Pediatric flatfoot: cause, epidemiology, assessment, and treatment

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Purpose of review
The current review includes the most up to date literature on the cause, epidemiology, diagnosis, and treatment of pediatric flatfeet.

Recent findings
Recent systematic reviews concur that the evidence supporting the use of orthotics in pediatric flexible flatfeet is poor. Multiple studies have recently reported on the results of arthroereisis, yet these are mostly retrospective and do not include a comparative group or long-term follow up. Other options for symptomatic flatfeet may include osteotomies and/or fusions, but similarly high quality comparative studies are lacking.

Summary
Pediatric flatfeet range from the painless flexible normal variant of growth, to stiff or painful manifestations of tarsal coalition, collagen abnormalities, neurologic disease, or other underlying condition. Most children with flexible flatfeet do not have symptoms and do not require treatment. In symptomatic children, orthotics, osteotomies, or fusions may be considered. Arthroereisis has gained popularity in Europe, but has not been widely adopted in North America. Children with asymptomatic rigid flatfeet may not require treatment, whereas those with pain or functional deficits may benefit from orthotics, osteotomies, or fusions. A careful history, clinical exam, and selective diagnostic testing can be used to determine the appropriate treatment option for each child.

Keywords
arthroereisis, flexible, orthotics, planovalgus, pediatric, pes planus, reconstruction, rigid

INTRODUCTION

Flatfeet are a frequent cause of presentation to the pediatrician, podiatrist, and pediatric orthopedic surgeon. Pediatric flatfeet span a wide spectrum of severity, ranging from a painless, flexible normal variant of growth, to a stiff or painful manifestation of tarsal coalition, collagen abnormality, neurologic disease, or other underlying pathology. The current review focuses on recent developments in the cause, epidemiology, diagnosis, and treatment of pediatric flatfoot.

By definition, a flatfoot (pes planus) has a diminished or absent longitudinal medial arch. The deformity may occur in isolation, or may include an abnormality to the hindfoot, typically valgus alignment (pes planovalgus). Additional deformities may be present depending on the underlying cause of the flatfoot.

Infants are born with flatfeet, and, because of physiologic ligamentous laxity, the lack of medial arch usually persists throughout the toddler and early childhood years. A medial arch may be visible at rest (Fig. 1a), but with weight bearing the ligaments stretch and allow mild subluxation of the tarsal bones; hence, the appearance of a flatfoot (Fig. 1b).

Physiologic ligamentous laxity typically improves with age and the majority of children develop an arch in the first decade of life [1]. Morley [2] documented flatfeet in 97% of 18-month-olds, whereas only 4% of 10-year-olds had flatfeet. In a study of 835 children [3], the incidence of flatfoot in children aged 3–6 years was ascertained. Flatfeet were present in 54% of 3-year-olds and 26% of 6-year-olds. Boys were more likely to be flatfooted

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KEY POINTS

- Almost all toddlers and children under the age of 6 have flexible flatfeet.
- The medial arch typically develops within the first decade of life, although a small proportion of flatfeet persist into adulthood.
- Obese and overweight children are more likely to have flatfeet.
- No evidence exists to support the role of orthotics in changing the natural history of arch development.
- Orthotics or surgery may be an option for symptomatic children, whether the deformity is flexible or rigid.

than girls (52 versus 36%). Obesity was associated with flatfeet. Flatfeet were present in 62% of obese, 51% of overweight, and 42% of young children with normal body weight. Similarly in adolescents, there is a greater prevalence of flexible flatfoot in males, those with decreased stature, and those with greater body mass index [4▪]. The true prevalence of flatfoot in children is difficult to ascertain, as there is no consensus on the exact clinical and radiographic thresholds for diagnosis.

Children without arch development by age 10 may have limited potential for natural resolution of their flatfeet. Children with a family history of flatfeet may be more likely to have persistent flatfeet as adults. The prevalence of flatfeet in adults is 15–23% [5]

A flatfoot can be painless or painful. It may cause perceived or real functional deficits due to ankle or subtalar instability, pain, or abnormal mechanics. It may also simply be a cosmetic concern for the family. The flatfoot can be either flexible or can easily be manipulated into a normal position, or rigid, and fixed with limited motion. The degree of the deformity may be static, or it may improve or worsen over time.

Most cases of painless flexible pediatric flatfoot do not require treatment. Rigid or painful flatfeet, however, are more likely to require orthotics or surgical intervention. There remains considerable debate regarding the use of orthotics in painless, flexible flatfeet. Recent systematic reviews of the current literature demonstrated that there is very limited evidence for the efficacy of nonsurgical interventions for children with flexible flatfeet [6▪,7]. Furthermore, there is no reliable means of predicting the course of flatfeet in children and no evidence to suggest that orthotics will alter this course. Although 10% of American children with flatfeet are treated with orthotics, only 1–2% are symptomatic [3], leading authors to suggest that 'greater than 90% of the treatments were unnecessary'. Although many clinicians may believe that they are causing no harm by prescribing an orthotic for a flexible flatfoot, negative psychological effects have been demonstrated in adults who wore orthotics as children [8]. Careful history, physical exam, and in some cases diagnostic testing can clarify the cause of the flatfoot, and determine if the flatfoot is one of the small proportion of cases that may benefit from treatment.

HISTORY

The main factors differentiating a physiologic flatfoot from a pathologic flatfoot, which may require treatment, are the flexibility of the deformity, the presence of pain, and the age of the child. The age of onset should be determined, along with any obvious changes in foot shape over time. In the presence of pain, location, timing, quality and triggers should be identified. Any history of trauma should be elicited. Inquiring about limping or refusal to weight

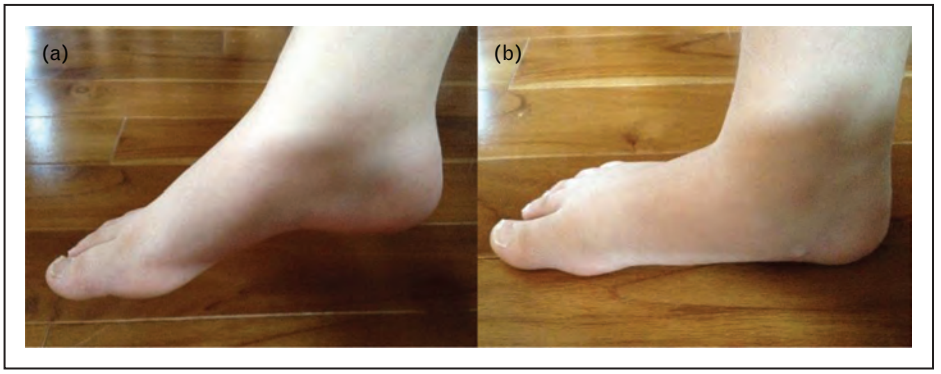


FIGURE 1. Seven-year-old with asymptomatic flexible flatfeet. (a) Nonweight bearing, the arch is visible. (b) Weight bearing, the arch is diminished.

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bear in young children who cannot communicate their pain may be helpful.

As flatfeet can, in rare cases, be associated with rheumatologic, inflammatory, neoplastic, or neurologic disease [9], the presence of morning stiffness, night pain, pain at rest, numbness, weakness, muscle wasting, constitutional symptoms, and polyarticular pain or swelling should be documented. The familial presence of hyperlaxity or syndromes often associated with flatfeet, such as Ehler–Danlos or Marfans's [10], should be determined. Inquiries about recurrent injuries or sprains, difficulties with shoe wear, walking bare foot, walking on uneven surfaces, and the presence of callouses or skin irritation should be made. It is important to clarify whether the family is most concerned about the appearance of the feet, or whether they think the flatfeet are causing pain or functional problems with walking, running, or other activity participation.

PHYSICAL EXAM

The physical exam should include a gait assessment both in shoes and barefoot. Assessing gait as the child walks into the examination can be helpful, as children may alter their gait when they are aware of being watched. The child should be asked to walk with a regular heel strike, on their toes, and on their heels. Inability to heel or toe walk, or any asymmetry in gait, may indicate an underlying neurological problem that requires further investigation. The foot progression angle should be assessed, estimating the direction that the foot points in relation to the direction of gait.

The feet should then be assessed in neutral stance with the legs shoulder width apart. The presence of the medial arch in weight bearing should be documented, as well as prominence of the navicular within the medial arch. Heel valgus can be measured by estimating the angle between the posterior calcaneous and the axis of the lower leg (Fig. 2a). Tiptoeing should accentuate the arch and the calcaneus should swing into varus (Fig. 2b). The arch is considered flexible if it reconstructs. It is deemed rigid if it does not reconstruct.

Torsion should then be assessed in the prone position. The thigh-foot angle, which measures the axis of the foot in relation to the axis of the thigh, represents tibial torsion (Fig. 3). Tibial torsion changes throughout childhood, with a normal range encompassing 5° internal to 15° external. Excess external tibial torsion may contribute to the appearance of flatfeet. Torsion of the femur should also be checked in the prone position, by assessing internal and external rotation at the hip. Femoral torsion also changes throughout childhood. Significant asymmetry between internal and external rotation can indicate femoral anteversion, femoral retroversion, or, in rare cases, muscular contractures [11].

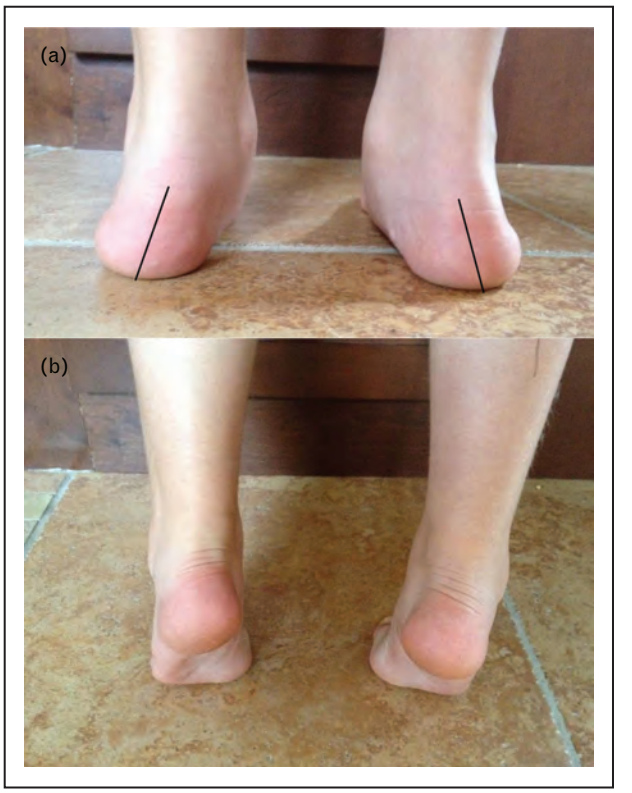


FIGURE 2. Seven-year-old with asymptomatic flexible flatfeet. (a) Weight bearing, the arch is diminished, and hindfoot valgus is apparent. (b) Weight bearing on toes, the arch reconstructs and the hindfoot appropriately swings into varus.

In the supine position, range of motion of the hips, knees, ankles, subtalar, and forefoot joints should be assessed. Ankle range of motion should be checked with the knee both flexed and extended (Silfverskiold test), as restricted dorsiflexion can contribute to flatfeet [12]. Care should be taken to ensure that the subtalar joint is not in valgus while assessing ankle range of motion. If dorsiflexion is more restricted with the knee extended than with the knee flexed, this indicates differential tightness of the gastroc, whereas restricted dorsiflexion with the knee both flexed and extended indicates tightness of both gastroc and soleus. With an intact windlass mechanism, passive extension of the 1st metatarsophalangeal joint should result in accentuation of the arch through attachments of the plantar fascia (Fig. 4).

Areas of tenderness, swelling, skin irritation, and callouses should be identified. A complete neurologic exam including light touch, vibration sense, deep tendon reflexes, clonus, and Babinski should

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FIGURE 3. Thigh-foot angle demonstrates mild external tibial torsion.

be performed. Ligamentous laxity should be assessed not only in the feet, but in all extremities, including elbows, knees, thumbs, fingers, and spine. The quality and laxity of the skin must also be noted.



FIGURE 4. Seven-year-old with asymptomatic flexible flatfeet. Extension of the toe reconstructs the arch through attachments of plantar fascia.

X-RAYS

X-rays should be obtained for feet found to be severely flat, rigid, painful, or with other significant abnormality.

Anterior–posterior foot

If possible, this view should be done with the patient weight bearing. The anterior–posterior Meary's angle, talar–metatarsal angle, can identify abduction frequently seen in flatfeet. The percentage of talar uncovering can also be measured (Fig. 5a). Coalitions and accessory bones, such as the accessory navicular, may also be visualized on this view.

Lateral foot and ankle views should also be obtained with the patient weight bearing. The degree of flatness can be assessed using the lateral Meary's angle (talar–metatarsal angle) and calcaneal pitch (Fig. 5b). Navicular height can also be used to assess severity of the flatfoot. When excess valgus is present, the subtalar C sign may be evident. Subtalar coalitions may be visualized on this view.

The internal oblique view is typically nonweight bearing and is used for identifying coalitions between the calcaneus and the navicular. The external oblique view is nonweight bearing and is best for identifying an accessory navicular. The Harris–Beath view visualizes the middle facet of the subtalar joint. Bony coalitions may be easily identified, whereas an oblique medial facet angulated greater than 20° is highly suggestive of a subtalar coalition, even in the absence of bony connection (Fig. 5c). The Saltzman view is an axial weight bearing view, and is useful to identify the degree of heel valgus with weight bearing. Maximum plantar flexion and dorsiflexion lateral views can be used to differentiate between oblique talus and congenital vertical talus [13].

MRI AND COMPUTED TOMOGRAPHY

Computed tomography (CT) is the gold standard for the assessment of tarsal coalitions. On CT, the coalition type (bony, cartilaginous, fibrous, or mixed), extent, and secondary degenerative changes can be visualized [13]. MRI may provide further information on fibrous and cartilaginous coalitions, as well as abnormalities to the posterior tibial tendon, and other tendons and ligaments within the foot. Asymmetry of the feet or any neurologic abnormalities may warrant an MRI of the leg, spine or brain.

BLOODWORK

Laboratory studies may be warranted if infection or neoplastic, rheumatologic or inflammatory disease

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FIGURE 5. (a) A–P foot X-ray showing talar under coverage. (b) Lateral X-ray showing decreased calcaneal pitch and apex plantar Meary's angle. (c) Harris–Beath view showing an oblique medial facet consistent with fibrous subtalar coalition. A–P; anterior–posterior.

is suspected. Tests may include, but are not limited to, complete blood count, erythrocyte sedimentation rate, C-reactive protein, antinuclear antibodies, anti-DNA, and rheumatoid factor.

TREATMENT: FLEXIBLE FLATFOOT

The majority of flexible flatfeet do not require treatment. Even with severe flexible deformity, in asymptomatic patients, there is no evidence to support the role of orthotics or surgery in delaying or removing risk of future symptoms. Pain symptoms are more common in flexible flatfeet with a short Achilles tendon [14]. Children with painful flexible flatfeet may benefit from treatment.

ORTHOTICS

Although some authors advocate orthotics for children with asymptomatic flexible flatfeet, there is no convincing evidence to support this practice. The few studies that support orthotics in flexible flatfeet lack adequate sample size and comparative controls [6▪,7,15]. Three randomized trials have assessed the efficacy of orthotics in children with flatfeet. Whitford and Esterman [16] compared generic orthoses with custom orthoses and a control in children aged 7–11 with flexible flatfeet. There was no significant difference between groups. Similarly, Wenger [17] did not find a difference among groups of children aged 1–6 with flexible flatfeet who were randomized to shoes, heel cups, University of California Berkeley/Biomechanics Laboratory orthotics or no orthotic. Powell *et al.* [18] examined custom orthotics, neoprene inserts and athletic shoes in children with painful flatfeet in the setting of juvenile idiopathic arthritis. The use of orthotics did improve pain, function, and quality of life. Overall, evidence supports the use of orthotics in a select group of children with painful flexible flatfeet, but not in children with asymptomatic flexible flatfeet.

SURGICAL INTERVENTIONS

Surgical treatment of flexible flatfeet may include soft tissue plications, tendon lengthenings or

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transfers, osseous excisions, osteotomies, fusions, arthroereisis, and combinations of these procedures. Soft tissue plications and bone excisions have largely been abandoned because of high failure rates and their destructive nature [14].

Common osteotomies reported in the setting of flexible flatfeet include medial slide calcaneal osteotomy, lateral column lengthening through the calcaneous or cuboid, medial cuneiform osteotomy, and osteotomy of the first metatarsal [19]. Another option involves permanently fixing the bones into the preferred position by fusion (removal of the joint cartilage and fixation across the joint to encourage bone formation between the bones). Common fusions include isolated fusions of the talonavicular joint or subtalar joint, or fusions of multiple joints such as the triple arthrodesis (talonavicular, subtalar, and calcaleocuboid fusions). Although fusion reliably improves alignment, the loss of motion at fused joints has been shown to increase forces through remaining joints of the foot, and lead, years later, to degenerative change at neighboring joints [14].

Arthroereisis involves the placement of an implant or bone graft within the sinus tarsi to restrict excessive motion at the subtalar joint. Theoretically, this implant limits valgus of the subtalar joint and, by limiting hindfoot collapse, may help maintain the longitudinal arch. Numerous methods of arthroereisis have been reported and multiple implant designs and materials have been proposed, including stainless steel screws and biodegradable wedges. No consensus has been reached regarding the optimal implant design.

With a mean follow up of 7.4 years, Pavone *et al.* [20▪] reported a 96.83% good to excellent level of patient satisfaction in 242 consecutive patients (410 flatfeet) treated with arthroereisis. Jerosch *et al.* [21], Giannini *et al.* [22], Koning *et al.* [23], Roth *et al.* [24], and Kellermann *et al.* [25▪] similarly reported good clinical outcomes. Jay and Din [26▪] showed improved function, cosmesis, and shoe wear in 20 children aged 4–7 years old after arthroereisis and gastrocnemius recession. Waizy *et al.* [27▪] retrospectively compared arthroereisis with Evans calcaneal lengthening in neurogenic flatfoot. Although arthroereisis was found to more significantly correct the radiographic findings of pes planovalgus, both operations provided similar clinical results and were thus both deemed suitable for the treatment of neurogenic flatfoot [27▪].

Unfortunately, the majority of studies on arthroereisis are retrospective, and do not include a control group. In the absence of controls, it is difficult to attribute improvement to the surgical procedure itself, as the natural history of flexible flatfeet in children includes improvement with age. Complications of arthroereisis include screw loosening, peroneal muscle contracture, infection, and talar fracture [28▪]. Arthroereisis is potentially a simple, minimally invasive procedure, but complications are not uncommon, and improvement beyond the natural history of flatfeet has not been proven. Prospective comparative studies with long-term follow up are necessary prior to adoption of this technique.

TREATMENT: RIGID FLATFOOT

Rigid flatfeet may be due to tarsal coalition, congenital vertical talus, and neurologic, neoplastic, or posttraumatic pathologies [10]. As with asymptomatic flexible flatfeet, asymptomatic rigid flatfeet do not necessarily require treatment.

Congenital vertical talus

Congenital vertical talus typically manifests in infancy as a rigid rocker-bottom foot. The primary deformities are plantarflexion of the talus and dorsal dislocation of the navicular on the talus. Historically, congenital vertical talus was treated with early radical surgery, sometimes involving excision of entire bones. Over time serial casting has become the preferred technique. The talonavicular joint is reduced using techniques modeled after Ponseti Clubfoot casting. Once reduced, the child undergoes percutaneous Achilles tenotomy and temporary K-wire fixation of the talonavicular joint. Early results are favorable, although no long-term studies exist, and the upper age limit for this less invasive procedure has not been documented [13].

Tarsal coalition

Tarsal coalitions involve two or more tarsal bones that are adjoined by fibrous, cartilaginous, or bony material. This connection reduces motion in the hindfoot or midfoot, and typically results in a planovalgus foot, although normal alignment and cavus have been described. The prevalence of coalitions is 0.04–1.4% [13], with 90% of coalitions involving either the calcaneonavicular or talocalcaneal joints. Coalitions can, however, occur in other tarsal joints. Bilateral occurrence may be as high as 86% [29]. Many coalitions are asymptomatic, and in the absence of symptoms no treatment is necessary. For symptomatic coalitions, conservative measures can be attempted and may include casting, splints, orthoses, and modified weight bearing [13]. If nonsurgical interventions fail, surgical treatment should be considered.

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Calcaneonavicular coalitions can be treated with excision and either fat, wax, or extensor digitorum brevis interposition [30–32]. Talocalcaneal (subtalar) coalitions typically involve the middle facet. Current surgical treatments for subtalar coalitions include excision of the coalition alone, excision and flatfoot reconstruction as single or staged surgery, or fusion of the subtalar joint [19]. No prospective studies comparing interventions for tarsal coalition exist. Treatment should take into account the size of the coalition, degree of deformity, age of child, and any secondary degenerative changes present within the foot.

Rigid neurologic flatfoot

The deformity of neurologic flatfoot is frequently more severe, and, because of concerns for recurrence as well as frequent association with weakness, contracture, and spasticity in the extremities, more involved surgical intervention may be required for the symptomatic rigid neurologic flatfoot. Lateral column lengthening has been advocated [33], but some authors report an unacceptable recurrence rate in children with a neurologic cause [34]. Subtalar joint fusion is also an option, but this has not been universally accepted because of frequent over or under-correction associated with this technique [35]. Talonavicular fusion has recently been presented as an option for this population. de Coulon *et al.* [36] report satisfactory clinical and radiographic results using this technique. Triple arthrodesis has also been used in this population, but in the ambulatory child may lead to degenerative changes in remaining joints. No prospective comparative study of these techniques exists in this patient population. Treatment may include a combination of fusions, osteotomies and tendon lengthenings, as dictated by the type and severity of the deformity and other clinical factors.

CONCLUSION

Pediatric flatfeet range from a painless, flexible, normal variant of growth, to a rigid, painful manifestation of tarsal coalition, collagen abnormalities, neurologic disease or other underlying pathology. Most children with flexible flatfeet are asymptomatic and do not require treatment. Symptomatic children, however, may benefit from orthotics, osteotomies, or fusions. Arthroereisis has gained popularity in Europe, but has not been universally adopted in North America. Much like children with asymptomatic flexible flatfeet, children with asymptomatic rigid flatfeet may not require treatment. Children with painful or functionally limiting rigid flatfeet may benefit from orthotics, osteotomies, or fusions. A careful history, clinical exam and selective diagnostic testing can determine the appropriate treatment option for each child.

Acknowledgements

None.

Conflicts of interest

There are no conflicts of interest.

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