Anatomy, Biomechanics, and Gait
of the Foot and Ankle

J. W. Thomas Byrd, MD
info@nsmfoundation.org

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I. Ankle ligaments

A. Epidemiology
1. Lateral ankle complex is the single most frequently injured structure in athletics (approximately 40% of all injuries)
2. One sixth of all time lost from sports is due to ankle sprain
3. 85% of ankle injuries are sprains
   a) 85% are inversion sprains of the lateral ligaments
   b) 5% deltoid ligament injuries
   c) 10% syndesmosis injuries

B. Lateral Ligaments (Figure 1)
1. Anterior talofibular ligament
   a) Thickening of the anterior capsule
   b) Anterior/oblique course from anterolateral malleolus to anterior lateral talus
   c) Tight in plantarflexion (position of most ankle sprains)
   d) Most frequently injured
   e) Resists anterior drawer test
2. Calcaneofibular ligament
   a) Discrete, separate ligament
   b) Traverses from apex of the lateral malleolus to the prominence on the lateral calcaneus
   c) Usually injured after the anterior talofibular ligament with mechanism of injury involving plantarflexion/inversion (supination)
   d) Isolated injury can occur with pure inversion or varus stress
   e) Major restraint to inversion (talar tilt test)
      - Combined restraint with the anterior talofibular ligament when the foot is plantarflexed

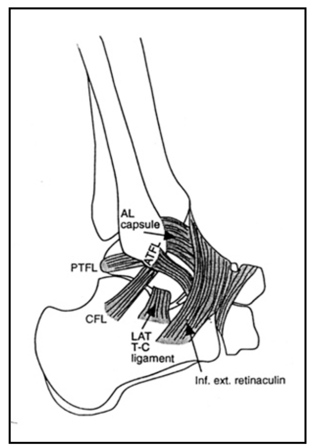

Figure 1

3. Posterior talofibular ligament
    a) Intraarticular structure
    b) Short course from posteromedial aspect of the lateral malleolus to posterior talus
    c) Restraint only when both the anterior talofibular and calcaneofibular ligaments are disrupted (rarely significant in management of lateral ankle sprains)
    d) Strongest of the lateral ligaments, rarely injured except with ankle dislocation

C. Medial (deltoid) ligament
1. Superficial and deep component functions as a single structure
2. Superficial deltoid ligament
    - fans out from the medial malleolus to insert on the:
    a) Talus posteriorly
    b) Calcaneus medially
    c) Navicular anteriorly
3. Deep deltoid ligament
    a) Anterior fibers insert on the neck of the talus
    b) Posterior fibers insert on the posteromedial tubercle of the talus

D. Tibiofibular ligament
1. Dense fibrous structure maintaining the integrity of ankle mortise (tibiofibular articulation)
2. Source of “high ankle sprain” (prolonged morbidity!)
3. Injury occurs from inversion, especially with the foot dorsiflexed
4. One millimeter lateral shift of the talus within the ankle mortise reduces the contact area of the ankle joint 42%

II. Walking cycle

A. Stance phase (60%), Swing phase (40%)
   - Double limb support (10%): both feet on the ground

B. Swing phase
   1. Begins at toe off, ends at heel strike
   2. Three intervals
      a) Acceleration
         - Immediately after toe off
      b. Mid swing
      c) Deceleration
         - Immediately precedes heel strike

C. Stance Phase
   1. Begins at heel strike; ends at toe off
   2. Three intervals
      a) First interval
         (1) Begins at heel strike; ends at foot flat
         (2) Absorption and dissipation of forces generated by foot striking the ground
      b) Second interval
         (1) Begins at foot flat; ends at heel lift
         (2) Center of gravity of the body passes over the weight bearing leg
      c) Third interval
         (1) Begins at heel lift; ends at toe off
         (2) Body is propelled forward as weight is progressively transferred to the opposite foot

III. Axes of Rotation (Implications in Gait)

A. Ankle joint
   1. Axis rotated laterally and posteriorly in the transverse plane (external tibial torsion)
   2. Axis directed downward laterally in the coronal plane (Figure 2&3)
      a) Thus, with leg fixed and foot free (Figure 4);
         (1) Dorsiflexion results in outward deviation of the foot
         (2) Plantarflexion results in inward deviation
      b. With foot fixed, dorsiflexion-plantarflexion results in rotation of the leg (Figure 5):
         (1) Dorsiflexion results in internal rotation
         (2) Plantarflexion results in external rotation

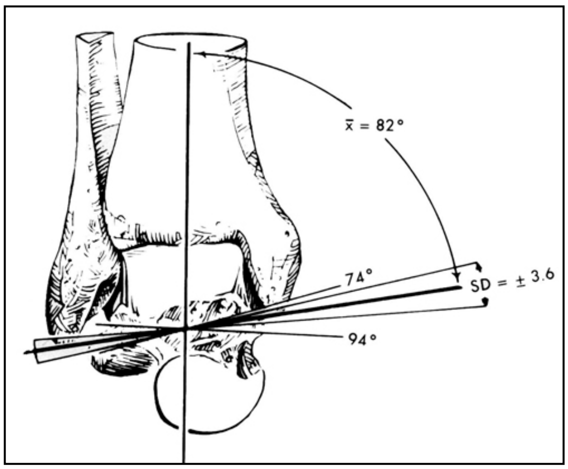

Figure 3

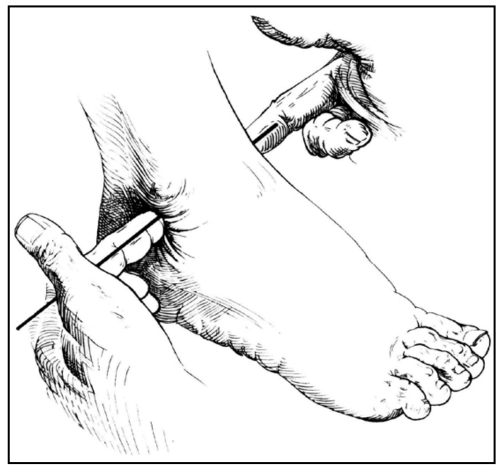

Figure 2

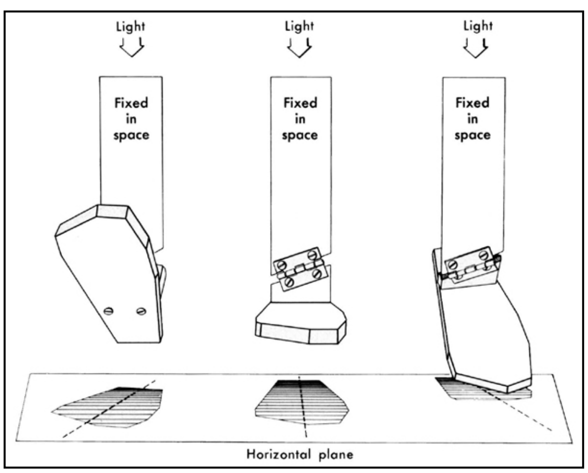

Figure 4

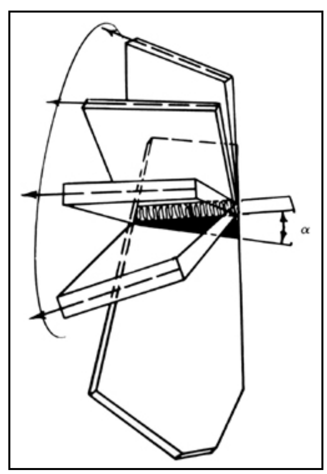

Figure 5

B. Subtalar joint
   1. Like the ankle, the subtalar joint is a single axis joint
   2. Axis averages 23° from the sagittal plane (Figure 6)
   3. Axis averages 41° from the horizontal plane (Figure 7)
      a) Eversion and inversion of the subtalar joint are directly tied to internal and external rotation of the tibia (Figure 8)

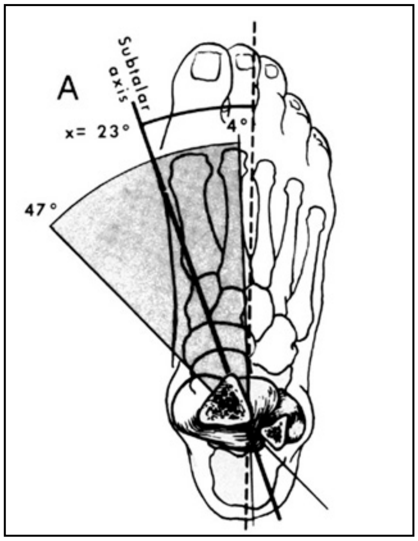

Figure 6

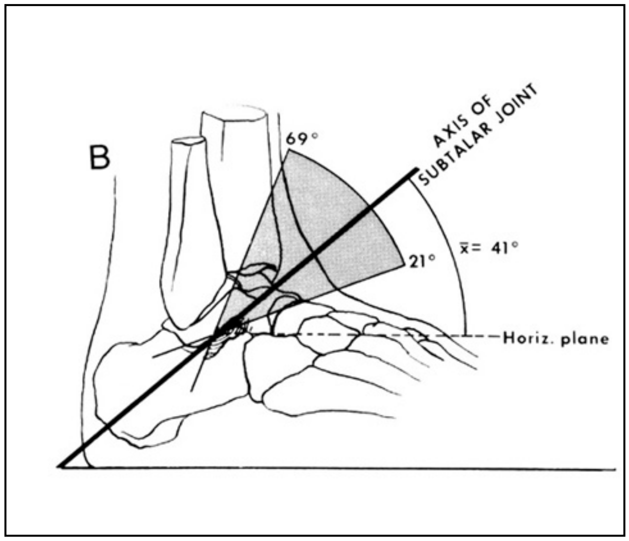

Figure 7

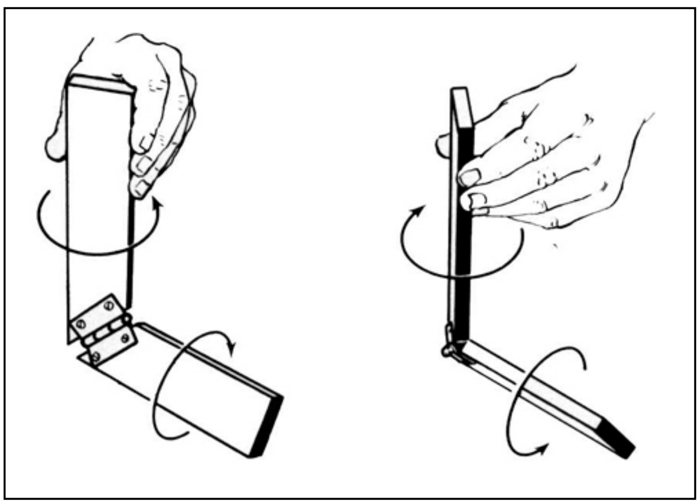

Figure 8

C. Transverse tarsal articulation
   1. Allows motion within the subtalar joint while the foot is fixed on the ground (Figures 9)
   2. Comprised of the calcaneocuboid and talonavicular articulations (Figure 10 & 11)
      - Functions as one joint
   3. Motion can occur when the two joints are in parallel (Figure 12)
      a) Joints are parallel when the foot is everted
      b. With foot inverted, the joints are nonparallel, making the transverse tarsal articulation rigid

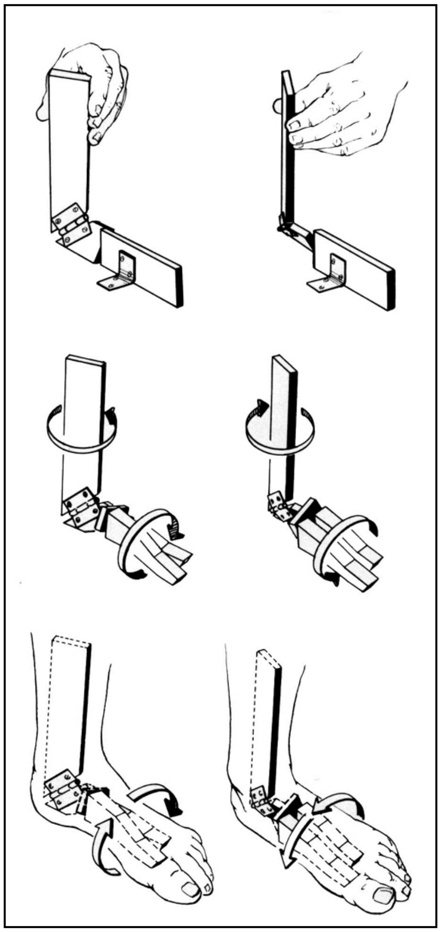

Figure 9

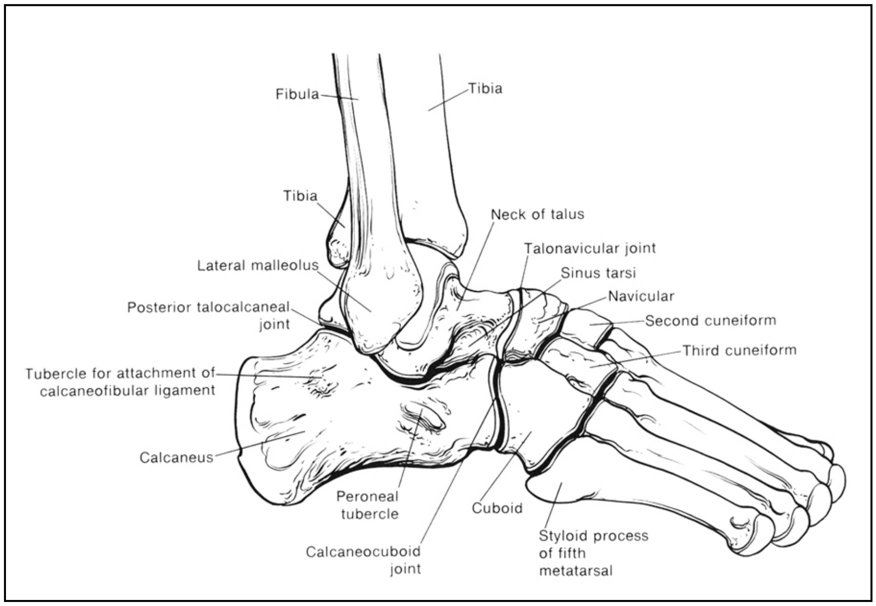

Figure 10

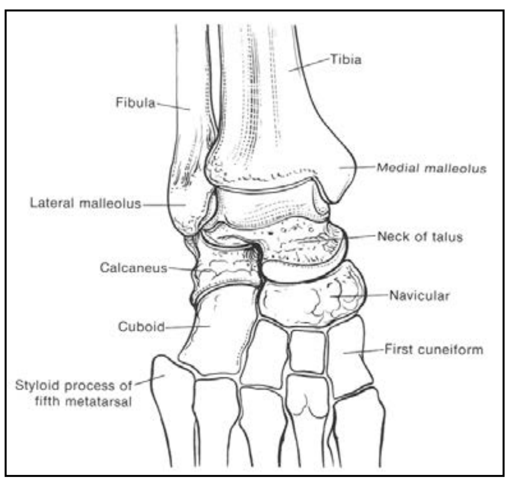

Figure 11

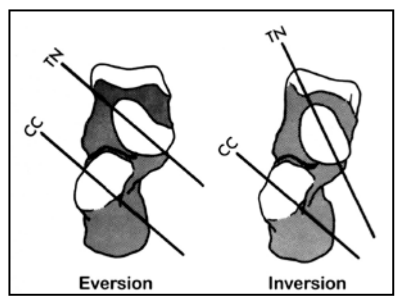

Figure 12

D. Metatarsophalangeal break
   1. When the heel is elevated, the weight bearing forces are evenly distributed across the metatarsal heads (Figure 13)
   2. The oblique orientation of the metatarsophalangeal crease causes the foot to supinate and laterally deviate as the heel rises (Figure 14)
      a) In absence of subtalar motion, this would cause the leg to incline laterally and externally rotate
      b. Compensatory supination of the subtalar joint allows the leg to remain v

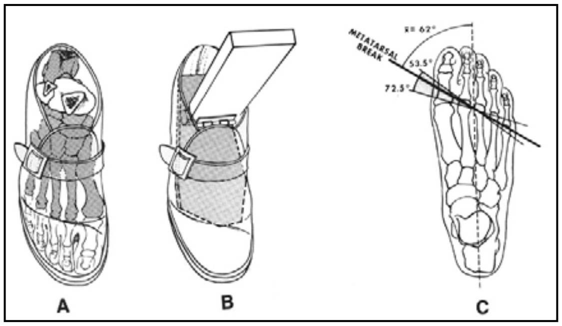

Figure 13

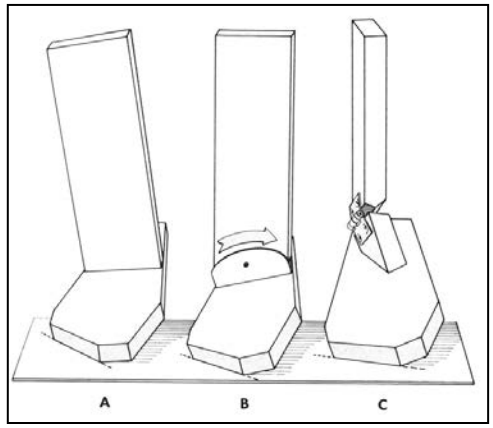

Figure 14

E. Plantar aponeurosis
   1. Arises from the calcaneus, passing distally to insert into the base of the proximal phalanx (Figure 15)
   2. Windlass mechanism (Figure 15D)
      - 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 (Figure 16)
   3. The windlass effect also causes inversion of the calcaneus and resultant external rotation of the tibia

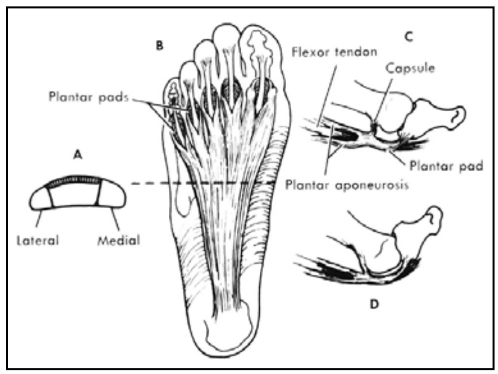

Figure 15

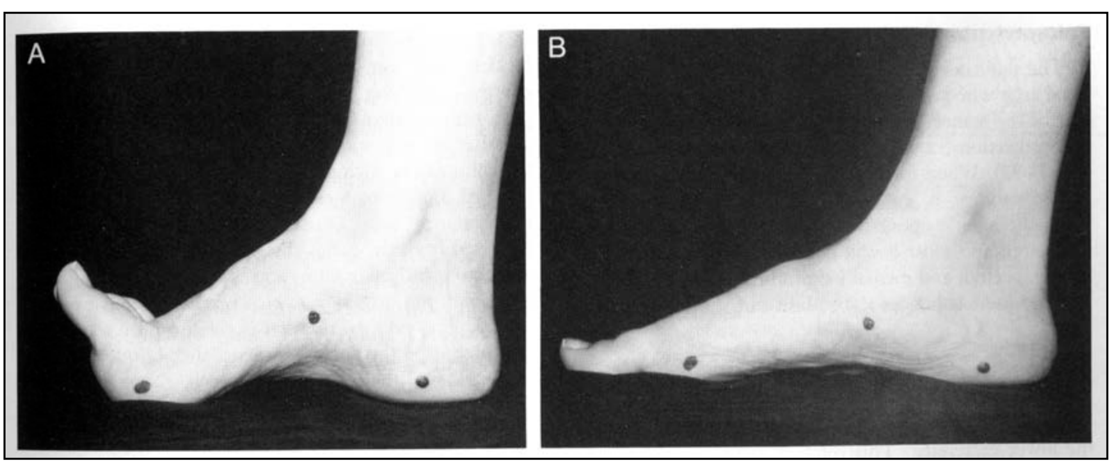

Figure 16

IV. Events of Walking Cycle (actions of the foot and ankle during stance phase)

A. First interval: heel strike to foot flat (body weight decelerated by ground contact, then immediately accelerated upward to carry over the extending lower extremity)
   1. Rapid plantarflexion of the ankle
   2. Foot loaded in pronation as body weight is applied
   3. Pronation (eversion of the subtalar joint) results in inward rotation of the lower leg
   4. Eversion unlocks the transverse tarsal joint
   5. Main thrust is absorption and dissipation of the forces generated by the foot striking the ground

B. Second interval: foot flat to heel lift (center of gravity of the body passes over the weight bearing leg)
   1. Ankle undergoes dorsiflexion
   2. Subtalar joint undergoes progressive inversion
      a) External rotation of the lower extremity (due to swinging of the contralateral limb) transmitted into inversion of the subtalar joint
      b. Oblique axis of the ankle, oblique setting of the metatarsal break, and function of the plantar aponeurosis all contribute to inversion
      c) Inversion increases the stability (rigidity) of the transverse tarsal articulation
      d) Midfoot transformed from a flexible to rigid structure

C. Third interval: heel lift to toe off (body propelled forward)
   1. Ankle undergoes rapid plantarflexion
   2. Longitudinal arch stabilized by windlass effect of the plantar aponeurosis as toes are brought into dorsiflexion
   3. Subtalar joint continues to invert (enhanced by obliquity of the ankle joint) maximizing rigidity of the transverse tarsal joint at toe off

V. Mechanics of Running

A. Difference between walking and running
   - There is now a period of time when both feet are off the ground (float phase)

B. Basic kinematics of the foot and ankle not significantly altered during running

C. Gait cycle shortened

D. Stance phase shortened as a portion of the gait cycle

E. Vertical forces during stance phase increase to 2 ½ to 3 times body weight

F. Range of motion of joints is increased 50%

G. Phasic activity of lower extremity muscles altered