# Chapter Seven

## Foot and ankle

### CHAPTER CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overview</td>
<td>330</td>
</tr>
<tr>
<td>Gait</td>
<td>330</td>
</tr>
<tr>
<td>Conditions resulting in an inturned foot</td>
<td>331</td>
</tr>
<tr>
<td>Calcaneus varus/inverted calcaneus/rearfoot varus</td>
<td>331</td>
</tr>
<tr>
<td>Assessment of calcaneus varus</td>
<td>333</td>
</tr>
<tr>
<td>Metatarsus adductus</td>
<td>334</td>
</tr>
<tr>
<td>Clubfoot/talipes equinus varus</td>
<td>334</td>
</tr>
<tr>
<td>Conditions resulting in an out-turned foot</td>
<td>335</td>
</tr>
<tr>
<td>Talipes calcaneovalgus/rearfoot valgus</td>
<td>335</td>
</tr>
<tr>
<td>Rocker-bottom foot/vertical talus</td>
<td>336</td>
</tr>
<tr>
<td>Pes planus</td>
<td>336</td>
</tr>
<tr>
<td>Assessment of medial arch</td>
<td>338</td>
</tr>
<tr>
<td>Active testing of calcaneus</td>
<td>339</td>
</tr>
<tr>
<td>Retraining dorsal and plantar flexors</td>
<td>339</td>
</tr>
<tr>
<td>Dropped lateral arch</td>
<td>340</td>
</tr>
<tr>
<td>Pes cavus</td>
<td>340</td>
</tr>
<tr>
<td>Pedal compensation in leg length discrepancies</td>
<td>341</td>
</tr>
<tr>
<td>Plantar fasciitis</td>
<td>341</td>
</tr>
<tr>
<td>Sever disease (calcaneal apophysitis)</td>
<td>341</td>
</tr>
<tr>
<td>Treatment of the foot and ankle</td>
<td>342</td>
</tr>
<tr>
<td>Balanced ligamentous tension (BLT) calcaneus – child</td>
<td>343</td>
</tr>
<tr>
<td>Alternate BLT calcaneus – athlete</td>
<td>344</td>
</tr>
<tr>
<td>BLT decompression ankle mortise/talus</td>
<td>345</td>
</tr>
<tr>
<td>BLT compression talocrural</td>
<td>346</td>
</tr>
<tr>
<td>BLT talocalcaneonavicular</td>
<td>347</td>
</tr>
<tr>
<td>Springing/articulatory navicular/medial arch</td>
<td>348</td>
</tr>
<tr>
<td>BLT navicular/medial arch</td>
<td>349</td>
</tr>
<tr>
<td>BLT cuboid/lateral arch</td>
<td>350</td>
</tr>
<tr>
<td>Decompression transverse arch/2nd cuneiform</td>
<td>351</td>
</tr>
<tr>
<td>BLT metatarsal–cuneiform junction</td>
<td>352</td>
</tr>
<tr>
<td>The use of foot orthotics</td>
<td>353</td>
</tr>
<tr>
<td>Traumatic injuries</td>
<td>354</td>
</tr>
<tr>
<td>Anterior tibia on talus</td>
<td>354</td>
</tr>
<tr>
<td>Thrust technique talocrural joint – prone</td>
<td>354</td>
</tr>
<tr>
<td>Thrust technique talocrural joint – supine</td>
<td>355</td>
</tr>
<tr>
<td>BLT talocrural joint</td>
<td>355</td>
</tr>
<tr>
<td>Inversion ankle sprain</td>
<td>356</td>
</tr>
<tr>
<td>Myofascial milking technique – athlete</td>
<td>358</td>
</tr>
<tr>
<td>Thrust technique talotibial/inversion sprain</td>
<td>359</td>
</tr>
<tr>
<td>Thrust technique fibular head with ankle sprain</td>
<td>360</td>
</tr>
<tr>
<td>References</td>
<td>361</td>
</tr>
</tbody>
</table>
OVERVIEW

The foot is a marvelous instrument that meets all the challenges nature has placed upon it. It is flexible but stable. It is sensitive to slight changes in surface texture and position, but insensitive to the 40-pound rucksack on your back. In utero, the feet are typically supinated and tucked against the thighs. The knees and hips are flexed, with the tibias crossed and internally rotated. This intrauterine position influences the shape of the long bones of the leg, such that congenital torsions and bowing are often present at birth. The shape of the long bones will in turn affect the morphology of the feet, especially the integrity of the arches, which are dependent upon normal functional relationships in the long restrictor muscles of the ankle and distal leg. The arch arrangement is also dependent on the bony framework of the foot and is supported by the long restrictor muscles of the distal leg: the tibialis anterior and posterior, and the peroneus longus. Bony deformities such as tibial torsions can distort the relationship of the soft tissue structures that support the platform upon which the arches are built. This influences foot mechanics.

The arches of the feet are extremely important for several reasons. The arch arrangement provides the foot with the flexibility to adapt to the various contours and textures of the surfaces it contacts. The arches help to disperse the forces of gait, thereby protecting the articular surfaces of the feet, ankles and knees. The arches are instrumental in the tensegrity system of the foot and contribute to the propulsive mechanism of gait. During gait, energy is absorbed and released through a musculofascial–ligamentous sling involving the plantar tissues of the feet, the peroneus longus, biceps femoris, gluteal muscles, contralateral latissimus dorsi and upper extremity. This system allows conservation of energy. The small short restrictor muscles of the plantar surface are heavily innervated with proprioceptive fibers that play a role in balance and posture. Biomechanical dysfunctions affecting the structural relations of the foot or its flexibility have the potential to alter the mechanics of the ankle, knee, hip, pelvis, back and even upper extremity through both mechanical and neurological mechanisms.

The ankle has its greatest range of dorsiflexion at birth. If dorsiflexion is limited, one must consider deformity, spasticity or strictures. Because the nervous system is immature, spasticity is often difficult to detect in newborns and young infants. Deep tendon reflexes are unreliable. Muscle tone is greater in flexor muscles than extensor muscles, which increases the baby’s resistance to passive extension. Strictures or tightness may develop in the gastrocnemius or soleus muscles due to abnormal lie. To differentiate spasticity from strictures, one can compare ankle dorsiflexion with the knee extended and flexed. Restricted ankle motion in both positions suggests involvement of both muscles. This finding points to a neurological problem, whereas if restriction is present only in knee extension then the gastrocnemius is probably the cause, and the etiology is more likely to be mechanical and focal to that muscle. Deformity of the ankle or subtalar joint will present as abnormal positioning of the foot. Ankle dorsiflexion should be measured to rule out bony pathology. In infants and toddlers it is necessary to stabilize the subtalar joint and isolate the motion to the ankle mortise to accurately assess pure ankle motion. Active dorsiflexion of the foot typically includes ankle and mid-foot motion. In younger children, dorsiflexion of the forefoot is greater than of the hindfoot. As a result, intact forefoot dorsiflexion can mask limited talocural motion.

As the infant matures, spasticity may present as delayed motor skills or persistence of primitive reflexes, such as the plantar or Babinski reflex. For some children, toe-walking is a normal variant in the early stages of learning to walk. However, spasticity and undiagnosed deformity need to be included in the differential diagnosis of toe-walking. In toddlers and older children the talocural motion should be assessed from three perspectives: muscle resistance to the passive stretch required for movement, the presence of an abnormal physiological barrier due to bony abnormality, and mechanical resistance producing a restrictive barrier. Muscular resistance to passive stretch at the ankle associated with elevated deep tendon reflexes or persistence of primitive reflexes is indicative of neuropathology above the lumbar cord. Deformities of the foot can cause toe-walking and delayed motor milestones. Primitive reflexes will not persist in these children, and although resistance to joint motion is often present, the deep tendon reflexes are bilaterally symmetrical and not elevated. Neuropathology typically involves more than one muscle group, such as the knee and hip flexors on the ipsilateral side. Biomechanical dysfunction can also cause the child to toe-walk. For example, excessive pronation of the forefoot can present as limited range of motion without elevated reflexes.

GAIT

Infants typically begin walking after their first birthday. Their gait is wide based – about 70% of the width of the pelvis. Contralateral arm swing is absent, step length is short and step cadence is increased. This pattern emerges because of immature motor patterning and balance mechanisms. Early walkers lack good control of ankle dorsiflexor muscles. This affects forceful dorsiflexion at heel-strike and eccentric contraction during the stance phase. Consequently, the ankle is unable to transition smoothly from dorsiflexion to plantar flexion. This gives the appearance of a mild foot drop and results in a flatfoot strike rather than a true heel-strike. During swing and stance phases, infants tend to keep the knee more flexed because of the immature
quadriceps. There is an appearance of exaggerated ankle dorsiflexion as the weight of the body is carried forward. During the second year of life, most children establish contralateral arm swing patterns, ankle dorsiflexion improves a little, the appearance of foot drop resolves, and the time spent in single-leg support during the swing phase increases. Around the age of 2 years, the child may begin to develop a heel-strike pattern. This corresponds with the ability to flex the weightbearing knee during the mid-stance phase (Burnett and Johnson 1971). Achieving knee flexion on the supporting limb requires eccentric contraction of the quadriceps and stabilization of the hip. Children with primary muscle disease or neurological conditions may not be able to sustain this position owing to weakness and/or lack of postural control mechanisms. Step length should increase and cadence decrease as the child’s gait cycle matures. The step length should correspond to limb length. By 3 years of age, hip rotation improves and the base of support has narrowed to 45% of the pelvic width. Gait continues to mature, and by 7 years most children have a mature gait pattern with a narrow base of support, a true heel-strike mechanism and appropriate single-leg stance time. Although cadence is higher and velocity slower in this age group, these will improve with limb growth.

During early walking the toddler does not use the heel-strike and toe-off phases of gait. Instead, the child lands with a flat foot and the following stride is initiated by the knee and hip, rather than the propulsive mechanism of the foot. At this age the plantar arches are typically flat with weightbearing, although they are flexible with passive testing. The range of motion in the joints of the foot is greater in infants and early walkers than in older children. Limited motion between the joints or in the arches suggests bony deformity or soft tissue rigidity. Restriction in the arches will impede development of the heel-to-toe sequence, which creates the propulsion for the next stride. This sequence of movements generally does not appear until the third year. The weightbearing arches should begin to develop around the same time. Valgus and varus deformities of the forefoot can impede normal development of this sequence. Most children will not ‘grow out’ of deformities or misalignments at the midtarsal joint. These generally require conservative treatment, although surgical correction may be necessary in severe cases.

Gait abnormalities can be differentiated by observing the relationship of the foot to the leg and hip. In-toeing may be due to internal torsion of the tibia or femur, internal tibial rotation, clubfoot or metatarsus adductus. The alignment of the patella and foot when the leg is extended and in a neutral position or the child is standing, can determine the location of the problem. Generally, if the patella and foot are turned in the same direction, the problem is usually in the hip or femur. If the patella is in the midline and the foot is deviated, then the problem involves the tibia or the foot itself. For example, an in-turned but normal-appearing foot associated with a medially positioned patella suggests a tightness of the hip rotator muscles or a femoral torsion. A normal but in-turned foot associated with a neutral or lateral patella suggests a tibial torsion, internally rotated tibia or a rotational deformity of the foot. An externally positioned patella and foot suggests external femoral torsion, slipped capital femoral epiphysis (in an older child) or biomechanical dysfunction involving the hip rotators.

An abnormal appearance of the foot with a neutral or deviated patella suggests a primary foot deformity. Clubfoot and metatarsus adductus are rotational foot deformities. Clubfoot involves positional changes of the entire foot in which the forefoot and part of the midfoot are adducted on the midtarsal joint. Metatarsus adductus is a deformity isolated to the forefoot, which is adducted on the midfoot.

CONDITIONS RESULTING IN AN INTURNED FOOT

CALCANEUS VARUS/INVERTED CALCANEUS/REARFOOT VARUS

Clinical Notes

Heel varus refers to the angle created by the calcaneus and Achilles tendon during stance. The varus angle occurs when the calcaneus is inverted and the midfoot and forefoot are positioned medially in relation to the talus. Calcaneus varus may be congenital or late onset. At birth the calcaneus is in a relative varus position that is exacerbated in appearance by the presence of primitive reflexes and the increased flexor tone in the hips and legs. As the plantar reflex is lost, the foot assumes a more neutral posture. Once the child begins standing the absence of developed plantar arches gives the foot a functional pes planus, and the calcaneus may even appear to be everted or valgus. However, by the age of 4 or 5 the calcaneus should be in a neutral position during weightbearing. Excessive inversion at birth or persistence of the inverted appearance after 4 years may be structural or functional. Abnormal positioning or morphology of the talus or calcaneus will cause a structural varus that is typically rigid. More often, however, calcaneus varus is functional and due to biomechanical strains in the hindfoot, leg or hip.

In newborns and infants with calcaneus varus the foot is inverted and supinated, but flexible. Both active and passive repositioning of the foot is possible. The Achilles tendon is palpable and deviates medially from the midline of the leg. There may be increased tension through the adductor muscle group of the femur and the somatic tissues of the medial column of the distal leg. The femur is typically
externally rotated, which may be secondary to myofascial restriction or increased adductor tone. However, in some cases the position of the femur is due to an articular dysfunction and is contributing to the adductor hypertonicity. The presence of a mild genu varus or tibia varus may be due to intrauterine molding.

In older children and adolescents with calcaneus varus the medial longitudinal arch often appears functionally intact in the stance position. However, during gait the foot compensates for the inverted calcaneus by creating excessive eversion at the subtalar joint, resulting in a flattened medial arch. The resultant torque placed into the foot compromises the stability of the ankle and forefoot. This gait adaptation also increases the load on the posterior tibialis muscle and may contribute to shin splints in older children and athletes. Compensation for the varus position of the foot often includes adaptations at the knee that result in an internally rotated tibia. This further exacerbates the functional pes planus during gait and contributes to stresses in the patella and medial joint line of the knee. Older children and athletes with heel varus may complain of pain in the forefoot due to increased stress under the second and third metatarsals. Younger children may alter their stride to reduce the time spent in single-leg stance on the affected limb. Often the plantar surface of the metatarsals is callused and the shoes may show wear under the metatarsal arch.
Assessment of Calcaneus Varus (Fig. 7.1)

1. The patient is standing. The alignment of the Achilles tendon is noted. In calcaneus varus the tendon may splay medially.

2. The child is observed from behind while walking. At heel-strike the lateral aspect of the foot initially comes into contact with the ground. Then the foot rolls into pronation. It may appear that the foot slaps against the ground. (The calcaneus in this child appears almost normal; however, it is rather pronounced with walking.)

3. Shoes will be unevenly worn, with marked wear along the lateral aspect of the heel and the medial aspect of the forefoot. The first and second metatarsal heads may be callused.
**METATARSUS ADDUCTUS**

**Clinical Notes**

Metatarsus adductus is a deformity of the foot usually noted in infancy. The metatarsal bones and toes are positioned medially (Fig. 7.2) in relation to the hindfoot. Some molding of the forefoot may be present. Severe metatarsus adductus can be confused with clubfoot in infants and newborns. However, unlike clubfoot, the adduction deformity only involves the forefoot whereas the hindfoot is quite flexible. When the condition is mild it is often missed at birth and may first present with walking. The affected child exhibits an intoed gait with a neutral patella and femur. Metatarsus adductus is most often idiopathic and probably due to intrauterine positioning. It is associated with restrictions in the transverse arch, manifesting as a resistance to passive lifting. There is tightness in the medial fasciae and adductor muscles of the forefoot, as well as torsion of the first and second metatarsal bones and inversion rotation of the first cuneiform. The calcaneus may be everted. The lateral longitudinal arch is sometimes flattened with the fibula posterior.

Initiation of treatment should begin immediately upon diagnosis. Once the child begins walking the deformity becomes more rigid and less amenable to treatment. As an adjunct to manual treatment, parents should be taught to passively stretch the plantar tissues. If the deformity is severe, serial casting may be required in addition to manual treatment and stretching. Conservative treatment is less successful if not initiated before the age of 3. After this age surgical correction may be necessary.

**CLUBFOOT/TALIPES EQUINUS VARUS** (Fig. 7.3)

**Clinical Notes**

Clubfoot is a complex deformity involving dislocation of the talonavicular joint, deformity of the neck of the talus, inversion of the calcaneus, supination of the midfoot and adduction of the forefoot. Internal torsion of the tibia is present, with external rotation of the ankle. In severe cases mild hypoplasia of the fibula, tibia and osseous components of the foot may be present, as well as mild atrophy of the gastrocnemius, soleus, peroneus and tibialis muscles. The blood vessels supplying the dorsal tissues of the foot may be narrowed or absent. Clubfoot can be described as an abnormal molding of the foot, the severity of which is determined by the degree of resistance to correction. Clubfoot is typically classified into three groups: rigid or uncorrectable, postural or partially correctable, and correctable, depending on how it responds to active and passive testing. Active testing refers to the ability of the infant to self-correct the position of the foot. This is done by gently scratching repeatedly along the length of the peroneus muscle from the level of the mid-fibula to the malleoli (Fig. 7.4).
irritation causes the peroneus longus to contract reflexively, which should evert and abduct the foot. If the child can actively reduce the deformity via this reflex, the condition should respond to conservative management.

Treatment Notes

The definitive etiology of clubfoot is unknown; however, intrauterine position, neuromuscular disorder and hereditary factors may all play a role. There have been reports of abnormalities in nerve conduction studies, monosynaptic reflexes, somatosensory fibers and the histochemical analysis of the involved muscles. In spite of this no conclusive studies have been carried out, and as a result specific treatment protocols vary. Consultation with an orthopedic surgeon should be obtained with a suspected diagnosis of clubfoot. In all but the worst cases, conservative management such as casting, taping and manual therapy are tried during the first 3–4 months of life. When conservative management fails, surgery is necessary. This usually involves correction of the talonavicular and subtalar joints and release or lengthening of the flexor tendons of the toes, the peroneus, Achilles and tibialis tendons. Serial casting, splinting and stretching are performed in the postoperative months. Most authors recommend weightbearing as soon as possible to reinforce the surgical corrections. If not corrected, the deformity will worsen as the child grows, the muscles shorten and the lateral aspect of the foot becomes longer than the medial. Some authors suggest that surgical correction should take place before the first birthday to prevent additional bone deformity secondary to growth. Other authors suggest that surgery be delayed until after the first birthday, closer to the time when the child will walk.

In the newborn, the clubfoot deformity most directly influences the structures throughout the limb, pelvis and lumbar spine. The somatic tissues of the medial column of the leg are taut, with myofascial restriction. Shortening of the tibialis anterior and posterior muscles is usually present, with compensatory lengthening of the peroneus muscles. Bowing of the tibia is also present. There is often restriction in the iliotibial band with an outflared and posterior innominate, which usually produces compression of the ipsilateral sacroiliac joint.

The foot abductor muscles need to be strengthened and their resting length shortened. In the newborn, this can be done by repeated stimulation of the peroneus muscles and passive stretching by the parents or caregivers. This is a good home assignment for parents, who can use each diaper change and feed as an opportunity to stimulate the eversion reflex and apply gentle stretching to the medial column of the leg and foot.

CONDITIONS RESULTING IN AN OUT-TURNED FOOT

TALIPES CALCANEovalgus/REARFOOT VALGUS

Clinical Notes

Calcaneus valgus is a condition that occurs in the newborn due to the intrauterine position. It is typically unilateral. The forefoot is dorsiflexed and abducted and the heel is in a valgus position. There is reduced motion at the ankle. An external tibial torsion may occur as compensation for the foot position, and in some cases there is an externally rotated tibia. The fibular head may be posterior, with increased tension in the ipsilateral peroneus longus muscle and iliotibial band, as well as restricted ipsilateral sacroiliac mechanics. As with other congenital deformities, muscle deconditioning and abnormal firing patterns are often present. The plantarflexor and inversion muscles need to be rehabilitated. Parents should be taught to stimulate the foot to encourage plantar flexion and inversion. This can be done by stimulating the plantar grasp reflex or gently pressing on the medial plantar aspect of the infant’s foot. The stimulus should not be irritating or the withdrawal reflex will be activated. If the child is unable to right the foot with stimulation, the valgus position may be maintained by somatic dysfunction of the peroneal muscles, and in some cases muscle contractures may even be present.

The differential diagnosis for calcaneus valgus in newborns includes vertical talus. Differentiation can be made on physical examination. Whereas in calcaneus valgus there is normal positioning of the bones of the hindfoot, in congenital vertical talus there is true displacement of the talus and the foot is rigid. Congenital calcaneus valgus typically
resolves with conservative treatment such as manipulation and stimulation. As with many other congenital molding deformities, growth plays a role in resolution of the problem. However, if muscle imbalances and dysfunction are not addressed, the deformity may actually worsen with growth. When treating young children, it is prudent to remember the old adage: 'as the twig is bent, so grows the tree.'

Calcaneus valgus may also present in older ambulating children or young athletes. It is then referred to as rearfoot valgus. If it is congenital, there is typically a history of delayed walking. However, more often it is late onset and due to postural factors rather than an undiagnosed congenital condition. Adolescents and young athletes with rearfoot valgus typically present with complaints of ankle or knee pain. Rearfoot valgus is usually associated with increased adductor and internal hip rotator tone and weak gluteus and abdominal muscles. This combination allows the pelvis to tilt anteriorly and the femurs to internally rotate, which loads the medial leg and foot, encouraging further eversion of the calcaneus and pronation of the midfoot. In older children and young athletes the rearfoot valgus is associated with flattening of the medial longitudinal arch with weightbearing. However, the medial arch is flexible and is usually present in non-weightbearing positions. The pes planus is a functional adaptation to the abnormal loading placed on the mid and forefoot by the calcaneal misalignment. The rearfoot mechanics must be addressed before any change in the arch can be sustained. The valgus position of the calcaneus undermines the support system for the anterior talus. Consequently, the talus tends to be in a more plantarflexed position when the foot is loaded in weightbearing. This restricts talocrural motion and places increased stress on the ankle mortise and the medial aspect of the knee. The plantar talus allows the navicular to drop and the integrity of both the medial longitudinal and transverse arches is compromised.

ROCKER-BOTTOM FOOT/ VERTICAL TALUS

Clinical Notes

A rocker-bottom foot is a rare deformity that is often associated with other malformations or part of a congenital syndrome. There are, however, instances where uterine lie or improper casting may produce a rocker-bottom type foot. This occurs when the forefoot is cast in a more dorsiflexed position than the hindfoot. Although the foot appears deformed, it will be quite flexible, unlike a true rocker-bottom foot. In a true rocker-bottom or vertical talus, the talus is displaced inferiorly and medially, towards the plantar surface of the foot. The calcaneus lies lateral to the talus, the forefoot is dorsiflexed and the talonavicular joint is dislocated. The plantar surface has a convex appearance. The subtalar joint is stiff or rigid, and the level of flexibility in the forefoot depends on the severity of the deformity. The displaced talus fails to articulate correctly with the tibia, limiting ankle motion. With weightbearing the calcaneus moves further posteriorly and the heel does not come in contact with the ground. Contractures of the muscles of the lower leg often develop, contributing to the overall rigidity of the foot and restriction in ankle dorsiflexion. Orthopedic consultation should be sought for all children with suspected vertical talus. In most cases orthotics can be introduced as the child grows, to assist with gait mechanics and improve function. A trial of manipulation and casting is often employed as the initial treatment. In moderate and mild cases this may be enough. However, some children require open surgical correction.

PES PLANUS

Clinical Notes

Pes planus describes a pronated foot with flattening of the medial longitudinal arch. The foot may be flexible or rigid. Rigid pes planus is rare and may be due to peroneal spasm, fusion of the tarsal bones or rigid deformity, such as vertical talus. Flexible pes planus can be either structural or functional.

In toddlers, the plantar arch system is not well formed, giving a flat foot appearance. This is due in part to the immaturity of the osseous structures, particularly the navicular, which does not begin its ossification process until the child is 2 or 3 years old. The ligamentous structures supporting the arches are also immature, and there is a certain amount of physiological ligamentous laxity, which peaks by 3 years and then diminishes. These factors, combined with neuromotor immaturity and the normal varus position of birth, encourage foot pronation. By the age of 4 or 5 the arch system should be established and maintained in the weightbearing position.

Structural pes planus is caused by foot deformities such as calcaneus valgus, accessory navicular and vertical talus. Depending on the severity of the deformity, there is reduced flexibility to passive motion testing of the medial and transverse arches. Structural pes planus is typically present early in life and is often first noted in 3–5-year-olds as the foot thins out and the appearance of the talus becomes more prominent with weightbearing. Structural pes planus may arise as compensation for minor congenital deformities in the forefoot, leg and hips. In early walkers, excessive genu or tibia varum results in compensatory over-pronation at the subtalar and midtarsal joints. If the deformity of the leg does not correct, the foot develops...
with a pronated stance. There will be tightness and restriction in the somatic tissues of the medial column of the leg, but the peroneus muscle will be tight as well. In children with a varus forefoot, the foot compensates by evert ing the calcaneus and pronating the midfoot to maintain contact with the ground. The everted calcaneus produces shortening in the tissues of the lateral column. Excessive external rotation at the hip also promotes pronation by abducting the foot. Although at birth external rotation is greater than internal rotation, this discrepancy should improve by the age of 4. Persistent shortening or restriction in the external hip rotators will maintain the pronated posture in the foot. Weakness of the tibialis muscles due to immaturity or neurological paresis will also result in a pes planus.

In most cases flexible pes planus is functional (i.e. postural) and develops later, in early childhood. It usually arises as a postural compensation in the foot to a mechanical or motor dysfunction in the leg, hip or hindfoot. In these children the calcaneus is everted, the talus is in a position of plantar flexion and may be prominent, and the navicular is abducted and dorsiflexed. The key finding is flexibility. Passive dorsiflexion may produce some change at the medial arch, but active engagement of the arch usually fails in these children. Often the concave appearance of the foot diminishes when non-weightbearing is compared to weightbearing. Persistence of the convex appearance in non-weightbearing is typically said to be indicative of a rigid pes planus. However, the author has found that in older children and athletes who have a history of untreated functional pes planus, the convex appearance of the foot may not change in the non-weightbearing position. Children with this problem typically have articular and myofascial dysfunction in the foot which has resulted in shortening of the plantar tissues. Similarly, children who have been wearing rigid orthotics and have not received manipulative treatment of the articular dysfunction or appropriate muscle rehabilitation may also present with persistent pes planus in the non-weightbearing position. In these cases, passive and active testing should be performed to ascertain the functional capabilities and rehabilitation potential of the foot.

Finally, functional pes planus may be caused by poor footwear, deconditioning of muscles and lazy gait mechanics. Biomechanical dysfunctions associated with functional pes planus include internal rotation of the tibia, internal torsion of theibia or femur, genu valgus, eversion of the calcaneus, and anteriorly tipped pelvis. With chronic pronation the peroneus and Achilles tendons shorten and the tibialis tendons stretch, reinforcing the abnormal posture. During rapid growth phases the appearance of the pes planus may worsen due to the postural influences on the developing bones. The influences of the foot extend beyond the ankle. Poor foot mechanics increase the load on the joints and muscles of the feet, knees and hips. As these areas become strained, the child will compensate by altering gait mechanics, which may further exacerbate the mechanical dysfunctions. As a result, pes planus can be a contributing factor in Osgood–Schlatter syndrome, patellofemoral issues, recurrent ankle sprains, midline joint pain in the knee, shin splints and mechanical hip pain.

In terms of assessment, three components need to be considered in functional pes planus: the change in the arch from non-weightbearing to weightbearing posture; the degree of pronation present with gait; and the flexibility of the arch. If the arch resists active correction but changes with passive correction, manipulative treatment and retraining will be effective. If the arch resists passive correction and the talus is displaced, then treatment will be more protracted and it may be necessary to augment manipulation with a supportive orthotic. Over-pronation during gait needs to be addressed before any correction in the arch can occur. Often simply treating an everted calcaneus will correct the medial arch deformity, but in many patients dysfunctions of the limb and pelvis contribute to the hindfoot dysfunction. Over-pronation not only affects the medial arch, it will also cause loss of the anterior and lateral longitudinal arches and, if excessive, the transverse arch can become rigid and somewhat flattened.
Assessment of Medial Arch

Passive Testing Arch (Figs 7.5 and 7.6)
The child is standing with his weight evenly distributed on both feet. The great toe of one foot is passively dorsiflexed (Fig. 7.6). This maneuver puts tension through the plantar fascia and compresses the first ray of the foot, elevating the medial arch. If the arch does not elevate, one must consider congenital joint fusion, contractures of the plantar tissues, primary muscle disease, rheumatoid arthropathy and spasticity. If the arch can be stimulated this suggests functional pes planus even if the pes planus persists in the non-weightbearing position. Older children should then be assessed for active engagement of the arch.

Non-weightbearing and Weightbearing
The distance from the floor to the base of the navicular can be measured both in weightbearing and non-weightbearing. The difference should be less than 3 mm.

Active Testing Arch
In an older child, functional pes planus can be differentiated from a neurological pes planus by asking the child to grip the ground with his toes (Figs 7.7 and 7.8). This should cause the arch to elevate to some degree. The change in arch height should be compared with that which was achieved with the passive testing (Fig. 7.9). A common reason that the arch does not elevate is muscle weakness, particularly the tibialis muscles. The weakness may be due to neuropathology, myopathy or deconditioning. Strictures of the plantar tissues may also prevent the child from actively engaging the arch.
**Active Testing of the Calcaneus** (Fig. 7.10)

Asking the child to stand on his toes will cause the everted calcaneus to move to a neutral or inverted position. If the foot is truly rigid, the calcaneus will remain everted. This is also a useful test in children with hypotonia or deconditioning of the plantar flexors to assess the level of dysfunction.

**Treatment**

**Retraining Dorsal and Plantar Flexor Muscles**

The child can be taught to do repetitive toe raises and heel walking to stimulate recruitment of the muscles supporting the arches (Figs 7.10 and 7.11). Asking the child to slowly rise up on his toes and then to slowly drop down requires eccentric contraction of the gastrocnemius, peroneus longus and flexor hallucis. Asking the child to walk on his heels recruits the tibialis anterior and posterior muscles.
DROPPED LATERAL ARCH

Clinical Notes

Flattening of the lateral arch may be a concurrent finding with pes planus, or it may be secondary to calcaneus varus or peroneus muscle imbalance. Flattening of the lateral arch is often associated with a posterior fibula and may develop after an ipsilateral inversion ankle sprain. The child may complain of discomfort on the lateral aspect of the foot, heel or lateral malleoli. Calluses or blisters may develop on the small toe, which tends to be curled and supinated. In addition to a primary foot problem, flattening of the lateral arch may be secondary to somatic dysfunctions of the fibula, pelvis and sacrum, as well as the peroneus muscle or the hamstring group. The lateral arch is part of the myofascial lateral column system, which supports the sacroiliac joint. This column extends from the inferior sacroiliac ligaments that insert onto the ischial tuberosity. It is contiguous with the tendon of biceps femoris muscle, through the adjacent tendon of the peroneus longus muscle along the fibula and across the lateral arch to the plantar surface of the foot (Fig. 7.12).

This tensegrity system supports the pelvis, torso and limb in weightbearing and contributes to the propulsion mechanism of gait. Dysfunction of any of the components of the system affects the other components and undermines the integrity of the entire system. This leads to altered gait mechanics, increased load across articular cartilage, overuse syndrome in muscles and increased oxygen consumption.

The lateral column tensegrity system is dependent on proper conditioning of the muscular components. In addition to organic pathology, muscular imbalances can develop as a result of improper training, a sedentary lifestyle and improper footwear. Once this system is disrupted by one dysfunction, the other components develop compensatory adaptations that themselves often represent mechanical dysfunctions. This is particularly important in children with spasticity and hypotonia, where the workload of ambulation is already increased.

PES CAVUS

Clinical Notes

Pes cavus refers to a markedly high medial longitudinal arch. It is not present at birth, but develops in mid to late childhood. It is often uncomfortable, and may present with frank pain with weightbearing. In severe cases the child may develop claw toes or hallucis valgus. It can be seen in demyelinating neuropathies, spina bifida, cerebral palsy, muscular dystrophies and cerebellar disease. In many cases the cause is an imbalance between agonist and antagonist muscle groups. Common imbalances contributing to pes cavus include weak gastrocnemius and strong plantar flexors, weak tibialis anterior and strong hallucis extensors, and weak peroneus brevis and strong peroneus longus. In mild cases orthotics and stretching may help with symptoms, but surgical release may be necessary in severe cases.

When the arch is exaggerated, the child may compensate by turning the forefoot medially during weightbearing. This creates a forefoot varus position. The navicular and talus resist this varus position, so the calcaneus compensates by evertting or moving into a valgus position. This increases the pronation of the entire foot, further stressing the plantar tissues.

Some families have hereditary high arches. These children should use footwear that will support their arch, especially when engaged in running or activities requiring sudden stops and starts. In general, children with high medial arches are at risk for injuries and overuse syndrome owing to the rigidity of the arch. A high arch tends to be more tightly packed, with less interosseous movement to accommodate sudden changes in the surface shape or weight. The transverse arch is often compressed laterally and elevated, which increases the load on the metatarsals heads and plantar fasciae. Consequently,
young athletes are at risk for developing stress fractures, and children with pes cavus are at risk for developing plantar fasciitis in adulthood.

PEDAL COMPENSATION IN LEG LENGTH DISCREPANCIES

Foot mechanics are affected by differences in leg length. When the child has a short leg, the foot on the ipsilateral side is under greater compressive force from the weight load and may assume a more pronated position. The foot may then compensate by over-supinating at the subtalar joint and by carrying the weight on the lateral aspect of the heel and foot. The contralateral foot will assume a more pronated position with internal rotation of the tibia and femur (see Chapter 5, Femur, Hip, Pelvis for a discussion of evaluation of leg length differences).

PLANTAR FASCIITIS

Clinical Notes

Although commonly thought of as a condition of aging, plantar fasciitis can develop in young athletes through a combination of improper training, poor footwear and/or abnormal foot mechanics. Plantar fasciitis is an overuse syndrome that develops when excessive tensile loads are placed on the plantar fascia, causing repetitive microtrauma. Typically it is common in running sports and sports with sudden stops and starts. However, in the author’s experience, plantar fasciitis can also occur in situations where ankle dorsiflexion is limited but forward propulsion is still used, such as roller blades with rigid bottoms, and alpine skiers who spend significant time walking in their boots. Dancers who train en pointe place significant stress on the plantar fascia and are at risk for developing plantar fasciitis, especially in the early stages of training or during periods of intense training.

The plantar fasciae can be subjected to excessive tensile loads through several mechanisms. Under normal conditions the plantar fascia lengthens as the foot contacts the ground from the heel-strike to the stance phase of gait, and then shortens as the foot moves into toe-off. This action is a component of the forward propulsion mechanism of the foot. Limited ankle dorsiflexion during stance forces the forefoot to compensate with dorsiflexion and pronation, which increases the stretch on the plantar fascia. Calcaneus varus or a posterior calcaneus shifts the origin and insertion of the fasciae away from each other, increasing the tensile force. Children with pes cavus have naturally shortened and tight plantar fasciae, which are more susceptible to trauma from stretch.

The forces generated during gait are normally absorbed by the plantar arch system. If the arch system is dysfunctional, greater forces are transferred into the fasciae and plantar ligaments, causing microtrauma and inflammation. Overpronation of the subtalar joint stretches the plantar fascia with weightbearing. This can occur because the calcaneus is everted or the tibia is internally rotated. The plantar fascia is an extension of the Achilles tendon; consequently, tight calf muscles or tibial dysfunction may play a role in the development of fasciitis. Tightness of the gastrocnemius and soleus affects the tensile forces in the plantar fasciae by lifting the calcaneus. Hamstring tightness that prevents full knee extension can also be a contributing factor. Consequently, children with spasticity are at risk for developing fasciitis. Children with subtle leg length discrepancy often compensate by limiting heel-strike on the affected side. This places increased stress on the plantar fascia and may progress to fasciitis.

Most plantar foot pain is due to plantar fasciitis. However, when symptoms do not improve with appropriate management one must consider other causes, such as rheumatological disease, tarsal tunnel syndrome with or without thyroid disease, calcaneal apophysitis, myositis of the abductor hallucis or Achilles tendon, and rheumatoid arthritis. In most cases the etiology is mechanical. Leg length discrepancy should be ruled out with leg length tomography. A standing postural study only evaluates standing sacral base unleveling and femoral head heights. Both may be altered by pelvic rotation. In addition, total leg length may be equal, with discrepancies between the lengths of the femurs and tibias. This will significantly affect gait mechanics and alter plantar forces.

SEVER DISEASE (CALCANEAL APophysitis)

Calcaneal apophysitis is a condition where the apophysis at the insertion of the Achilles tendon becomes inflamed secondary to repetitive microtrauma from either elevated tensile forces or repetitive compression. It tends to be more common in boys than girls, and in children who participate in activities that require repetitive running and stopping, such as soccer, track and basketball. It typically presents between 8 and 16 years, when the two ossification centers of the calcaneus begin to fuse. There are two proposed mechanisms for the condition. Both involve microtrauma and microtears to either the Sharpey’s fibers inserting onto the apophysis or the apophysis itself. The patient complains of pain with weightbearing. A highly indicative sign is focal pain when the lateral and medial aspects of the calcaneus are squeezed together. Increased tone or tension in the gastrocnemius and soleus will exacerbate the condition. The goal of treatment is to reduce the tensile load on the tissues. Techniques to stretch the dorsiflexor muscles and fasciae, and to correct mechanical dysfunction in the hind and mid-
foot should be employed. Heel lifts may be used to shift the center of gravity forward and reduce the tensile load on the calcaneus. In severe conditions casting may be necessary. In general, recovery is slow and may take up to a year.

**TREATMENT OF THE FOOT AND ANKLE**

**Treatment Notes**

In the vast majority of chronic foot deformities, gait disturbances and developmental conditions in all age groups, it is necessary to treat all the structures of the foot to correct the problem. In children, the flexibility of the structural relationships allows for significant adaptive and compensatory changes to develop. The interrelatedness of the structures is so profound that it is extremely rare for any condition to localize to any one structure without creating compensatory changes throughout the entire unit. This is especially true in developmental and chronic problems, but may also be appropriately suitable in non-acute traumatic injuries and athletes. Obviously, specific approaches are more effective in certain conditions, but an overall rebalancing of foot biomechanics should be carried out in addition to the specific manipulation.

As a general rule, balanced ligamentous techniques are used in the treatment of congenital and chronic problems in all age groups, even in younger children. Articulatory and thrust techniques may be useful in the treatment of acute injuries in athletes and older children. As a rule, treatment of the hindfoot and ankle mortise should precede treatment of the forefoot. The hindfoot and ankle need to be treated as a functional unit. Typically, this area is addressed first because it is subjected to most of the compressive force entering the foot. The medial arch is treated next because its keystone, the navicular bone, influences both the medial and the transverse arches. This is followed by the transverse and lateral arches. The position of the metatarsals and phalanges is dependent on the arches, so they are addressed once the arches are treated. The plantar fasciae are typically left for last because the tensile forces on these tissues are determined by the functional relations of the aforementioned structures.
BALANCED LIGAMENTOUS TECHNIQUE

Calcaneus

Child

Depending on the size of the child, one of two hand positions can be used (see Alternate technique).

1. The patient is seated or supine with the knee extended.
2. The calcaneus is held in the palm of the physician’s hand with the fingers around it posterior and inferior to the malleoli. The other hand stabilizes the talus and the ankle mortise (Fig. 7.13).
3. A firm but gentle traction is placed on the calcaneus to decompress it from the talus and establish balanced ligamentous tension. Initially the traction is in a posterior inferior direction and then the vector is changed to anterior and superior, following the path described in Figure 7.14. Valgus, varus, eversion, inversion, supination, and pronation vectors are introduced to establish balanced ligamentous tension in the talocalcaneal, tibiocalcaneal, and calcaneofibular tissues.
4. Once balanced tension is established, the position is maintained until there is a change in tissue texture, a correction of the mechanical strain or an improvement in tissue function.
Alternate Hand Position

Athletes and Adolescents

1. The athlete or adolescent is seated or supine with the knee extended and the foot suspended off the table.

2. In athletes and adolescents the physician grasps the calcaneus inferior to the malleoli with the thenar eminences of both hands, interlacing the fingers around the posterior aspect of the heel (Fig. 7.15).

3. A firm but gentle traction is placed on the calcaneus to decompress it from the talus and establish balanced ligamentous tension. Initially the traction is in a posterior inferior direction, and then the vector is changed to anterior and superior following the path described in Figure 7.14. Valgus, varus, eversion, inversion, supination and pronation vectors are introduced to establish balanced ligamentous tension in the talocalcaneal, tibioalcaneal, and calcaneofibular tissues.

4. Once balanced tension is established, the position is maintained until there is a change in tissue texture, a correction of the mechanical strain or an improvement in tissue function.
DECOMPRESSSION BALANCED LIGAMENTOUS TECHNIQUE

Ankle Mortise and Talus (Talocrural Joint)

Supine Athlete

1. The patient is seated or supine with the knee extended. In an athlete or adolescent, the foot is suspended off the edge of the table.

2. The physician grasps the malleoli bilaterally, either between the index finger and thumb of each hand, or by hooking the knuckle of each index finger posterior to the malleoli (Fig. 7.16).

3. The physician places a firm but gentle traction on the malleoli in an anterior direction allowing the heel and foot to be suspended (Fig. 7.17) (gray arrow). The weight of the suspended foot places a natural posterior traction on the talus and calcaneus (stippled arrow). This counterbalances the anterior lift applied by the physician. A slight lateral vector is introduced into the malleoli through the posterior contact, which distracts the malleoli away from each other (black arrow).

4. This position is fine-tuned to achieve balanced ligamentous tension between the talus, tibia and fibula. Once balanced tension is established the position is maintained until there is a change in tissue texture, a correction of the mechanical strain or an improvement in tissue function.

5. Fibular dysfunction may need to be treated prior to the ankle mortise, especially in traumatic injuries such as inversion sprains.

6. There are instances when more decompression needs to occur at the talocrural articulation than can be generated by the suspended foot. To augment the decompression created by the weight of the foot, the physician can contact the sides of the calcaneus with the knuckles of the middle and ring fingers and provide an inferior traction by spreading the fingers that are contacting the calcaneus away from the thumbs, which are contacting the malleoli.

7. In infants and younger children, the physician may be tempted to grasp both malleoli with the thumb and fingers of one hand and the calcaneus with the other, similar to the position used for treatment of the calcaneus. However, this hand position creates compression across the distal tibiofibular articulation and interferes with the decompression used in this approach.
**COMPRESSION BALANCED LIGAMENTOUS TECHNIQUE**

**Talocrural Joint**

In traumatic injuries and in larger children and athletes there may be significant compression in the ankle mortise. Often these patients will not respond to decompression but need to be treated with compression.

1. The patient is prone with the knee flexed and the foot up. The physician stands beside the patient (Fig. 7.18).
2. The hand distal to the patient is placed over the plantar surface of the foot, grasping the calcaneus. The other hand wraps around the ankle so that contact is made with the distal end of the tibia.
3. With the foot in a neutral position the hand contacting the calcaneus introduces a firm but gentle compression towards the knee to engage the talus. At the same time the tibia is gently taken posteriorly.
4. Dorsiflexion, plantar flexion, inversion and eversion of the calcaneus and talus are introduced as the tibia is gently taken into internal and external rotation to achieve balanced ligamentous tension.
5. Once balanced tension is established, the position is maintained until there is a change in tissue texture, a correction of the mechanical strain or an improvement in tissue function.
BALANCED LIGAMENTOUS TECHNIQUE

Talocalcaneonavicular Joint

1. The patient is seated or supine with the knee extended and the calcaneus resting on the table or on the physician’s leg in a slightly dorsiflexed position. This stabilizes the calcaneus.

2. The physician reaches across the ankle mortise and contacts each malleolus and the tibia (Fig. 7.19). This creates a compressive force across the ankle mortise and stabilizes the talocrural joint. With the other hand, the physician reaches over the dorsum of the foot and wraps her fingers around the medial longitudinal arch, contacting the navicular and talus (Fig. 7.20).

3. With the lateral three fingers grasping the navicular, cuneiform and metatarsals, a gentle anterior traction is used to disengage the subtalar joint (gray arrow). The index finger and thumb of the two hands apply anterior, posterior, dorsiflexion, plantar flexion, inversion and eversion movements to the talus and navicular to achieve balanced tension in the talocalcaneonavicular joint (white arrows).

4. Once balanced tension is established, the position is maintained until there is a change in tissue texture, a correction of the mechanical strain or an improvement in tissue function.
SPRINGING/ARTICULATORY TECHNIQUE

Navicular and Medial Longitudinal Arch

1. The patient is seated or supine with the knee extended. The foot is resting on the table or off the table’s edge.

2. The physician sits alongside the patient's leg. The hand that is nearest to the patient's knee is positioned so that the forearm lies on top of the tibia. The talus and ankle are stabilized by the hypothenar eminence and the weight of the arm. The index finger is wrapped around the navicular (Fig. 7.21).

3. The other hand is placed across the dorsum of the foot with the index finger wrapped around the first cuneiform. The index finger contacting the navicular acts as a fulcrum. The cuneiform and forefoot are taken into pronation as the navicular is taken into supination until the restrictive barrier is engaged.

4. A short quick thrust is applied simultaneously with both hands in opposite directions, taking the navicular into supination and the cuneiform and forefoot into pronation (Fig. 7.22). This buckles the arch and allows the navicular to spring back into position.
**BALANCED LIGAMENTOUS TECHNIQUE**

### Navicular and Medial Longitudinal Arch

1. The patient is seated or supine with the knee extended and the foot resting on or suspended from the table. The physician sits beside the leg to be treated. The hand that is closest to the patient’s knee is positioned so that the arm rests on top of the distal leg, stabilizing the tibia and the ankle. The index finger grasps the talus (Fig. 7.23).

2. The other hand is placed across the dorsum of the foot, with the index finger grasping the navicular and the other fingers grasping the first cuneiform and metatarsal.

3. The cuneiform and metatarsal are tractioned anteriorly away from the navicular (gray arrow). Using opposing motions, the talus and navicular are alternately brought into supination, pronation, plantar and dorsiflexion, compression and decompression to achieve balanced ligamentous tension between the talus and navicular.

4. Once balanced tension is established, the position is maintained until there is a change in tissue texture, a correction of the mechanical strain or an improvement in tissue function.
BALANCED LIGAMENTOUS TECHNIQUE

Cuboid and Lateral Longitudinal Arch

In most patients the lateral arch is dysfunctional or flattened. In children it is generally the last arch to develop.

1. The patient is supine or seated with the knee extended and the foot resting on the table or the physician’s leg. The physician is positioned opposite to the side of the foot that needs to be treated. The hand proximal to the patient reaches across the leg and grasps the cuboid between the thumb and the index finger (Fig. 7.24).

2. The other hand reaches over the dorsum of the forefoot to grasp the fourth and fifth metatarsals along their entire lengths (Figs. 7.25 and 7.26).

3. The metatarsals are gently tractioned away from the cuboid (gray arrow) until a slight freedom of motion is perceived at the cuboid. Then the metatarsals are taken into adduction and supination as the cuboid is lifted superiorly (dorsally) and taken into pronation or supination to establish balanced tension (black arrows).

4. Once balanced tension is established, the position is maintained until there is a change in tissue texture, a correction of the mechanical strain or an improvement in tissue function.
DECOMPRESSIÓN

Transverse Arch and Second Cuneiform

The transverse arch usually becomes compressed and rigid as a result of poor foot mechanics or ankle trauma. Typically the middle cuneiform is wedged between the first and third cuneiforms. This packs the arch tightly, so that it loses what little flexibility it has. As a result, the forces entering the foot are transferred to the metatarsal heads. This can create pain at the ball of the foot or between the metatarsal bones. The second and third metatarsals are most often affected.

1. The patient is supine with the knee extended and the foot resting on the table. The physician sits facing the foot. The thumbs are placed on the plantar surface (Fig. 7.27) under the middle (second) cuneiform, with the fingers over the dorsum of the foot.

2. The thumbs lift the cuneiform as the fingers spread the transverse arch. This position is maintained until there is a tissue release. In older children positional cooperation can be employed and the child is asked to curl his toes down, thereby exaggerating the lift on the cuneiforms.

Fig. 7.27
BALANCED LIGAMENTOUS TECHNIQUE

Metatarsal–Cuneiform Articulation

Both the position and the function of the metatarsals are directly influenced by the transverse arch. Compression or dropping of the transverse arch produces flattening at the anterior arch and splaying of the metatarsal heads. With weightbearing, there is increased pressure on the plantar surfaces of the proximal part of the metatarsals. The splaying causes curling of the toes. The line of gravity is shifted laterally in the foot, increasing pressure between the second and third metatarsals, and often causing pain in the lumbrical muscles.

Elevation of the transverse arch can result from wearing rigid orthotics or from trauma to the plantar surface of the foot. When the arch is elevated, the second cuneiform is compressed between the first and third cuneiforms. The medial and lateral arches may appear to be intact, but they are inflexible. There is increased pressure on the heads of the metatarsals, especially the first, with weightbearing, which may result in a flexor hallucis longus tendonitis.

1. The patient is supine or seated with the knee extended. The physician grasps the proximal metatarsal between the thumb and index finger of one hand and its articulating cuneiform with the other (Figs 7.28, 7.29 and 7.30). For the fourth and fifth metatarsals, the cuboid is contacted.

2. Balanced ligamentous tension is established at the articulation by simultaneously introducing vectors of motion into the metatarsal and the articulating bone. Figure 7.26 demonstrates treatment of the first metatarsal. The metatarsal is gently taken into supination, pronation, abduction, adduction, plantarflexion and dorsiflexion as the cuneiform is rotated and translated.

3. Once balanced tension is established, the position is maintained until there is a change in tissue texture, a correction of the mechanical strain or an improvement in tissue function.

4. In older children this same handhold can be used to apply an articulatory force into the joint to establish correction.
THE USE OF FOOT ORTHOTICS

Clinical Notes

Orthotic devices can be very useful to support the foot in a physiological position and in reinforcing proper mechanics. In general, for ambulating children the author prefers orthotics with some flexibility. Whereas the foot seems to mold passively to a rigid orthotic, orthotics made of polypropylene or some other flexible material encourage some degree of movement between the structures of the foot. It is normal for a few degrees of pronation to occur when one moves from heel-strike to midstance position and there is a minimal amount of pronation in the forefoot which occurs at terminal stance. Rigid orthotics often prevent this natural change to the medial arch and forefoot. Many rigid orthotics are cast with the subtalar joint in a neutral position. In recent years some controversy has arisen around this positioning. The subtalar neutral position is only present for a short time. In general, for ambulating children the author prefers orthotics made of polypropylene or some other flexible material to encourage some degree of movement between the structures of the foot. It is normal for a few degrees of pronation to occur when one moves from heel-strike to midstance position and there is a minimal amount of pronation in the forefoot which occurs at terminal stance. Rigid orthotics often prevent this natural change to the medial arch and forefoot. Many rigid orthotics are cast with the subtalar joint in a neutral position. In recent years some controversy has arisen around this positioning. The subtalar neutral position is only present for a short time.

Although orthotics are typically considered for overpronation of the medial arch, all three arches should be addressed by any orthotic placed in the shoe. In children, orthotics should be used as an adjunct to manipulation and rehabilitation in all but the most extreme cases. All too often orthotics turn into a crutch that allow the child's foot and leg to become deconditioned and lose any functional capacity it once had. The younger the child, the better the chances are for optimizing functional capacity. This is an important consideration in children with spasticity who are placed in ankle foot orthotics with locked ankle position. The combination of a locked ankle position and a rigid foot orthotic forces the child to adapt to postural perturbations at the knee, hip and pelvis. This produces greater sway and torque, leading to instability.

The hindfoot also needs to be taken into account when using orthotics. A well-structured heel cup that stabilizes the calcaneus in a neutral position is important to encourage a neutral heel when the child has a calcaneal displacement, tibial torsion or genu deformity. Owing to the flexibility of the pedal structures, younger children will often accommodate dysfunction in the tibia, knee or hip by altering the placement of the foot. For example, toddlers with untreated internal tibial torsions or genu valgus may compensate by shifting their weight medially and creating a rearfoot valgus. If these developmental deformities are not addressed, the child will 'grow into' the pattern through training of muscle firing patterns, resting muscle lengths and bone growth adaptations. The foot adaptation reinforces the dysfunction of the leg and hip and a cycle of adaptation is created. This cycle can often be interrupted by an orthotic that supports the correct rearfoot position until the dysfunctions of the leg and hip are resolved.

Good foot orthotics will affect more than the feet: changes will occur throughout the legs, pelvis and spine. The characteristics of the orthotics are determined by appropriate foot measurements and gait assessment. However, the clinician will still need to evaluate the effect of the orthotics on the child's posture and balance to determine whether or not they are appropriate. Proper fit can be assessed by viewing the child while he is standing in the orthotics. The Achilles tendon should lie in the midline of the leg without valgus or varus deviation. The tibias should be in a slightly externally rotation position, the femurs slightly internally rotated but not aneverted, and the pelvis neutral. Standing leg lengths, iliac crest heights, PSIS and ASIS landmarks should be symmetrical and equal, assuming there is no leg length difference. There should be no innominate rotation, and the standing flexion test should be negative. On forward bending evaluation there should be a decrease in a rib asymmetry. In some children, the functional component of a scoliosis can be corrected with proper foot orthotics. On lateral view there should be a direct line between the ear, shoulder, hip and ankle. On anterior view, the line of gravity from the hip should pass through the center of the leg and ankle, lying between the first and second metatarsals. Postural stress testing should demonstrate good balance and symmetry.

Obviously, regardless of the thickness of the orthotic, it is imperative that any patient requiring an orthotic wears one in both shoes. Even the thinnest orthotic will create innominate rotation, pelvic imbalance and sacral unleveling unless an orthotic of identical thickness is worn in the contralateral shoe.
TRAUMATIC INJURIES

ANTERIOR TIBIA ON TALUS

Clinical Notes
This injury typically occurs in athletes wearing cleated shoes. The athlete suddenly stops while running, the foot is locked into position by the cleat, but the momentum of the body carries the athlete forward. This mechanism can also result in a posterior tibia on the femur, and if the force is strong enough, can cause injury to the posterior cruciate ligament. If the primary problem is the anterior tibia on the talus, then the athlete will complain of discomfort in the anterior aspect of the ankle and foot with dorsiflexion. The pain typically presents with running, climbing stairs, and at the end of the stance phase of gait. Compared to the contralateral ankle, passive and active range of dorsiflexion will be reduced and movement in other planes will be restricted when the ankle is dorsiflexed. There is often tenderness over the anterior aspect to the talus and tender points in the gastrocnemius and soleus muscles.

TREATMENT
Thrust Technique

Talocrural Joint

1. The patient is prone with the knee flexed and the foot up. The physician stands beside the leg and grasps the tibia with the hand closest to the patient's hip (Fig. 7.31).
2. The other hand grasps the calcaneus. The physician's wrist and forearm are placed along the plantar surface of the foot. The physician uses her forearm to dorsiflex the ankle to the restrictive barrier.
3. A firm but gentle thrust is employed with both hands simultaneously. The plantar hand takes the foot in an arc towards dorsiflexion, and the hand on the tibia brings the distal tibia posteriorly. There should be an improvement in dorsiflexion and resolution of the tenderness.

Fig. 7.31
Thrust Technique

Talocrural Joint

1. The patient is supine with the knee extended. The physician stands beside the leg to be treated. The proximal hand is placed over the ankle mortise as close to the talus as possible (Fig. 7.32).

2. The distal hand is placed under the heel. This hand cups the calcaneus while the wrist and forearm lie alongside the plantar surface of the foot.

3. A gentle pressure is used to push the tibia towards the table, as the foot is dorsiflexed to the restrictive barrier. A short firm impulse is employed to dorsiflex the ankle through the restrictive barrier as the tibia is simultaneously taken posteriorly (into the table).

Balanced Ligamentous Technique

Talocrural Joint

1. The patient is prone with the knee flexed and the foot elevated. The physician stands alongside the involved ankle. Similar to the articulatory technique, the proximal hand grasps the tibia and the distal hand grasps the heel with the wrist and forearm along the plantar surface (see Fig. 7.16).

2. A firm but gentle compression is placed into the subtalar joint until a slight increase in freedom of motion is perceived. If too much compression is used the joint will lock. The compression should create slack in the surrounding tissues, not engage the joint.

3. The tissues of the talocrural and subtalar joints are brought into balanced tension through the movements of the tibia and the foot. The tibia is internally and externally rotated and translated anteriorly and posteriorly. Abduction, adduction, inversion, eversion, plantar and dorsiflexion are introduced simultaneously into the subtalar and talocrural joints.

4. Once balanced tension is established, the position is held until there is a change in tissue texture, an improvement in tissue function or correction of the strain occurs.
The talocrural joint is more stable in dorsiflexion owing to lateral rotation and plantar flexion with medial rotation. The movement of the talus at the ankle mortise involves dorsiflexion with the navicular. Consequently, normal function of the joints: one with the ankle, one with the calcaneus and one with the navicular. The movement of the ankle is transmitted through the tibia to the dome of the talus and then into the foot. The talus forms three important joints: one with the ankle, one with the calcaneus and one with the navicular. In plantar flexion only the posterior aspect of the talus dome comes in contact with the tibia, and stability depends more on the surrounding ligaments than the bony mechanics.

In an inversion sprain the talus is plantarflexed and supinated as the weight descends onto the foot. This is the most vulnerable position for the talus. Its articulation with the ankle mortise is open, allowing for medial rotation and anterior displacement. The lateral collateral ligaments are under the greatest strain in this position, especially the anterior talofibular and calcaneofibular components. Inversion sprains can be graded by the degree of injury to the ligamentous structures. Minimum tearing of the anterior talofibular ligament is considered a grade 1 sprain. It presents as mild localization swelling, point tenderness and restricted motion. There is usually no ecchymosis. Grade 1 sprains usually occur when most of the injury is sustained in the plantarflexed position. With excessive supination the calcaneofibular ligament is stressed. Grade 2 sprains involve tearing or rupture of the anterior ligament and partial tearing of the calcaneofibular ligament. There is generalized swelling ecchymosis and tenderness over the lateral malleoli and lateral aspect of the hindfoot. The articular capsule may also be injured. The patient will have pain with weightbearing and be unable to stand on the affected foot. There may be some instability with passive testing. Grade 3 sprains occur when both the anterior and lateral ligaments are ruptured as well as the capsule. The patient is unable to bear weight. The lateral foot and ankle are diffusely swollen, ecchymotic and tender. There is obvious instability with passive testing. Anterior drawer sign will be positive if the anterior talofibular ligament has been ruptured. If it has been strained, the patient will complain of pain and there may be guarding. The talar tilt test evaluates calcaneal inversion. The foot is slightly plantarflexed and the heel inverted. The motion is compared with the contralateral leg. In grade 3 sprains the talar tilt and anterior drawer test will be positive. In grade 2 sprains the talar tilt test will result in pain but no instability if the ligament is still intact. Fractures need to be ruled out in younger children because of the vulnerability of the epiphyseal plate. The two most common fractures in inversion ankle sprains are Salter–Harris and avulsion type. The child with a fracture will have exquisite point tenderness over the site.

Inversion sprains create primary dysfunction at the subtalar and talocrural joints and secondary dysfunction in other areas. With an inversion sprain, the talus is drawn anteriorly and rotated medially, the calcaneus inverts and the transverse arch is bowed. The fibula is brought posteriorly by the stretch on the peroneus longus, and the tibia may rotate laterally. The displacement of the talus affects the subtalar joint and drops the medial longitudinal arch. The momentum of the forward-moving body collapsing the foot often creates a fascial strain extending into the pelvis, thoraco-lumbar fascia and contralateral rib cage (Blood 1980).

### Treatment Notes

The treatment sequence will depend on the chronicity and severity of the injury. However, correction of the talus, calcaneus and fibula is imperative to facilitate normal function.

In general, the displaced or strained talus can be treated immediately after injury by a trained and qualified clinician. Once the inflammatory phase begins, the treatment sequence often changes because the presence of the edema restricts the ligamentous tissues and can significantly limit joint mobility.

In the first 24 hours after the injury, elevation and compression are important. If the physician has the opportunity to see the patient in the immediate post-injury period and the ankle is stable, correction of the talus and calcaneus can improve the patient’s condition significantly. If there is any instability of the ankle, correction of the talus should be reserved for those physicians trained and qualified to perform joint reduction. Instead, manipulative treatment should be directed at improving venous drainage and arterial flow to facilitate wound healing. Venous and lymphatic drainage may be improved by addressing the junctional areas of the torso, the pelvic diaphragm and the popliteal fossa. The use of anti-inflammatory medication for pain management is somewhat controversial because of its suppressive...
effects on connective tissue healing. Assisted weightbearing with a crutch or cane is prudent, even in grade 1 sprains, because the distorted proprioceptive input from the area can lead to temporary balance issues.

In patients with grade 1 and 2 injuries management will depend on the severity of the injury at presentation. The sequence of treatment of the primary and secondary strains is based on the level of discomfort. Commonly, once the initial inflammatory response has occurred, pain and swelling often make it difficult to mechanically address the primary strain in the subtalar and talocrural joints. In these cases, initial treatment goals should include lymphatic drainage, relieving muscle spasm and correcting secondary strains. This can be done by treating the junctional areas of the spine, the rib cage, the pelvis, popliteal fossa, peroneus and fibula. Gentle passive techniques such as BLT, passive range of motion and FPR can be introduced after the first 24–36 hours. Venous and lymphatic drainage techniques, elevation and compression should continue to be employed. As the edema improves, it becomes easier to address the foot mechanics. In general, patients should begin non-weightbearing range of motion exercises on the day after the injury. A very comfortable manner in which to begin this process is to have the patient soak the foot and ankle in a cool bath while slowly moving them through the full range of motions. Such motions should include abduction, adduction, flexion, extension, inversion and eversion, as well as more subtle movements to stimulate proprioception, such as outlining the letters of the alphabet with her foot. This should be done without a wrap or compression, and it should be painless. Pain should not be ignored. The patient should rehabilitate the ankle within the confines of painless activities only. In young adolescents, persistent pain with non-weightbearing may be indicative of occult fracture. As soon as possible the patient should progress to exercises against controlled resistance, such as riding a stationary bicycle. Again, this should be painless. Depending on the extent of tissue damage, sometime between the first and third weeks after the injury, the patient should begin weightbearing exercises such as side-stepping, climbing stairs, stepping backwards, rising on toes, rising on heels. Complaints of stiffness are typical, but the exercises should be modified if there is pain.

In patients with grade 3 injuries, casting or rigid bracing is usually necessary. Initial osteopathic management should focus on facilitating arterial, venous and lymphatic flow to support tissue healing and treating other areas of the body affected by the abnormal gait and use of crutches. The thoracolumbar and lumbar junctions, the rib cage, thoracic spine, shoulders, and thoracic inlet are common areas of dysfunction due to the walking cast or crutches. Strains involving the fibular head, tibia, peroneus, biceps femoris and innominate are usually secondary to the injury and should be treated using gentle techniques. From an osteopathic perspective, removing the secondary strains facilitates the body’s natural healing ability and assists repair at the site of injury. The patient should be re-examined at least weekly to maintain function in these areas. Towards the end of the second week, the mechanics of the foot may be gently addressed. Again, begin away from the talus, freeing and rebalancing the structures surrounding it. Articulatory, thrust and muscle energy techniques are contraindicated in unstable ankles, with one exception: a trained and qualified clinician may perform manipulative adjustment for specific reduction of a displaced or dislocated structure. Gentle balancing, unwinding or myofascial techniques can be used to treat the calcaneus, the distal fibula, the navicular and distal tibia. Once there is some freedom in the structures surrounding the subtalar and talocrural joints, treatment can be directed at the mechanical strain or displacement of the talus. The specific technique chosen will depend on the feel of the tissue, the age of the patient, patient comorbidities and practitioner preference. It may take the unstable ankle 3 or more weeks to achieve sufficient ligamentous integrity to perform non-weightbearing range of motion exercises, which should begin as soon as is appropriate. Use of a water bath provides some passive resistance. The same types of motions should be employed as described for milder sprains. Muscle atrophy is a problem in the cast leg, and patients benefit from both isometric exercises and visualization movements while still in the cast.

In patients with chronic or recurrent ankle problems after an ankle sprain the problem is often related to non-reduction of the talus dysfunction coupled with compensatory adaptations in the midfoot and calcaneus. In these patients, the talus may still have some component of planter flexion, medial rotation or supination remaining after the sprain has healed. The calcaneus and navicular have to adapt to the subsequent shift in the placement of weight. Typically the calcaneus was inverted by the injury, so contact on heel-strike is displaced laterally. The patient compensates by over-pronating the forefoot. The medial longitudinal arch may be flat with standing, but sometimes the pronation is only present with ambulation. The calcaneus often shifts posteriorly, placing more stress on the plantar tissues. Myofascial restriction extending through the peroneus–biceps femoris mechanism may further complicate the biomechanical picture with lumbar, pelvic and sacral dysfunctions. In addition to normalizing foot mechanics, these other areas need to be addressed with a combination of manipulation, proprioceptive retraining and rebalancing and strengthening exercises.
Myofascial Milking Technique

Athlete

A general rule in all fluid, lymphatic and fascial milking techniques is to treat the most proximal areas first, then move distally. In all cases, the junctional areas of the spine should be treated before the extremity. This technique was also described in the treatment of compartment syndrome and shin splints; whereas in those conditions the palpatory focus is the compartment and the pressure is very light, in the case of foot and ankle edema the palpatory focus is more superficial but the pressure applied is increased.

1. The patient is supine. The physician stands contralateral to the leg to be treated. The lower leg (inferior to the knee) is visually divided into thirds. Beginning at the most distal end of the most proximal third, the physician contacts the tissues with both hands.

2. Using both hands, the physician employs a gentle kneading motion moving in a distal to proximal direction within that proximal third of the lower leg (Fig. 7.33). This is repeated twice.

3. Then the physician moves her hands to the distal end of the middle third of the leg (Fig. 7.34). Working in a distal to proximal direction the physician employs a gentle kneading motion with both hands noting any change in tissue texture. This is repeated twice.

4. The physician then moves her hands to the distal end of the distal third of the lower leg (Fig. 7.35). Working in a distal to proximal direction, the physician employs a gentle kneading motion with both hands, noting any change in tissue texture. This is repeated twice.

5. The entire sequence may be repeated two to three times until a change in tissue texture or an improvement in tissue function is noted.
HIGH-VELOCITY LOW-AMPLITUDE TALOTIBIAL/INVERSION SPRAIN

The patient often complains of pain with dorsiflexion and loading, there is tenderness at the anterior aspect of the talotibial junction, and dorsiflexion is limited on active and passive testing.

1. The patient is supine with the hips and knees extended. The physician sits at the patient’s feet. The physician’s hands are clasped over the dorsum of the foot with the thumbs on the plantar surface (Fig. 7.36).

2. The physician dorsiflexes and everts the foot to engage the restrictive barrier.

3. A short, quick impulse introducing traction, dorsiflexion and eversion is applied to the foot to reseat the talus in the ankle mortise.
THRUST TECHNIQUE FOR A POSTERIOR FIBULAR HEAD

This technique is also described in Chapter 6, on the Lower Leg. It is repeated here because it should be done following the reseating of the talus in patients with inversion ankle sprains. This is especially true if there is tenderness at the posterior margin of the fibular head or restricted motion of the fibula with ankle dorsiflexion and plantar flexion.

1. The patient is supine with the hip and knee flexed.
2. The physician places the metacarpophalangeal joint of the first and second fingers posterior to the fibular head. The other hand grasps the distal end of the tibia and fibula (Fig. 7.37).
3. The knee is flexed to the barrier while maintaining contact with the fibular head.
4. Simultaneously the physician employs two short, firm thrusts. One brings the patient’s foot towards the ischial tuberosity (white arrow) and the other (black arrow) moves the fibular head anteriorly.
References

