Journal of Regenerative Biology and Medicine

ISSN: 2582-385X
Slater G, et al., 2022- J Regn Bio Med
Review Article

Idiopathic Symptomatic Planovalgus Foot- Current Concepts in Minimally Invasive Correction

Gordon Slater[1*], Luke Mathen[2] and Tayla Slater[2]

[1]MBBS FRACS FA OrthoA, Clinical Private Practice, Double Bay NSW Sydney, Australia

[2]BEng (Hon)/MBiomedEng, Clinical Private Practice, Double Bay NSW Sydney, Australia

[*]**Corresponding Author:** Slater G, MBBS FRACS FA OrthoA, Clinical Private Practice, Double Bay NSW Sydney, Australia.

Received Date: 04-12-2022

Accepted Date: 04-21-2022

Published Date: 04-28-2022

Abstract

This paper presents a literature review and the author's current recommended surgical treatment for idiopathic symptomatic planovalgus foot. This condition has gained recognition as a diagnosis entity over the past several years. There have only been brief case reports prior to this paper. The authors aim to describe the anatomical and morphological features indicative of idiopathic pes planovalgus (ISP). This also includes the distinct features of the flat medial arch and how the medial rotation of the talus affects the different types of ISP. ISP, in essence, is a diagnosis of exclusion. It is distinct from conditions such as tibilias posterior failure and as such, the approach to management is different.

The review aims to describe and analyze the biomechanical function of the medial arch of the talus under normal conditions. This is compared to the biomechanics of the ISP foot. There are several theories that have been proposed to explain the incidence of acquired ISP foot dysfunction. These include degenerative tendinosis, chronic inflammation, trimalleolar impingement, and hypervascularity. However, it is worth noting that these cases are not linked to any exact etiological aspect and are hence termed "idiopathic." A few classifications have been proposed, considering MRI discoveries or clinical presentation.

Recent advances in minimally invasive techniques lead to an increased opportunity to correct even the most advanced deformities at multiple levels using image-guided key-hole surgery. In many cases this can be performed with the need to perform fusion surgery.

Keywords: Planovalgus; Idiopathic; Symptomatic planovalgus; Flat foot; Minimally invasive.

Introduction

The normal foot is supported by two-foot arches, which are the anterior transverse arch and the medial longitudinal arch. These arches support the normal kinematics of locomotion and give the classic footprint. Both the anterior transverse arch and the longitudinal arch are essential to foot

Citation: Slater G, Mathen L, Slater T. Idiopathic Symptomatic Planovalgus Foot- Current Concepts in Minimally Invasive Correction. J Regen Biol Med. 2022; 4(2)1-22
DOI: https://doi.org/10.37191/Mapsci-2582-385X-4(2)-109

biomechanics. The arches enable a spring-like mechanic to assist in weight-bearing and shock absorption. Pes planovalgus (PPV) is a multifactorial advanced foot defect characterized by a flat medial arch with medial rotation of the talus and the forefoot abduction. Currently, PPV is differentiated into two types. The first is "flexible", which is characterized by a normal arch when unloaded and flattening of the medial arch with hindfoot valgus when weight-bearing [1-3]. The other is the "fixed" type which does not correct when loading is released.

Several authors claim that the cause of flatfoot may be associated with several deformities that might be present in adulthood. These deformities can worsen and are recommended to be treated early [4-6]. In this current concept review, emphasis will be on the ISP foot which is symptomatic and recalcitrant to conservative measures. Family predisposition is a high-risk factor in the development of IPS [7].

Lower extremity deviation, which includes knock-knees and bow leggedness, can be associated with the ISP deformity. A detailed medical history and clinical examination are required. Investigations with X-ray, CT and MRI not only give some measure of the severity of the collapse, also serve to diagnose that there aren't any co-commitant or primary causes of collapse. In particular, inter-tarsal arthritis tibialis posterior failure or coalition needs to be excluded.

Treatment options are numerous, and include soft tissue procedures, osteotomy, and arthroereisis. These options vary in utility based on fixed or flexible cases, and success also varies across patients. In cases where a joint/s is not salvageable through the above methods, arthrodesis, commonly known as fusion, is required.

Unlike in humans, planovalgus can be useful for certain aquatic creatures, and enables animals, such as the seal to improve swimming efficiency through effective paddling (Figure 1). Flat footedness does not have the same benefits in land-dwelling creatures such as humans and indicates a lack of support from ligamentous and muscular structures. It has a strong impact on ankle gait, and can make push-off poor, as well as potentially leading to knee valgus, tibia rotation, hip rotation, anterior pelvic tilt and spinal issues [3,5,7]. Literature indicates several factors in planovalgus feet compared to normal, including increased forefoot supination, hindfoot eversion with limited dorsiflexion and compensatory forefoot abduction [7].

Epidemiology of pes planovalgus

Epidemiology studies demonstrate that the normal childhood foot posture is planovalgus. The foot adopts its adult arch as the tarsal bones ossify and develop. PPV has been categorized among the most common foot defects presenting to orthopedic practice. According to García-Rodríguez, et al. PPV incidence has increased by 2.7% on a sampled 118 people between 4 and 13 years [8]. Pfeiffer, et al. conducted a study on preschool children and stated that the frequency of PPV decreased with the increased age of development of the respondents [9].

In a cluster of 3-year-old children, the occurrence was at 54%; however, in a group of 6-year-old children, only 24% was observed. The incidence of pathological PPV was found

Citation: Slater G, Mathen L, Slater T. Idiopathic Symptomatic Planovalgus Foot- Current Concepts in Minimally Invasive Correction. J Regen Biol Med. 2022; 4(2)1-22
DOI: https://doi.org/10.37191/Mapsci-2582-385X-4(2)-109

to be less than 1%. The highest number of children presented with PPV had flexible arches that did not warrant any intervention. Note that flexible PPV does not necessarily correct with age, nor does it necessarily need treatment.

Figure 1: Aquatic animal demonstrating pes planovalgus posture.

When making the decision to treat PPV, it is important to elicit not only whether the patient has pain symptoms, but also the functional profile of the patient. There can be a slow and indolent loss of function particularly from participation in sports.

With advancing age, PPV that what was once flexible becomes fixed as soft tissue contractions result in bone remodeling and subsequent joint deterioration. Rigid and pathological PPV should be differentiated since it's highly linked with other conditions, including, but not limited to, congenital vertical talus, tarsal coalition, and skew foot [3]. A study conducted on evaluating the footprints in >800 patients [10], established a similar trend that showed that 54% of 3-year-old children presented with IPS. However, the deformity frequency was seen to decrease to 26% of 6-year-old patients. This observation suggested that the ages 3 to 6 years may present an important period that influences the medial longitudinal arch. This same study also investigated footprints in a sampled population of sick personnel, revealing that IPS was within similar limits for adult patients.

Research conducted by Barn, et al. a medical practitioner at John Hopkins Hospital, showed that the United States is one of the leading countries in terms of population suffering from PPV [11]. The study sample size of 3000 revealed 1200 had PPV, 40% of the total sample size. This study showed that four in every ten people collected randomly are likely to be suffering from planovalgus. Each person is likely to have a different cause of PPV. To enhance research, the study categorized the planovalgus into four significant causes: hereditary, shortening of the Achilles tendon, deviation of the lower extremities, and pronounced joint hypermobility.

Citation: Slater G, Mathen L, Slater T. Idiopathic Symptomatic Planovalgus Foot- Current Concepts in Minimally Invasive Correction. J Regen Biol Med. 2022; 4(2)1-22
DOI: https://doi.org/10.37191/Mapsci-2582-385X-4(2)-109

Family predisposition is considered as the main cause of planovalgus according to Haraldsson, et al. [12]. Due to hereditary traits, the infliction may affect the whole family, Shortening of the Achilles tendon is another cause or potential consequence of planovalgus. Thirdly, the deviation of the lower extremities is also considered as another significant cause of infliction. These deformities interestingly include knock-knees and bow leggedness.

Lastly, pronounced joint hypermobility, which has a higher representation in younger people, is another cause of PPV.

Recently published studies have focused their efforts to evaluate factors that may predispose kids to progressive and persistent IPS. A study conducted by Chen, et al. revealed that among some factors like higher joint laxity, W-sitting, male gender, being overweight, and a young age were all linked with an increased risk of experiencing PPV [13]. Similarly, the male gender, coupled with being overweight, was linked with an increased risk of ISP in children between the ages of 7 and 8. Various articles affirm that obesity among children of the age of 13 to 16 years may predispose them to the persistence of ISP. There exists a lack of literature seeking to explain and highlight the factors that may increase the risk of developing ISP. This creates a gap and, thus, a latent area for future research development.

History of the planovalgus

Church, et al. conducted a study to evaluate the natural history of foot deformation among children with cerebral palsy [14]. The study showed that foot deformation (planovalgus) among the children who have cerebral palsy occurs due to the interaction of many issues such as muscle spasticity and imbalance of muscles, bony torsion, instability of joints and soft tissue contractures.

Gait maturation has a natural development history among children, from the beginning of strolling to the age of 7 years. Franzone, Kaufman, and Sees indicated that the normal history of walking development among youngsters with cerebral paralysis doesn't follow the same as normal children. Regular assessment, intervention and treatment gave better outcomes than neglect [15].

Harris, et al. examined the natural history of flexible PPV [16]. They suggest that the absence of a well-formed medial arch, and thus flat footedness, does not necessarily imply a pathologic condition. It only becomes a medical issue once symptoms develop. There is currently limited data to suggest that flexible flatfoot in children leads to morbidity in adults. Clinical observation seems to imply that holding the foot in alignment during a rapid growth phase may prevent progression of flatfoot into adolescence. An approach to flat foot is advised that is between two extremes of treatment. The first extreme is neglect of the issue, the second being an aggressive surgical approach.

Staheli, et al. conducted a study to evaluate the natural history of the planovalgus foot, affirming the work of Harris, implying that flat footedness is not problematic until symptoms appear [10]. Cultural attitudes towards flat footedness implying poor health and lower status still exist today, and thus represents something that needs to be addressed. Their study found that flat footedness is normal in children, and within a normal range for adult feet. They recommended documentation and observation as management strategies.

A study by Evans, et al. found a strong link between obesity and flat-footedness [17], with a significant difference between flat-foot and non-flat foot groups. One difficulty is the broad range of foot types, with different degrees of pronation.

Pathogenesis

There's no single root factor that has been identified as the major cause of flexible flat foot. However, there exist two standard models that seek to describe the etiology of the problem. The first theory attributes planovalgus to decreased foot muscle strength [18-20]. Another theory suggests that the occurrence of PPV arch is attributed to by failure of the intra-osseous-ligamentous complex [21-23]. The latter theory is backed up by the opinion that the spring ligament's ineffectiveness is a familiar and normal occurrence associated with the eventual loss of the normal medial arch during weight-bearing.

Current insights and reviews usually agree that the osseous and ligamentous structures are of utmost importance in sustaining the structure of the medial foot arch, even though this remains a debatable subject. The dynamic stabilizers of the muscles serve to further strengthen and steady the foot all through ambulation and guarding the ligamentous structures, rather than the definite figure of the foot [21,22]. A study conducted by Mann and Inman [24] established that people with planovalgus need more intrinsic muscle movement to necessitate ambulation and ensure a stable foot. This creates an explanation for the muscle pain felt by patients with symptomatic planovalgus. As muscles weaken with age, the deformity progresses.

In support of the muscle weakness theory, a study was proposed by Vittore, et al. that studied the stimulation of extensor muscle groups in patients with a flexible planovalgus [25]. The researchers applied shallow electromyographic testing to determine whether patients with flexible planovalgus would have deprived extensor muscle contraction on the heel-contact stage of the walking cycle.

Feebleness also existed in patients with idiopathic symptomatic planovalgus deformity (ISPD) during the rest period, compared to patients who did not exhibit any features of deformities associated with planovalgus. Additionally, the expanse and structure of extensor muscle feebleness was directly proportional to the extent of medial arch failure. The writers propose that extensor muscle weakness leads to a general imbalance amongst the foot muscles. Although several studies have tried to describe and explain the pathogenesis of the condition, the progressive nature of planovalgus is certainly multifactorial. This involves an interaction between bones, ligaments, and muscles of the foot.

The condition which starts as flexible becomes fixed with time. Bones remodel to adopt the shape that the foot has adopted. Joint capsules contract and undergo hypertrophy, becoming fixed in position. Joints also experience arthritis during this stage. This is a slow and progressive process

Citation: Slater G, Mathen L, Slater T. Idiopathic Symptomatic Planovalgus Foot- Current Concepts in Minimally Invasive Correction. J Regen Biol Med. 2022; 4(2)1-22
DOI: https://doi.org/10.37191/Mapsci-2582-385X-4(2)-109

which is important to bear in mind when the foot is suddenly corrected in surgery. It is also likely that through obesity, PPV will increase in its incidence. PPV has a higher incidence in obese children [17]. This has a negative feedback cycle as weight increases with the reduction of weight-bearing activity. Other studies have shown that adiposity and ligament laxity are two major contributing factors to childhood flatfoot, using markers such as adiponectin, IL-6 and resistin [26].

Pathology of the planovalgus foot

PPV deformity is characterised by an external rotation of the calcaneus relative to the talus, creating an outward foot position. Plantar flexion is also indicative of PPV. Given an increased contraction of the achilles tendon associated with PPV, normal dorsiflexion is limited in the midstance phase of the walking gait cycle [27].

Obesity and Planovalgus

Literature has previously correlated a link between an increased body mass index (BMI) and planovalgus [28]. Riddiford-Harland, et al. analysed the relationship between weight and foot structure, with more obese children having a lower longitudinal arch [29]. This was backed up by Pfeiffer, et al. who found a high flat foot prevalence in obese children, particularly boys, in terms of a medial arch [9]. These studies, among others demonstrating a link between obesity and flat footedness, have failed to study the foot radiographically. A study by Villaroya, et al. [30] that used direct radiographic measurements and footprints aimed to evaluate different foot arches in obese children. Obese children saw a decrease in foot angle and an increase in Chippaux Smirak index scores, implying a lower medial longitudinal arch (MLA). This study also found a lower MLA in boys.

Normal biomechanics of locomotion and effect of planovalgus

Studies of the biomechanics of the movement of the ankle have revealed that the posterior facet contact area increases from heel strike to toe-off, as well as an increase in mean joint contact pressure [30].

The posterior facet of the subtalar joint takes as much as 80% of the load on heel strike. This reduces to 50% on midstance. Vertical force on the sinus tarsi allows forward propulsion [10]. The longitudinal arch is locked during the midstance component of the gait cycle. Malalignment leads to increasing stress on ligaments holding alignment of the talus on the calcaneus and across the talar tarsal joints (TTJ).

Health effects of planovalgus

A malaligned foot does not realign by itself once out of childhood. There are no long-term radiographic studies to show that a realignment of paediatric flatfoot will spontaneously correct when out of childhood. Adult PPV deformity also progressively worsens.

The occurrence of planovalgus is likely to be associated with many health problems that could require intervention. Research conducted by Caravaggi, et al. [7] showed that over time, the arch's flattening is likely to cause valgus at the hindfoot and lateral ankle impingement which can result in excessive pain when walking barefoot. The study also showed that flatfoot (planovalgus) is likely to cause shin pain and aching of the knee, hips, and lower back. The pain from the feet is passed to the knees and the lower back due to the feet's inability to support the whole body.

Other significant effects of the planovalgus are excessive inner heel wear patterns, which may be seen in shoes. This is caused by loss of the medial longitudinal arch, which causes abnormal wear patterns in shoes, and causes the inner sole to wear due to the inability to support the pes planus foot [31].

Because of the flattening of the arch and rolling of the ankle, the condition may cause progressive deformity, stretching of the spring and deltoid ligaments. This in turn can lead to arthritis of the intertarsal and ankle joints. Kadhim & Miller [32] showed that flexible flatfoot is most likely to be bilateral while posterior tibial tendon dysfunction is generally unilateral. Due to these effects of the planovalgus, early diagnosis effectively reduces the occurrence of arthritis. Other possible repercussions are plantar fasciitis, tibilais posterior dysfunction and, bunion deformities hallux rigidus and tarsal tunnel syndrome. In orthopaedics we seldom consider the psychological impacts of not being able to participate in sports. But adult patients presenting with severe fixed planovalgus later in life will attest to how this has affected their lives.

Idiopathic Symptomatic Planovalgus Deformity (ISPD)

Planovalgus is usually not painful with most of the patients, especially children presenting for evaluation due to parental concern [33]. During the diagnosis of the condition, it is valuable to ask about a family history of aching feet or any special shoe requirements. Numerous studies have shown planovalgus may be linked to familial history. Furthermore, understanding the developmental and past health records may offer hints to the incidence of diseases with musculoskeletal signs and symptoms [16,34].

It is important to note that the ISPD can be classified into various categories according to the occurrence of the diseases and the age of the patient. These categories include the hypermobile flexible planovalgus, and the flexible PPV, which has a tight heel cord, while the third classification of the planovalgus is rigid flatfoot with a tarsal coalition [35]. The hypermobile flexible PPV is associated with a generalized ligamentous laxity where the feet have a lower extremity rotational problem and are perceived as bilateral.

A footprint-based classification of planovalgus has been considered and proposed by Gris, et al. [36]. This method divides IPS into three grades. Grade 1 involves support for the lateral side of the foot that adds up to half of the support offered by the metatarsals. Grade 2 is indicated where support on the central part of the foot and the forefoot are equal. In Grade 3, the support in the central part of the foot is larger than the breadth of the metatarsal support.

Classifications

Tibialis Posterior Failure

The most well-known classification of PPV relates to Tibialis Posterior dysfunction. Stage I is portrayed by early disease and is symptomatic with no clinical or radiological disfigurements.

In stage II, with the stretching of the TPT, there is loss of the medial arch, but the

Citation: Slater G, Mathen L, Slater T. Idiopathic Symptomatic Planovalgus Foot- Current Concepts in Minimally Invasive Correction. J Regen Biol Med. 2022; 4(2)1-22
DOI: https://doi.org/10.37191/Mapsci-2582-385X-4(2)-109

deformity is correctable. The deformity becomes fixed and non-correctable in stage III, and stage IV is the end stage, with osteoarthritis of the inter-tarsal joints. Plain weight bearing radiographs are valuable to determine if there are any co-commitant pathologies, and the bony alignment. Ultrasound and MRI are valuable to evaluate ligament pathology.

Traditional treatment (rest, orthoses, shoe alterations, NSAIDs) may ease symptoms in patients with little deformation yet isn't viable in cases with severe deformity and fixed deformities. Contention remains concerning which strategy or blend of strategies is ideal. Stage I is a suitable for synovectomy, alongside a reconstruction of the deltoid tendon in young patients. Alternatively, treatment can follow in the form of a transfer of the flexor digitorum longus or the flexor hallucis longus. Treatment of stage II is dubious; the current pattern is to consolidate ligament movement with a joint-saving surgery. Stage 3 requires fusion surgery.

IPS Classification

To make a classification and diagnosis of PPV, there's a need to start with a general musculoskeletal physical examination. This involves evaluating the rotational outlines of the limbs. This is more reliable and well evaluated by measuring both the interior and exterior torsion of the hips and the thigh-foot position. The assessment is done while the patient lies in a prone position (Figure 2). Inspection for hyper elasticity can be done using the 9-point Beighton score. A score ≥ of 5 might show a hypermobility syndrome in children >5 years old [37]. General ligamentous laxity or exterior tibial rotation, particularly if combined with extreme femoral anteversion, predispose to the development of ISP.

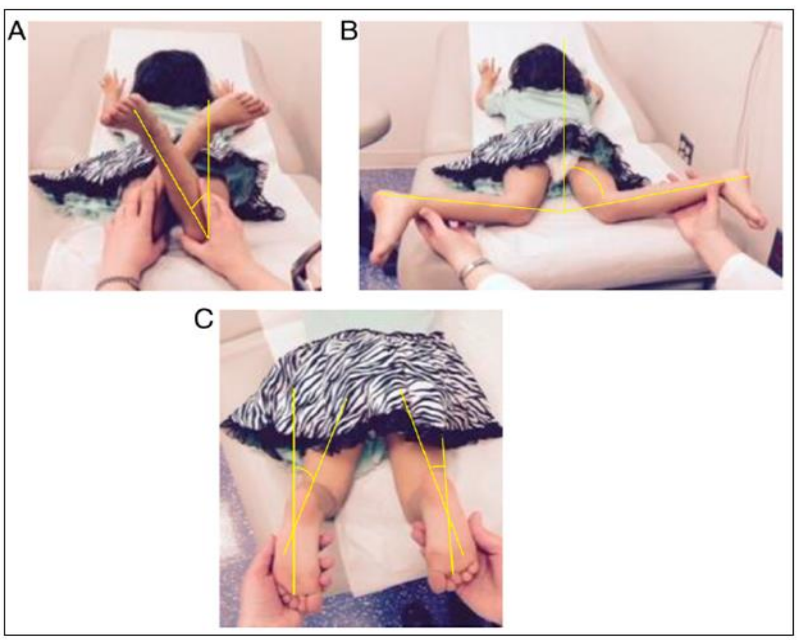

Figure 2: Rotational profile of the pediatric hips. Outside and inside hip pivot, which is estimated with the patient in an inclined position, the legs can be applied as a goniometer like a vertical line. A: valuation of outside rotation. B: Evaluation of internal rotation. C: Measurement of thigh foot angle [38].

Citation: Slater G, Mathen L, Slater T. Idiopathic Symptomatic Planovalgus Foot- Current Concepts in Minimally Invasive Correction. J Regen Biol Med. 2022; 4(2)1-22
DOI: https://doi.org/10.37191/Mapsci-2582-385X-4(2)-109

This classification concludes that the foot's outline is because of the sum of several connections between a variety of joints, muscles, ligaments, and tendons. The hindfoot, midfoot, and forefoot are interconnected and influence the general presentation of the foot. Patients with PPV can have a valgus hindfoot, dorsiflexed and abducted midfoot, and pronated or exteriorly rotated forefoot (Figure 3). This blend in totality contributes to the forfeiture and diminishing of the median foot arch.

Figure 3: Examples of basic foot highlights as seen in pediatric feet. A: Pediatric PPV brings about hindfoot valgus as shown. B: Abduction of the midfoot and pronation of the forefoot is also observed with the lower leg joint's internal breakdown, bringing about a rotation of the forefoot away from the central axis. C: planovalgus brings about a high average longitudinal arch when not loaded, best observed from the sagittal view. D: Normal pediatric foot with maintained average longitudinal curve while standing [39].

During an assessment, the practitioner should include foot inspection in both the standing and sitting positions, and when the patient is walking. The clinician ought to scrutinize the feet from the anterior and the posterior while the patient is standing. When observing the posterior foot, a valgus heel, or the presence of "too many toes" may exhibit. Generally, the evaluator making the diagnosis ought to have the ability to observe only the fifth and half of the fourth toe when observing the patient from a fixed point from the rear, as well as throughout walking. Other toes are viewed because of external rotation and abduction in planovalgus (Figure 4).

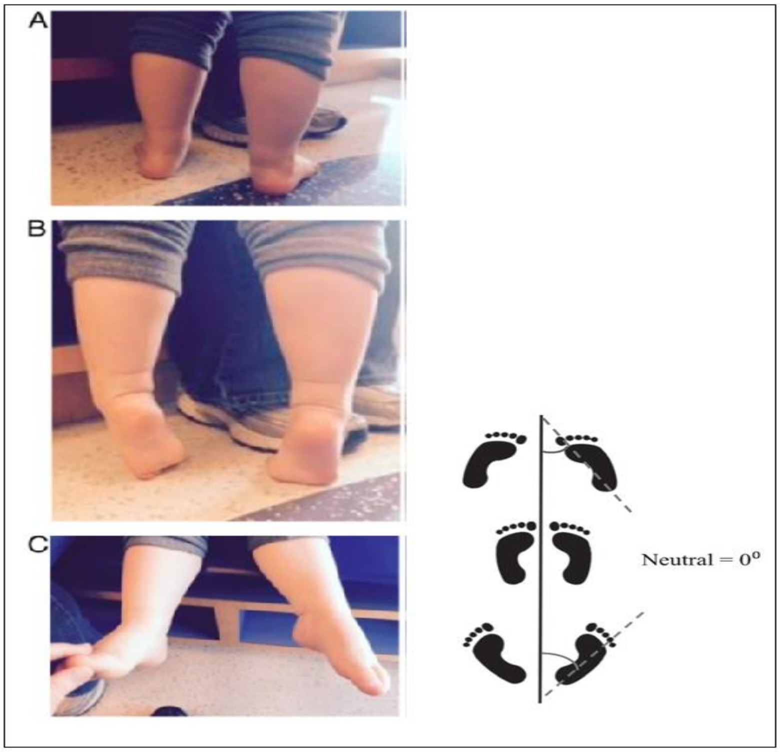

Figure 4: Typical physical findings in, Flexible planovalgus. A Rearview assessment of the heel uncovering a valgus hindfoot and "too many toes sign". B, Reconstitution of the medial longitudinal arch is seen on toe raise. C, Reconstitution of the average curve is additionally observed with constrained dorsiflexion of the great toe during the "jack test" [40].

The use of counting the toes from behind is a useful measure. Generally, one and half toes can be seen. The measuring factors such as rotation at the hips, knees, ankles, or foot might give the impression of how the gait pattern is altered (Figure 4).

Proposed Classification of ISP by Slater, et al

We have identified important parameters that not only can categorize ISP serve as a template for the treatment of the condition. These parameters are age of the patient, flexibility (correctability of the deformity) and the degree of the translation of the 2nd metatarsal and the hindfoot from the biomechanical axis.

Flexible ISP (FL)

Reference 2nd metatarsal translation from the axis.

1. Under 16
   - **A.** Under5 cm (ISP FL 1A)
   - **B.** over 5cm (ISP FL 1B)
2. Adult
   - **A.** under 3cm from axis (ISP FL 2A)
   - **B.** 3-5cm from axis (ISP FL 2B)
   - **C.** Greater than 5cm (ISP FL 2C)

Fixed ISP (FI)

As the deformity persists into later life it becomes fixed in position. Standing on toes becomes impossible in the more severe deformities. Gentle pressure on the sinus tarsi

Citation: Slater G, Mathen L, Slater T. Idiopathic Symptomatic Planovalgus Foot- Current Concepts in Minimally Invasive Correction. J Regen Biol Med. 2022; 4(2)1-22
DOI: https://doi.org/10.37191/Mapsci-2582-385X-4(2)-109

and placing the foot in a dorsiflexed position does not lead to correction of the deformity.

a) Less than 3cm shift from the axis. (Midpoint calcaneus) (Forefoot less than 5cm from the axis.)
b) Greater than 3 cm shift from the axis. (Midpoint of the calcaneus) (Forefoot greater than 5cm from the axis)

Treatment

Flexible

The choice to observe instead of treating a planovalgus patient is based on the patient's history and a physical assessment. In young children, normal physiological posture can indicate only observation is necessary. It is contentious as to whether to treat a misaligned foot which is asymptomatic apart from its shape. Given the natural history of gradual deterioration, asymptomatic feet may need to be treated while it is still flexible. The question then arises as to what form that treatment should take. Examination is always the first stage. If treatment is initiated to change the shape and alignment most instances of planovalgus necessitate operative intervention. For patients with pain-free, flexible planovalgus, studies have not yet determined whether any available treatment can change the normal progression of the deformity. Non-operative treatments confirm this observation, which as previously discussed, will not alter the natural history. Physiotherapy can aid in strengthening the tibialis posterior tendon, but eventually the deformity will overcome its strength.

Technique	Explanation	Achievable outcome	Limitations
Soft tissue procedures	Achilles lengthening, Medial collateral, and spring ligament plication	May be utilized as an adjunct	Less appropriate when used alone
Osteotomy	Osteotomy and realigning of tarsal bones	Offers superior outcomes without need for fusion by restoring hindfoot and midfoot alignment	Results depend on bone healing and technical correction
Arthrodesis	Fusion of bones to lessen development and maintain joint arrangement	Gives complete remedy, with the possibility to make extreme corrections.	Irreversible disposal of joint development and degeneration of nearby joints.
Arthroereisis	Inclusion of metal, silicone, or biodegradable implant into sinus tarsi	Useful with an osteotomy or soft-tissue procedures to support the medial arch for adults.	Irritation of the sinus tarsi, biomaterial failure, or an over / under correction.

Table 1: Surgical Choices for the Management of Idiopathic Symptomatic Flexible planovalgus.

The first option of treatment for the painful yet flexible planovalgus is non-operative treatment. Conservative intervention methods, e.g., resting the foot, activity modification, ice packs, soft tissue manipulation, inner soles, and NSAIDS, are the initial steps that can be undertaken to ease pain. In clients with a fixed achilles tendon, the talus is always plantarflexed, and the use of orthotics may exacerbate symptoms [41]. A physical therapy program conducted and monitored at home, including achilles tendon stretches, should be started. Recently, a study conducted by Blitz, et al. [42] demonstrated that the use of stretches on the Achilles tendon might aid in counteracting equinus deformity. Studies have outlined that the use of orthotics in flexible symptomatic planovalgus can reduce pain [23,37,43]. The application of customized orthotics, such as customized inner soles, has not been clearly demonstrated to provide significant outcomes as compared to over-the-counter orthotics. Therefore, its logical to recommend the least expensive orthotic first [44]. Currently, there is only one study that has established pain reduction with the application of custom-made orthoses in clients who were diagnosed with arthritis and planovalgus [45]. Note that orthotics does not change the shape nor the natural history of the deformity.

Surgery is hardly ever indicated in flexible planovalgus. Surgical management consists of a cascading range of options from arthroereisis devices through to more complex combinations of soft tissue procedures, Illizarov frames and fusion procedures. This is illustrated above in Table 1.

Soft tissue reconstruction

A few soft tissue alternatives incorporate plication of the medial longitudinal structures, elongation of the peroneus brevis, or Achilles' ligament lengthening. Studies have demonstrated that these methods have poor outcomes because of the high dissatisfaction rates given the structure of the foot is unaltered [46]. These methods are commonly performed alongside osteotomies, and use of an arthroesis plug. Fusion of joints in the foot isn't recommended for pediatrics unless a neuromuscular foot posture exists. Fusion is irreversible and eventually results in degradation in the neighboring joints. [47-49]. It is ideal to spare as much functionality for development as possible in a pediatric patient, so fusion is generally avoided in the treatment of the typical, flexible planovalgus. Regardless, in pediatric or adult patients with neuromuscular conditions, fusion maybe the practical decision.

Figure 5: Pre-Op and post-op children idiopathic foot [45].

Citation: Slater G, Mathen L, Slater T. Idiopathic Symptomatic Planovalgus Foot- Current Concepts in Minimally Invasive Correction. J Regen Biol Med. 2022; 4(2)1-22
DOI: https://doi.org/10.37191/Mapsci-2582-385X-4(2)-109

The above picture (figure 5) is a pre-op juvenile bilateral ISP greater than 5cm axial drift (classification Slater FL1B). patient has been treated with an Archit 9mm plug and is shown 6 months post treatment.

Figure 6: Bilateral IPS in an adolescent patient [49].

Figure 7: Classification ISP FL1B. Correction minimally guided insertion of Arch IT [33].

Osteotomies

Osteotomies address the basic distortions in flexible planovalgus [50]. These include the standard calcaneal osteotomy with medial shift, opening wedge osteotomies or hindfoot lengthening (e.g., Evans's osteotomy), and the Triple-C (calcaneus, cuneiform, cuboid) osteotomy. The standard calcaneal osteotomy can successfully correct a valgus heel by moving the heel medially, altering the delivering vector of the Achilles tendon in a medial direction [51]. The calcaneal osteotomy correction can increase with the use of around the corner translation or the use of bone plug to become an opening wedge. The osteotomy takes a number of weeks to heal with patients required to wear a boot [50,52]. Postsurgical assessment has exhibited huge improvement of foot shape along with clinical improvement of 89.5% after surgery [53]. The calcaneal lengthening osteotomies or detraction fusion (at the calcaneocuboid joint) at the same time can correct hindfoot valgus and forefoot abduction. Mosca [34] illustrated a satisfactory clinical outcome in 93.5% of cases. After opening calcaneal osteotomy, patients showed huge biomechanical plantar weight estimation enhancements as well [54]. The postsurgical after-effects of a Triple-C osteotomy have generally been sound from a clinical and radiographic assessment, although these outcomes have been observational without the comparison of a control group [40,55].

Figure 8: Pre op of severe ISPD [53]. Deformity is correctable.

The above figure 9 shows a severe ISPD in a 78-year-old adult female with a greater than 5 cm flexible PPV deformity with a strong tibialis posterior. The images show the initial results of surgery using single stage minimally invasive technique.

Figure 9: Post Op Calcaneal shift M1 repair [18]. The above image shows the post-op correction. Calcaneal shift MI around the corner, MCL repair with "ArchIT".

Citation: Slater G, Mathen L, Slater T. Idiopathic Symptomatic Planovalgus Foot- Current Concepts in Minimally Invasive Correction. J Regen Biol Med. 2022; 4(2)1-22
DOI: https://doi.org/10.37191/Mapsci-2582-385X-4(2)-109

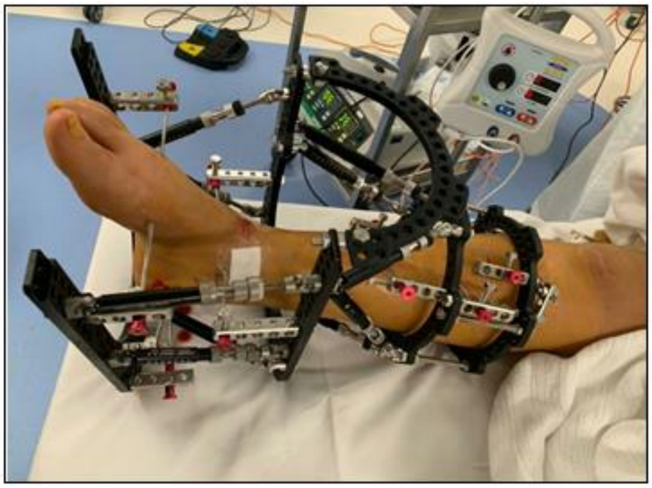

Figure 10: Post Op Osteotomy of a patient showing Taylor spatial frame supporting and correction of IPPV [8]. The above Figure 10 shows the initial post-op M1-M5 Ca MI image-guided osteotomies hexagonal frame. The frame has two mobile components. One correcting and displacing the heel whilst the forefoot components restore arch, rotates the forefoot, and corrects abduction.

Figure 11: Post Op removal of frame four weeks post-surgery [43].

The above image shows the shape and formation of the leg four weeks after removing the frame. The idea is guided by the stabilization of the osteotomies with "ArchIT". This implies that the leg is close to recovery and stabilizing while the deformation disappears with time. Regular checkups and exercise help enhance rehabilitation, as well as post-operative footwear [52].

Citation: Slater G, Mathen L, Slater T. Idiopathic Symptomatic Planovalgus Foot- Current Concepts in Minimally Invasive Correction. J Regen Biol Med. 2022; 4(2)1-22
DOI: https://doi.org/10.37191/Mapsci-2582-385X-4(2)-109

Figure 12: Post Op six weeks correction surgery [35].

At this point the patient can begin to weight bear slowly stimulating the osteotomy sites which are still consolidating. As strength is gained the patient can increase their weight bearing tolerance [55].

Figure 13: Post Op six months correction and recovery [1].

Over the next few months, physiotherapy is started so the patient can begin to rehabilitate. Gait retraining is required. Use of the great toe during the gait cycle and tibialis posterior are essential. As such, toe standing can begin.

Arthroereisis

Arthroereisis is a non-fusion strategy in which the movement of a joint is confined but without complete immobilization. First presented during the 1900s, this methodology involves inserting a metal or bioabsorbable implant into the sinus tarsi (Figure 6). This limits eversion of the subtalar joint, therefore supporting the medial longitudinal arch from collapse. The appeal of this technique in that it is minimally invasive and joint preserving. It is suitable particularly in young patients (under 18) who have a flexible pes planus. Osteotomy is not required often, however in adult patients arthroereisis can be combined with an osteotomy and medial longitudinal reconstruction. Studies have demonstrated immediate improvement in radiographs and restitution of the arch of the foot [56,57]. Arthroereisis plug treatment has demonstrated radiographic osseous normalization, decreased plantar fascial, posterior tibial nerve and tendon strain, and improved emotional status. Paediatric patients noted their quality of life improved. One of the fundamental concerns with respect to this treatment is a high complication rate in 4-18% of cases in an ongoing review [40]. This includes malposition of the device, overcorrection, expulsion of the device, unpredictable response of the tarsal bones and chronic tarsal synovitis. More severe complications include talar neck fracture [40,58]. Although many of the case studies on arthroereisis give great radiographic outcomes and improved foot alignment [59], the inconvenience rate is high and long-term results into adulthood need to be monitored. Arthroereisis plugs are devices essential to blocking peritalar rotation and do not simply open the subtalar joint. As the talus is relatively fixed in the ankle joint, rotation of the calcaneus around the talus occurs in planovalgus. The talus can plantar flex just like in a congenitally vertical talus.Perhaps the main criticism is that the device has a high removal rate. This is a likely component of treatment in adults. In rare circumstances the patient will begin to weight bear on the lateral border of their foot. This can be due to over-sizing, or more likely from the patient walking with the foot everted to stop contact of the device in the sinus tarsi. Device removal will alleviate this. Its ability to lead to long term correction with a minimally invasive technique makes it indispensable in the management of flexible pes planus. Removal is more frequent in larger size devices that are needed in bigger patients and for more significant corrections. Arthroereisis plugs need a good fit, protection whilst ingrowth into the implant occurs, and be supportive of weight bearing and rehabilitation. Usage of an arthroereisis plug requires the foot to be flexible. An adult fixed flat foot without arthritis can be turned into a flexible flat foot with use of multiple keyhole osteotomies and application of an external frame with distraction. The frame is used to both gradually move the osteotomies to an improved position but does not need to be used once the correction has been obtained. During the correction phase the foot is also stretched so that it becomes flexible. This allows for frame removal and P/C screw insertion as the definitive treatment, which is useful given the cumbersome nature of frames.

In the authors experience in use of over 200 arthroereisis plugs, removal in children (under 18) has not been necessary. However, removal in adults is almost routine as the plug irritates the sinus tarsi. Removal does not lead to recurrence of the deformity.

Citation: Slater G, Mathen L, Slater T. Idiopathic Symptomatic Planovalgus Foot- Current Concepts in Minimally Invasive Correction. J Regen Biol Med. 2022; 4(2)1-22
DOI: https://doi.org/10.37191/Mapsci-2582-385X-4(2)-109

Figure 14: A: Preoperative horizontal radiograph of a young adult patient with serious right flatfoot. B: Intraoperative fluoroscopic radiograph after inclusion of arthroereisis case, anteroposterior and horizontal. C: Postoperative horizontal radiograph uncovering stable situation of arthroereisis and improved average foot curve [60].

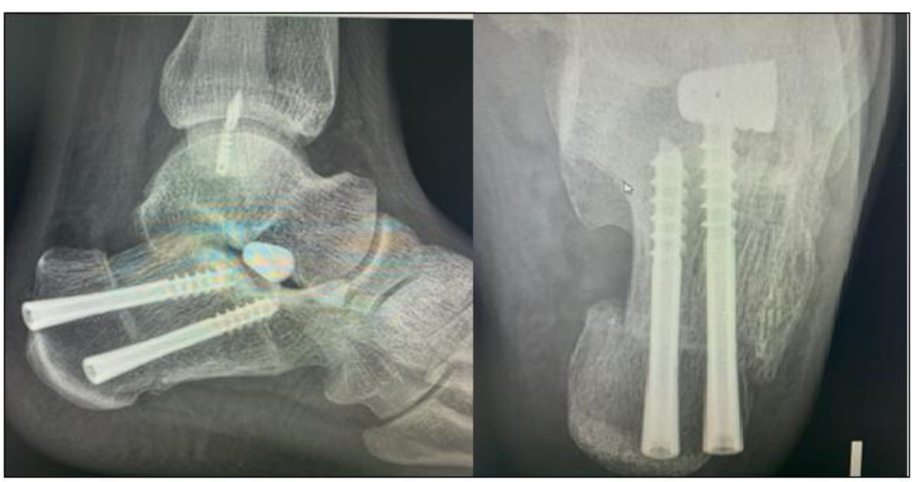

Figure 15: Horizontal lateral and posterior radiograph post screw and arthroereisis plug insertion.

Citation: Slater G, Mathen L, Slater T. Idiopathic Symptomatic Planovalgus Foot- Current Concepts in Minimally Invasive Correction. J Regen Biol Med. 2022; 4(2)1-22
DOI: https://doi.org/10.37191/Mapsci-2582-385X-4(2)-109

Conclusion

The planovalgus foot has emerged as a significant component of foot and ankle practice. Its incidence would appear to be increasing in western society due to a variety of factors. It is not a benign condition and nor does it simply go away for the patient. It slowly progresses through life and has effects on the biomechanics of the body leading to potential damage to other joints and psychological effects.

In the child, the normal foot habitus is to be pes planus. But as the child develops, the typical medial, longitudinal, and transverse arches develop into the appropriate axial alignment common in adults appears.

Its management is somewhat controversial given that in many cases its initial presentation is often not associated with pain. This generally makes the clinician begin with recommending non-operative management. Long term studies have shown these treatments to be ineffective in altering the alignment of the foot. Malalignment of the foot has been shown to have negative repercussions.

Prophylactic surgical treatment of an asymptomatic foot can be difficult to propose but perhaps arthroereisis plug usage will gain in popularity as further long-term studies become available.

In this paper, a classification of idiopathic pes planovalgus deformity to devise a treatment plan based on the deviation from the axial plane and the flexibility of the deformity is proposed.

Disclosure

The author is a senior designer for Integrant and company director. He has a pecuniary interest in Albury day surgery.

References

1. Arangio GA, Reinert KL, Salathe EP. A biomechanical model of the effect of subtalar arthroereisis on the adult flexible flat foot. Clin Biomech. 2004;19(8):847-52. PubMed | CrossRef
2. Rosati G. The prevalence of multiple sclerosis in the world: an update. Neurol Sci. 2001;22(2):117-39. PubMed | CrossRef
3. Sullivan AJ. Pediatric flatfoot: evaluation and management J Am Acad Orthop Surg. 1999;7(1):44-53. PubMed | CrossRef
4. Schon LC. Subtalar arthroereisis: a new exploration of an old concept. Foot Ankle Clin. 2007;12(2):329-39. PubMed | CrossRef
5. Staheli LT. Planovalgus foot deformity. Current status. J Am Podiatr Med Assoc. 1999;89(2):94-9. PubMed | CrossRef
6. Giannini S. Operative treatment of the flatfoot: why and how. Foot Ankle Int.1998;19(1):52-6. PubMed | CrossRef
7. Caravaggi P, Sforza C, Leardini A, Portinaro N, Panou A. Effect of plano-valgus foot posture on midfoot kinematics during barefoot walking in an adolescent population. J Foot Ankle Res. 2018;11(1):1-9. PubMed | CrossRef
8. Garcıa-Rodrıguez A, Martın-Jiménez F, Carnero-Varo M, Gómez-Gracia E, Gómez-Aracena J, Fernández-Crehuet J. Flexible flat feet in children: a real problem? Pediatrics. 1999;103(6):84. PubMed | CrossRef
9. Pfeiffer M, Kotz R, Ledl T, Hauser G, Sluga M. Prevalence of flat foot in preschool-aged children. Pediatrics. 2006;118(2):634-9. PubMed | CrossRef
10. Staheli LT. Evaluation of planovalgus foot deformities with special reference to the natural history. J Am Podiatr Med Assoc. 1987;77(1):2-6. PubMed | CrossRef

Citation: Slater G, Mathen L, Slater T. Idiopathic Symptomatic Planovalgus Foot- Current Concepts in Minimally Invasive Correction. J Regen Biol Med. 2022; 4(2)1-22
DOI: https://doi.org/10.37191/Mapsci-2582-385X-4(2)-109

11. Barn R, Brandon M, Rafferty D, Sturrock RD, Steultjens M, Turner DE, et al. Kinematic, kinetic and electromyographic response to customized foot orthoses in patients with tibialis posterior tenosynovitis, pes plano valgus and rheumatoid arthritis. Rheumatology. 2014;53(1):123-30. PubMed | CrossRef
12. Haraldsson S. Operative treatment of pes planovalgus staticus juvenilis: Preliminary communication. Acta Orthop Scand. 1962;32(1-4):492-8. PubMed | CrossRef
13. Chen KC, Tung LC, Yeh CJ, Yang JF, Kuo JF, Wang CH. Change in flatfoot of preschool-aged children: a 1-year follow-up study. Eur J Pediatr. 2013;172(2):255-60. PubMed | CrossRef
14. Church C, Lennon N, Alton R, Schwartz J, Niiler T, Henley J, et al. Longitudinal change in foot posture in children with cerebral palsy. J Child Orthop. 2017;11(3):229-36. PubMed | CrossRef
15. Heydemann JA, Abousamra O, Franzone JM, Kaufman BE, Sees JP. What's new in the management of foot deformities in children with cerebral palsy. J Pediatr Orthop. 2018;38(1):20-4. PubMed | CrossRef
16. Harris EJ. The natural history and pathophysiology of flexible flatfoot. Clin Podiatr Med Surg. 2010;27(1):1-23. PubMed | CrossRef
17. Evans AM. The paediatric flat foot and general anthropometry in 140 Australian school children aged 7-10 years. J Foot Ankle Res. 2011;4(1):1-8. PubMed | CrossRef
18. Jones BS. Flat foot: a preliminary report of an operation for severe cases. J Bone Joint Surg Br. 1975;57(3):279-82. PubMed | CrossRef
19. Darrall-Jones JD, Jones B, Till K. Anthropometric and physical profiles of English academy rugby union players. J Strength Cond Res. 2015;29(8):2086-96. PubMed | CrossRef
20. Haraldsson S. Pes plano-valgus staticus juvenilis and its operative treatment. Acta Orthop Scand. 1965;35:234-56. PubMed | CrossRef
21. Basmajian JV, Stecko G. The role of muscles in arch support of the foot: an electromyographic study. J Bone Joint Surg Am. 1963;45(6):1184-90. PubMed | CrossRef
22. Gray EG, Basmajian JV. Electromyography and cinematography of leg and foot ("normal" and flat) during walking. Anat Rec.1968;161(1):1-5. PubMed | CrossRef
23. Hicks JH. The mechanics of the foot: I. J Anat.1953;87(4):345. PubMed
24. Mann R, Inman VT. Phasic activity of intrinsic muscles of the foot. J Bone Joint Surg Am. 1964;46(3):469-81. PubMed | CrossRef
25. Vittore D, Patella V, Petrera M, Caizzi G, Ranieri M, Putignano P, et al. Extensor deficiency: first cause of childhood flexible flat foot. Orthopedics. 2009;32(1):28. PubMed | CrossRef
26. Alghadir AH, Gabr SA, Rizk AA. Plasmatic adipocyte biomarkers and foot pain associated with flatfoot in schoolchildren with obesity. Rev Assoc Med Bras. 2019;65:1061-6. PubMed | CrossRef
27. Dogan A, Albayrak M, Akman YE, Zorer G. The results of calcaneal lengthening osteotomy for the treatment of flexible pes planovalgus and evaluation of alignment of the foot. Acta Orthop Traumatol Turc. 2006;40(5):356-66. PubMed
28. Cass AD, Camasta CA. A review of tarsal coalition and pes planovalgus: clinical examination, diagnostic imaging, and surgical planning. J Foot Ankle Surg. 2010;49(3):274-93. PubMed | CrossRef
29. Riddiford-Harland DL, Steele JR, Storlien LH. Does obesity influence foot structure in prepubescent children? Int J Obes Relat Metab Disord. 2000;24(5):541-4. PubMed | CrossRef
30. Sangeorzan A, Sangeorzan B. Subtalar joint biomechanics: from normal to pathologic. Foot Ankle Clin. 2018;23(3):341-52. PubMed | CrossRef
31. Caravaggi P, Giangrande A, Berti L, Lullini G, Leardini A. Pedobarographic and kinematic analysis in the functional evaluation of two post-operative forefoot offloading shoes. J Foot Ankle Res. 2015;8(1):1. PubMed | CrossRef
32. Kadhim M, Miller F. Crouch gait changes after planovalgus foot deformity correction in ambulatory children with cerebral palsy. Gait Posture. 2014;39(2):793-8. PubMed | CrossRef
33. T. Cappello, KM Song. Determining treatment of flatfeet in children. Curr Opin Pediatr. 1998;10(1):77-81. PubMed | CrossRef
34. Mosca VS. Flexible flatfoot in children and adolescents. J Child Orthop. 2010;4(2):107-21. PubMed | CrossRef

35. Nejib K, Delpont M. Medium-term results of calcaneus lengthening in idiopathic symptomatic flat foot in children and adolescents. J Child Ortho. 2020;14(4):286-92. PubMed | CrossRef
36. Gris D, Ye Z, Iocca HA, Wen H, Craven RR, Gris P, et al. NLRP3 plays a critical role in the development of experimental autoimmune encephalomyelitis by mediating Th1 and Th17 responses. J Immunol. 2010;185(2):974-81. PubMed | CrossRef
37. Rathjen KE, Mubarak SJ. Calcaneal-cuboid-cuneiform osteotomy for the correction of valgus foot deformities in children. J Pediatr Orthop. 1998;18(6):775-82. PubMed | CrossRef
38. R. Wadey. A Multiple Mediation Analysis. Rehabil Psychol. 2014;59(3):256-66. PubMed | CrossRef
39. Lui TH. Spontaneous subtalar fusion: an irreversible complication of subtalar arthroereisis. J Foot Ankle Surg. 2014;53(5):652-6. PubMed | CrossRef
40. Singh A, Kumar A, Kumar S, Srivastava RN, Gupta OP. Analysis of ankle alignment abnormalities as a risk factor for pediatric flexible flat foot. Internet J Medical Update. 2010;5(1).
41. Blitz NM, Stabile RJ, Giorgini RJ, DiDomenico LA. Flexible pediatric and adolescent pes planovalgus: conservative and surgical treatment options. Clin Podiatr Med Surg. 2010;27(1):59-77. PubMed | CrossRef
42. Evans AM. The flat-footed child—to treat or not to treat: what is the clinician to do? J Am Podiatr Med Assoc. 2008;98(5):386-93. PubMed | CrossRef
43. Rome K, Ashford RL, Evans A. Non-surgical interventions for paediatric PEs planus. Cochrane Database Syst Rev. 2010(7). PubMed | CrossRef
44. Powell M, Seid M, Szer IS. Efficacy of custom foot orthotics in improving pain and functional status in children with juvenile idiopathic arthritis: a randomized trial. J Rheumatol. 2005;32(5):943-50. PubMed
45. Maynou C, Naudi S, Staquet V, Parent S, Boniface O. Pied plat valgus statique de l'adulte (y compris synostoses congénitales). EMC - Appareil locomoteur. 2010. CrossRef
46. Saltzman CL, Fehrle MJ, Cooper RR, Spencer EC, Ponseti IV. Triple arthrodesis: twenty-five and forty-four-year average follow-up of the same patients. J Bone Joint Surg Am. 1999;81(10):1391-402. PubMed | CrossRef
47. Sharma N, Slater G. Pantalar Arthrodesis Using the Fuse It Arthrodesis Plug in Charcot. EC Orthopaedics. 2019;10(2):84-9.
48. Alles WF, Powell JW, Buckley W, Hunt Jr EE. The national athletic injury/illness reporting system 3-year findings of high school and college football injuries. J Orthop Sports Phys Ther. 1979;1(2):103-8. PubMed | CrossRef
49. Slater G, Clifton T. Minimally Invasive Opening Wedge Calcaneal Osteotomy Using a Titanium Structural Fusion Device. EC Orthopaedics. 2018;9:626-31.
50. Arangio GA, Salathé EP. Medial displacement calcaneal osteotomy reduces the excess forces in the medial longitudinal arch of the flat foot. Clin Biomech (Bristol, Avon). 2001;16(6):535-9. PubMed | CrossRef
51. Slater G, Slater T. Current Concepts Review: Orthotics in Post-operative Foot and Ankle Surgery. J Regen Biol Med. 2022;4(1):1-4. CrossRef
52. Koutsogiannis E. Treatment of mobile flat foot by displacement osteotomy of the calcaneus. J Bone Joint Surg Br. 1971;53(1):96-100. PubMed | CrossRef
53. Davitt JS, MacWilliams BA, Armstrong PF. Plantar pressure and radiographic changes after distal calcaneal lengthening in children and adolescents. J Pediatr Orthop. 2001;21(1):70-5. PubMed | CrossRef
54. Moraleda L, Salcedo M, Bastrom TP, Wenger DR, Albiñana J, Mubarak SJ. Comparison of the calcaneo-cuboid-cuneiform osteotomies and the calcaneal lengthening osteotomy in the surgical treatment of symptomatic flexible flatfoot. J Pediatr Orthop. 2012;32(8):821-9. PubMed | CrossRef
55. Giannini S, Ceccarelli F, Benedetti MG, Catani F, Faldini C. Surgical treatment of flexible flatfoot in children: a four-year follow-up study. J Bone Joint Surg Am. 2001;83(2):73-79. PubMed | CrossRef
56. Metcalfe SA, Bowling FL, Reeves ND. Subtalar joint arthroereisis in the management of pediatric flexible flatfoot: a critical review of the literature. Foot Ankle Int. 2011;32(12):1127-39. PubMed | CrossRef
57. Kumar V, Clough TM. Talar neck fracture-A rare but important complication following subtalar arthroereisis. Foot (Edinb). 2014;24(4):169-71. PubMed | CrossRef
58. Kumar V, Clough TM. Talar neck fracture-A rare but important complication following subtalar arthroereisis. Foot (Edinb). 2014;24(4):169-71. PubMed | CrossRef

Citation: Slater G, Mathen L, Slater T. Idiopathic Symptomatic Planovalgus Foot- Current Concepts in Minimally Invasive Correction. J Regen Biol Med. 2022; 4(2)1-22
DOI: https://doi.org/10.37191/Mapsci-2582-385X-4(2)-109

59. Metcalfe SA, Bowling FL, Reeves ND. Subtalar joint arthroereisis in the management of pediatric flexible flatfoot: a critical review of the literature. Foot Ankle Int. 2011;32(12):1127-39. PubMed | CrossRef
60. Arangio GA, Salathé EP. Medial displacement calcaneal osteotomy reduces the excess forces in the medial longitudinal arch of the flat foot. Clin Biomech (Bristol, Avon). 2001;16(6):535-9. PubMed | CrossRef

Citation: Slater G, Mathen L, Slater T. Idiopathic Symptomatic Planovalgus Foot- Current Concepts in Minimally Invasive Correction. J Regen Biol Med. 2022; 4(2)1-22
DOI: https://doi.org/10.37191/Mapsci-2582-385X-4(2)-109