal mechanics
Gait analysis posterior view
Posterior view gait running and spine
Thank You!