Flatfoot Deformity in Children and Adolescents: Surgical Indications and Management

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Abstract

Most children with flatfeet are asymptomatic and will never require treatment. In general, flatfoot deformity is flexible and will not cause pain or disability; it is a normal variant of foot shape. Thus, it is essential to reassure and educate patients and parents. A flatfoot with a contracture of the Achilles tendon may be painful. In these cases, a stretching program may help relieve pain. Scant convincing evidence exists to support the use of inserts or shoe modifications for effective relief of symptoms, and there is no evidence that those devices change the shape of the foot. The surgeon must be vigilant to identify the rare rigid flatfoot. Indications for flatfoot surgery are strict: failure of prolonged nonsurgical attempts to relieve pain that interferes with normal activities and occurs under the medial midfoot and/or in the sinus tarsi. In nearly all cases, an associated contracture of the heel cord is present. Osteotomies with supplemental soft-tissue procedures are the best proven approach for management of rigid flatfoot.

Although flatfoot deformity is a common reason for a child to present for evaluation by a healthcare provider, understanding of the deformity and consensus regarding its management is poor, particularly among healthcare providers in different medical specialties. This is due to several factors, including the poor methodology of published reports, the lack of controlled research studies, and conflicting evidence in the literature. Studying the natural history of the flatfoot is difficult because most affected patients are asymptomatic and do not seek medical attention. Moreover, because no established clinical or radiographic criteria exist to define the flatfoot, the true prevalence of the deformity is unknown. Traditionally, flatfoot was described as a low or absent medial longitudinal arch, with the hindfoot in excessive valgus alignment. The present consensus is that flexible flatfoot is present from birth and exhibits good joint mobility and normal muscle function. Despite the lack of high-quality research, it is clear that most flatfoot deformities in children are flexible, painless, and functional and do not require treatment. Children with a painless flatfoot who visit an orthopaedist are generally brought in because their parents are concerned that the foot deformity will cause pain and/or disability in adulthood. The role of the orthopaedist is to reassure patients and parents of children with flexible flatfeet that no treatment is necessary and to identify and treat the rare flatfoot deformities that may become disabling.

In their 1947 study of foot pathology in 3,600 Canadian soldiers, Harris and Beath reported that flatfeet were seen in approximately 23% of the recruits. Sixty-four percent of flatfeet were...
flexible and were rarely the cause of pain or disability. The authors concluded that a flexible flatfoot was within the spectrum of normal. Flexible flatfoot with a short Achilles tendon and rigid flatfoot accounted for the remaining flatfeet, and these deformities sometimes led to pain and disability.

**Epidemiology**

The literature suggests that the prevalence of flatfoot deformity varies with age, sex, body weight, and ethnicity. In general, the incidence of flatfoot in adults is at least 20%. Most infants, however, are born without a medial longitudinal arch. According to Staheli et al., in most children, the arch develops naturally by the middle of childhood (approximately age 5 years). In a study of 835 school children in Austria, Pfieffer et al. reported that 54% of children aged 3 years had a flatfoot deformity, whereas only 24% of children aged 6 years had flatfeet. The overall prevalence of flexible flatfoot deformity was 44%, and <1% of children had rigid flatfoot. The authors also found that boys were twice as likely as girls to have a flatfoot deformity, and children who were obese were three times as likely as those with a healthy weight. The authors’ results are within the range of prevalence reported in earlier studies in which flatfoot was seen in as many as 70% of children aged 3 to 4 years and as few as 9.1% of children aged 7 years. In a recent Cochrane review, Evans and Rome estimated that flatfoot deformity affects approximately 45% of preschool children and 15% of older children (average age, 10 years). The authors also noted a higher prevalence of flatfoot in obese children and those with generalized joint hypermobility. Dowling et al. and Bordin et al. also reported a higher incidence of flatfoot in obese children.

Ethnicity may also play a role. Mann noted a higher incidence of flatfoot deformity in blacks than in Caucasians. Studies of specific populations (eg, Chinese), have also suggested that consistently shod feet are more likely to develop flatfoot deformities. These findings do not support the tendency to prescribe shoe inserts and braces for correction of the flatfoot shape.

In all of the previously mentioned papers, most of the patients with flatfoot deformities were asymptomatic.

**Pathogenesis and Natural History**

In the literature, there are two main theories that explain the development of flexible flatfoot deformity. Duchenne, Jones, and others believed that maintenance of the longitudinal arch was based on muscle strength. However, Basmajian and Stecko believed that the height of the arch was determined by the ligament complex. They provided evidence that muscles function to maintain balance, propel the body forward, and navigate uneven terrain but do not determine the shape of the foot.

Based on their study of Canadian soldiers, Harris and Beath subdivided flatfeet into three types. Flexible flatfoot, which represented two thirds of the total flatfeet, was characterized by full range of motion of the ankle and subtalar joints and rarely causes symptoms or disability. Flexible flatfoot with a short Achilles tendon accounted for 27% of the flatfeet and was characterized by restricted ankle dorsiflexion. Patients with this deformity often report pain. Finally, rigid flatfoot was characterized by decreased subtalar joint motion and was present in 9% of all flatfeet in the study. This deformity is most commonly associated with tarsal coalitions (TCs) and is occasionally symptomatic.

**Evaluation**

**History**

A careful history must be taken to determine the reason for the consultation. Often, the concern about flatfoot is purely cosmetic or anxiety exists regarding possible problems in the future. If a patient presents with symptomatic flatfoot, the orthopaedist must elicit the child’s birth history, medical history, family history, onset and location of pain, pain triggers and relievers, difficulty with shoe wear, skin problems, functional disability, and the results of any attempted treatment.

Rigid or pathologic flatfoot may be associated with paralytic or neuromuscular conditions such as cerebral palsy and myelomeningocoele, congenital deformities such as a TC or accessory navicular, and intrauterine positional consequences such as calcaneovalgus. Flatfoot is also part of the spectrum of deformity associated with skewfoot deformity. Flexible flatfoot and generalized ligamentous laxity can be familial; therefore, obtaining a thorough family history is essential.

Locating the pain and its precipitating causes can be helpful in determining the type of the flatfoot deformity. When painful, flexible flatfeet are typically sore under the plantarmedial aspect of the midfoot and, occasionally, at the sinus tarsi. This is especially true in patients with a concomitant contracture of the Achilles tendon. In patients with rigid flatfeet, pain can occur in multiple areas, including the medial hindfoot, the sinus tarsi and, occasionally, the plantarmedial aspect of the midfoot. In patients with flexible flatfoot, pain is typically related to activity, although this is also true of rigid flatfoot. Night pain as well as swelling, warmth, and redness are unusual in flexible and rigid flatfoot. Indications for surgery include intractable pain and disability that do not respond to nonsurgical.
treatment; thus, obtaining a detailed history is an important part of flatfoot assessment.\textsuperscript{1,14}

Clinical Examination

A physical examination of the child is performed, with particular attention paid to the lower extremities. The orthopaedist should focus on torsional and angular variations in the lower extremities gait patterns, ligamentous laxity, and signs of related medical conditions (eg, Marfan syndrome, Down syndrome, other connective tissue disorders).\textsuperscript{1} Although there is no association between flexible flatfoot and developmental dysplasia or dislocation of the hip, a focused examination of the hip should be performed as a routine part of the physical examination in an infant who is being evaluated for flatfoot or any other musculoskeletal deformity.

It is important to assess the overall shape of the foot. A flexible flatfoot will have a low or absent longitudinal arch and hindfoot valgus and may have mild abduction of the midfoot. Infants will have a flat arch in all positions. By walking age, children with flexible flatfoot will appear to have an arch when sitting with the foot dangling and a flat arch when weight bearing. In patients with a physiologic flexible flatfoot, the medial longitudinal arch will elevate, and the hindfoot valgus will change to varus when standing on the toes (Figure 1). In patients with a rigid flatfoot, the arch will be flat, and the hindfoot will remain in valgus whether the foot is dangling or weight bearing and during toe standing.\textsuperscript{1}

Determining whether a heel cord contracture is present is essential because this deformity can help the orthopaedist differentiate between asymptomatic flexible flatfoot and the frequently symptomatic flexible flatfoot with a short Achilles tendon.\textsuperscript{1} To clinically identify a tight heel cord that limits ankle dorsiflexion, the Silfverskiold test is performed (Figure 2). The position of the hindfoot is important. The subtalar joint must be inverted to neutral and held locked in that position to isolate and assess the motion of the talus in the ankle joint. The knee is flexed, and the ankle is dorsiflexed while neutral alignment of the subtalar joint is maintained. Dorsiflexion is measured as the angle between the plantar lateral border of the foot and the anterior tibial shaft. Dorsiflexion of $<10^\circ$ indicates contracture of the soleus muscle, which indicates a contracture of the entire Achilles tendon. The orthopaedist then extends the knee while maintaining
neutral alignment of the subtalar joint and trying to maintain dorsiflexion of the ankle joint. Dorsiflexion is again measured as the angle between the plantarlateral border of the foot and the anterior tibial shaft. If dorsiflexion $>10^\circ$ is possible with the knee flexed, but $<10^\circ$ of dorsiflexion is possible with the knee extended, a contracture of the gastrocnemius muscle alone is present.

The shoes and any inserts or braces should also be examined. Asymmetric medial wear of the sole of the shoe is common in the patient with flexible flatfoot. Medial wear at the heel of the shoe is most common. When the Achilles tendon is tight, wear is typically seen at the medial midfoot.\(^1\)

**Imaging**

Radiography is not indicated when evaluating patients with asymptomatic physiologic flexible flatfoot,\(^1,14\) but it may be required for assessment of a painful and/or rigid flatfoot. In these cases, radiographic evaluation should include weight-bearing AP and lateral views of the foot and an AP view of the ankle. An oblique view of the foot and a Harris axial view of the hindfoot can be ordered if there is concern for a TC. This view can provide an inexpensive and quick (although not definitive) assessment of the subtalar joint. If the physical examination and Harris view raise concern for a possible talocalcaneal TC, then CT can be performed for a more definitive evaluation.\(^1\) Several studies have attempted to determine which radiographic measurements are most useful to diagnose flatfoot and to assess the adequacy of surgical reconstruction. The most commonly used and validated angles are the calcaneal pitch, the talus-first metatarsal angle on AP and lateral views, and talonavicular coverage\(^14,15\) (Figure 3).

In the literature, normal values for these angles vary and no clear consensus exists regarding what constitutes abnormal values. Meary\(^16\) believed that a foot with a normal longitudinal arch should have an angle of $0^\circ$ from the axis of the talus and the axis of the first metatarsal on both the AP and lateral views.\(^1\) However, Davids et al\(^15\) showed that these angles vary (mean of $10^\circ$ in the AP plane and $13^\circ$ in the lateral) even in normal feet. Davids et al\(^15\) also reported that the normal calcaneal pitch angle was an average of $17^\circ$ and talonavicular coverage was $20^\circ$.

Advanced imaging is rarely indicated for assessment and/or management of flatfoot deformity, with the exception of TC. CT can better delineate the extent and exact location of the coalition, the health of the remainder of the subtalar joint, and the degree of hindfoot deformity.\(^17-20\) (Figure 4).

**Management**

**Nonsurgical**

Children with flexible or rigid flatfoot who experience pain or have difficulty with shoe wear require treatment. A small number of uncontrolled studies have suggested that shoe modifications,
arch supports, and orthoses can create a longitudinal arch in a flatfoot.21,22 Others have refuted the effectiveness of these devices in creating a longitudinal arch.23-24 In a prospective, randomized study, Wegner et al24 demonstrated no treatment effect or permanent elevation of the arch associated with the use of shoe modifications and orthoses in otherwise normal children compared with an untreated matched cohort at a minimum follow-up of 3 years. Intrinsic muscle strengthening exercises also have no effect on the height or development of the longitudinal arch.25

Uncontrolled and controlled studies have reported on alleviation of pain with the use of certain types of arch support.22-24 In the patient with a supple flatfoot deformity, inversion of the hindfoot may unload pressure points and decrease exaggerated muscle activity, thereby reducing pain.14 A recent Cochrane review by Evans and Rome6 reported that the pediatric flatfoot was often unnecessarily treated. With the lack of evidence to support the use of orthoses, the authors recommended the use of inexpensive, over-the-counter devices on the rare occasions that they are indicated for ongoing symptoms. The use of custom orthotics and shoes should be reserved for patients with arthritis or those who are unresponsive to other nonsurgical treatments, including over-the-counter orthotics.26 However, in a patient with a rigid flatfoot deformity or flexible flatfoot with a short Achilles tendon, using these devices is likely to worsen symptoms.1,26 As the orthosis or shoe attempts to invert the rigidly everted subtalar joint or dorsi-flex the rigidly plantar-flexed ankle joint, increased pressure is concentrated under the medial midfoot, which exacerbates the pain.5

If the flexible flatfoot deformity is accompanied by a tight Achilles tendon, the child may benefit from a stretching program.1 The child and parents can learn the program and perform it daily at home. It is important to instruct them in techniques to ensure that the forefoot is supinated and the hindfoot is inverted to neutral during the heel cord stretch. This can prevent injury to the midfoot and false dorsiflexion through the subtalar joint, respectively.1,14

Surgical

Evans and Rome6 concluded that surgery was rarely indicated for pediatric flatfoot. In the patient with flexible flatfoot, surgery is indicated after failure of prolonged nonsurgical attempts to relieve pain that occurs under the medial midfoot and/or in the sinus tarsi and that interferes with normal
activities.\textsuperscript{1,6,14} In nearly all cases, an associated contracture of the heel cord is present.\textsuperscript{1} Surgery should rarely be performed in early childhood.\textsuperscript{3}

Soft-tissue procedures such as tendon transfers, plications, and isolated Achilles tendon lengthening are rarely successful.\textsuperscript{1,14} Arthrodesis, either talonavicular or subtalar (triple), will realign the foot but will significantly reduce mobility, eliminate the shock absorbing function of the foot, and increase the risk of developing arthritis in adjacent joints.\textsuperscript{27}

Arthroereisis is a technique that attempts to correct the flatfoot by restricting excessive subtalar eversion with a synthetic, metal, or bone implant inserted into the sinus tarsi. Outcomes of the procedure have been poorly studied. Advocates suggest that it is minimally invasive and preserves subtalar joint motion, whereas opponents are guarded about the long-term effects of placing a foreign body that restricts motion into the subtalar joint.\textsuperscript{6} The reported rate of complications, including undercorrection and overcorrection, implant resorption, inflammatory reactions, and persistent pain, has been as high as 30\%\textsuperscript{1} (Figure 5). At this time, insufficient evidence exists to define the indications for arthroereisis or support its use.\textsuperscript{1,6}

Osteotomies, which can realign the foot without sacrificing mobility or risking the development of early arthritis, have become the mainstay of surgical management of flexible flatfoot deformity.\textsuperscript{28} Several types of osteotomies have been described, although two techniques have become popular: calcaneal lengthening osteotomy (CLO) and calcaneo-cuboid-cuneiform (triple C) osteotomy.

CLO was originally described by Evans.\textsuperscript{29} This surgical procedure corrects all of the components of valgus/eversion deformity of the hindfoot at the site of the deformity. A long-term follow up study performed at Evans’ institution confirmed the efficacy of this approach.\textsuperscript{30} However, because the description of the technique was terse, poor outcomes were often achieved by others who attempted to perform the procedure. The technique was interpreted, modified, and further developed by Mosca,\textsuperscript{14} who described the strict indications for the procedure, the specific location of the osteotomy, and the shape of the bone graft (Figure 6). In addition, the author described the management of the medial and lateral soft tissues, the need to temporarily stabilize the calcaneocuboid joint, and the need to assess and concurrently manage rigid forefoot supination deformity and contracture of the Achilles tendon or gastrocnemius muscle. Recognition and concurrent management of coincident forefoot deformity and heel cord contracture are critical components of the procedure. The Silfverskiöld test is performed after correction of the hindfoot deformity to determine whether the Achilles tendon or the gastrocnemius muscle alone should be lengthened. Consistently good results, with satisfaction rates as high as 93.5\%, have subsequently been reported.\textsuperscript{1,14} Similar results have been achieved with the use of autograft or allograft.\textsuperscript{28,31}

Rathjen and Mubarak\textsuperscript{32} developed the triple C osteotomy. It consists of sliding and medial closing wedge osteotomies of the posterior calcaneus, a plantar-based closing wedge osteotomy of the medial cuneiform, and an opening wedge osteotomy of the cuboid. This technique creates deformities of the hindfoot/midfoot to compensate for the valgus/eversion deformity of the hindfoot rather than correcting the deformity. A recent prospective study by Moraleda et al.\textsuperscript{28} compared this osteotomy with CLO (as described by Mosca\textsuperscript{14}) after nonsurgical interventions failed in symptomatic pediatric patients with flexible flatfeet. The authors reported that both techniques achieved good clinical and radiographic outcomes. CLO produced significantly better correction of the subluxated navicular on the head of the talus (talonavicular coverage on an AP radiograph) and improvement of the talus-first metatarsal angle on the AP view, but the procedure was associated with a marginally higher rate of complications. Most of these complications were related to subluxation of the calcaneocuboid joint and can be avoided with proper stabilization of the joint, as described in the literature.

The Dwyer lateral opening wedge osteotomy of the posterior calcaneus,\textsuperscript{33} which attempts to correct the hindfoot valgus alone, has also been used to manage flexible flatfoot. The use of double osteotomies, such as a combined calcaneal lengthening and a posterior medial calcaneal slide osteotomy, has been described, as well.\textsuperscript{14}

**Figure 5**

Axial CT of the foot demonstrating osteolysis secondary to a metal arthroereisis implant. (Reproduced with permission from Mosca VS: Flexible flatfoot and skewfoot, in McCarthy JJ, Drennan JC, eds: Drennan’s The Child’s Foot and Ankle, ed 2. Philadelphia, PA, Lippincott Williams & Wilkins, 2009, pp 136-159.)

**Calcaneovalgus Deformity**

This deformity, which is present at birth, consists of hyperdorsiflexion at
the ankle and mild valgus alignment at the ankle and subtalar joints (Figure 7). The longitudinal arch is present, with normal alignment at the talonavicular joint. This deformity may be present in 30% to 50% of neonates and is likely due to intrauterine positioning. Calcanevalgus foot deformity resolves spontaneously and has not been found to lead to a flatfoot deformity or any disability. It must be differentiated from congenital vertical talus (CVT), which is a rigid, rocker-bottom foot deformity that always requires treatment.

**Congenital Vertical Talus**

CVT presents at birth as a rigid flatfoot. It is characterized by dorsi-flexion through the midfoot, which may create a rocker-bottom deformity, and hindfoot equinovarus (Figure 8, A). The toe extensors may also be contracted. The deformities cannot be passively corrected and require management in the form of casting, surgery, or both. The etiology of CVT is still unknown. Ogata et al reported that the deformity can have a familial tendency. It is frequently found in children with myelomeningocele and arthrogryposis. Radiographic assessment of the foot shows vertical alignment of the talus with the axis of the tibia on a lateral view. The navicular, midfoot, and forefoot are dorsally dislocated on the talar head and neck, as seen in Figure 8, B. The midfoot and forefoot remain dorsiflexed, even in forced plantar flexion.

Management of CVT has evolved in recent years from purely surgical treatment to one in which serial casting and minimally invasive surgery is frequently successful, particularly in idiopathic cases. For feet that do not respond to nonsurgical management, the dorsal approach for surgical reconstruction is the treatment of choice.

**Tarsal Coalition**

TC is the abnormal fusion of two or more bones in the midfoot or hindfoot and has a reported prevalence of 2%, although it may be as high as 13%. Talocalcaneal and calcanevalgus coalition are the most common types. Up to 75% of feet with coalitions are asymptomatic. If pain develops, it is usually not until age 8 years, when ossification or maturation of a fibrous coalition to a cartilaginous coalition takes place. Pain may be experienced at the site of the coalition, at adjacent joints, or under the medial midfoot. It is worse with activity and forced foot inversion. As mentioned previously, TCs are typically diagnosed with radiography and CT (Figure 4). MRI may be useful in the case of a fibrous coalition, but treatment decisions are based on CT findings.

Initially, patients with symptomatic feet and TCs are treated nonsurgically. When nonsurgical management fails to relieve the pain, surgery may be considered. TC resection involves removal of the bar and interposition of either fat, tendon, muscle, or bone wax at the coalition site. Good short-
and long-term outcomes have been reported following resection of a calcaneonavicular coalition.\textsuperscript{19,34,40,41}

Reported outcomes following resection of talocalcaneal coalitions have not been as good. The results seem to correlate with the size of the coalition, the health of the posterior facet of the subtalar joint, and the degree of hindfoot valgus deformity.\textsuperscript{18,19,34} Historically, subtalar or triple arthrodesis has been recommended for large coalitions (>50\% of the joint), inadequate pain relief after resection, recurrence of the coalition, and significant hindfoot valgus malalignment, and when significant degenerative changes are present.\textsuperscript{17,19,34}

In a recent retrospective review of 32 resected TCs in 24 patients, Khoshbin et al\textsuperscript{31} reported good long-term clinical and functional outcomes when the coalition involved >50\% of the joint and hindfoot valgus exceeded 16\°. Of note, one patient required a concurrent Achilles tendon lengthening and two had concomitant Dwyer osteotomies. Gantousides et al\textsuperscript{30} published a retrospective review on 49 feet (32 patients) treated with excision and fat graft interposition for symptomatic talocalcaneal coalitions. They reported that 11 feet (22\%) required subsequent surgery: 8 (16\%) needed flatfoot reconstruction, 2 (4\%) had re-excision for recurrence or incomplete excision, and 1 (2\%) required wound débridement.

Recently, Mosca and Bevan\textsuperscript{18} reported on an algorithmic approach to the surgical management of talocalcaneal coalitions that includes resection and fat grafting alone, deformity correction with CLO alone, or resection and fat grafting with concurrent deformity correction and CLO. Management of TC requires a thoughtful plan based on the size and type of coalition, health of the posterior facet, and presence of concurrent deformity.

**Skewfoot**

The exact etiology and natural history of idiopathic skewfoot are unknown. Skewfoot can be present at birth, develop during growth, or exist as a postoperative iatrogenic deformity. It is characterized by a Z-shape, with significant hindfoot valgus and metatarsus adductus\textsuperscript{1,14} (Figure 9).

In our experience, symptoms caused by skewfoot deformity in early childhood typically manifest as calluses and difficulty with shoe wear related to the metatarsal adductus segmental deformity. In adolescence, symptoms are similar to those of a painful flatfoot with a tight Achilles tendon. Patients present with pain at the plantar medial midfoot and possibly impingement-type pain in the sinus tarsi region. Coincident tightness of the Achilles tendon is typically identified.

Although modified shoe wear, orthotics, and insoles are successful in relieving symptoms in some cases, surgical management may be required in recalcitrant cases.\textsuperscript{14} A CLO with medial cuneiform opening wedge osteotomy and Achilles tendon lengthening can correct segmental deformities in most cases, while maintaining subtalar joint motion. Good results have been reported with this approach for severe skewfoot deformity.\textsuperscript{14}

**Summary**

Most flexible flatfoot deformities are asymptomatic, will not lead to future pain or disability, and do not require treatment. Patient and parent reassurance and education by the
orthopaedist are essential. For the rare painful flatfoot, there is little convincing evidence that nonsurgical treatment is consistently effective. If shoe modifications, inserts, or orthoses are prescribed, cost should be kept in mind.

Indications for surgery are strict, thereby making surgery for flatfoot uncommon. Indications include intractable pain and disability despite prolonged attempts at nonsurgical management. In nearly all cases, an associated contracture of the Achilles tendon is present. Osteotomies are generally the best approach, with concurrent procedures performed as needed. The surgeon must also be vigilant to identify the rare rigid flatfoot because a different treatment approach is required.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references 6 and 24 are level I studies. Reference 21 is a level II study. References 28, 31, and 41 are level III studies. References 18, 22, 37, and 40 are level IV studies.

References printed in bold type are those published within the past 5 years.


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