# Painful Flatfoot in Children and Adolescents: They're Not All the Same

*Arya Minaie, MD[1]; Maksim Shlykov, MD[1]; Pooya Hosseinzadeh, MD[1]; Vincent Mosca, MD[2]*

*[1]St. Louis Children's Hospital, St. Louis, MO; [2]Seattle Children's Hospital, Seattle, WA*

**Abstract:** Most infants and toddlers have flatfeet which are both normal and asymptomatic; older children and adolescents may have flatfeet that are painful. Some have classified flatfeet as flexible or rigid; with flexible feet considered painless, while rigid feet are more likely painful. This is not always the case as there are many instances of flexible feet that hurt and rigid feet that do not. Causes of painful flatfeet include tight achilles tendon with or without connective tissue disorders, tarsal coalitions, inflammatory arthropathies, accessory navicular, stress fractures, foreign bodies, infections, and tumors. Nonoperative treatment is usually sufficient. A variety of surgical methods (tendon lengthening, resection of bone, osteotomy, etc.) can be considered when symptoms and disability persist. The purpose of this review is to outline our approach to painful flatfeet.

**Key Concepts:**

- There is very little evidence for the efficacy of nonsurgical (orthotics) or surgical intervention to affect the shape of the foot or to influence potential long-term disability in toddlers and children with painless flatfoot.
- Multiple orthotic options exist to relieve pain in painful flatfeet and some may exacerbate the pain.
- For painful feet recalcitrant to nonoperative measures, differing surgical options (osteotomy, resection of bone, soft tissue balancing) are available and are chosen based upon pathology and foot alignment.
- Using the concept of the calcaneal pedal unit, surgical correction of symptomatic flexible and rigid flatfoot starts with realignment of the hindfoot valgus/eversion deformity with calcaneal lengthening osteotomy.

## Introduction

Flatfoot is characterized clinically by hindfoot valgus/eversion, forefoot supination in relation to the hindfoot, and a diminished or nonexistent medial longitudinal arch. Flexible flatfoot is ubiquitous in newborns and young children and is rarely symptomatic. Of the roughly 20-25% of flatfooted adolescents and adults, approximately 90% are flexible or rigid, most of which are physiologic or associated with tarsal coalitions and do not cause pain or functional disability.[1]

Flexible flatfoot is characterized clinically by restoration of the medial longitudinal arch when tip toe standing and with the foot in a nonweight-bearing position. Conversely, rigid flatfoot maintains the flatness of the arch and valgus of the hindfoot when tip toe standing and with the foot in a nonweight-bearing position. It is most often due to a tarsal coalition. Like its flexible counterpart, it uncommonly causes pain or functional disability. Unlike the gradual age-related elevation of the longitudinal arch in flexible flatfoot, there is typically a gradual depression of the medial longitudinal arch in rigid flatfoot as the child ages.[1]

Flatfoot differs in presentation, evaluation, and treatment. Those who treat these conditions require thorough understanding of the differences. This review will focus on how to appropriately evaluate, differentiate, and manage those that become painful.

## Pathoanatomy/Biomechanics of Flatfoot Deformity

The most important joint, and the location of all major foot deformities, is the subtalar joint complex (STJC), recognizing that the talo-calcaneal joint (the true subtalar joint) can only move in combination with the talo-navicular joint. The axis of motion of the STJC is a constrained ball and socket-type joint that rotates three-dimensionally around a fixed oblique axis. In 1818, Scarpa described the acetabulum pedis (AP) based on his observed similarities between the hip joint and the subtalar joint. In the hip, the femoral head rotates within the acetabulum. In the subtalar joint, the acetabulum pedis (socket), which is comprised of the navicular, the anterior and middle articular facets of the calcaneus, and the spring ligament, rotates around the talar head (ball).[2] More recently, the concept of the AP has been expanded to develop that of the calcaneopedal unit (CPU), which is a term used to describe the entire foot including that beyond the acetabulum pedis or subtalar joint complex.[3]

All major foot deformities, including flatfoot, have rotationally opposite static deformities within the CPU in relationship to the subtalar joint deformity. In flatfeet, the hindfoot assumes a valgus position with eversion of the STJC, or more accurately, external rotation, dorsiflexion, and pronation of the AP/CPU around the talus. In flatfoot, the rotationally opposite direction deformity within the CPU is supination. These rotationally opposite direction deformities enable a flatfoot to maintain a plantar-grade tripod configuration. Valgus/eversion (pronation) of the hindfoot with rotationally opposite direction supination of the forefoot enable weightbearing on the plantar-medial corner of the calcaneus and the 1st and 5th metatarsal heads.[2,3]

## Differential Diagnosis of Pediatric Flatfoot Deformity

<u>Flexible</u>

- Physiologic flexible flatfoot
- Physiologic flexible flatfoot with short tendo-Achilles
- Flexible flatfoot associated with accessory navicular
- Paralytic (spastic and flaccid) flatfoot

<u>Rigid</u>

- Rigid flatfoot with tarsal coalition
- Rigid flatfoot without tarsal coalition, so-called peroneal spastic flatfoot
- Inflammatory arthritic flatfoot
- Neoplastic flatfoot

## Clinical Presentation & Diagnosis

Most babies have physiologic flexible flatfeet. The medial longitudinal arch typically starts to develop around the age of 2 years with development continuing until age 6-10 years, at which point approximately 20-25% of individuals remain flatfooted.[1] Most children's feet are, and remain, pain free whether or not they develop a longitudinal arch. Some young children with physiologic flatfeet present with bilateral non-localized activity-related and/or nocturnal foot and/or leg pain without any findings of redness, swelling, tenderness, or warmth. Early fatigue and rapid shoe breakdown may be reported. The child typically awakens in pain 1-2 hours after going to sleep and returns to sleep after comforting and foot/leg massage. This type of pain is considered to be the result of muscle overuse, as it is typically seen following particularly active days in children with physiologic ligamentous laxity.[1]

Pain that develops in flexible flatfeet in late childhood or early adolescence can be associated with the development of tendo-Achilles or gastrocnemius contractures in this age group. The reason for the development of heel cord contractures is unknown, but it apparently affects about 25% of those individuals with persistent flatfoot shape. The pain in flexible flatfoot with short tendo-Achilles (FF-STA) is activity-related, relieved with rest, and located under the medial midfoot and/or in the sinus tarsi area.

Up to 13% of individuals have tarsal coalitions.[2,4-5] In patients with tarsal coalitions, the arch usually becomes flatter with age, which is in contrast to flexible flatfeet in which the low arch either persists or remains the same during that time period. In this age range, feet with tarsal coalitions also lose flexibility, i.e. become stiffer. Between the ages of 8-16 years, approximately 20% of tarsal coalitions become painful, earlier in that age range for calcaneo-navicular coalitions and later in the range for talo-calcaneal coalitions. Symptomatic patients begin complaining of localized or diffuse foot and/or ankle pain that is aggravated by physical activity and often relieved with rest and other anti-inflammatory interventions. Patients often report recurrent ankle sprains.[6]

Pain in a foot with a tarsal coalition can be localized to the coalition if it is still in the fibrous or cartilaginous stage. If the coalition ossifies, it is usually not considered a pain generator, as a synostosis is essentially an idiopathic arthrodesis. Pain in a foot with a rigid tarsal coalition can be experienced in adjacent joints due to stress transfer, however, these rarely develop degenerative changes in children and adolescents. Finally, pain in a foot with a tarsal coalition may be experienced under the head of the talus and/or in the sinus tarsi area, exactly the locations where pain may develop in a flexible flatfoot. As in flexible flatfoot, the rigid flatfoot with a tarsal coalition often has an associated contracture of the tendo-Achilles or gastrocnemius.[2,5]

There are some painful rigid flatfeet that have all the characteristics of tarsal coalitions, but none can be found on advanced imaging. These are most often found in obese adolescents. Harris and Beath identified them in 12% of the rigid flatfeet in their landmark study on flatfeet and labeled them peroneal spastic flatfeet. The peroneal tendons appear to be tenting the skin under and around the lateral malleolus because the peroneal muscles are continuously contracting. Attempts to passively and rapidly invert the subtalar joint are met with forceful, involuntary peroneal muscle contractions that are similar to those seen in children with cerebral palsy, i.e., spastic. The etiology is unknown, as is a consistently effective treatment.

The pain associated with flexible and rigid flatfeet is usually gradual in onset, activity related, and relieved with rest. Deviations from this pattern should broaden the differential diagnosis. For instance, neoplastic and infectious etiologies should be considered in a child or adolescent who presents with painful flatfoot that was acute in onset, is worse at night, is associated with fever, is not relieved or at least significantly improved with activity modification, rest, immobilization NSAID's, or even opioids.[7] Rheumatologic disorders should be considered in the differential diagnosis for chronic, insidious onset rigid painful flatfeet in children and adolescents, especially if associated with swelling, redness, or warmth. These physical findings are not observed in flexible flatfeet, with or without short tendo-Achilles, or in tarsal coalitions. Inflammatory arthritis of the foot may be unilateral or bilateral. These feet usually look worse than they feel. Posterior tibial tendinitis or dysfunction does not exist in children and adolescents. Plantar-medial midfoot pain in children and adolescents in the region of the insertion of the tibialis posterior tendon on the navicular is most commonly due to a painful accessory navicular (Kidner's disease).

Deformity-related foot pain is located at the site or sites of pressure and stress overload, such as under the medial midfoot in a flexible flatfoot. Patients with cavus feet will have pain at the base of the 5th metatarsal and under the head of the 1st MT. These locations may have redness, exaggerated callus formation, blistering, and even ulceration. With longstanding deformities, degenerative arthritis with associated pain may develop in certain joints, but that is extremely rare in children and even in adolescents and young adults. Dysesthesia, redness, vasomotor changes, pain that exists every waking minute, and hyperesthesia are consistent with chronic regional pain syndrome, AKA pain amplification syndrome or reflex sympathetic dystrophy. Prolonged immobilization and orthopedic surgery can only make this pain worse. Multidisciplinary pain clinics are helpful to manage these patients.[8,9]

## Physical Examination

Evaluation of a foot for assessment of shape, function, and pain is both passive and active. Both feet should be observed with the patient standing, walking, toe walking, heel walking, squatting, and hopping, as well as sitting with feet dangling off the exam table. Posterior visualization of the flatfoot in weight-bearing can demonstrate a "too many toes" sign as a surrogate for the valgus/everted hindfoot.[1,2] Normally, only the fifth and half of the fourth toe should be visible laterally when looking from the rear of the foot. However, in a flatfoot, external rotation of the subtalar joint, as a component of valgus/eversion, causes more toes to be seen laterally. The external rotation of the foot through the subtalar joint is often inappropriately attributed to external rotation of the tibia. Additionally, the hindfoot of a flatfoot is in valgus alignment and there is loss of medial longitudinal arch height.[2]

Passive and active subtalar joint movement is assessed to determine whether the motion is full or restricted, as well as if the motion is painless or painful. Accurate assessment of subtalar motion is difficult and must be performed properly, i.e., with the ankle at neutral and with a hand cupping the heel and moving the subtalar joint "down and in" (plantar flexion and internal rotation) for inversion and "up and out" (dorsiflexion and external rotation) for eversion. Inversion and eversion using the forefoot as the movement generator is not appropriate and will give false assessment of subtalar motion.[2]

Of paramount diagnostic importance is the exact localization of pain, which should begin with the report and manual identification by the child. For example, in the flexible flatfoot with short heel cord, there is often tenderness under the collapsed medial midfoot at the site of excessive callus formation and erythema. Forceful eversion of the subtalar joint may create impingement type pain laterally in the sinus tarsi at the site of reported activity related pain.[7]

*Silfverskiold Test*

A gastrocnemius or triceps surae contracture is important to document, because it is usually a contracture of one or the other structure that makes an otherwise pain free flatfoot painful.[1,2] With the knee flexed 90 degrees and with the subtalar joint inverted to neutral, the ankle is dorsiflexed. If there are at least 10 degrees of ankle dorsiflexion, measured as the angle between the plantar-lateral border of the foot and the anterior tibia, the soleus muscle is of normal length, i.e., not contracted. The knee is then fully extended while maintaining a neutral (inverted) subtalar joint. If there are not at least 10 degrees of ankle dorsiflexion, the gastrocnemius is contracted. Less than 10 degrees of ankle dorsiflexion with the knee both flexed and extended indicates contracture of the entire triceps surae.[2]

*Heel-raise, or Toe Stand, Test*

During the standing portion of the exam, with the examiner observing from behind the patient, the patient is asked to lift their heels off the ground and rise onto their toes. In a flexible flatfoot, the heel valgus will invert to neutral and the longitudinal arch will form, whereas in a rigid flatfoot, such as one with a tarsal coalition, the heel valgus will persist and the longitudinal arch will remain flat.[2]

*Connective Tissue Disorders*

Joint hypermobility has been associated with an increased risk of flatfoot development independent of age, potentially making those with connective tissue disorders more susceptible.[10] When evaluating patients with suspected connective tissue disorders, examination for generalized laxity can be very helpful. This can be done using the 9-point Beighton score which can test for hypermobility.[10] Scores greater than 5 on this scale in a child older than five years old indicates hypermobility.

## Diagnostic Imaging

Radiographs are not indicated in the evaluation of painless flatfeet. Evaluation for painful flatfeet includes weight-bearing (standing) antero-posterior (AP), lateral, and oblique plain radiographs.[1,2] A calcaneo-navicular tarsal coalition will be seen on the standard medial oblique plain radiograph. If a coincident accessory navicular is suggested by physical exam as the cause for pain, a lateral oblique view is indicated. If a talo-calcaneal tarsal coalition is suspected, a Harris axial view should be obtained.

When evaluating foot deformities, the foot-CORA method, described by Mosca, can and should be used to reliably evaluate and diagnose foot deformities, including flatfoot.[2] With this method, the relationship of the axis of the 1st metatarsal and that of the talus is assessed on standing AP and lateral radiographs of the foot. In a flatfoot, those 2 axes intersect in the head of the talus with the axis of the 1st MT abducted greater than 10 degrees from the axis of the talus on the AP view, and with the axis of the 1st MT dorsiflexed greater than 10 degrees from the axis of the talus on the lateral view. The 1st MT is a proxy for the CPU (described earlier), because there is very little motion between the bones within the CPU. It is ossified at birth and, even then, accurately represents itself and the rest of the CPU radiographically. On the other hand, the two major foot deformities of the hindfoot, valgus/eversion (as seen in flatfoot and skewfoot) and varus/inversion (as seen in clubfoot and cavovarus foot), are malalignments between the CPU and the talus. Relating the axes of the 1st MT and the talus reveals the desired information regarding the alignment at the talonavicular joint and, thereby, deformities of the hindfoot.

*Advanced imaging*

All tarsal coalitions should be evaluated preoperatively with CT scan imaging with 3-dimensional image reconstructions. The algorithms for management of tarsal coalitions are based on CT findings.[11,12] It is important to point out that there is no concern for gonadal radiation, even with a CT scan of the foot in a small, short limbed child. MRI's are helpful in the diagnosis of peroneal spastic flatfoot after the CT scan fails to identify a tarsal coalition in a rigid flatfoot in a typically obese adolescent. Occasionally edema at the calcaneal navicular articulation will herald a fibrous coalition not fully appreciated on a CT scan. If the pain pattern is atypical (as in chronic regional pain syndrome), an MRI or bone scan can be used to help identify the site or sites and etiology of pain. MRI scans are also helpful in the diagnosis of pain in a flatfoot that is coincidentally afflicted with infection, inflammation, or neoplasm.

## Case-Based Approach to Evaluation and Management of Painful Flatfoot

**<u>Case 1</u>:**

A 2-year-old girl presents with parental concerns of bilateral flatfoot deformity, which have been present since her birth, and 6 weeks of a slightly swollen, pink, and warm right ankle. She remains active and is still able to ambulate but has a slight limp. No recent history of trauma is reported. She has been afebrile. She sleeps well throughout the night but is most uncomfortable upon awakening in the morning. On exam, she has flexible flatfoot deformity bilaterally with mild swelling, pink coloration, warmth, and slight restriction of motion in the right ankle. She tolerates passive motion fairly-well.

**Discussion:** Congenital, physiologic, flexible flatfoot deformity does not cause swelling, redness, pain, or restriction of foot or ankle movement in young children. This child, therefore, has either infection or inflammation. Infection initially feels worse than it looks, and inflammation (over time) looks worse than it feels. Her symptoms, including their duration, are almost pathognomonic for oligoarticular juvenile idiopathic arthritis. Radiographs will show soft tissue swelling. Further work-up should include blood tests (CBC with differential, ANA, RF, ESR, and CPR), and referrals to pediatric rheumatology and ophthalmology. Iridocyclitis, which is associated with JIA, is a painless cause of preventable and treatable blindness.

## Case 2:

A 5-year-old boy with bilateral flatfoot deformity wakes up almost every night 1-2 hours after going to sleep complaining of non-localized pain in both feet and/or lower legs. His parents have never noticed any swelling, redness, or discoloration, nor have they identified any site or sites of tenderness. The pain is almost always bilateral and symmetric. He typically goes back to sleep after being comforted by his parents. He awakens the next morning refreshed and comfortable and is immediately active. His parents report that he awakens more often at the end of days in which he's been especially active than after those in which he's been more sedentary. Physical examination shows only bilateral flexible flatfoot deformity and generalized ligamentous laxity.

**Discussion:** Young children with congenital, physiologic, flexible flatfoot deformity and generalized ligamentous laxity may occasionally awaken soon after falling asleep and complain of non-localized, frequently bilateral foot and/or leg pain. There are no visible or palpable physical findings. This pain is believed to be a manifestation of muscle overuse that is related more to the ligamentous laxity than to the flatfeet. Often referred to as growing pains, the symptoms are most common in children from age 4-7 years and then typically resolve. A key diagnostic feature that supports a benign etiology of the pain is that it is most often bilaterally symmetric. Serious conditions like infections, JIA, and tumors are rarely, if ever, bilaterally symmetric. Inexpensive over-the-counter (OTC) shoe inserts or arch supports may decrease the frequency of symptoms.

## Case 3:

An 11-year-old girl with flatfoot deformity complains of pain under the medial mid-foot when participating in soccer and dance. The pain is relieved with rest and an occasional NSAID. She reports worse pain under her fallen arches when wearing the custom-molded hard plastic "arch support." Physical examination shows bilateral flexible flatfoot deformities with 5 degrees of ankle equinus contracture assessed with her subtalar joints inverted to neutral and her knees in full extension; she has 15 degrees of dorsiflexion with her subtalar joints inverted to neutral and her knees flexed 90 degrees.

**Discussion:** In the presence of a tight gastrocnemius or triceps surae, an individual with otherwise normal, painless flexible flatfeet often experiences pain under the plantar flexed talar head in the medial mid-foot and/or in the sinus tarsi region. A callous may form under the plantar flexed talar head when wearing hard, unyielding arch supports. Pain in the sinus tarsi is due to impingement of the lateral process of the talus on the beak of the calcaneus in the critical angle of Gissane when the subtalar joint is fully everted.

Initial treatment for this patient should be heel cord stretching exercises performed with the knee extended and, even more importantly, with the subtalar joint inverted to neutral. This joint positioning will help to ensure that the heel cord is stretched rather than merely everting the subtalar joint more than it already is.

Cushioned flat shoe inserts may provide further comfort. Failure of prolonged attempts to relieve the pain nonoperatively is the only research-supported indication for flatfoot surgery. The calcaneal lengthening osteotomy with supplemental soft tissue procedures has been shown to be the most efficacious.

## Case 4:

A 12-year-old boy presents with progressive flattening longitudinal arch of the right foot and activity-related pain along the medial hindfoot. He has had recurrent ankle "sprains" over the past 6 months. Physical examination shows a rigid right flatfoot deformity with limited subtalar motion. There is tenderness to palpation of the medial hindfoot just plantar to the medial malleolus. The hindfoot remains in valgus alignment and the arch does not elevate with toe standing.

**Discussion:** Progressive flattening of the longitudinal arch in a child between the ages of 8 and 16 years with the development of a rigid flatfoot deformity is most likely due to an underlying tarsal coalition. Patients often volunteer a history of recurrent ankle sprains, likely due to stress transfer to the ankle joint which is forced to compensate for restricted subtalar motion.

On physical exam, restriction of subtalar motion is complete and absolute in TCC's and limited in CNC's. The hindfoot valgus does not change to varus and the medial arch does not reconstitute with toe standing or with the Jack toe raise test. A rigid varus hindfoot deformity has been very rarely reported for both CNC's and TCC's. A double medial malleolus sign may be seen in a TCC as a result of a widened middle facet that creates a bony prominence inferior to the medial malleolus.

Standing AP, lateral, oblique, and axial Harris radiographs can show direct evidence of a coalition or indirect signs such as the C-sign of Lateur, the anteater nose sign, dorsal beaking of the talar head/neck, a broad lateral process of the talus, and joint space

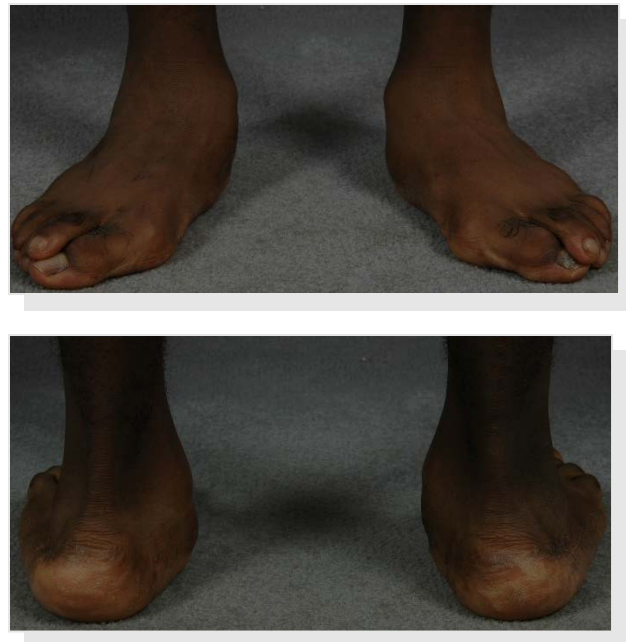

***Figure 1.*** *Case 5: Clinical photograph of bilateral rigid flatfoot deformity in an adolescent with peroneal spastic flatfoot.*

narrowing/degeneration.[5,11-19] Advanced imaging is needed for detailed assessment and surgical planning for all coalitions.

Asymptomatic tarsal coalitions, which make up the majority of cases, do not need treatment. Reported success rates of nonoperative management for symptomatic coalitions vary. Coalition resection, osteotomies, and/or arthrodesis is indicated only for those feet that remain painful despite these attempts.

For CNC's, a resectable coalition is one that is painful and tender at the site. If the CNC is fully fused and the pain is not at the site of the coalition but plantar medially due to the flatfoot deformity, deformity correction and treatment of gastrocnemius or heel cord contracture can be performed with good relief of pain.

For TCC's, a resectable coalition is one in which the surface area of the middle facet coalition is less than 50% the surface area of the posterior facet and the posterior facet is thick and healthy.[11,12] Flatfoot deformity should be corrected concurrently or in a staged manner with osteotomies if the calcaneus is in exaggerated valgus as assessed on the coronal CT scan images (greater than 16 degrees). If the coalition is not resectable, the pain is usually due to the deformity; in which case deformity correction with the calcaneal lengthening osteotomy (with lengthening of any triceps surae contracture) has been shown to relieve symptoms.[2,5,11]

## Case 5:

A 12-year-old obese boy presents with bilateral painful flatfeet. Pain is mostly localized to the lateral mid-hindfoot and has been gradually getting worse over the past 18 months.

Physical examination shows bilateral rigid flatfoot deformities (Figure 1). He is unable to walk on his toes with heels off the ground. His peroneal tendons are in a state of apparent permanent contraction seeming to tent the overlying skin. His BMI is 37. Tarsal coalitions cannot be identified on plain radiographs (Figure 2).

**Discussion:** This patient has rigid flatfoot deformities in the absence of tarsal coalitions. He has peroneal spastic flatfoot, a condition for which there is not a clear etiology, known natural history, consistently reliable and successful treatment, or prognosis.

Many forms of treatment have been recommended with variable, though limited, success. If an MRI demonstrates inflammation due to impingement in the sinus tarsi region, flatfoot deformity correction by means of a calcaneal lengthening osteotomy is a logical solution. In some cases, a supplemental concurrent posterior calcaneal displacement osteotomy is needed.

***Figure 2.*** *Case 5: Standing anteroposterior and lateral radiographs of the patient showing flatfoot deformity with no radiographic signs of tarsal coalition.*

Subtalar or triple arthrodesis may be needed primarily as a salvage procedure. As with all flatfoot surgery, a medial cuneiform osteotomy (to correct forefoot supination) might be required, along with a tendo-Achilles lengthening or gastrocnemius recession.

## Summary

In conclusion, there is a wide range of pediatric flatfoot deformities with different etiologies and natural histories. Most flatfeet are physiologic variations in shape that do not cause pain or functional disability throughout the life of the affected individual. With that knowledge, one must carefully evaluate pain in an individual with flatfoot to determine the true cause of the pain as it might not be the simple presence of a low longitudinal arch. A complete history and physical exam are vital. Plain radiographs and advanced imaging may be necessary for diagnosis. There is no indication to treat asymptomatic flatfoot (flexible or rigid) deformities in children and adolescents. Painful flatfoot should be treated nonoperatively with the goal of eliminating the pain, not the deformity. Surgery is indicated for flatfeet only after prolonged attempts at nonoperative management have failed to relieve the pain. Osteotomies are the proven techniques of choice for elimination of pain, correction of deformity, preservation of joint motion, and restoration of function.

## References

1. Mosca VS. Flexible flatfoot in children and adolescents. J Child Orthop. 2010;4(2):107-21.

2. Mosca VS. Principles and Management of Pediatric Foot and Ankle Deformities and Malformations. Philadelphia, PA: Wolters Kluwer/Lippincott Williams & Wilkins, 2014.

3. Ghanem I, Massaad A, Assi A, Rizkallah M, Bizdikian AJ, el Abiad R, Seringe R, Mosca V, Wicart P. Understanding the foot's functional anatomy in physiological and pathological conditions: The calcaneopedal unit concept. J Child Orthop 2019;13:134-146.

4. Lawrence, D.A., et al., Tarsal Coalitions: Radiographic, CT, and MR Imaging Findings. HSS J, 2014. 10(2): p. 153-66.

5. Mosca, V.S., Subtalar coalition in pediatrics. Foot Ankle Clin, 2015. 20(2): p. 265-81.

6. Cass, A.D. and C.A. Camasta, A review of tarsal coalition and pes planovalgus: clinical examination, diagnostic imaging, and surgical planning. J Foot Ankle Surg, 2010. 49(3): p. 274-93.

7. Carr, J.B., 2nd, S. Yang, and L.A. Lather, Pediatric Pes Planus: A State-of-the-Art Review. Pediatrics, 2016. 137(3): p. e20151230.

8. Tileston KR, Griffin A, Wagner JFM, O'day MN, Krane EJ. Team Approach: Complex Regional Pain Syndrome in Children and Adolescents. JBJS Rev. 2020;8(4):e0174.

9. Krane E. Elliot Krane: The Mystery of Chronic Pain. Presented at TED2011; March 2011; Long Beach, CA. https://www.ted.com/talks/elliot_krane_the_mystery_of_chronic_pain?language=en. Accessed June 10, 2020.

10. Beighton, P., L. Solomon, and C.L. Soskolne, Articular mobility in an African population. Ann Rheum Dis, 1973. 32(5): p. 413-8.

11. Mosca VS, Bevan WP. Talocalcaneal tarsal coalitions and the calcaneal lengthening osteotomy: the role of deformity correction. J Bone Joint Surg Am 2012;94:1584-1594.

12. Wilde PH, Torode IP, Dickens DR, Cole WG. Resection for symptomatic talocalcaneal coalition. J Bone Joint Surg Br. 1994;76(5):797-801.

13. Docquier, P.L., P. Maldaque, and M. Bouchard, Tarsal coalition in paediatric patients. Orthop Traumatol Surg Res, 2019. 105(1S): p. S123-S131.

14. Denning, J.R., Tarsal Coalition in Children. Pediatr Ann, 2016. 45(4): p. e139-43.

15. Lawrence, D.A., et al., Tarsal Coalitions: Radiographic, CT, and MR Imaging Findings. HSS J, 2014. 10(2): p. 153-66.

16. Pouliquen, J.C., et al., The too-long anterior process calcaneus: a report of 39 cases in 25 children and adolescents. J Pediatr Orthop, 1998. 18(3): p. 333-6.

17. Brown, R.R., Z.S. Rosenberg, and B.A. Thornhill, The C sign: more specific for flatfoot deformity than subtalar coalition. Skeletal Radiol, 2001. 30(2): p. 84-7.

18. Crim, J.R. and K.M. Kjeldsberg, Radiographic diagnosis of tarsal coalition. AJR Am J Roentgenol, 2004. 182(2): p. 323-8.

19. Clarke, D.M., Multiple tarsal coalitions in the same foot. J Pediatr Orthop, 1997. 17(6): p. 777-80.