

Subtalar fusion

Anatomy & Pathophysiology

BONY ANATOMY

- The ankle joint includes the tibia, talus, and fibula [2].
- The talar dome is biconcave with a central talar sulcus [2].
- The radius of curvature of the talar dome is greater laterally [2].
- The talus features an anterior calcaneal surface, a posterior calcaneal surface, and a middle calcaneal surface [7].
- The talus features an articular surface for the navicular and an articular surface for the calcaneonavicular ligament [7].
- The talus features a groove for the flexor hallucis longus tendon [7].
- The talus features a medial tubercle and a lateral tubercle [7].
- The talus features an articular surface for the medial malleolus and an articular surface for the lateral malleolus [7].
- The talus features an articular surface with the distal end of the tibia [7].
- The talus features a sulcus tali [7].
- The foot bones include the talus, navicular, cuneiform bones, cuboid, first metatarsal bone, fifth metatarsal bone, and calcaneus [10].
- The foot possesses a transverse arch [10].

LIGAMENTS

- The deltoid ligament is composed of two layers [7].
- The superficial layer of the deltoid ligament includes the tibionavicular and tibiocalcaneal ligaments [7].
- The superficial layer of the deltoid ligament crosses both the ankle and subtalar joints [7].
- The deep layer of the deltoid ligament includes the anterior and posterior tibiotalar ligaments [7].
- The deep layer of the deltoid ligament crosses only the ankle joint [7].

- The lateral fibular ligaments include the anterior talofibular ligament (ATFL), calcaneofibular ligament (CFL), and posterior talofibular ligament (PTFL) [7].
- The ATFL is the weakest of the lateral ligaments and is intracapsular [7].
- The ATFL is most commonly injured with a lateral ankle sprain [7].
- The CFL crosses both the ankle and the subtalar joint [7].
- Plantar flexion tightens the ATFL [7].
- Inversion with neutral flexion tightens the CFL [7].
- The interosseous talocalcaneal ligament is also known as the cervical ligament [10].
- The interosseous talocalcaneal ligament attaches proximally to the talus and distally to the calcaneus [10].
- The calcaneocuboid/calcaneonavicular ligament is also known as the bifurcate ligament [10].
- The bifurcate ligament attaches proximally to the calcaneus and distally to the cuboid and navicular [10].
- The calcaneocuboid-metatarsal ligament is also known as the long plantar ligament [10].
- The long plantar ligament attaches proximally to the calcaneus and distally to the cuboid and first to fifth metatarsals [10].
- The plantar calcaneocuboid ligament is also known as the short plantar ligament [10].
- The short plantar ligament attaches proximally to the calcaneus and distally to the cuboid [10].
- The plantar calcaneonavicular ligament is also known as the spring ligament [10].
- The spring ligament attaches proximally to the sustentaculum tali and distally to the navicular [10].
- The tarsometatarsal ligament is also known as the Lisfranc ligament [10].
- The Lisfranc ligament attaches proximally to the medial cuneiform and distally to the base of the second metatarsal [10].
- The tibionavicular ligament attaches proximally to the medial malleolus and distally to the navicular tuberosity [10].
- The tibionavicular ligament limits talar external rotation [10].
- The tibiocalcaneal ligament attaches proximally to the medial malleolus and distally to the sustentaculum tali [10].
- The tibiocalcaneal ligament limits hindfoot eversion [10].
- The anterior tibiotalar ligament attaches proximally to the medial malleolus and distally to the medial surface of the talus [10].
- The anterior tibiotalar ligament limits lateral displacement of the talus and external rotation [10].
- The posterior tibiotalar ligament attaches proximally to the medial malleolus and distally to the inner side of the talus [10].
- The posterior tibiotalar ligament limits lateral displacement [10].
- The anterior talofibular ligament attaches proximally to the lateral malleolus and distally transversely to the talus anteriorly [10].

- The anterior talofibular ligament limits inversion in plantar flexion [10].
- The calcaneofibular ligament attaches proximally to the lateral malleolus and distally obliquely to the calcaneus posteriorly [10].
- The calcaneofibular ligament limits inversion in neutral or dorsiflexion [10].
- The posterior talofibular ligament attaches proximally to the lateral malleolus and distally transversely to the talus posteriorly [10].
- The posterior talofibular ligament limits posterior talus displacement and external rotation [10].

NEUROVASCULAR ANATOMY

- The tarsal tunnel is a fibroosseous tunnel within the posteromedial ankle and hindfoot [3].
- The tibial nerve, posterior tibial artery, accompanying veins, posterior tibial tendon, flexor digitorum longus, and flexor hallucis longus tendons pass through the tarsal tunnel into the foot [3].
- The flexor retinaculum acts as the roof of the tarsal tunnel [3].
- The flexor retinaculum extends from the medial malleolus to the medial side of the calcaneal tuberosity [3].
- The medial distal tibia, talus, and calcaneus make up the floor of the tarsal tunnel [3].
- Septa projecting from the fibrous roof to the calcaneus separate the posterior tibial, flexor digitorum longus, and flexor hallucis longus tendons [3].
- The tibial nerve divides into three terminal branches before reaching the foot: the medial calcaneal nerve (MCN), lateral plantar nerve (LPN), and medial plantar nerve (MPN) [3].
- The tibial nerve typically branches within the tarsal tunnel just proximal and deep to the upper edge of the abductor hallucis muscle [3].
- The MCN branches first from the tibial nerve and travels posteriorly to the subcutaneous tissue [3].
- The LPN passes under the abductor hallucis, over the medial fascia of the quadratus plantae, deep to the plantar fascia, and under the heel to the flexor digitorum brevis [3].
- The LPN terminates in the fourth web space and supplies a branch to the third web space [3].
- The LPN supplies motor branches to the intrinsic muscles [3].
- The MPN innervates the abductor hallucis and continues under the abductor and plantar fascia to form common digital nerves [3].
- The common digital nerves from the MPN terminate in the first, second, and third web spaces [3].
- The MPN supplies motor branches to the interossei and lumbricals [3].
- The dorsalis pedis artery is a continuation of the anterior tibial artery that passes deep under the inferior extensor retinaculum [4].
- As the dorsalis pedis artery passes anterior to the ankle joint, it lies between the tendons of the extensor hallucis longus medially and the extensor digitorum longus laterally [4].
- The deep peroneal nerve lies immediately lateral to the dorsalis pedis artery [4].
- The dorsalis pedis artery gives off medial and lateral tarsal arteries as it passes over the tarsal bones [4].

- The arcuate artery arises from the dorsalis pedis artery in the region of the bases of the metatarsals and passes laterally [4].
- The second, third, and fourth dorsal metatarsal arteries arise from the arcuate artery [4].
- The first dorsal metatarsal artery is the continuation of the dorsalis pedis artery [4].
- The first dorsal metatarsal artery runs distally on the dorsal surface of the first dorsal interosseous muscle [4].
- The deep plantar, or communicating, artery leaves the dorsalis pedis at the base of the first metatarsal [4].
- The deep plantar artery passes toward the plantar surface of the foot between the heads of the first dorsal interosseous muscle [4].
- The deep plantar artery communicates with the lateral plantar artery to complete the plantar arterial arch [4].
- The first dorsal metatarsal artery may lie superficial to or within the substance of the first dorsal interosseous muscle in 78% to 88% of feet [4].
- The first dorsal metatarsal artery may lie plantar to the first metatarsal in 12% to 22% of feet [4].
- The diameter of the dorsalis pedis artery may range from 1.8 to 3 mm [4].
- The venous drainage from the dorsum of the toes and foot flows into the dorsal venous arches, feeding the greater and lesser saphenous systems [4].
- The dorsal surfaces of the toes and foot receive sensory innervation through branches of the superficial peroneal nerve [4].
- The first web space is innervated by the deep peroneal nerve [4].
- The plantar surface of the foot is innervated by the digital branches of the medial plantar nerve [4].

MUSCULAR ANATOMY

- The major tendons crossing the anterior ankle joint, from lateral to medial, are peroneus tertius, extensor digitorum longus (EDL), extensor hallucis longus (EHL), and tibialis anterior [10].
- The major tendons crossing the medial ankle joint are tibialis posterior, flexor digitorum longus, and flexor hallucis longus [10].
- The major tendons crossing the lateral ankle joint are the peroneal tendons, with peroneus longus superficial and peroneus brevis deep [10].
- The peroneus longus inserts on the plantar aspect of the medial cuneiform and base of the first metatarsal [10].
- The peroneus longus tendon is located posterior and lateral to the peroneus brevis tendon behind the fibula [10].
- The peroneus brevis has a low-lying muscle belly compared to the peroneus longus [10].
- The peroneus brevis inserts on the lateral aspect of the base of the fifth metatarsal [10].
- At the level of the peroneal tubercle, the peroneus brevis lies dorsal to the peroneus longus [10].
- The Achilles tendon has a maximum anteroposterior dimension of 8 mm on MRI [10].

- The extensor digitorum brevis (EDB) is the only dorsal intrinsic muscle of the foot [10].
- The EDB is innervated by the lateral terminal branch of the deep peroneal nerve [10].
- Plantar heel spurs originate in the flexor digitorum brevis [10].
- The flexor digitorum brevis is innervated by the medial plantar nerve [10].
- Lumbrical muscles are located plantar to the transverse metatarsal ligament [10].
- Interosseous tendons are located dorsal to the transverse metatarsal ligament [10].
- The tibialis anterior originates from the lateral tibia and inserts on the medial cuneiform and first metatarsal [7].
- The tibialis anterior acts to dorsiflex and invert the foot [7].
- The tibialis anterior is innervated by the deep peroneal nerve (L4) [7].
- The extensor hallucis longus originates from the midfibula and inserts on the distal phalanx of the great toe [7].
- The extensor hallucis longus acts to dorsiflex and extend the great toe [7].
- The extensor hallucis longus is innervated by the deep peroneal nerve (L5) [7].
- The extensor digitorum longus originates from the tibial condyle and fibula and inserts on the middle and distal phalanges of the toes [7].
- The extensor digitorum longus acts to dorsiflex and extend the toes [7].
- The extensor digitorum longus is innervated by the deep peroneal nerve (L5) [7].
- The peroneus tertius originates from the fibula and extensor digitorum longus tendon and inserts on the fifth metatarsal [7].
- The peroneus tertius acts to evert, dorsiflex, and abduct the foot [7].
- The peroneus tertius is innervated by the deep peroneal nerve (S1) [7].
- The peroneus longus originates from the proximal fibula and inserts on the medial cuneiform and first metatarsal [7].
- The peroneus longus acts to evert, plantar flex, and abduct the foot [7].
- The peroneus longus is innervated by the superficial peroneal nerve (S1) [7].
- The peroneus brevis originates from the distal fibula and inserts on the tuberosity of the fifth metatarsal [7].
- The peroneus brevis acts to evert the foot [7].
- The peroneus brevis is innervated by the superficial peroneal nerve (S1) [7].
- The gastrocnemius originates from the posterior medial and lateral femoral condyles and inserts on the calcaneus [7].
- The gastrocnemius acts to plantar flex the foot [7].
- The gastrocnemius is innervated by the tibial nerve (S1) [7].
- The soleus originates from the fibula and tibia and inserts on the calcaneus [7].

- The soleus acts to plantar flex the foot [7].
- The soleus is innervated by the tibial nerve (S1) [7].
- The plantaris originates from the lateral femoral condyle and inserts on the calcaneus [7].
- The plantaris acts to plantar flex the foot [7].
- The plantaris is innervated by the tibial nerve (S1) [7].
- The popliteus originates from the lateral femoral condyle and fibular head and inserts on the proximal tibia [7].
- The popliteus acts to flex and internally rotate the knee [7].
- The popliteus is innervated by the tibial nerve (L5, S1) [7].
- The flexor hallucis longus originates from the fibula and inserts on the distal phalanx of the great toe [7].
- The flexor hallucis longus acts to plantar flex the great toe [7].
- The flexor hallucis longus is innervated by the tibial nerve (S1) [7].
- The flexor digitorum longus originates from the tibia and inserts on the distal phalanges of the second to fifth toes [7].
- The flexor digitorum longus acts to plantar flex the toes and foot [7].
- The flexor digitorum longus is innervated by the tibial nerve (S1, S2) [7].
- The tibialis posterior originates from the tibia, fibula, and interosseous membrane and inserts on the navicular and medial cuneiform [7].
- The tibialis posterior acts to invert and plantar flex the foot [7].
- The tibialis posterior is innervated by the tibial nerve (L4, L5) [7].

PATHOPHYSIOLOGY

- Cavus foot is defined as a foot with an abnormally high arch [1].
- Cavus foot frequently accompanies hindfoot varus deformity, known as cavovarus foot [1].
- Cavovarus foot may be associated with clawing of the toes and demonstrable weakness of ankle or foot muscles [1].
- Calluses beneath the metatarsal heads and heel skin are common in cavus foot [1].
- Hindfoot varus in individuals with a cavovarus deformity is nonstructural if it can be corrected with the “block test” [1].
- Anterior ankle pain is one of the most common symptoms of cavus foot [1].
- Anterior ankle pain in cavus foot is sometimes associated with toe walking [1].
- In cavus foot, the forefoot is severely plantar flexed on the hindfoot, requiring marked ankle dorsiflexion to compensate [1].
- When cavus deformity becomes too severe, ankle dorsiflexion is blocked, leading to anterior ankle impingement and pain [1].

- The inability to dorsiflex further in severe cavus foot compromises forefoot clearance, eventually allowing only the metatarsals to contact the floor [1].
 - This condition can be misinterpreted as an ankle plantarflexion contracture, potentially leading to unnecessary heel cord release [1].
 - The cause of cavus foot is usually muscle imbalance in a growing foot [1].
- **Cavus foot is rarely found in early childhood but is fairly frequent after 8–10 years of age [1].**
-

Clinical Presentation

- Patients with tarsal coalitions often present with a symptomatic flatfoot [22].
- Pain associated with tarsal coalitions is typically located in the sinus tarsi or along the medial longitudinal arch [22].
- Limited subtalar motion may present as difficulty with movement on uneven ground [22].
- Limited subtalar motion may present as frequent ankle sprains [22].

Investigations

RADIOGRAPHIC EVALUATION

- Weight-bearing radiographs are required for the evaluation of pes cavus [21].
- An increased Meary angle is defined as the long axis of the talus intersecting the long axis of the first metatarsal dorsally on the lateral view of the foot, with a normal value of 0° to 5° [21].
- An increased calcaneal pitch is defined as the intersection of a line running along the undersurface of the calcaneus and the floor, where a pitch greater than 30° indicates a calcaneocavus foot [21].
- Medial and lateral oblique projections allow better assessment of the subtalar joint [17].
- The calcaneum is usually X-rayed in axial and lateral views [17].
- Weight-bearing X-rays are helpful in showing the coronal relationship of heel to tibia in stance [17].
- Stress X-rays complement clinical tests for ankle stability and can be carried out under general anaesthesia if stress manoeuvres are painful [17].

ADVANCED IMAGING

- Computed tomography (CT) scans are important in assessing fractures and for congenital bony coalitions [17].

- Radio-isotope scanning is excellent for localizing areas of abnormal blood flow or bone remodelling activity, which suggest the presence of covert infection [17].
- Magnetic resonance imaging (MRI) and ultrasound are used to demonstrate soft-tissue problems, such as tendon and ligament injuries [17].
- MRI and ultrasound can be used to diagnose joint effusions and bone infections [17].
- MRI of the spine is indicated with unilateral involvement in pes cavus [21].
- Diagnosis of cavus foot requires a thorough search for the underlying cause and may require neurologic consultation, spinal MRI, and electromyographic (EMG) studies [1].

CLINICAL EXAMINATION

- Hindfoot flexibility is assessed by placing a 1-inch block under the lateral border of the foot (Coleman block test) [21].
- A neurologic examination and a family history are essential for the evaluation of pes cavus [21].
- Unilateral involvement suggests a focal diagnosis, such as spinal cord anomaly or nerve injury [21].
- Bilateral involvement and a positive family history are common with Charcot-Marie-Tooth disease [21].
- The physical examination of the foot and lower extremity begins with the patient standing to note deformities of the toes, such as clawing, a long second ray, or swelling around joints [18].
- The plantar aspect of the foot is carefully evaluated for evidence of callus formation [18].
- The metatarsal heads are palpated individually to assess for generalized plantar fat pad atrophy, a prominent fibular condyle, synovitis, or possibly a transfer lesion beneath a metatarsal head resulting from previous forefoot surgery [18].

References

[1] A Lange Medical Book Current Diagnosis Treatment In Orthopedics Fifth Edition. **10Pediatric Orthopedic Surgery > 4. Cavus Foot.**

[2] Aaos Comprehensive Orthopaedic Review 3. Anatomy and Biomechanics of the Foot and Ankle > I. Anatomy.

[3] Campbell S Operative Orthopaedics 4 Volume Set. COMBINED HAMMER TOE AND MALLET TOE DEFORMITY WITH ASSOCIATED DOUBLE CORNS > TARSAL TUNNEL SYNDROME.

[4] Campbell S Operative Orthopaedics 4 Volume Set. RESULTS OF SUTURE OF THE SCIATIC NERVE > NEUROVASCULAR ANATOMY.

[7] Miller S Review Of Orthopaedics. SECTION 16 PATELLAR TRACKING IN TOTAL KNEE ARTHROPLASTY > 2. Arthrology.

[10] Miller S Review Of Orthopaedics. SECTION 16 PATELLAR TRACKING IN TOTAL KNEE ARTHROPLASTY > 2. Arthrology > 3. Muscles.

- [17] Apley And Solomon S Concise System Of Orthopaedics And Trauma. CONGENITAL ABNORMALITIES.
- [18] A Lange Medical Book Current Diagnosis Treatment In Orthopedics Fifth Edition. **8Foot and Ankle Surgery > METATARSALGIA.**
- [21] Aaos Comprehensive Orthopaedic Review 3. Pediatric Foot Conditions > Pes Cavus.
- [22] Aaos Comprehensive Orthopaedic Review 3. Pediatric Foot Conditions > Tarsal Coalition.