



THE FOOT AND ANKLE

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Foot and Ankle

The foot is a complex structure at the end of the leg that is made of more than 26 bones and 33 joints. It provides balance, assists in mobility, and performs other essential functions for humans.

The foot is the lowest point of the human leg. The foot's shape, along with the body's natural balance-keeping systems, make humans capable of not only walking, but also running, climbing, and countless other activities.

The ankle joint acts like a hinge, but is much more than a simple hinge. The ankle is made up of several important structures. The unique design makes it a very stable joint. It has to be stable to withstand 1.5 times your body weight when standing and 8 times your weight when running.

Figure 1 Three functional areas of foot

The foot's complex structure contains more than 100 tendons, ligaments, and muscles that move nearly three dozen joints while bones provide structure. The structure of the foot is similar to that of the hand, but because the foot bears more weight, it is stronger and less mobile.

The foot functions at right-angles to the leg, so the terminology relating to the foot and ankle movements is also different to the wrist and hand.

Bones of Ankle and Foot

The ankle region (posterior, as seen in fig. 1) consists of three bones:

- The inferior ends of the tibia and fibula
- The superior surface of the talus
- Also included here is the Calcaneum, or heel bone.

Figure 2 The Right Ankle seen from the front

Note this joint looks rather like a mortise and tenon joint with the articular cartilage being about 6mm thick.

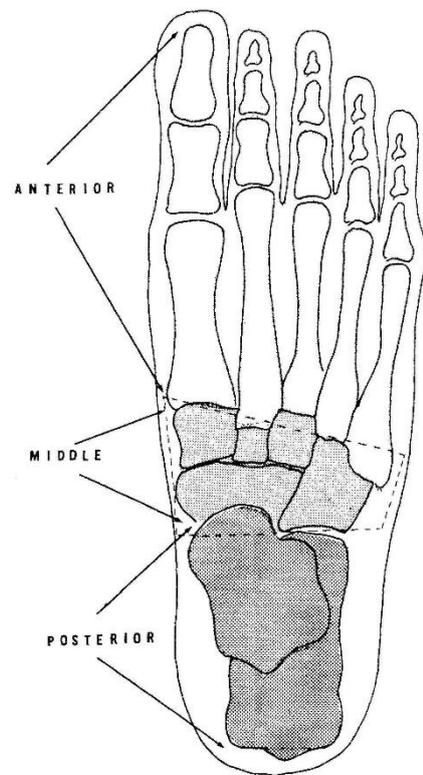




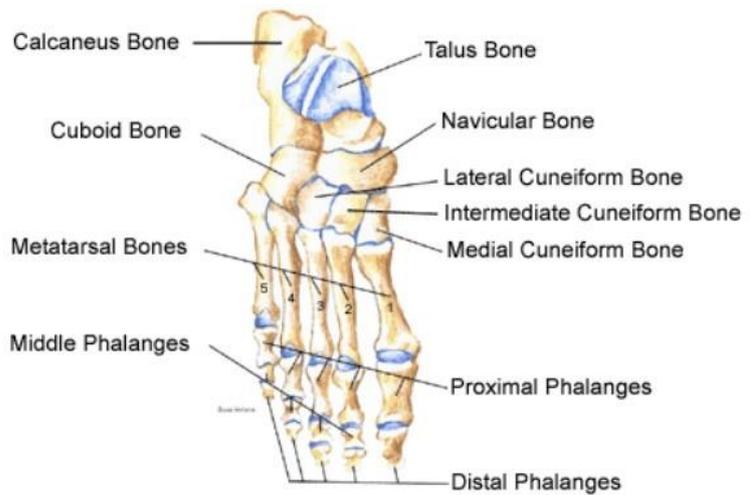
Figure 3 The Right Ankle seen from the Lateral Side

The rest of the foot consists of the middle and anterior regions:

Figure 4 Bones of the Foot

This shows the foot seen from above. It includes the middle section:

- Navicular
- Cuneiform bones
 - Middle
 - Intermediate
 - Lateral
- Cuboid



The anterior region consists of the metatarsals and the phalanges

- The metatarsals are bones 'inside' the foot
- The phalanges are the digits; the toes

Between these bones are 33 joints:

- Tibial/taloid
 - Hinge
- Cubo-calcaneal
 - Saddle
- Talo-calcaneal-navicular
 - Functional ball and socket
- Cubo-cuneiform-metatarsals
 - Gliding
- Navicular cuneiforms
 - Gliding
- Intercuneiforms
 - Gliding
- Metatarsal-phalangeal
 - Hinge
- Interphalangeal
 - Hinge

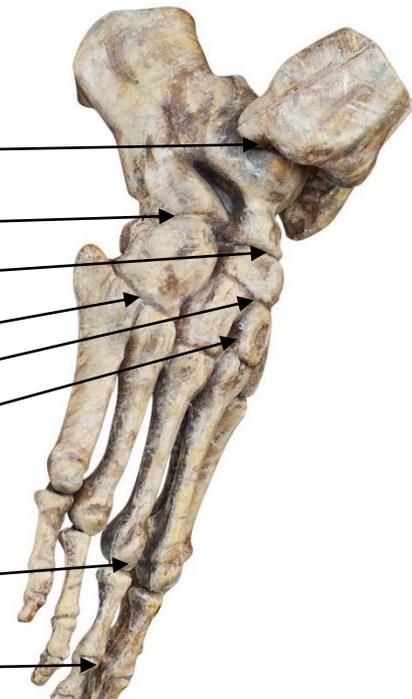


Figure 5 Joints of the Foot seen from lateral aspect

All these joints create a relatively mobile structure but, understandably, the foot requires great stability – the ligaments

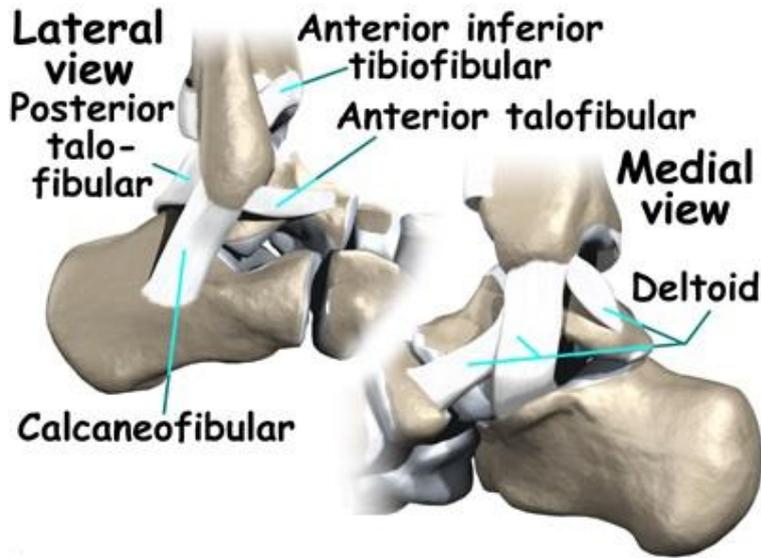


Figure 6 Ligaments of medial and lateral ankle

The main ligaments on the medial and lateral sides of the ankle are there to limit excess motion across those sides of the joint.

Medial ligament	Lateral Ligaments
Deltoid ligament Named after its shape <ul style="list-style-type: none"> ○ Anterior talo-tibial ○ Tibio-navicular ○ Calcaneo-fibular ○ Posterior talo-tibial Stabilises the medial side of the joint	Anterior tibio-fibular (weakest) Calcaneofibular Posterior talofibular (2 ¹ / ₂ times stronger cf. anterior) Talocalcaneal Stabilises Lateral side of joint

In addition to these are the plantar ligaments

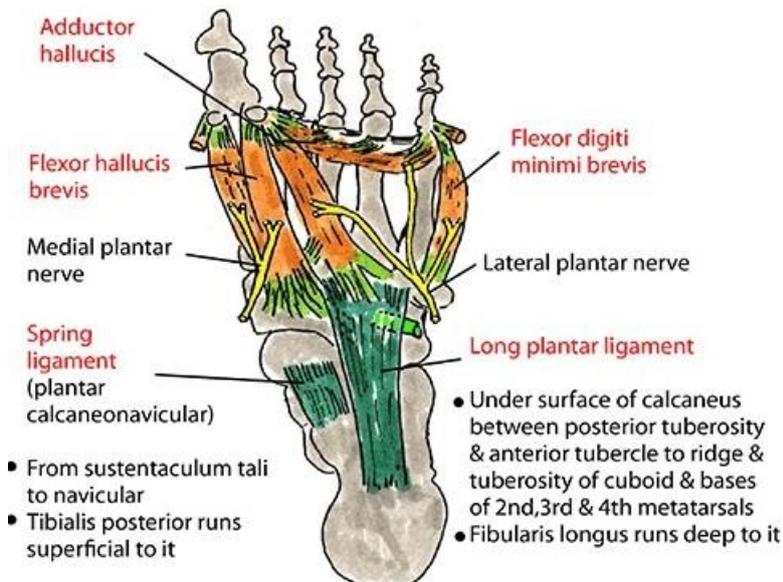
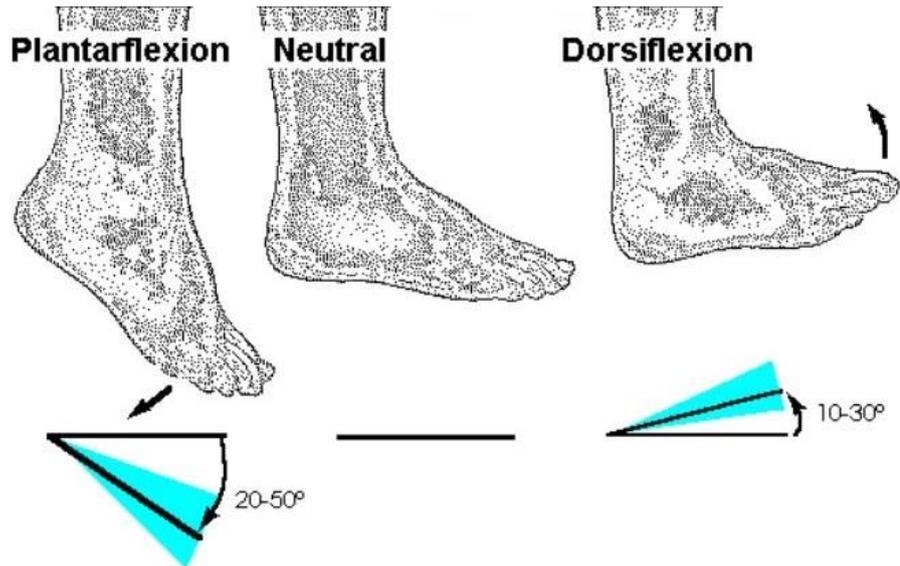


Figure 7 Plantar ligaments

The plantar ligaments are of particular significance as they act to support and maintain the arches of the foot.

Figure 8 Movements of the ankle



The medial and lateral ligaments create a plane of movement. As the foot is at right angles to the leg, there is no flexion/extension, per se. Instead it has

- **Plantar flexion**
 - Pointing the toes distally
- **Dorsiflexion**
 - Pulling the toes proximally

The talocalcaneal joint, or sub-talar joint, is between the inferior surface of the talus and the superior surface of the calcaneum.

There are three articular surfaces with a distinct gap between the middle and posterior surfaces.

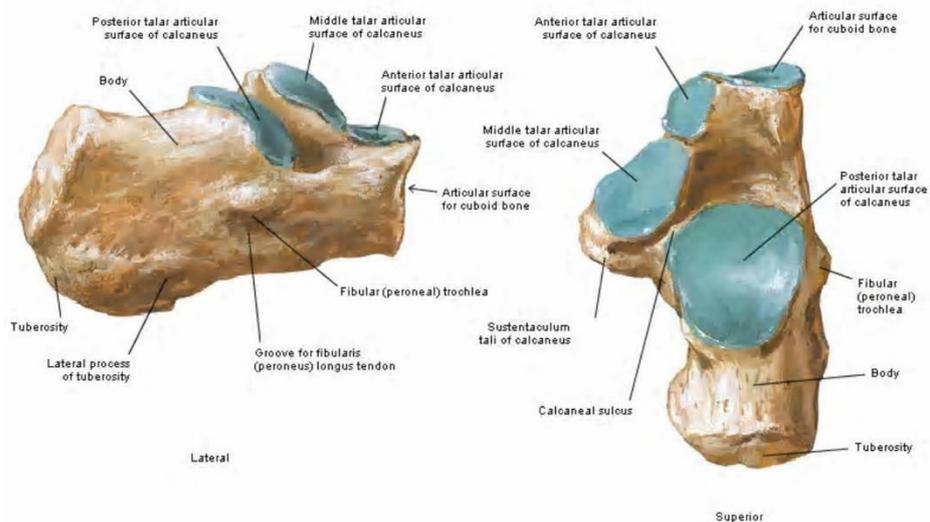
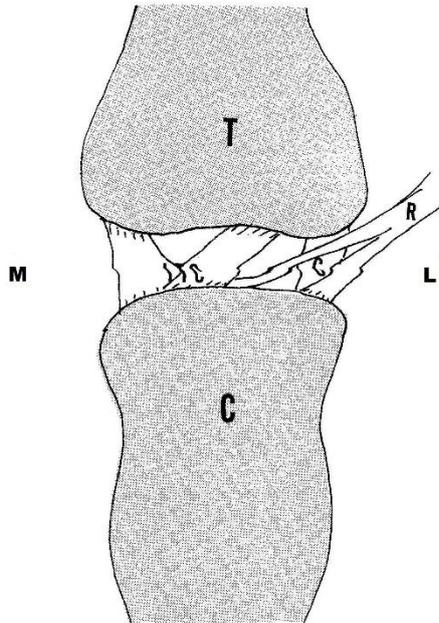


Figure 9 Superior aspect of the Calcaneus, showing articular surfaces

The middle articular surface is on the sustentaculum tali, a small shelf-like projection on the medial side of the calcaneum supporting the medial aspect of the talus.



The talocalcaneal ligaments, here, hold the two bones together, though they are included in the lateral ankle ligaments.

Figure 10 Talocalcaneal ligaments

Broadly speaking, the top of the calcaneus is convex, with a concave lower talus; even wedge shaped. This joint configuration allows:

- Inversion
- Pulling the foot inwards
- Eversion
- Pulling the foot outwards

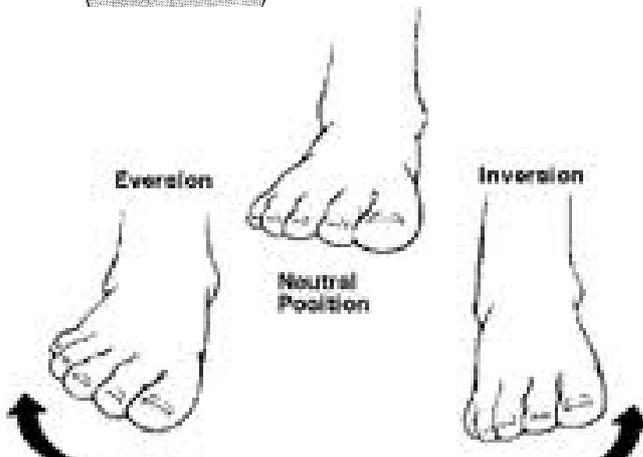


Figure 11 Eversion and Inversion of ankle

Some books and sports shops will have you believe that the ankle undergoes supination and pronation, but this is incorrect; have you ever seen a person in the standing position with their foot sole facing up?

The degree of movement in the ankle joint depends upon the talus/mortise relationship. Here the left picture shows the axis of rotation passing through the fibula below the tip of the tibia. The right picture shows the joint from above and the medial malleolus is anterior to the lateral; the axis of rotation is 16° toe out stance. The stance is broader anteriorly than posteriorly. This arrangement locks up the ankle joint with dorsiflexion.

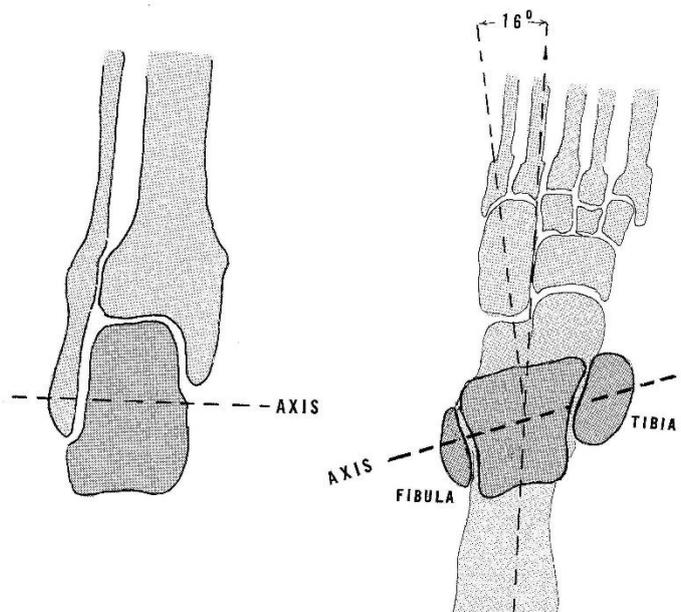


Figure 12 Axes of movement in the ankle

In addition to the locking of the ankle joint with dorsiflexion, there is the effect on the interosseous membrane between the tibia and fibula.

With dorsiflexion the fibula is pushed laterally and proximally, pushing the tibia and fibula apart and tightening the I/O membrane. With neutral and plantar flexion, the I/O membrane reverts to 'normal' with the fibres directed down and laterally.

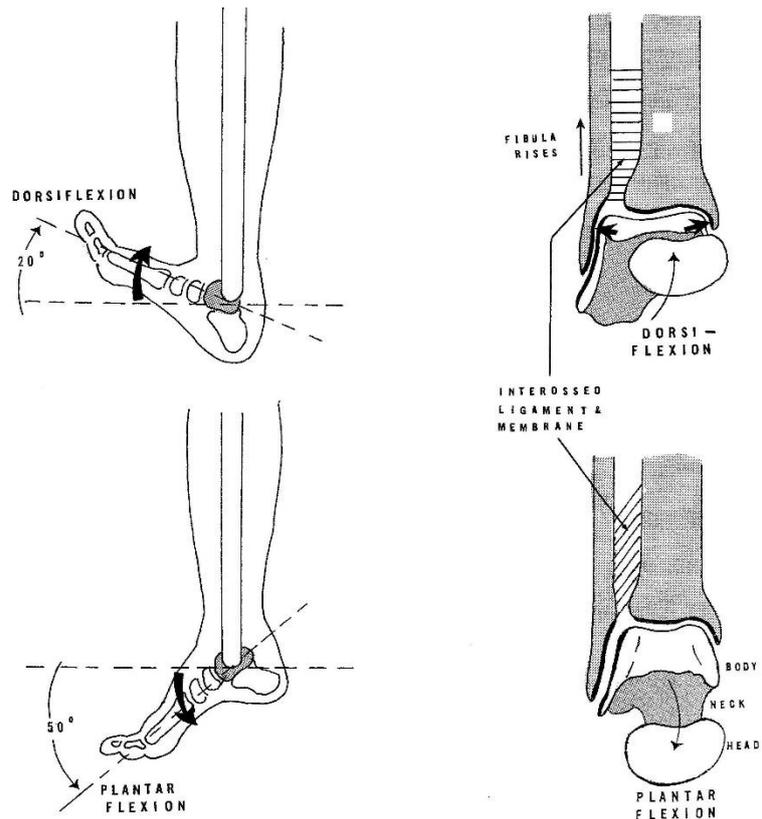


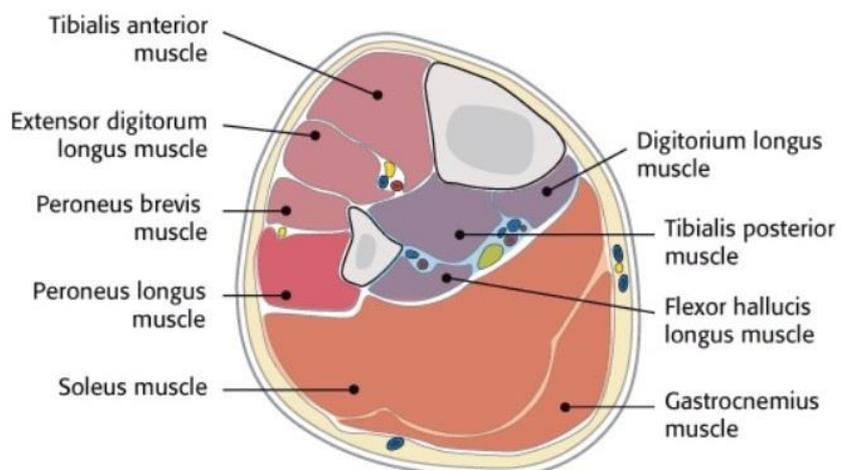
Figure 13 Tibio-fibular interosseous membrane with plantar and dorsiflexion

Muscles moving the ankle and foot

All the large muscles moving the foot, toes and ankle originate in the calf. Here the leg (everything below the knee and above the ankle) is divided in three distinct compartments:

- Anterior
- Posterior
- Lateral

Figure 14 Compartments of leg



Anterior compartment

Muscles of the anterior compartment are:

- **Tibialis anterior**

- Originates upper 2/3 of tibia and I/O membrane
- Passes down and medially, crossing the front of the ankle
- Inserts medial aspect of medial cuneiform and first metatarsal
- Dorsiflexes and inverts foot

Figure 15 Tibialis anterior



- **Extensor digitorum**

- Originates upper fibula and I/O membrane
- Passes down and inserts into distal phalanx of 4 lateral toes
- Extends toes

Figure 16 Extensor digitorum longus

- **Extensor hallucis longus**

- Originates from the medial half of the fibula, between Tibialis anterior and extensor digitorum longus
- Passes down and medially to the distal phalanx of the big toe
- Extends the big toe, Dorsiflexes and inverts foot

Figure 17 Extensor hallucis longus





- **Peroneus tertius**
 - Originates lower end of fibula and I/O membrane
 - Passes down and inserts on dorsum of proximal shaft of 5th metatarsal
 - Everts foot
 - Even though it is an anterior compartment muscle, it is named in terms of its function (see peroneal muscles; lateral compartment)

Figure 18 Peroneus tertius

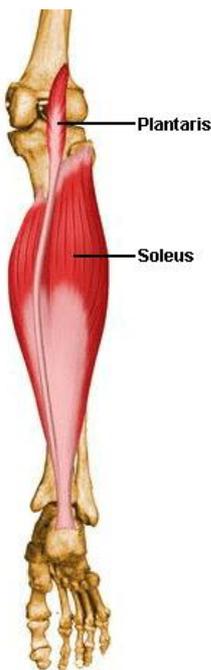
Posterior compartment

- **Gastrocnemius**

- Originates from lower end of Femur, just over medial and lateral condyles
- The two heads converge, pass down and insert onto calcaneus via Achilles tendon
- Plantar flexes the foot



Figure 19 Gastrocnemius



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- **Soleus**

- The upper end of the posterior aspects of the fibula and the tibia (from the soleal line) and the I/O membrane, deep to gastrocnemius
- It passes down and inserts onto the calcaneus via the Achilles tendon
- It plantar flexes the foot

Figure 20 Soleus

- **Tibialis Posterior**

- It originates from the upper tibia and fibula and I/O membrane
- It passes down, with the tendon passing around the medial aspect of the ankle joint
- It inserts onto the medial side of the navicular and medial cuneiform bones
- It inverts and plantar flexes the foot

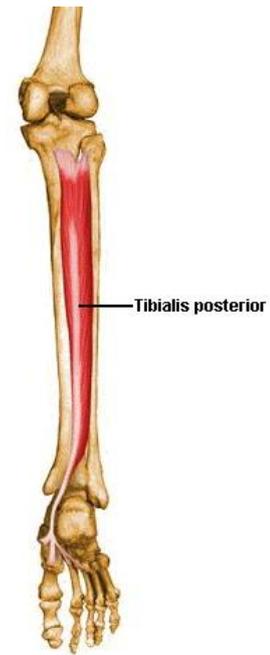


Figure 21 Tibialis Posterior

- **Flexor Digitorum Longus**

- It originates from the posterior aspect of the tibia
- It passes down, past the medial side of the ankle
- It inserts into the distal phalanges to the digits 2-4
- It acts to flex the 4 lateral toes and plantar flex the foot

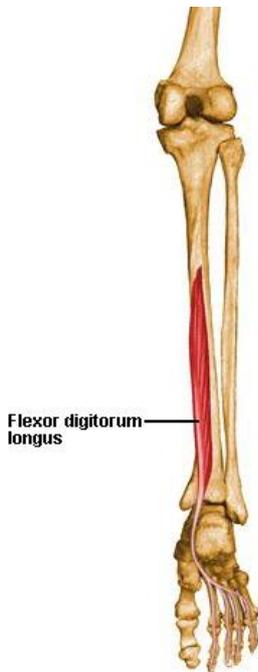


Figure 22 Flexor Digitorum Longus

- **Flexor Hallucis Longus**

- It arises from the lower end of the fibula
- It passes down, passed the medial side of the ankle
- It inserts on the distal phalanx of the big toe
- It flexes the big toe and the foot

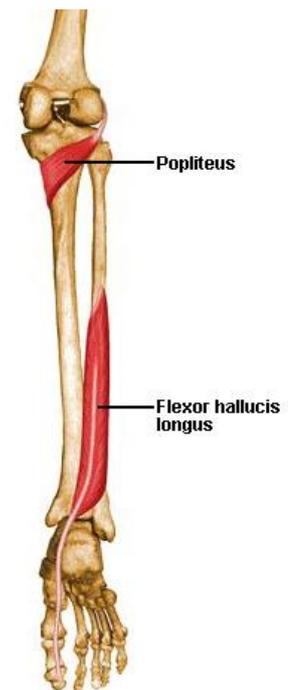


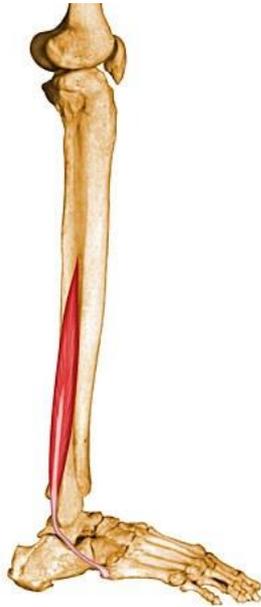
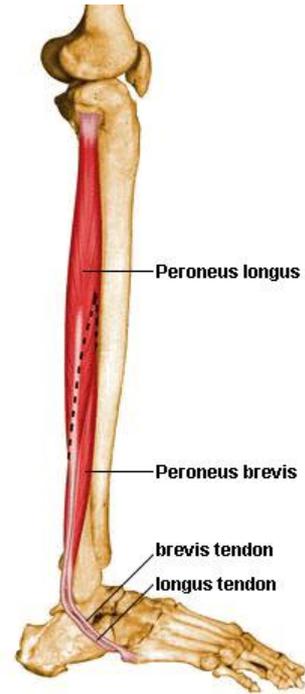
Figure 23 Flexor Hallucis Longus

Lateral Compartment

• Peroneus Longus

- It originates from the head of the lateral aspect of the top of the fibula
- It passes down behind the lateral malleolus and through its own groove on the plantar aspect of the foot
- It inserts onto the first metatarsal and medial cuneiform bones
- It everts and plantar flexes the foot

Figure 24 Peroneus longus



• Peroneus Brevis

- It originates from the lower lateral aspect of the fibula
- It passes down posterior to the lateral malleolus
- It inserts onto the proximal end of the 5th metatarsal
- It everts and plantar flexes the foot

Figure 25 Peroneus Brevis

Ankle Injuries

Ligamentous injuries of the ankle usually occurs at the moment of impact with the ground, when the foot is plantar flexed and inverted. The ligaments absorb the bulk of the stress because the peroneal muscles are unable to contract sufficiently rapidly to absorb the impact.

Sprains

Injury may vary from a simple strain, i.e. a mere elongation of the ligaments with microtraumata, to major disruption of the ligamentous cords with or without bony avulsion. The greatest traumatic injury is a total dislocation. Complete ligamentous tear occurs with 75% of common sprains associated with capsular tears. It has been said that it is worse to sprain the ankle than to break it.

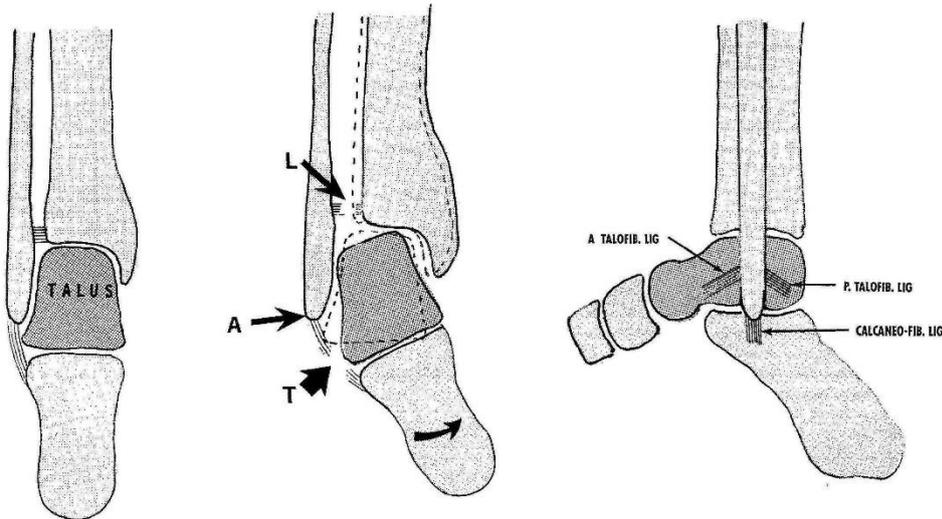


Figure 26 Ankle sprain - lateral collateral ligament

Fig 25 shows a lateral collateral tear. The left drawing shows an anterior view of a normal ankle and the right is a view of a normal from the lateral aspect. The middle drawing shows a severe inversion injury of the talus and calcaneum (curved arrow), which causes a talar tilt. This can cause a tearing of the lateral collateral ligament (T), a possible avulsion (A) of the lateral [fibular] malleolus, and a possible tear of the interosseous membrane (L).

Ankle sprains have been classified:

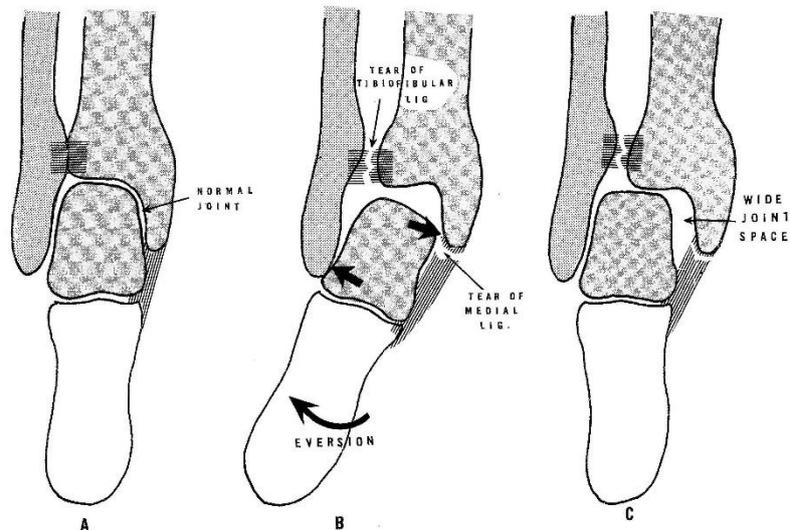
- Grade 1: Partial interstitial tearing of ligaments
- Grade 2: More severe, but incomplete tearing. Gross stability maintained
- Grade 3: Gross instability of the ankle

Another classification has been suggested:

1. Only lateral ligaments are involved (Fig 25)
2. Both medial and lateral ligaments are involved (fig 26)
3. Both medial, lateral and distal talo-fibular ligaments are involved

Figure 27 Medial collateral ligament tear

Looking at Fig 26 and a medial collateral (deltoid) tear, (A) shows a normal ankle and its ligaments. (B) Shows a severe eversion injury (curved arrow) causing a talar tilt and tearing of the interosseous membrane and medial ligaments. (C) Shows the result of the injury as a widening of the ankle mortise from the tearing of these ligaments.



Patients often describe the injury as a feeling of the ankle 'giving way' with the precise mechanics of the injury remaining unclear as it happened so quickly. Pain is usually present with swelling and ecchymosis. Pain is increased with eversion.

Treatment

Grade 1 and 2 usually do well with conservative (non-surgical) treatment.

RICE, ultrasound with gentle plantar and dorsiflexion exercises; these with gradual increased resistance.

Grade 3 treatments are more controversial. Young, high performance, athletes, workers who do heavy manual labour and patients who have avulsion fractures are considered for surgery. This could be 5-6 weeks of short leg casting with the foot in slight eversion, followed by rehabilitation exercises of the peroneal muscles. Achilles stretching and proprioceptive training.

Rehabilitation has 3 phases:

1. Limitation of injury
2. Restoration of motion (along with proprioception)
3. Regaining agility and endurance

Eversion strains also occur, though are less common. They can be associated with ligamentous instability at the lower tib/fib joint and also with Pott's fractures (inferior end of the fibula, primarily, with the tibia secondarily).

Pott's Fracture

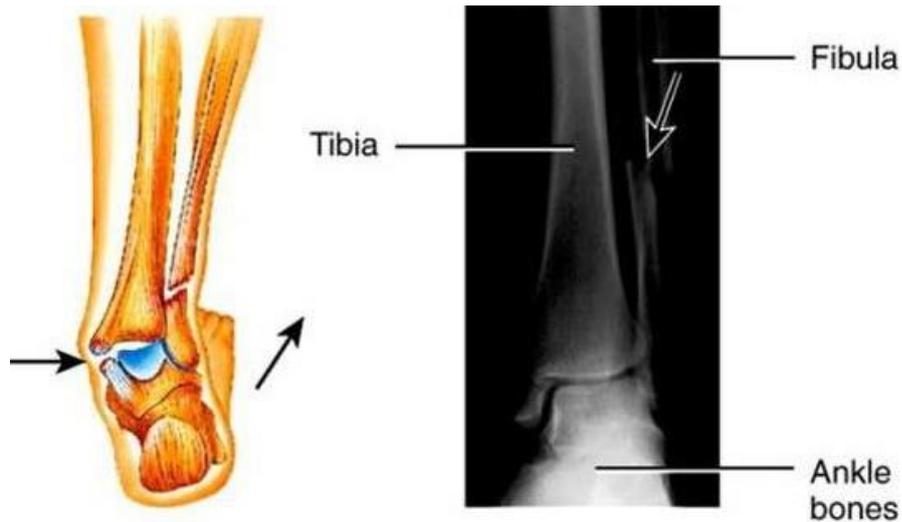
A Pott's fracture is a fracture affecting one or both of the malleoli. During activities such as landing from a jump (volleyball, basketball) or when rolling an ankle, a certain amount of stress is placed on the tibia and fibula and the ankle joint. When this stress is traumatic, and beyond what the bone can withstand, a break in the medial, lateral or posterior malleolus may occur. Also activities involving a sudden change of direction, such as football and rugby, can cause fractures around the malleoli. When this happens this condition is known as a Pott's fracture.

It is a fracture of the lower end of the fibula and medial malleolus of the tibia with rupture of the internal lateral ligament of the ankle, and is caused by outward and backward displacement of the leg while the foot is fixed.



A Pott's fracture often occurs in combination with other injuries such as an inversion injury, a dislocation of the ankle or other fractures of the foot, ankle or lower leg. Pott's fractures can vary in location, severity and type including displaced fractures, un-displaced fractures, bimalleolar (both malleoli) fractures or compound fractures. It can be difficult to distinguish clinically between a fracture and a moderate to severe ligament sprain. Both conditions may result from inversion injuries, with severe pain and varying degrees of swelling and disability.

Figure 28 Pott's fracture



Symptoms

Patients with a Pott's fracture typically experience a sudden sharp and intense pain around the ankle or lower leg immediately at the time of injury. The pain is situated at the front, back, inner or outer part of the ankle or lower leg. The patient may have heard a "crack" as well. Due to the pain the patient limps to protect the injury. In severe cases weight bearing may be impossible. Patients with a Pott's fracture usually experience swelling, bruising and pain on firmly touching the affected region of bone. Pain may also increase during certain movements of the foot or ankle or when attempting to stand or walk. When it is a displaced fracture, an obvious deformity may be noticeable.

Medical and physiotherapy management

One of the most important components of rehabilitation following a Pott's fracture is that the patient rests sufficiently from any activity that increases their pain. Activities which place large amounts of stress through the ankle should also be avoided, particularly excessive weight bearing activity such as running, jumping, standing or walking.

Displaced Pott's fractures where the anatomical relationship of the bones of the ankle has been disrupted need to be surgically fixed. This may be followed by the use of a protective boot, brace, or a plaster cast, and/or crutches for a number of weeks. Fractures that are not displaced, treatment may involve a plaster cast immobilization and the use of crutches, followed by the use of a protective boot or brace for a number of weeks. Patients with a Pott's fracture should perform pain-free flexibility, strengthening and balance exercises as part of their rehabilitation to ensure an optimal outcome. The physiotherapist may utilize techniques such as massage and joint mobilization which is essential to ensure optimal range of movement and flexibility. The aim of massage is to fight the formation of heterotopic ossification. This is the process by which bone tissue forms outside of the skeleton. The treatment may also involve electrotherapy, taping and bracing, exercises to improve strength, flexibility and balance, and hydrotherapy.

Lengthening of the tendon Achilles is proved to be a treatment for complicated Pott's fractures. Lengthening or stretching of this tendon can be done by performing a passive dorsiflexion of the foot while the leg/knee is straight. In the most severe cases of a Pott's fracture, patients usually make a full recovery with appropriate management. Return to activity or sport can usually take place in a number of weeks to months.

Stress Fractures (see March fracture later)

Over activity in sports of some uncoordinated people can cause overuse syndromes and also can cause stress fractures. These can appear in the fibula, tibia calcaneum and metatarsals.

Symptoms of this can appear as deep pain and tenderness over the affected area, which recur with resumption of the activity. Diagnosis is by (Tn⁹⁹) bone scan, which shows any increased vascular activity at the site of the fracture, or an X-ray at a later date, revealing signs of healing.

Figure 29 Stress fracture of 3rd metatarsal

Treatment is rest and ice with a soft orthotic where appropriate. The healing process can be facilitated with vitamin C, glucosamine and/or Comfrey cream (bone knit)



Talo-calcaneal (sub-talar) joint

The talo-calcaneal joint is a potentially complicated joint between the talus and the calcaneum. It consists of three synovial joints (Fig 8):

- A large posterior one – concave on the talus
- Two smaller ones – convex on the talus
 - These all have reciprocally shaped facets on the calcaneum

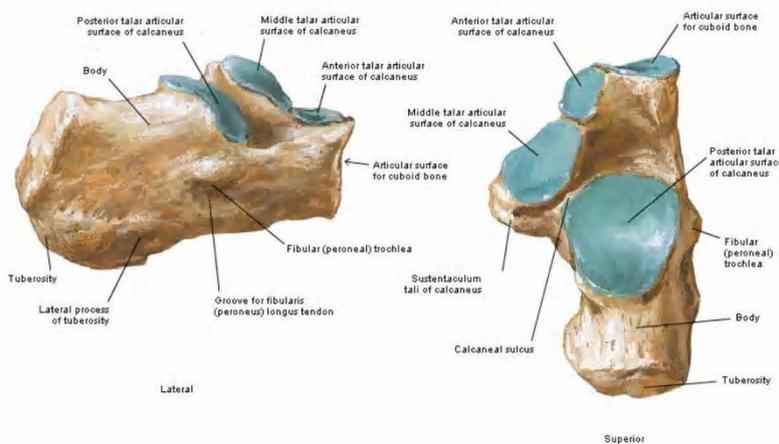


Figure 30 Subtalar joint

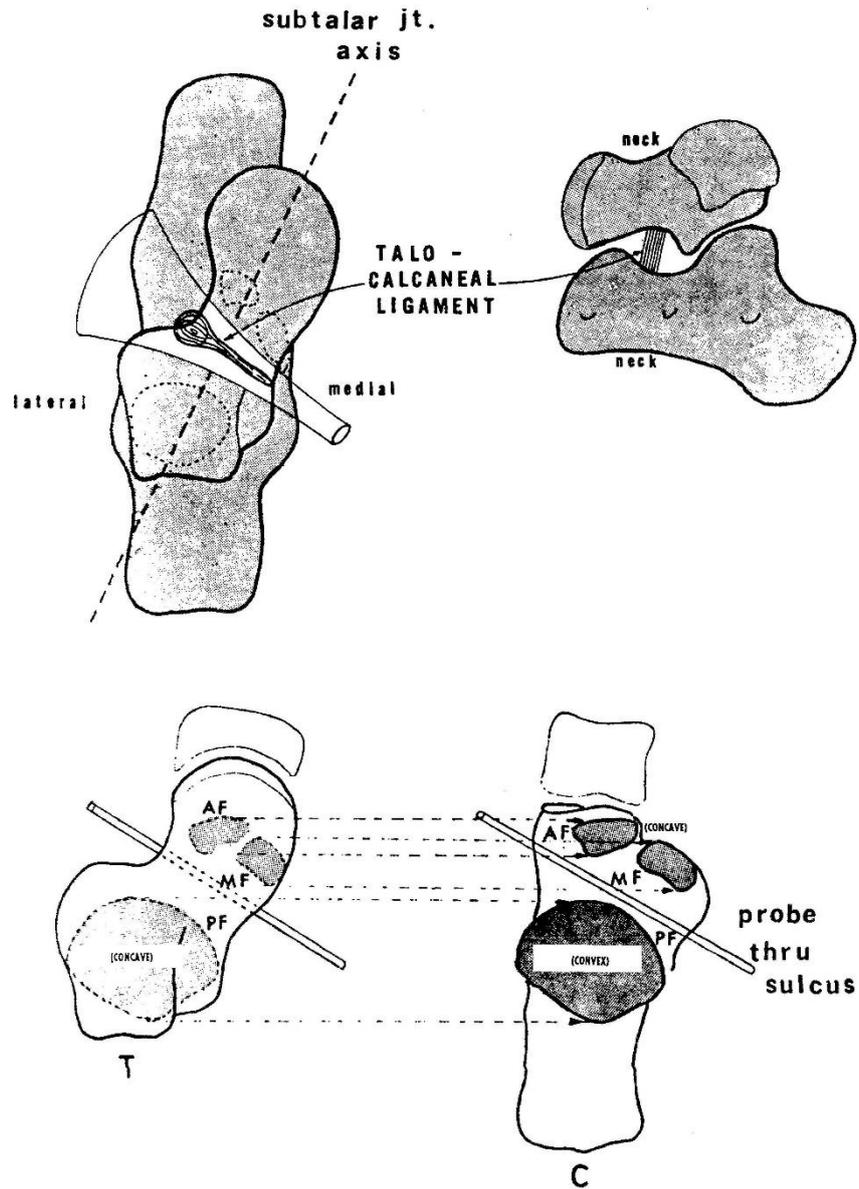


Figure 31 Talo-Calcaneal (subtalar) joint

The talus and calcaneum are joined by three facets:

- AF – anterior facet
- MF – middle facet
- PF – posterior facet

The tarsal tunnel in its oblique course (sulcus) contains the talo-calcaneal ligament.

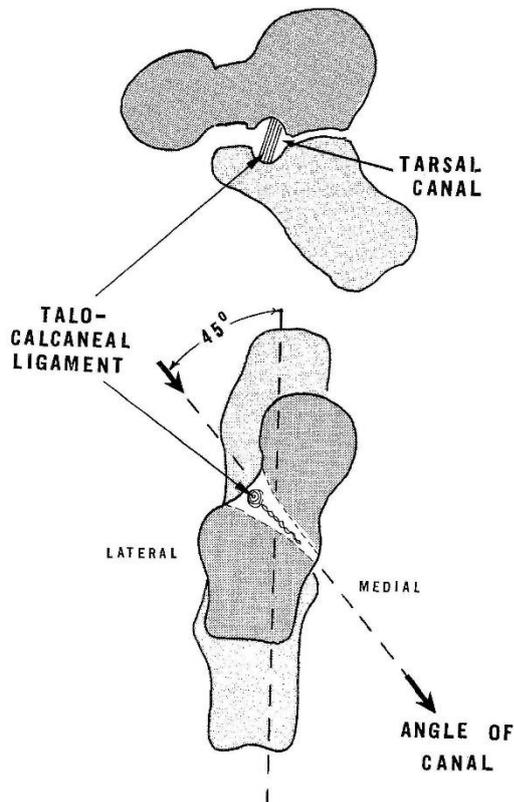


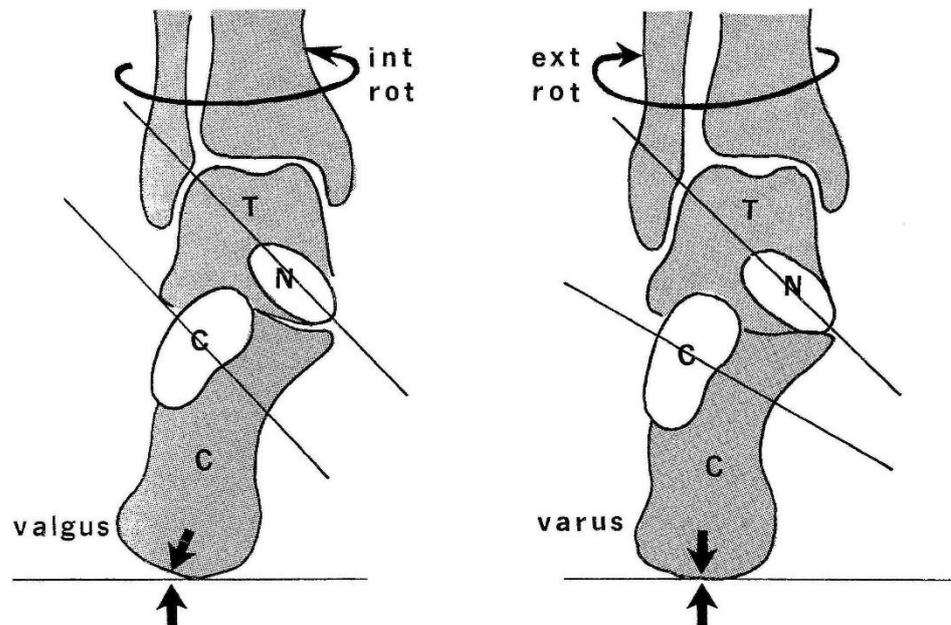
Figure 32 The sub-talar joint and tarsal tunnel

The talus and calcaneum form a tunnel, which forms a 45° angle with the A/P axis of the foot. The lateral opening is under the lateral malleolus and is readily palpable. A firm ligament joins the two bones. To lock up the

To articulate the talo-calcaneal joint, the foot must be fully dorsiflexed to lock up the tib-talar joint.

Figure 33 the left foot seen from the front

Inversion/eversion of the foot during rotation of the leg. C – cuboid, N – navicular facets.



In the weight bearing stance, internal rotation causes valgus of the foot (left). during weight bearing in the stance phase, external rotation causes the foot to rotate at the sub-talar joint and thus inverts the foot for the ultimate swing through phase.

Sub-Talar Ligamentous Injury

In plantar flexion the anterior talofibular ligament is vulnerable to an inversion injury at the ankle

Figure 34 Schematic of inversion sprain

If this is severe, it is followed by tearing of the talo-navicular ligaments and the talo-navicular capsule.

The sustentaculum tali (Fig 8) becomes the fulcrum about which the foot moves and the talus can dislocate laterally, the calcaneum moving medially, thus tearing the talo-calcaneal ligament. Rotation of the leg on the foot can also cause these injuries.



The Painful Foot

To be normal, the foot has to conform to certain criteria:

1. It is pain free in its function of weight bearing and ambulation
2. Normal muscle function
3. The heel should be central and reasonable sagittal
4. The toes should be straight and mobile
5. During gait and stance there must be three points of weight bearing (see arches)
6. There must be normal nerve supply to the foot

Pain is normally indicated by the patient, from there the practitioner must evaluate the motion to assess any dysfunction.

Acute problems

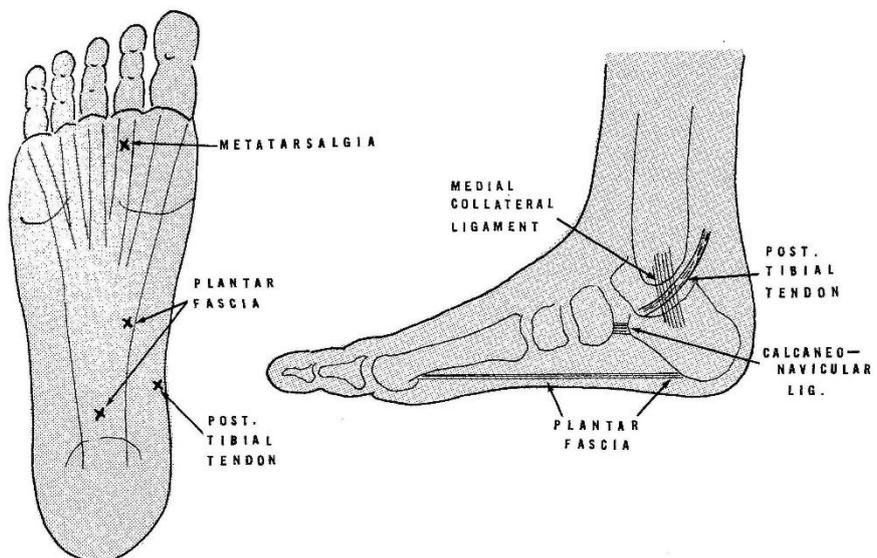
Dysfunction normally results from a specific activity, excessive activity or persistence of activity to which the patient is unaccustomed. Pain and tenderness can be muscular, ligamentous, periosteal or all of these.

Chronic problems

These can lead from acute problems if they are not treated, or from anatomical deviation from the normal. Here the foot must be examined for structural deviations in bone, muscular and ligamentous structures

Figure 35 Tender areas in painful foot strain

One effective treatment for painful feet and ankles



is via gentle traction to the foot. This can be through the foot and calcaneum, or even via the talus itself, along the axis of the leg. The important thing here is to 'make contact' with the tissues of the whole leg, not just the foot. It can be used as part of a 'balanced ligamentous technique'. This addresses the fascia around the whole foot and leg, allowing the tissues to unwind. It is slow, but effective.

All good sports shops have means of assessing gait of joggers to advise and recommend, possibly more expensive, footwear.

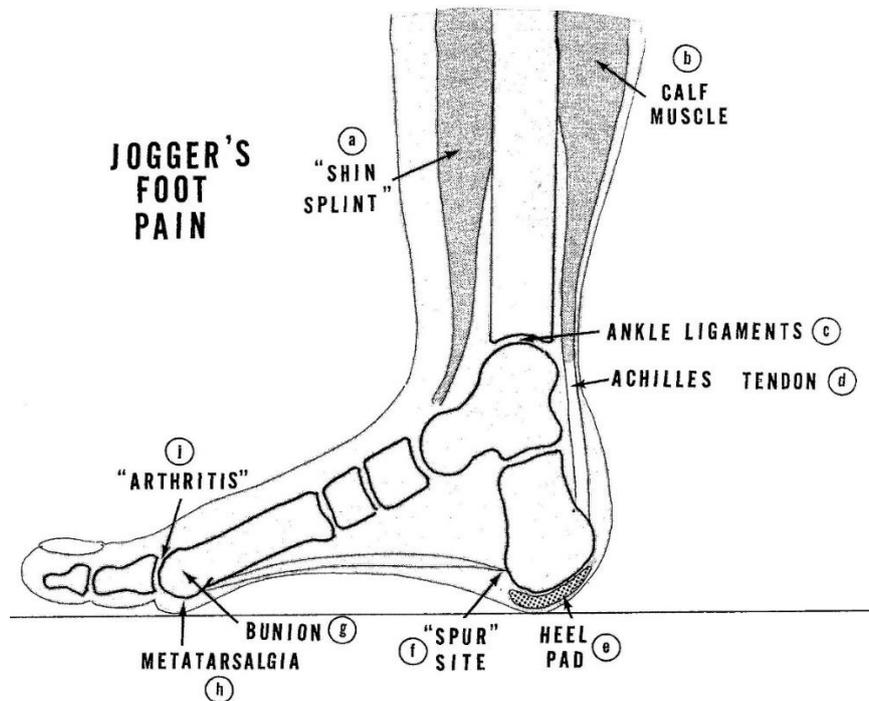


Figure 36 Jogger's foot pain

The foot, ankle and lower leg pains sustained by joggers are:

- a) Shin splints (myositis of Tibialis anterior)
- b) Calf pain
- c) Talo-tibial ligamentous sprain
- d) Achilles tendon strain
- e) Inflamed heel pad
- f) Plantar fasciitis, leading to 'spur' type pain
- g) Bunion pain if a hallux valgus exists
- h) Arthralgia of the big toe M/P joint

The everted foot is a frequent cause of foot strain (fig 32) because of its deviations from normal, though debate is ongoing on how the foot 'got there' in the first place. Here the foot is being supported by muscular activity, which becomes fatigued. In eversion, the talus slides medially, the forefoot abducts and broadens, depressing the metatarsal arch. Then the three metatarsal heads become weight bearing (Fig 33).

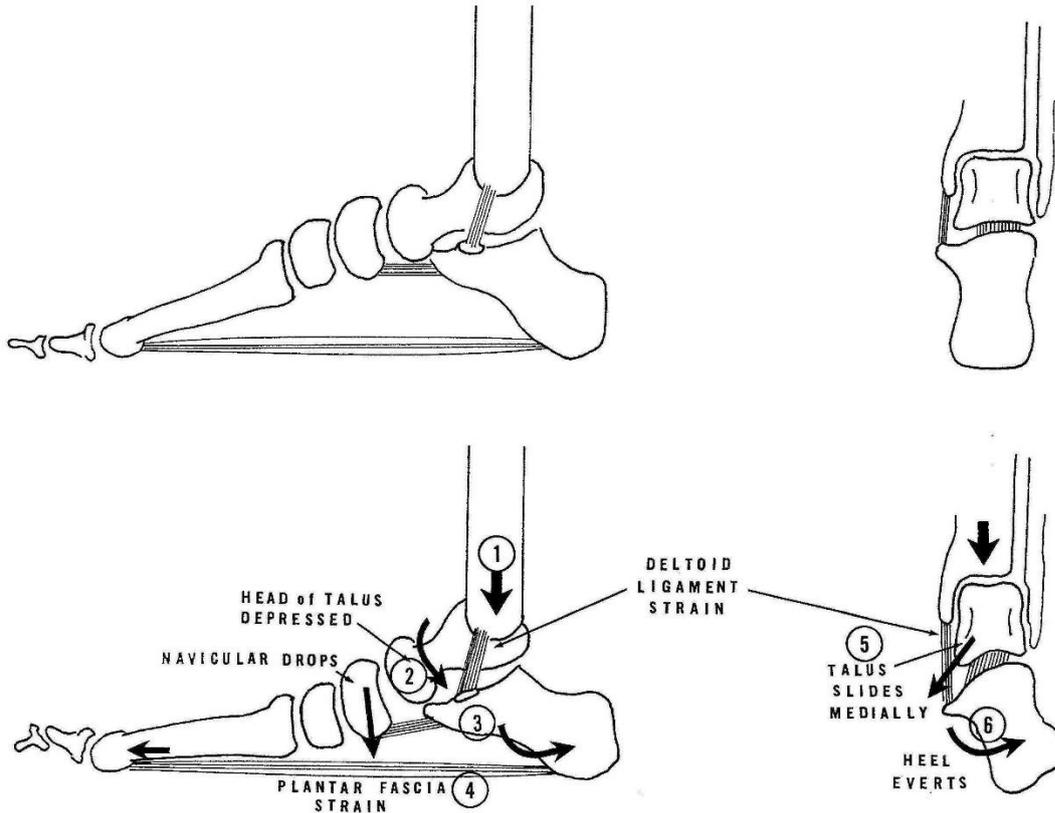


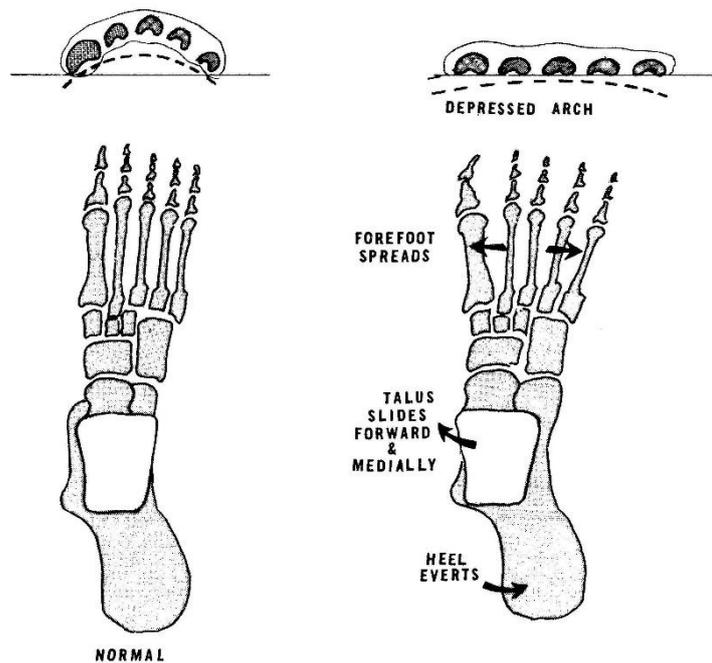
Figure 37 Mechanisms of foot strain

The upper drawing depicts the normal foot with a central heel and a good longitudinal arch. In the lower drawing, weight bearing (1) on misaligned structures causes the talus (2) to slide forward and medially (5) and causes the calcaneum (3) to rotate posteriorly. The plantar fascia (4) elongates, which places strain on its calcaneal site of insertion. This eversion causes a strain on the deltoid ligament.

The muscle most involved here is Tibialis anterior, which is an invertor and can elongate under stress, it then becomes tender and is rendered ineffective in weight bearing.

Figure 38 Pronation - eversion

In Fig 33 the left drawing depicts a normal foot with a good metatarsal arch. The right depicts a pronated foot, with the talus sliding forward and medially. This spreads the forefoot, which causes a depressed metatarsal arch. However the mechanics of how the foot begins to experience this state is unclear; is it in the foot, or an expression of mechanics from higher up the leg and expressing themselves in the foot?



Either way, in the long term the body still tried to cope. Here the evertors take up the slack. Then

the toe extensors change their alignment and become ankle-foot evertors. The talo-calcaneal ligament, taught in inversion, becomes inflamed and painful do to stress. The longitudinal arch becomes flatter and stresses the plantar fascia, causing heel and spur type pain.

The heel is s frequent source of pain. These can occur at the site where the plantar fascia attaches to the calcaneum where there is a repetitive stress during weight bearing.

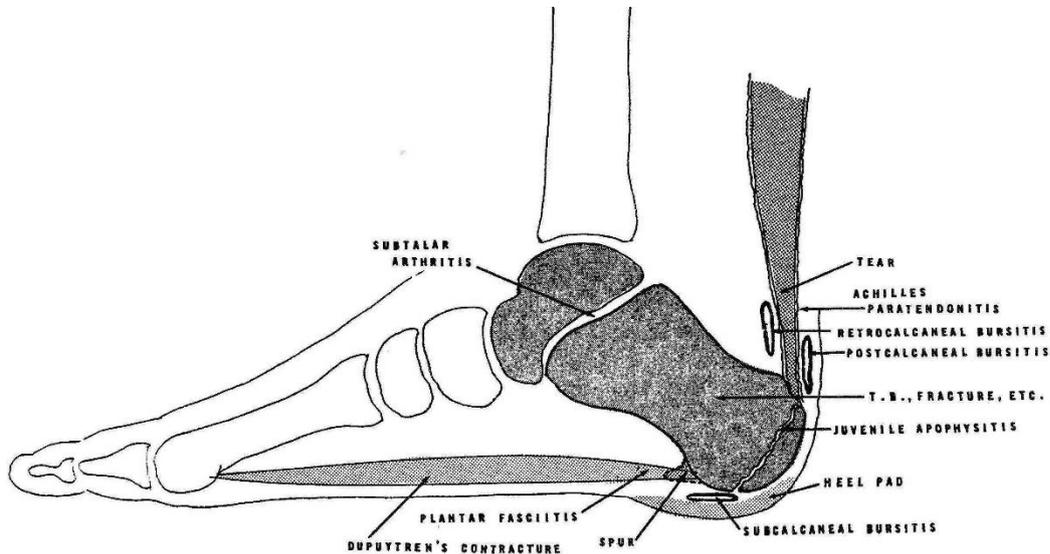
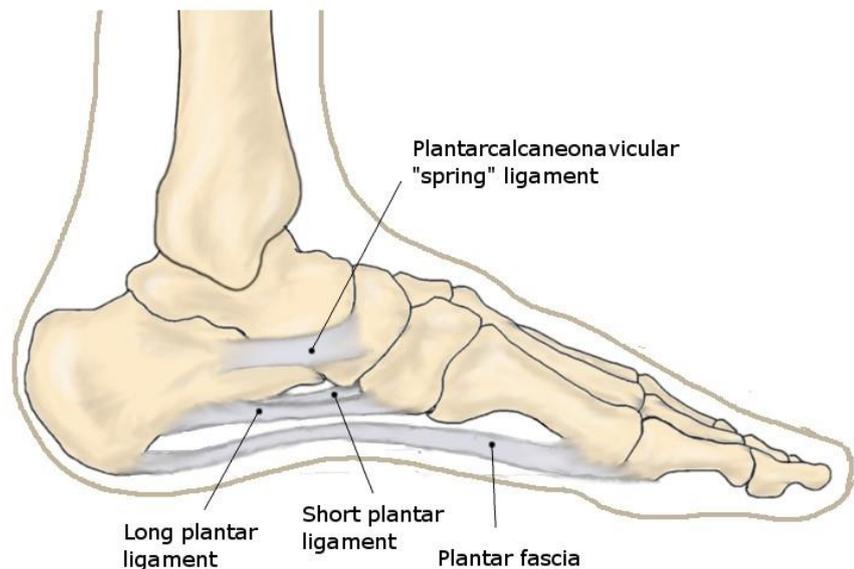


Figure 39 Sites of heel pain

The plantar fascia is a multi-layered fibrous aponeurosis originating from the medial calcaneal tuberosity and inserting into the complex of tissues of the metatarsophalangeal joints, the flexor sheaths and the bases of the proximal phalanges. It is one of five factors that help support the plantar arches (see later)

Figure 40 Plantar ligaments



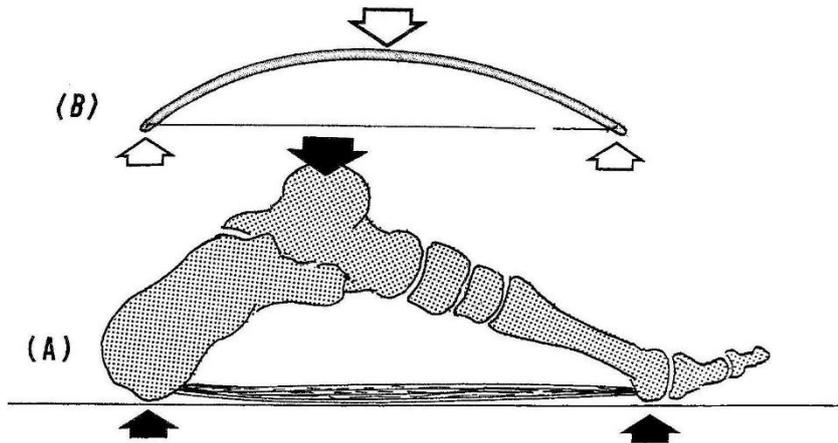


Figure 41 Mechanics of plantar fascia on the longitudinal arch

- (A) The large arrow depicts the body weight on the foot. The smaller arrows depict weight bearing on the heel (left) and the toes (right).
- (B) The arch is maintained by the articular structures with the plantar fascia merely reinforcing the strength of the arch.

When the toes are dorsiflexed (Fig 38), the complex of tissues at the base of the toes causes increased tension along the plantar fascia.

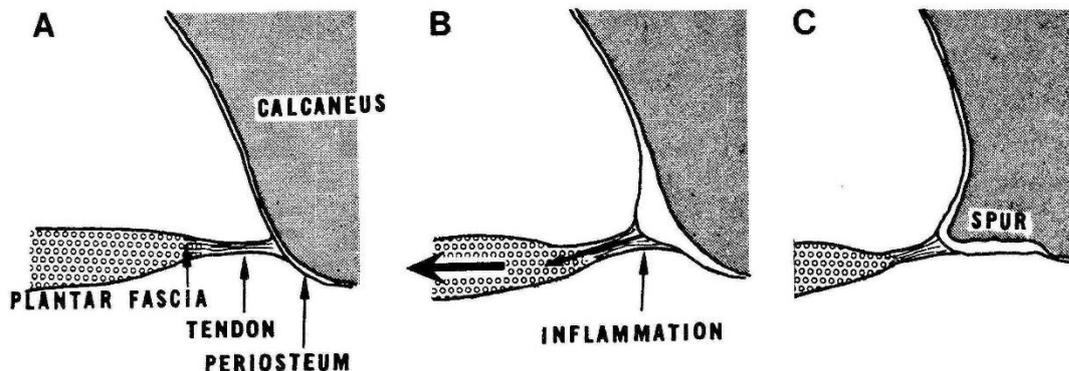


Figure 42 Mechanism of plantar fasciitis

- A. Is the normal relationship of the plantar fascia with its tendon attached to the calcaneum periosteum
- B. Depicts traction (arrow) pulling the periosteum from the calcaneum
- C. Depicts the bony changes that occur with chronic tension patterns in the plantar fascia. Bony changes are always indicative of long term soft tension patterns; here forming a calcaneal spur

Tension patterns in the plantar fascia pull on the periosteum of the calcaneum. Over time microtears can occur in the fascia and some wearing away of the attachments occurs.

Fatigue fractures and periostitis occurs, which can be seen radiologically. It manifests as local pain at its attachment to the calcaneum, possibly spreading from there distally towards the toes.

Figure 43 Calcaneal spur on X-ray

The pain is experienced mainly with weight bearing, but in severe cases can be more constant. If the dysfunction is persistent, the body tries to help the healing process at the point of the RSI by causing calcification of the proximal end of the plantar fascia. Thus appears a calcaneal spur.



As was said, calcaneal spur is always evidence of long term soft tissue tension, but by the time it is a calcaneal spur, it is a structural entity that needs structural remedies.

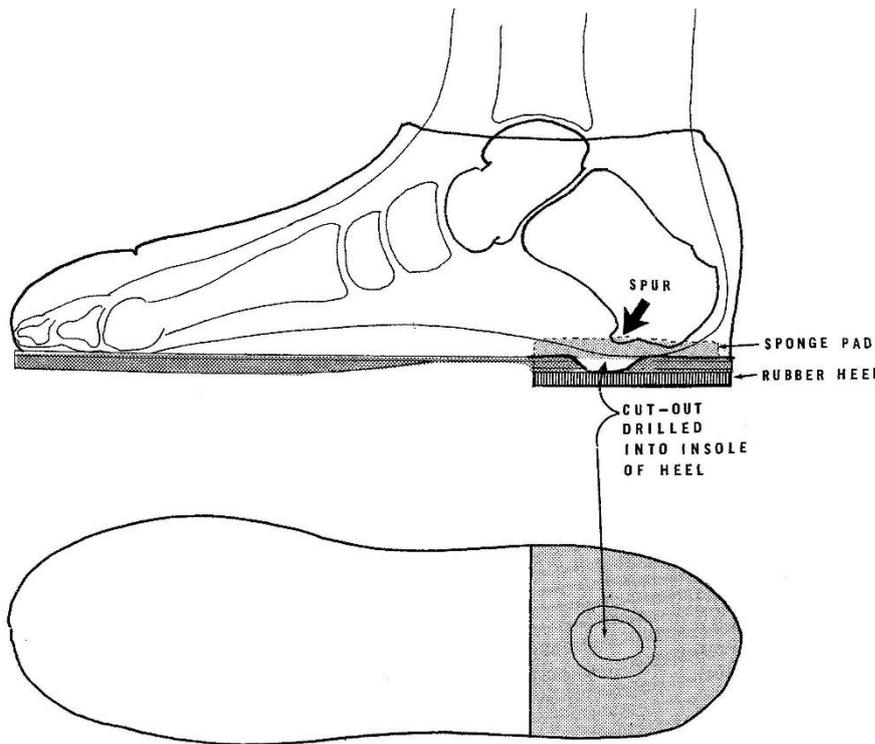


Figure 44 Shoe modification with calcaneal spur

Here a sponge pad can be inserted into the heel, which reduces the pressure on the calcaneum. In addition to this, a section can be cut out from the insole of the heel of the shoe.

Treatment for calcaneal spur is usually conservative, with ice, local massage friction and ultrasound as well as prescribed exercises to help the relaxation of the tissues down the back of the legs. The reason for the posterior muscle groups is the principle of continuity of tissues down the back of the legs. The back muscles are continuous with the hamstrings, on to the calf muscles down to the Achilles tendon to the calcaneum. Here the books will have you believe they stop, but other opinions claim the fascia continues 'around the corner' of the calcaneum and continues as the plantar fascia.

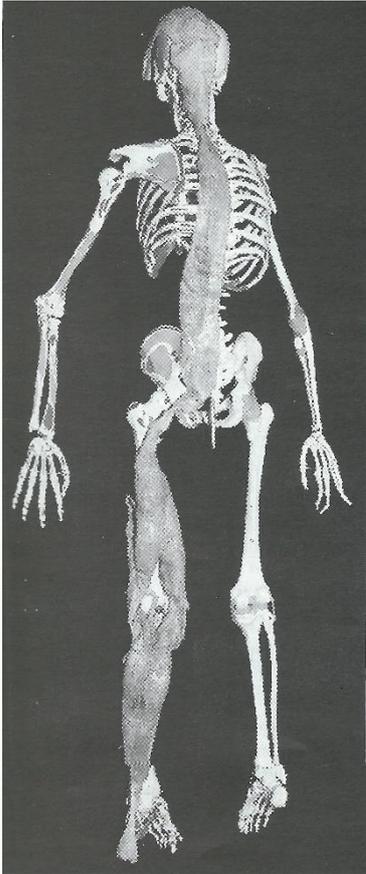


Figure 45 Continuum of fascia of back



Figure 46 Achilles tendon with plantar fascia

This continuum of fascia from (at least) the posterior compartment of the calf to the base of the toes assists the walking mechanism. This is especially significant in the latter stage of the three stages of walking:

- Heel strike
- Mid stance
- Toe off

It transmits the forces of plantar flexion directly into the M/P joint. As the foot plantar flexes with weight bearing, the toes are forced into extension. This creates tension along the plantar fascia creating a reciprocal tension at the M/P joints resulting in a 'spring in the step' with the 'toe off' phase.

Hence tension patterns a long way away can manifest in the locality of the plantar aspect of the foot, or even just the back of the calcaneum causing an increased bony size there with consequent problems in footwear.

The focus of this tends to be that of disease, with good footwear as a preventative factor. However barefoot running challenges this belief system.

Barefoot running remains a controversial topic and many argue it might not be suitable for all runners. *Runner's World* Editor-in-Chief, David Willey, wrote about barefoot running in a 2011 editorial and summed up barefoot running by stating, "There's no single answer or prescription that's right for every runner when it comes to footwear and running form."

In 1960 Ethiopia's Abebe Bikila, the greatest Olympic marathoner of all time, won the first of his consecutive gold medals sans shoes in a world record 2:15:17. While Bikila was making

Olympic history, England's Bruce Tulloh was running European record times from 1955 to 1967, almost always in bare feet. He ran 13:12 for three miles on grass, and 27:23 for six miles on cinders. Later, Tulloh taught in Africa, coached, wrote books, and ran solo across America (2,876 miles, albeit in shoes).

Charlie "Doc" Robbins and Zola Budd are two more important contributors to barefoot running. Robbins, winner of two USA National Marathon Championships in the late 1940s, completed 50 straight Thanksgiving Day Road Races in Manchester, Connecticut. Most Thanksgivings, Robbins went shoeless, though he would resort to a pair of socks if the temperature dipped below 20 degrees. Mention the name Zola Budd to the casual track fan and you'll likely get one (or all) of three responses: Barefoot. South African. Tripped Mary Decker. Budd set a track world record in January 1984 when, just 16, she ran 5000 meters in South Africa in 15:01.83, more than six seconds under Mary Decker's existing record.

Still, it wasn't until 2009 that barefoot running became a hot topic. The biggest impetus was Christopher McDougall's book *Born to Run*. While ostensibly the story of Mexico's Tarahumara Indians—who run barefoot or in tire-tread huaraches—controversial chapters in the book conclude that running shoes have done little to prevent injuries. The popularity of minimal shoes, such as the Nike Free and Vibram FiveFingers, has fuelled the fire.

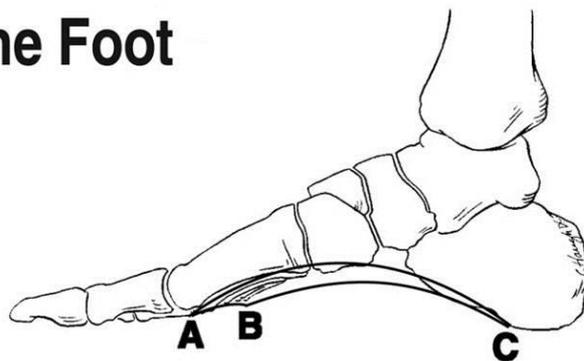
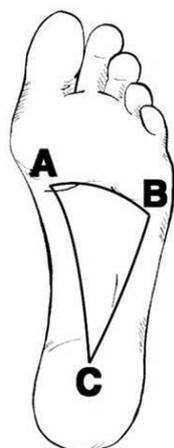
Arches of the Foot

There are three main arches of the foot

- Medial longitudinal
- Lateral longitudinal
- Transverse

The function of these arches is to create space and protect the vessels and nerves on the plantar aspect of the foot and so create an amount of spring and elasticity.

Arches of the Foot



A-B Anterior Transverse Arch
B-C Lateral Longitudinal Arch
A-C Medial Longitudinal Arch

Figure 47 Arches of foot

Fig 44 shows the arches and the consequent three points of contact with the ground

- The base of the big toe
- The base of the little toe
- The heel

These arches are supported by:

- Bony configuration
- Plantar ligaments
- Plantar fascia
- Short (intrinsic) muscles
- Long muscles
 - Tibialis anterior
 - Tibialis posterior
 - Peroneus longus

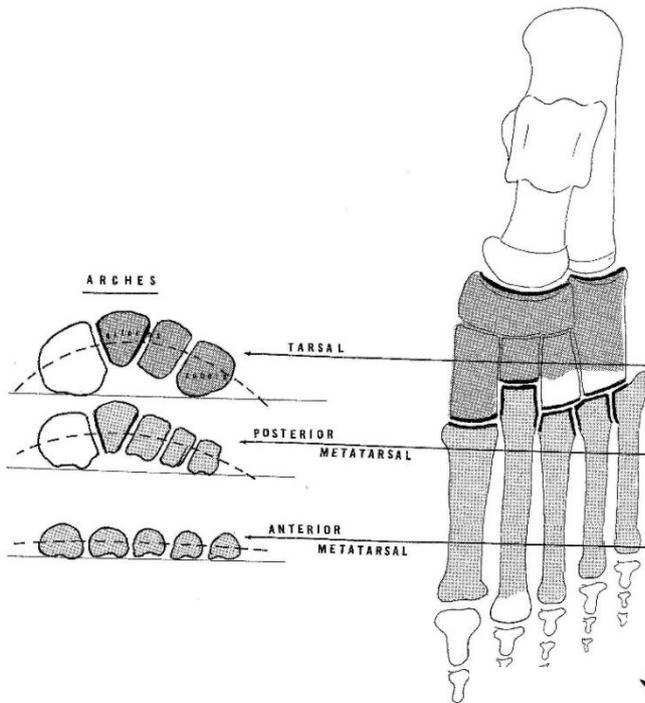
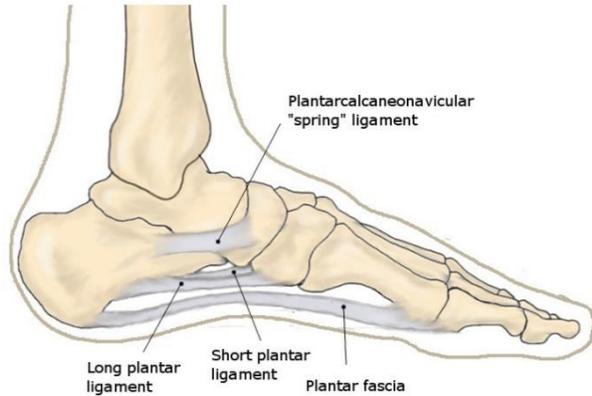


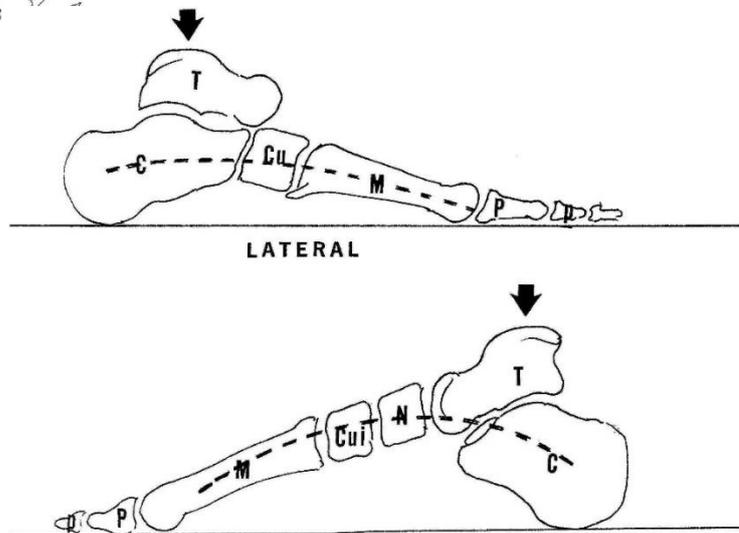
Figure 48 Transverse arches of foot

The left drawing depicts the fixed tarsal and metatarsal arches and the flexible anterior metatarsal arch.

The drawing on the right depicts the second receded cuneiform, which creates a mortise for the seating of the base of the second metatarsal.

Figure 49 Longitudinal arches

The longitudinal arch is formed by the continuity of the talus (T) with the calcaneum (C) and anteriorly with the navicular bone (N). Viewed medially, the navicular bone articulates with the cuneiforms (CU), then with the metatarsals (M) and the phalanges (P).



The normal arch of the foot is maintained by ligaments and the interosseous muscles within the compartments, seen here in the upper drawing

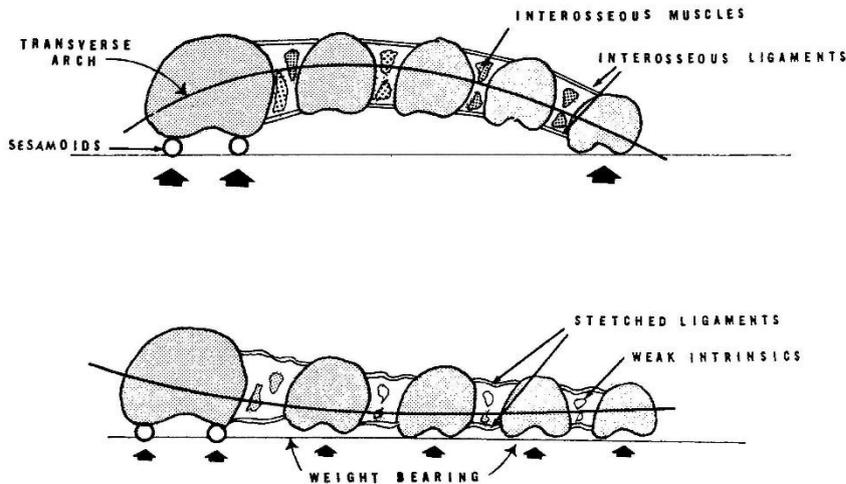
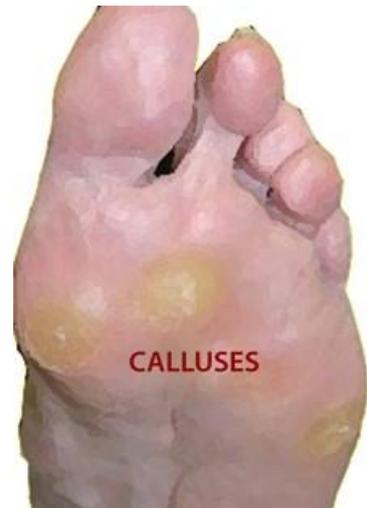


Figure 50 Splay foot

With a splay foot, the arch depresses, with weight bearing is now on the 2nd, 3rd and 4th metatarsal heads, causing metatarsalgia.

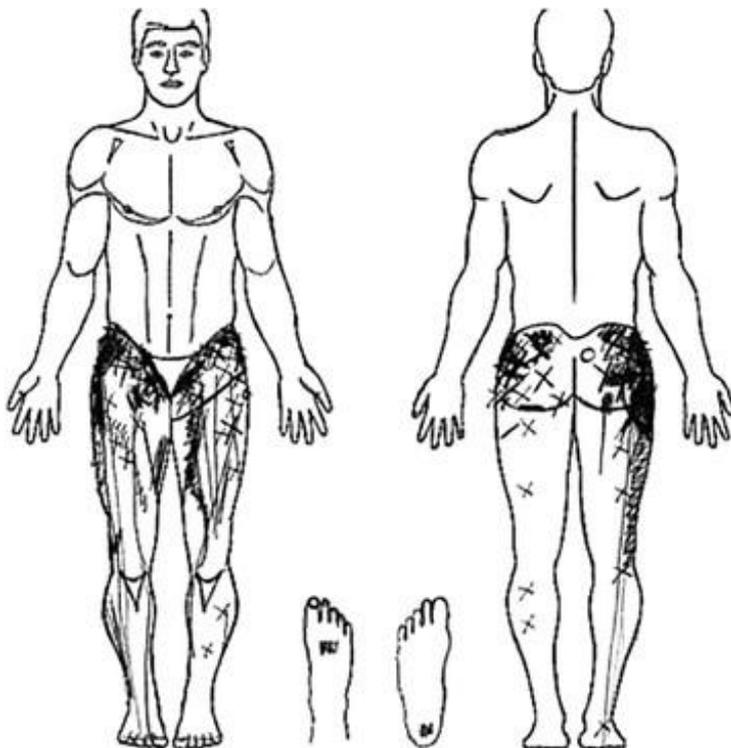
If the transverse arch begins to fail (Fig 47), the support is effectively taken off the middle M/P joints. Now the pressure here will effectively increase, especially with prolonged weight bearing with increased cornification of local skin.

Figure 51 Plantar callous formation



Referred Symptoms

There are other schools of thought that this can come from tension in areas elsewhere in the body, though immediate relief can come from orthotic use; in this case across the metatarsals just proximal to the M/P joints.



Regarding tension patterns originating elsewhere, referrals can come from the hips or even from visceral dysfunction. This creates interesting lines of thought, in that it is not just a referred pain, per se, manifesting in the foot, but a referral pattern not creating any overt pain. Instead of overt, it changes the way the person stands and moves. Now there is a pain syndrome as a manifestation of a postural or behavioural change.

Figure 52 Visceral referred pain

Fig 49 shows one such referral pattern, here possibly from the large intestine. The large intestine can refer pain to literally anywhere to which the bowel has a relationship:

- The low back
 - The ascending and descending colon are retroperitoneal, having a direct connection with the low back
- The pelvis
 - The caecum has ligamentous attachments here and the sigmoid has a line of mesentery
- The shoulders
 - Both the hepatic and splenic flexures have ligamentous attachments to the diaphragm, referring back up to the shoulders via the phrenic nerve
- The lower limb
 - The bowel has relations with psoas, iliacus and the kidneys (via the fascia of Toldt)
- The sacroiliac joints
 - Always involved with bowel and psoas

Referrals to the outside of the hips can affect the function of the muscles there, involving the iliotibial tract. This, in theory only stops just below the knee, but the pain can continue down to the lateral aspect of the calf. If it involves the peroneal muscles, eversion of the foot with consequent splaying can be easily seen.

Treatment

Longitudinal arch problems can show initially as plantar fasciitis. Here the quality of movements of the tarsal bones is important. People with flat feet (pes planus) can feel as if they have very 'soft' feet, floppy almost, when the person is younger and possibly 'hard' and generally very restricted in the older person from long term positional alignment. People with complain of tarsal pain – almost a presence in the foot. Massage to the plantar aspect of the foot can bring relief and help stimulate the intrinsic muscles of the foot, so that they contribute more to the arch support.

Other treatments include 'home' massage using coarse sand (builders gravel); this creates a diffuse but penetrating massage to the plantar side of the foot (walking along a beach of wet sand is a good second best). Also an exercise of trying to pick up a pencil using just the toes, though orthotic can be very valuable with symptomatic relief.

Other conditions can occur in foot mechanics, like pes cavus.



Figure 53 Pes cavus

Pes cavus results in an abnormally high arch in the foot. This results in an increased angle between the metatarsals and the ground; they are now effectively pointing towards the ground. Now the distal ends of the metatarsals are being 'pressed' into the ground creating symptoms to transverse arch problems. They can also be associated with 'hammer toes'; an increased flexion of the toes, producing a 'claw' effect. This can also show as thickening of skin at the pressure points on the top of the toes.

Other rare conditions are talipes equinus and talipes calcaneus



Figure 54 Talipes equinus

Talipes equinus can be from a congenital shortening of the posterior calf muscles producing a persistent plantar flexion of the ankle. Here, therefore, the foot will only be weight bearing on the M/P joints, with the heel not coming in contact with the ground with normal use.

Functionally, this is similar to wearing high heels



Figure 55 High heels

Another rare condition is pes calcaneus. This occurs when there is paralysis of the posterior calf muscles or hyperplasia of the anterior group.



Figure 56 Talipes calcaneus

If the calf muscles are paralyzed the contraction of the tibialis anterior and tibialis posterior pull up the arch and the contraction of the flexor brevis digitorum pulls the pillars closer together, therefore the heel descends, the arch ascends, and the plantar ligaments contract. If the extensor muscles are also paralyzed the toes drop and the anterior deformity is increased.

Foot usage and general posture during gait can be established by examination of the person's feet, whilst standing, and their shoes; e.g. people who an inverted foot when weight bearing and walking will show wear and tear around the heel and sole.

Metatarsalgia

Metatarsalgia is a loosely defined condition in which the pain is noted in the metatarsal heads. When the pain is in the lateral four metatarsal heads, it is called Metatarsalgia. If the pain is at the joint of the big toe, it is called a hallux valgus, or bunion; although it is also called sesamoid disease, or localised arthritis.

Hallux Valgus

Hallux valgus is a subluxation of the big toe outward. There is usually a deformity of the bone, the joint surface of the head of the first metatarsal being inclined obliquely out. As the toe becomes displaced outward the extensor hallucis longus by its contraction tends to increase the deformity. On the side of the head of the protruding metatarsal bone a bursa develops and becomes painful, forming a bunion. This bursa sometimes suppurates.



Figure 57 Mild bunion

Figure 58 Severe bunions with deformation



In some cases hallux valgus is due apparently to ill-shaped shoes, but in many cases, and these the worst, a rheumatic-gouty condition is the main factor. It may even have reflections on the arrangement and tension patterns of the intrinsic muscles of the foot, having a similarity with those of the thumb. The big toe has muscles that create 'opposition', as with the grip activity of the hand. The muscles of the foot are still there but their function are not as specifically defined as in the hand. Persistent tension patterns can pull the big toe across the foot, even pushing the adjacent toes out of the way (Fig 55).

In treatment the articular surface of the head of the first metatarsal bone is first resected. This enables the toe to be brought straight. To keep it straight the tendon of the extensor hallucis is displaced inward so that by its contraction it keeps the toe from again going outward.

Morton's Syndrome

Morton's syndrome (not neuroma) is a metatarsalgia of the second metatarsal head, which becomes weight bearing when the first metatarsal bone is too short. Examination will reveal tenderness and this can be confirmed, if necessary, by X-ray. Treatment can be via the appropriate orthotic to relieve the pressure there.

Gout

Another cause of pain at the base of the big toe is gout. Gout is a congenital condition, with a flaw in purine metabolism, resulting in the production of uric acid. Uric acid is very insoluble and crystallises out of the body's tissues, forming microscopic needle shaped crystals in and around the joint. Macrophages ingest these crystals but cannot digest them. The macrophages die and lyse, releasing inflammatory cytokines and other chemicals into the tissues, causing inflammation. In principle gout can occur anywhere, but 'traditionally' affects the base of the big toe.



Figure 59 Gout

Gout is usually treated via allopurinol tablets. However the person can help themselves via frequenting alkaline foods.

March Fracture

A March fracture is a stress fracture of a metatarsal shaft. It is so named because it was frequently noted after long military route marches. It showed as pain and tenderness over the site of the fracture.



Figure 60 March fracture

The initial fracture is not found on routine X-ray, as the X-ray needs to see through the line of the fracture to 'see' it. However, it can be seen about three weeks later with callous formation (fig57). Another means of identifying such a lesion would be via nuclear medicine and a T⁹⁹ bone scan.

Figure 61 Technetium 99 bone scan

With T⁹⁹ bone scans, the substance is put into the blood. When there is a situation of increased blood flow, as with bone healing, it will show up as a 'hot spot' on a scan.



Achilles Tendon Rupture

If there is acute pain in the posterior calf after physical injury, it may be that the Achilles tendon may have ruptured. Frequently, an audible 'snap' or 'pop' is reported and pain is immediate. The Achilles tendon tears because there is a forceful contraction of gastrocnemius against a fixed insertion. Direct trauma may be an affecting factor. Ecchymosis is often noted with a tear, with retraction of the gastrocnemius and soleus muscles.

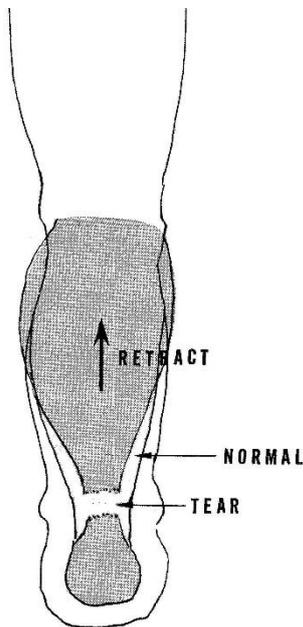


Figure 62 Achilles tendon rupture

Most Achilles tears occur about 2ins above the calcaneal insertion. If it is a complete tear, it can be tested via the Simmond's (Thompson) test (Fig 59): with the patient prone, squeeze the gastrocnemius muscle. If the tendon is intact, the foot will plantar flex; if it has ruptured, it will not. Even with this condition, the patient may still be able to walk, so lameness will not be diagnostic. It is possible that the person may not be able to stand on tip toe.

Treatment usually involves surgical repair. This is followed by placing the ankle in a cast for about 8 weeks, set with the foot in plantar flexion, followed by gradual rehabilitation (daily ultrasound) and physiotherapy.

Partial tears cannot be measured and diagnosis is made by tenderness, local pain and aggravation by stretching the tendon by dorsiflexion or trying to stand on tip toe. In these cases, treatment is by avoidance of physical activity for at least three weeks. Use of $\frac{3}{4}$ inch elevated heels help relieve the stretch of the tendon in the healing process.

Diabetic foot

With diabetes, foot problems should be carefully evaluated, as complication can be devastating. Hospitalisations for diabetic foot problems increased 25% in 1965 to 50% in 1985. The causes of foot damage are from ischaemia, neuropathic changes and neuropathic arthropathy. Ischaemia may include small or large vessels and sensory, motor or autonomic neuropathy. Large vessels pathology can appear as claudication and large, non-healing, ulcers. Diabetic ulcers have been classified:

- Grade I – a superficial ulcer involving only skin and subcutaneous tissue
- Grade II – ulcers extending to underlying tendon, bone and joint capsule
- Grade III – deep ulcers with associated osteomyelitis or abscess
- Grade IV – gangrene of toe or distal mid-foot
- Grade V – gangrene of mid-foot and hind-foot

The treatment of ulcers is beyond the scope of physical therapy. Diabetic neuropathy can be treated with drugs (carbamazepine), and all diabetes must be controlled by either diet, Glucophage or insulin treatment.

Orthotic Devices

Orthotics are many and various.

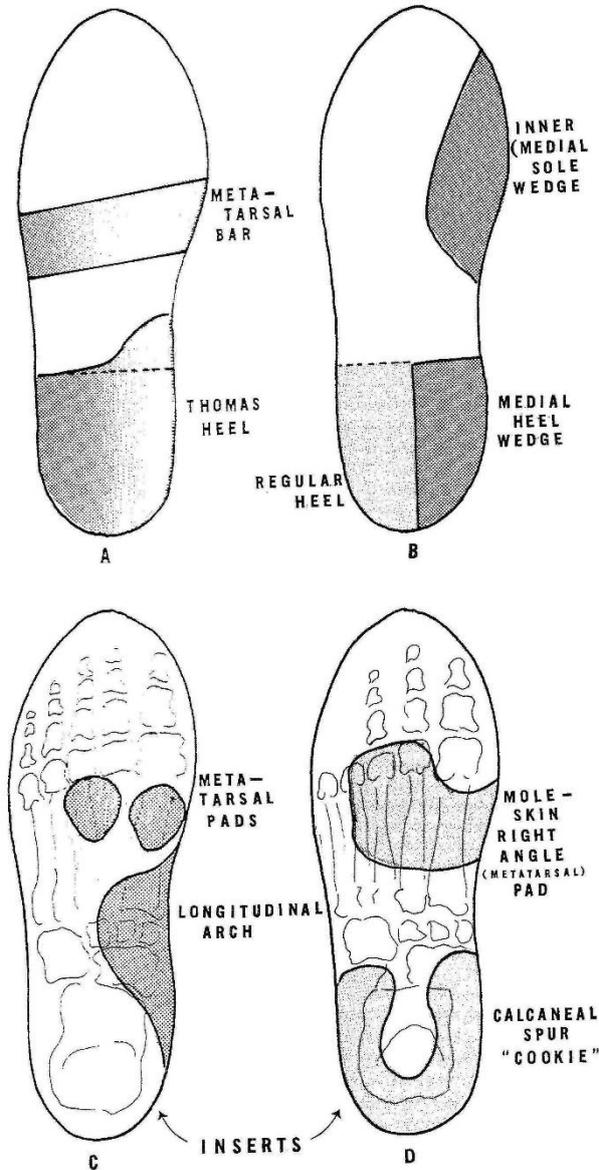


Figure 63 Basic orthotic shapes



There are adherents to the concept and use of orthotics, but their use revolves around the belief system of the problem is in the foot and everything above is an effect of it. But it has already been said that it could be that the 'problem' is one in the body, even the viscera, creating effects in the foot.

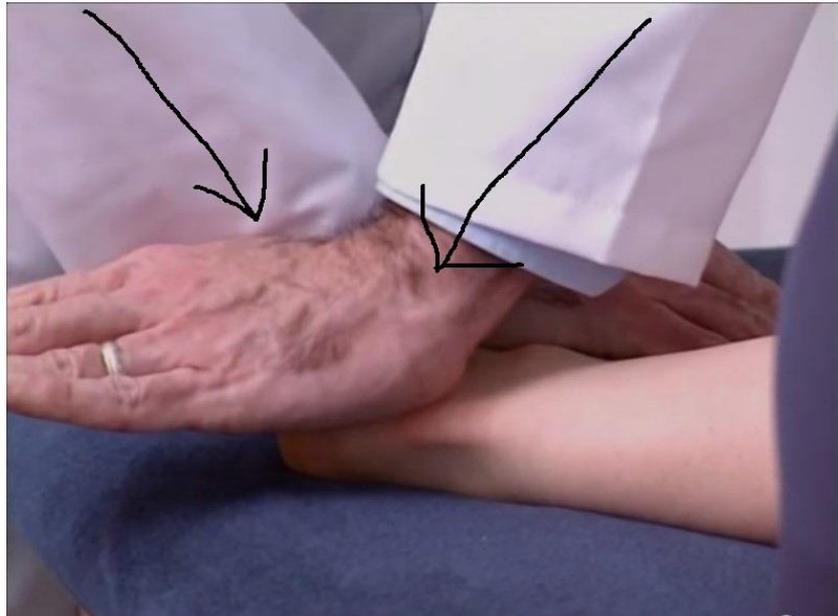
One example of their use is the correction of a valgus (as seen above). The picture on the left shows a deformity of the foot stance within the shoe. The right picture shows an inner heel wedge that corrects the deformity.

Ankle and Foot Manipulations

Sub-talar joint (talo-calcaneal joint)

- Patient side lying
- Medial side of ankle uppermost
- Dorsiflex the ankle (to lock it)
- Fix one hand across the foot, including the navicular, up beside the medial malleolus
 - Direct force cephalad and towards the table (here on the left)
- Fix the heel of the other hand on the medial side of the calcaneum
 - Direct the arm pedad and towards the table (here on the right)
- Find the point of tension
- The thrust is through the hand fixed on the calcaneum

Figure 64 HVT Talo-calcaneal joint



Distraction of talo-calcaneal joint

- Patient supine
- Wrap both hands around the talus and calcaneum
- Traction gently pedad, using body weight
- Follow any spontaneous releases



Figure 65 Distraction of talo-calcaneal joint

Cuboid

This is generally seen as one manipulation, but there are 5 joints around the cuboid, the force and focus can be adjusted accordingly

Supine - Combined leverage and thrust (CLT)

- Locate the plantar aspect off the cuboid; fix
- Dorsiflex the foot (i.e. push both foot and cuboid cephalad)
- With the other hand fix all the metatarsals and support the tibia with the forearm
- Thrust in the line of the joint



Figure 66 HVT location of cuboid before thrust

Prone (CLT)

- Flex knee to 90°
- Dorsiflex the foot and fix the metatarsals
- Fix on the plantar aspect of the cuboid
- Thrust in the line of the joint



Figure 67 Cuboid thrust - prone

Prone – Momentum induced thrust (MIT)

- Grasp foot and fix on plantar aspect of cuboid with both thumbs
- Dorsiflex foot and flex knee to 90°
- Take knee towards extension
- At same time plantar flex foot with slight inversion
- Thrust cuboid in the line of the joint



Figure 68 Cuboid MIT - prone

Cuneiforms

Only the medial cuneiform can be manipulated from the plantar aspect; all the others cannot be reached for specific fixation

Medial cuneiform – supine

- Grasp foot with both hands
 - Crossing index fingers across plantar aspect of medial cuneiform
- Grasp the foot to create a slight traction
- Gently oscillate the foot to feel the point of tension
- Thrust towards the dorsal aspect of the foot



Figure 69 Medial cuneiform - supine

Intermediate and lateral cuneiforms

- Patient supine
- Stand pedad to foot
- Locate affected cuneiform and cross fingers over the dorsal aspect of the bone
- Cross thumbs over relevant metatarsal on its plantar side
- Thrust the bone pedad



Figure 70 Cuneiforms thrust supine