RESEARCH ARTICLE

Flat and flat valgus foot: a complex deformity especially affecting the protarsus and the medial mesotarsus

Authors
Gheorghe Burnei[1,2], Simona Lacrimioara Gavrilescu [3,4] , Cosmin Gabriel Lală [5] , Ionut Daniel Raducan [6,7] , Cristian Burnei [8,9]

Affiliations
[1] Macta Clinic, Constanța, Romania
[2] Tinos Clinic, Bucharest, Romania
[3] University of Medicine and Pharmacy "Gr. T.Popa", Iași, Romania
[4] Clinical Emergency Hospital for Children, Sf Maria" Iași , Romania
[5] National Institute of Research and Development in Mechatronics and Measurement Techniques (INCDMTM), Bucharest, Romania
[6] "Vasile Goldis" Western University of Arad, Arad, Romania
[7] Medical Center ART, Arad, Romania
[8] "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania
[9] Clinical Emergency Hospital, Bucharest, Romania

Correspondence
Burnei Gheorghe , Professor Doctoral School
"Carol Davila" University of Medicine and Farmacy , Bucharest , Romania.
Head of Department Pediatric Orthopaedics Surgery, Macta Clinic, Constanta, Romania
E-mail: mscburnei@yahoo.com

Abstract

Background Context: All the flat and flat valgus feet with evolutional potential or rigid, excepting the ones without evolutional potential entail static and predominantly dynamic discomfort in idle and locomotive state. A part of these children and teenagers have a hard time in dealing with the discomfort and many of them interrupt their training in athletic carriers due to the enhancement of the symptomatology as they grow older.

Purpose: In order to limit this impact encountered in many children in the ambient environment or in the children who intend to become athletes, the investigation and conceptualisation of the flat and flat valgus foot notions provide the chance of an accurate professional orientation and of a suitable diagnostic and treatment. A special group includes the children with severe forms of rigid flat and flat valgus from cerebral paralysis and arthrogryposis where the management has to ensure the possibility of walking stability and current independence.

Study design: Synthesis of a retrospective observational survey carried out during 45 years of activity.

Outcome measures: The long-term assessment of hundreds of patients with flat and flat valgus foot with evolutionist potential, the comparisons of the pre-operatory and post-operatory state of patients recommended for surgery and the evolution of these patients, professional orientation and their degree of satisfaction.

Methods: All the patients included in the assessment benefitted from differential treatment based on their symptomatology, the type of deformation and the character thereof, i.e. either flexible or rigid. We took into account the etiopathology, the age, the degree of development of the medial arch and the classification referred to in the text.

The majority of the patients, in a quite overwhelming percent, benefitted from a non-surgical treatment. The feet (with evolutionary potential) labelled at a certain point by the supporters of the non-treatment of such deformities as asymptomatic and free of risk where identified, after remote assessments, as non-diagnosed and/or neglected rigid flat feet.

Results: The periodic assessment allowed me to note that a series of feet have an evolutionary nature and only a very small number are free of such potential and did not present any symptomatology r other inconveniences even after the age of 60. A part of the rigid or rigid flat- valgus feet encountered in cerebral paralysis or arthrogryposis could not be corrected through the current surgical methods and we applied to the reconstruction of the plantar arch on splint calcaneus- metatarsal 1, initially at interventions and then per-primam.

Conclusions: The flat and flat-valgus foot is a complex deformity, the subject of long discussions, controversial and debatable. The evolutionary potential cannot be currently established based on standardised criteria.

The flat foot is a different entity from the flat valgus foot. The classification is based on clinical and evolutionary criteria.

The occurrence of the plantar disease is systematically assessed at children with flat and flat valgus foot, especially during the age of 1 to 10 years.

The neurosurgical treatment must be eclectic, simultaneous and long-term. The surgical treatment is recommended for symptomatic and rigid forms. It consists in the application of interventions according to the methods Mosca, Dwyer, Maxwell- Brancheau, Grice sau Gianini. The calcaneus metatarsian splint 1 provides security in the rigid cases, especially in cerebral paralysis and arthrogryposis.

Keywords: complex deformities, flat foot, flat valgus foot, Socolescu longitudinal medial tarsal interline, medial mesotarsus, classification of the flat and flat valgus foot, reconstruction of the plantar arch by elongating the calcaneus - Mosca surgery; reconstruction of the plantar arch on calcaneus - metatarsian 1 splint - Burnei surgery.

Definition

Flatfoot (FF) is a deformity where the amplitude of the plantar arch is decreased or non-existent. Amplitude exaggeration occurs in hollow foot. FF is also referred to as *pes planus* or, currently, hollow foot (arches of the foot collapsed). The modification of the plantar arch causes the foot to rest on the entire sole. FF frequency is estimated at approximately 30% of the general population and occurs in either one foot or both.

Anatomy

The foot represents a structure which has to adapt in static fashion to support the body weight and in dynamic fashion to permit walking. There is a mechanical compromise between a rigid framework, represented by the osteo-ligamentous system, and the structures that allow motion and engage the musculo-tendinous elements. Actually, the tendons not only have propulsive function, but also a permanent role in joint stability. Without them, the joint is exposed to mechanical instability and structural damage. [1].

The arch of the foot, also called *fornix pedis* is arched longitudinally and transversally and it is hollowed more deeply at its medial edge due to the torsion of the skeleton [2] The key of the plantar arch is formed by the talus and the bone support is achieved at the back on the greater calcaneal tuberosity, and at the front on the ends of the metatarsals, especially on the first and the fifth ones, and on the fibular edge (fig. 1).

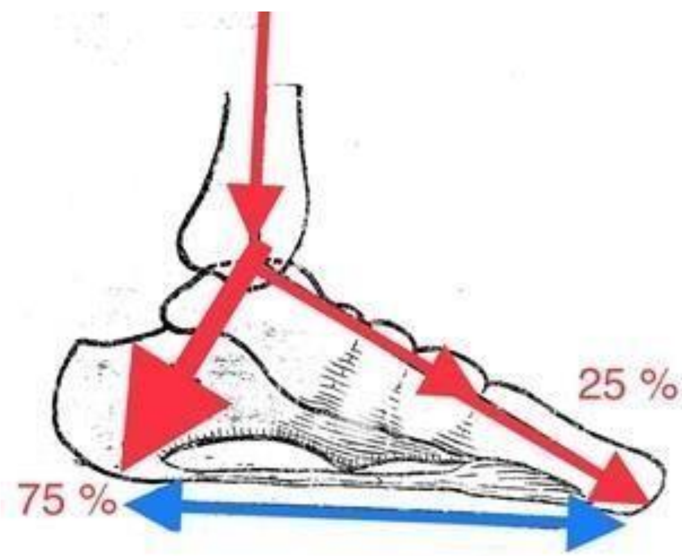


Fig. 1 Dispersion of pressure forces on the pillars of the protarsus and arches. The resistance displayed by the fibrous apparatus of the foot maintains the balance of the form and position in gait and movement.

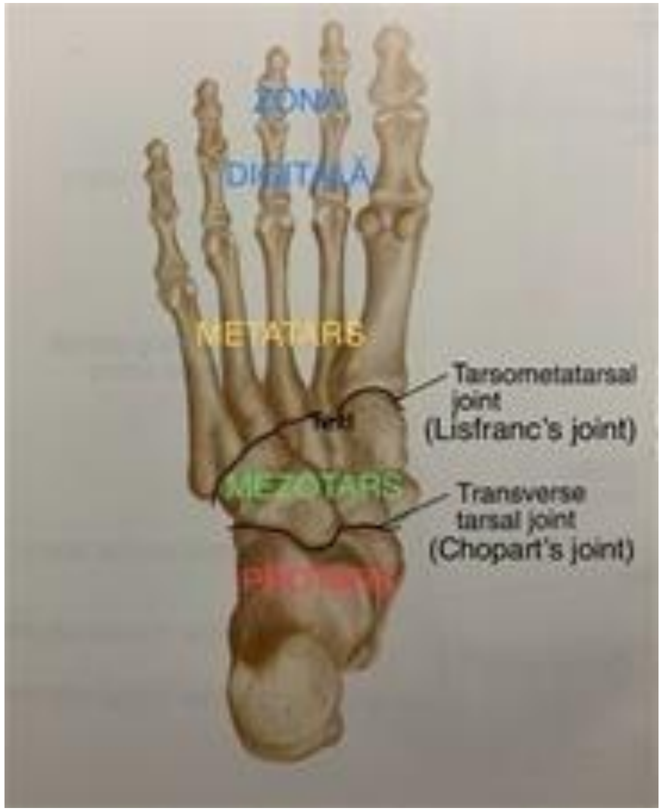


Fig. 2 Skeletal topography of the foot, plantar side: the protarsus, formed by the talus and the calcaneus, limited ventrally by the navicular Chopart joint, the three cuneiforms and cuboid, arranged between the Chopart‟s jointand Lisfranc‟s joint the metatarsus formed by the 5 metatarsals. Phalanges

The appearance varies according to the shape and depth of the vault and the extreme limits are the hollow foot and flatfoot.

The foot skeleton forms the plantar arches and are divided into protarsus, mesotarsus, metatarsus and phalanges (fig. 2). The phalanges have an auxiliary role in support and locomotion. The bones of the protarsus and mesotarsus are joined together by strong ligaments and fibrous extensions that give the foot great strength and elasticity so that it is able to adapt, due to its flexibility, to the relief of the ground. The maintenance of the plantar arch is given by the fibrous apparatus, with a passive role, and the neuromuscular system, with an active role. The active component intervenes both at rest, through muscle tone, and in movement, through contraction.

The foot has a structurally complex configuration. It is conferred by the 26 bones, 33 joints and over 100 muscles, tendons and ligaments.

The plantar arches help distribute the body weight both in the static support phase and during locomotion. The configuration of the arches induces a certain way of moving. The arrangement of the structural, bone, ligament and muscle-tendon elements ensures strength and flexibility.

Biomechanics

The lack or reduction of the amplitude of the plantar arches determines a more difficult adaptation to stress or to the movement on uneven surfaces. Initially, the discomfort appears at an early age, and later in older children, teenagers and adults.

The talus and mesotarsus pronate and the amplitude of the plantar arch decreases or disappears. Pronation concerns the medial radius of the protarsus and mesotarsus and is a consequence of the subluxation in the Socolescu interline. All changes are a cumulation of subluxations of the talus, navicular and cuneiform joints. Metatarsals 1-3 in the medial radius have a normal position, as does the entire lateral radius. This pronation occurs in orthostatism and locomotion. Patients with FF keep their feet outward in both static and movement positions. The vault is loaded with the body weight in orthostatism and during walking, either on both feet, when it takes over only half the body weight, each foot, or in one-side support, when the vault supports the entire weight.

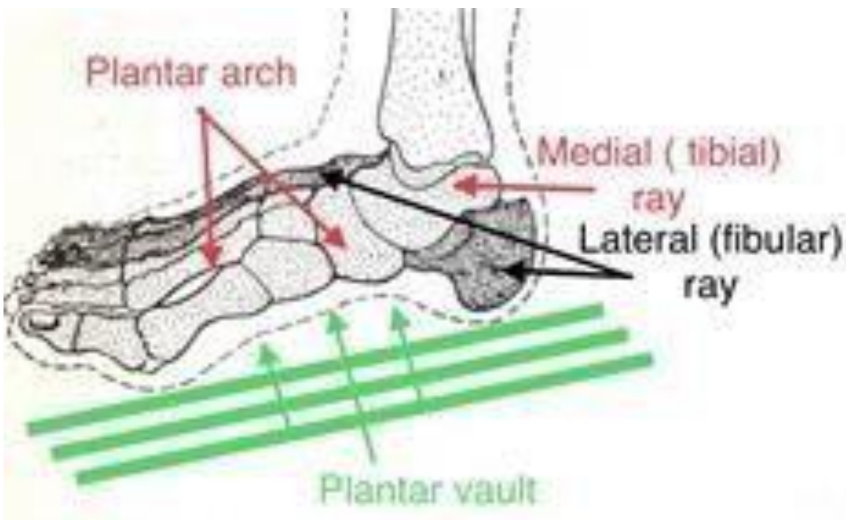
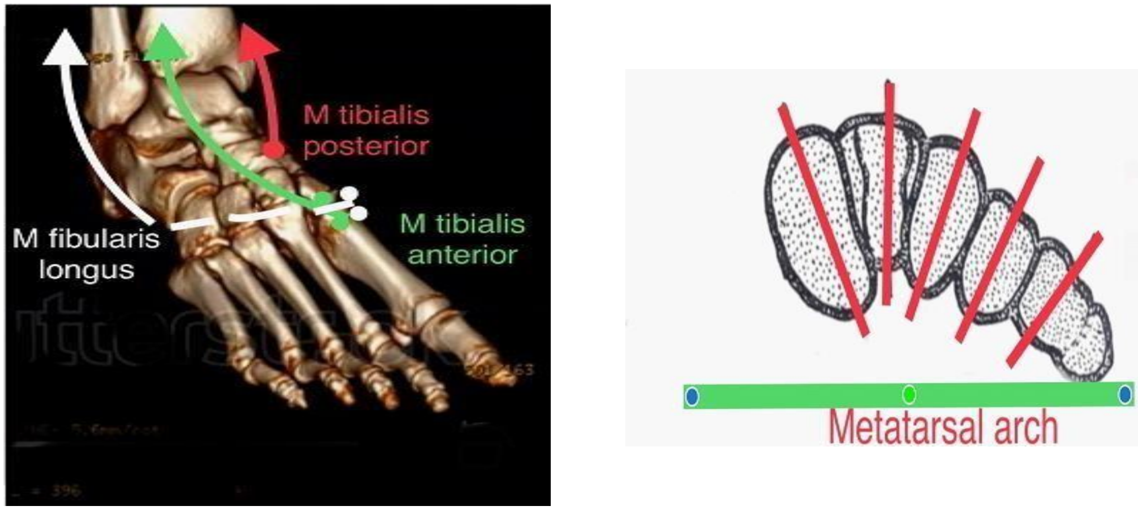


Fig. 3 Plantar vault and the radiuses (arches) of the foot. The medial radius formed by the talus, navicular, cuneiforms 1-3 and the first three metatarsals. The lateral radius consisting of the calcaneus, cuboid and metatarsals 4-5.

The architecture of the foot forms two supporting arches: medial (tibial) consisting of the talus, navicular, cuneiform and metatarsals 1-3 and lateral, consisting of the calcaneus, cuboid and metatarsals 4 and 5. Both arches are juxtaposed at the front and superimposed at the back, so that the medial arch is higher than the lateral one. (fig 3). The weight of the body is transmitted from the calf to the foot through the tibio-talar joint and is unevenly dispersed: 75% at the back, towards the calcaneus, and 25% at the front, towards the two arches. The arches take on the full weight when the heel is lifted off the ground. Thus, the talus is the most overstressed bone in this architectural complex. This stress has conditioned the differentiation of fibrous formations: anterior calcaneonavicular ligament, plantar aponeurosis, posterior tibial arch, fibular crossing [2]. These structures have a passive and active role in maintaining the plantar arch. The band of the plantar arch has an active role in the formation and remodelling of the plantar arch after non-surgical or surgical treatment. It consists of the tendons of the tibialis posterior, tibialis anterior and fibularis longus (fig. 4 a). Tibialis anterior and fibularis longus have symmetrical "mirrored" inserts and their dynamic synchronization forms and maintains the metatarsal arch (fig 4b) with a role in dampening the impact during walking.



a) b)

Fig. 4 a) Plantar band presented schematically and **b)** the metatarsal arch schematized on a cross section at the base of the metatarsals.

The tibialis posterior is regarded as the main dynamic structural support of the arch. When other supporting tissues are weakened, an even higher load is placed on the tibialis posterior to maintain the arch [3]

The loading of the foot tends to lower the arches and widen the foot across, as it happens in flexible flatfoot. The integral passive components support the vault and the active ones soften the configuration and adapt it to gait, running or daily or sports activities. Softening is a complex phenomenon that gives balance to the plantar vault and is provided by all the muscles.

Symptoms

Most patients with FF display no symptoms. Some of them complain of pain after the age of 10. Pain occurs as a result of muscle contraction and overstressing of the ligaments or tendons.

The FF induces the overloading of the knee, hip and then of the spine. FFs are less able to absorb shock, placing a consistent stress on the feet, ankles and knees [4] and repeated stress leads to chronic injuries. The first chronic injuries occur to the most overstressed joints in FF: tibiotalar, talocalcaneal and talonavicular joints.

In the rigid foot, the uneven distribution of the body weight can no longer be fully compensated, the pain becomes more frequent and more intense. Certain support points are overloaded and subjected to intense pressures that can lead to the appearance of plantar callus or erosive wounds that in time, can become atonic and difficult to heal due to muscular, nervous or diabetic dystrophies.

Etiopathogenesis

FF is often generated by genetic causes. If we note the presence of congenital deformities in the heredocollateral antecedents, we label the condition as a family disease on the level of the foot [5] [6]. These diseases are genetic in nature.

FF can occur in children when the plantar vault is forming. Frequently, the plantar vault is present and is developing in amplitude. The subcutaneous cellular tissue hides the arch that is being topographically configured.

In children under one year of age, the soft parts fill the space under the arch of the foot and give the image of a flat foot. In children between 1 and 3 years old, this soft tissue, abundantly placed under the arch, widens the support surface towards the medial area, but the footprint gives the appearance of a normal foot.

If new-borns or infants have spina bifida and flat feet, treatment of both conditions is required. In such cases, the untreated feet progress towards severe deformities.

Flat feet during childhood will not be flat later on. Only 4% of them will be diagnosed with flat feet and may have the following causes:

- ✓ Vertical talus
- ✓ Tarsal synchondrosis or tarsal synostosis.
- ✓ Diseases of the muscles or of the nervous system: cerebral palsy, spina bifida and muscular dystrophies
- ✓ Obesity, walking in force or excessively loads and overloads the foot and disrupts the normal dispersion of the forces on points
- ✓ Overstressing of the feet with dysfunctions of the plantar arch band
- ✓ Joint laxity from syndromic diseases
- ✓ Aseptic osteonecrosis of the medial bone
- ✓ Pregnancy and osteoporosis

Diagnosis

In order to establish the diagnosis, the anamnestic, clinical and imaging data, and sometimes the kinematic study of the gait, are corroborated.

Anamnesis. Patients are brought in by their parents because they have found that they wear down their shoes more on the inside, or that they do not step normally when walking barefoot. Most of these children have no pain and walk normally or with their feet turned outward (out-toe). Very few complain of pain in orthostatism or during physical exercise.

The pain is localized in the ankles, on the medial side and less often in the knees or hips. Pain may appear in those who have been asymptomatic and wear orthoses to support the medial radius. In some symptomatic patients, the pain does not subside with orthopedic footwear, or it worsens, and their feet feel stiffer and ineffective when exercising. Particular attention should be paid to patients with painful flat feet, whose pain worsens, and the foot takes on a rigid shape. When the plantar arch is recently collapsed and the pain has occurred simultaneously or in a short time, flatfoot is secondary to aseptic necrosis of the medial mesotarsal bones.

Clinical examination. The shape, direction and position of the foot in dorsal decubitus, orthostatism, gait and one-side support are analysed. The examination of the feet in dorsal decubitus may also reveal other pathological associations of the limbs.

The inspection is carried out ventrally, dorsally and medially. In flexible FF, the plantar arch is present when the patient lies in decubitus and in digitigrade position and disappears in orthostatism or the one-side support phase. In rigid FF the plantar arch is absent in all positions. In the digitigrade position, when it tends to be outlined, the patient becomes unbalanced and needs support. The position on the heels and movement is frequently incompatible, while in flexible foot they move casually.

Footprint study by pedograph. Footprint assessment is a widely used method for determining foot morphology and pressure on support points, but its effectiveness and validity are controversial. [7]

The dynamic study of footprints in children and teenagers shows that the change in medial arches also occurs during adolescence. The growth potential is variable depending on age and sex. The feet in the period between 6-17 years can have a high, intermediate, normal, low or absent amplitude of attacks in the severe form of the flat foot.

Footprint analysis performed by a pedograph is a simple, fast and efficient method. Normally, three measurements are used to diagnose the footprint: the Clarke angle, the Chippaux-Smirak index and the Staheli index. The fundamental premise of these indices is that the height of the arch is related to the footprint. [8]

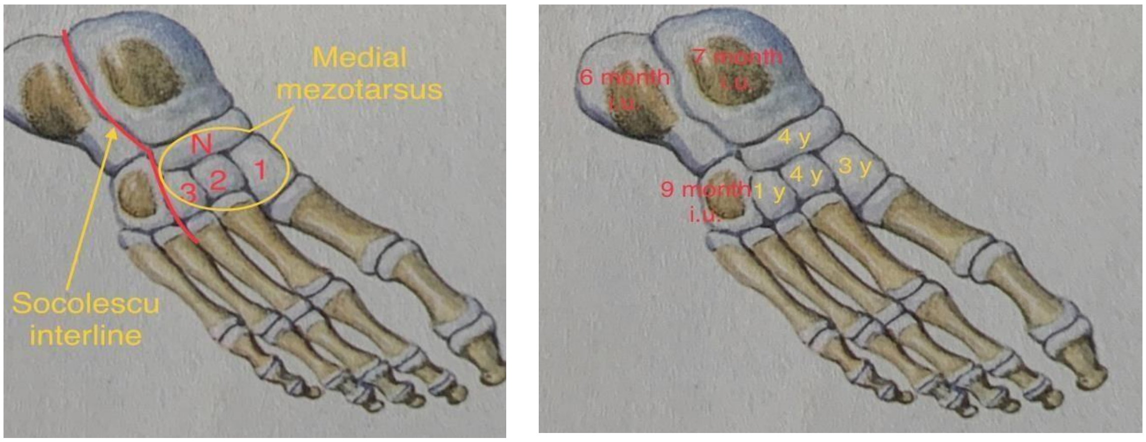
Imaging exploration. X-ray of the ankle and foot, face and profile, is usually carried out in children with painful FF. On the current X-ray, the talocalcaneal angle has normal values between 15° and 35°. An angle above 35° is indicative of posterior valgus. On the profile X-ray, the normal talocalcaneal angle is between 25° and 50°. The Meary angle (talometatarsal 1) has normal values of 0-4 degrees. An angle above 4° convex downwards is considered a flat foot, 15° - 30° a mild flat foot and above 30° a severe flat foot. The talonavicular coverage angle should not exceed 7 degrees.

Oblique radiography and Harris radiography show tarsal coalition, vertical talus, valgus position of the calcaneus and accessory navicular bone. Computed tomography indicates the presence of bone lesions and magnetic resonance imaging can be used for difficult to diagnose cases. [9]

Development of the medial arch

By the age of 2, 97% of children have flatfoot and, at the age of 10 only 4% remain flat-footed [10]. The development of the longitudinal arc takes place over several years and has a variable range, the broad spectrum being between 1 and 10 years, with the most active period being between 3 and 6 years [11]. The arch has a natural tendency to continue to develop after 6 years; numerous studies have shown that the prevalence of flatfoot is higher in 6-year-olds compared to 10-year-olds. [12].

Up to the age of 2, the prevalence is 97%, at 3 is 57%, at 6 is 26% and at the age of 10 is 4%. In new-borns, the foot has a predominantly cartilaginous structure and the medial mesotarsus is exclusively cartilaginous (Fig. 5). The increased muscle tone of the intrinsic muscle formations outlines a poorly configured plantar arch and difficult to view due to the filling of the area with subcutaneous cellular tissue. The plant has a soft appearance. The flexion and supination of the foot configure a palpable plantar vault. The arch is partially maintained or becomes rectilinear in normal position. This is a sign that shows that flatfoot in the new-born is normal. In children with talus valgus foot, this manoeuvre is painful, the new- born may become agitated and, in many cases the plantar arch remains rectilinear. Residual FF after congenital talus valgus foot responds slower to treatment and the correction of the arch requires a slow and progressive recovery with orthoses applied for a longer period and changed much more often.



a) b)

Fig. 5 Foot skeleton in new-borns. a) The medial mesotarsus delimited by the distal segment of the Socolescu interline (navicular and cuneiform 1-3) has no ossification nucleus. b) ossification nuclei appear between the ages of 1 and 4.

The prevalence of FF decreases with age but never reaches 0 level. After preschool age, those who remain with 1% FF are diagnosed with congenital malformations, aseptic osteonecrosis of the mesotarsal bones [13] [14] [15], neglected, obese [16] [17] and at 25% the arch is formed during school period, or even during adolescence.

Gradual correction is done under the influence of several factors. Genetic memory is present especially in cases where FF is familial. Intrinsic muscles have a proven role. Children who walk barefoot on a varied ground are more likely to have a normal development of the arch, usually between the ages of 4 and 6. The prevalence of flat feet is lower in people who started wearing shoes as late as possible. In various environments and for various reasons, some children wear shoes after the age of 16 [18].

Instead, shoes that cover the toes, used in young children, increase ligament laxity and prevent the formation of the medial arch [19].

Adequate treatment (orthotics, physical therapy and sports) of severe FF diagnosed at the age of 3 have evolved, up to the age of 7, towards improvement and healing. Similar cases in which spontaneous healing was expected, at the indication of the followers of this method [20] [21], have evolved towards rigid FF, FVF and rigid FVF.

There is a form of asymptomatic FF present in children that remains asymptomatic during the teenage years, adulthood and in the old age. This is a FF without evolutionary potential and allows the performing of sports activities, military service [22] [23] and athletic performance [24][25] [26].

The young athlete needs to understand that this form of FF can be a chronic problem, but that the extra work can help relieve the symptoms [27].

Not all asymptomatic FFs in children remain asymptomatic for life. Some become painful or rigid, incompatible with a normal daily lifestyle. It is not known which asymptomatic FFs allow a quality life in adulthood or in old age.

During the 1960s, M. Socolescu, an illustrious Romanian paediatric orthopaedist, described a longitudinal mid-tarsal interline separating the medial radius from the lateral radius (fig. 6) and designed a surgical intervention for the congenital “club foot” called Plantar Desinsertion and Longitudinal Medium-Tarsal Syndesmolysis. After the elongation of the Achilles tendon and the longitudinal medium-tarsal syndesmolysis, the foot straightens completely, Socolescu interline achieves plantar opening and the medial mesotarsus is placed from the supination position in the pronation position; the medial mesotarsus is subluxated by a cumulation of subluxations in the segments of the 3 articular interlines, Chopart, Lisfranc and Socolescu (fig. 7) and moves in pronation. The transverse plantar arch disappeared and the arch of the 3 cuneiforms decreased significantly. One of the possible complications of this surgical intervention is FF. Children with residual FF after the Socolescu surgical intervention coped well in the school and social environment and had no pain. There are patients older than 60 with post-surgery FF who have led a normal life and performed regular sports activities.

Fig. 6 Longitudinal mid-tarsal interline (Socolescu's joint) drawn on a frontal and semi-profile radiography in a 6-year-old flexible flat-footed child.

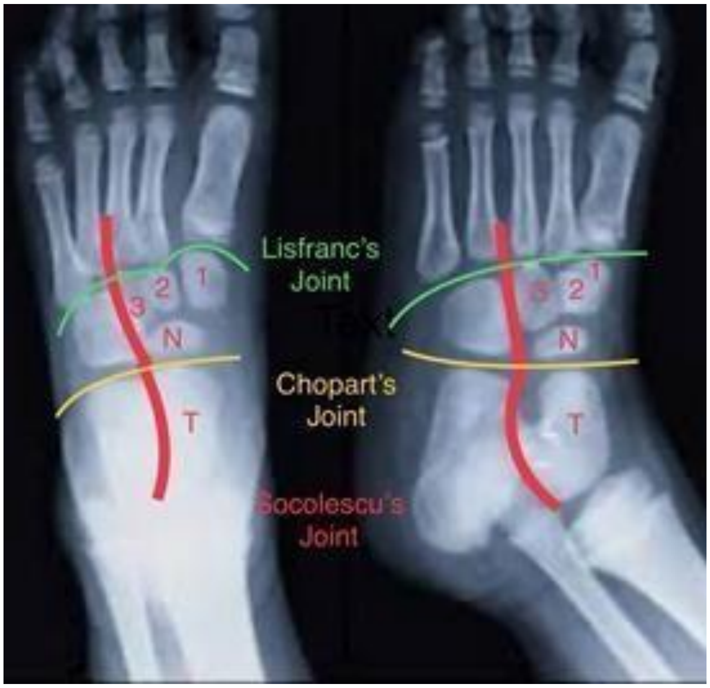


Fig. 7 In FF without evolutionary potential, the pronation of the medial mesotarsus takes place between the medial segments of the Chopart's joint, Lisfranc's joint and the distal segment of Socolescu's joint

When they start walking, around the age of 1, children force the position of the foot in pronation, to gain more stability [12]. This mechanism allows the occurrence of asymptomatic FF without evolutionary potential. The stress induced by the orthostatic and walking position, between the age of 1-3, disturbs the position of the medial mesotarsus formed only of cartilaginous tissue until the age of 1, mainly cartilaginous up to the age of 4 (fig. 5) and disposes the mesotarsus in pronation. Some of these children remain with FF without evolutionary potential.

Classification

A). FF with evolutionary potential

Transient FF is the foot forming the arch and the plantar vault. It is the normal foot, found in different proportions in relation to age, present in a very high percent in children up to the age of 10 and which have not been diagnosed with congenital synostosis or vertical talus.

Asymptomatic flexible FF (AFFF) has the plantar vault present but disappears in orthostatism and the one-side support phase. It is configured in the digitigrade position. Asymptomatic flexible FF should not be treated. These children should wear footwear appropriate for their age and foot configuration.

Asymptomatic flexible FF causes a series of discussions related to the prophylactic wearing of accessories or devices for footwear, or even orthoses. Patients in this group may develop pain or evolve towards rigid FF.

The scope of the treatment is to correct flatfoot and avoid progression towards other forms which may cause discomfort. Limited studies [28] [29] have shown the correction of the plantar arch with the help of devices and orthoses, although such cures can be attributed to the spontaneous evolution towards healing.

In children over 6 years of age, it has been found, after 2 years of treatment with rigid orthoses, that the development of the medial radius can be found radiologically [30]. Relevant studies on large groups and with control groups will clarify their need and role.

The dispute over whether or not to prescribe accessories or orthoses also resides due to the argument that these devices cause no harm. Opponents of this method claim that wearing them for a long time leads to unnecessary expenses, dependence on orthoses or psychological effects in adulthood.

The supporters of the treatment claimed that teenagers with moderate or severe FF have a double rate of knee or lumbar spine pain [31].

Such controversies call into question the existence of special workshops to make children's footwear according to unique standardized rules, as a number of authors point out that footwear is inadequate [32]. Children's footwear should be supple, provided with a plantar support, allow the foot to rest on the points of support and on the outer edge of the sole, to offer the possibility of developing a strong and elastic arch. Such footwear can replace accessories or orthoses, will give comfort for those with normal feet and a maximum capacity for effort and sports performance.

Symptomatic flexible FF (SFFF). The pain may occur inconsistently and may be exacerbated by exertion. In case of complications (tendinitis, tenosynovitis, plantar fasciitis, etc.) the pain becomes constant. The treatment consists of stretching and muscle strengthening exercises, orthoses and supportive soles. [33].

Occasionally, patients with asymptomatic, painless flatfoot who wear orthoses or not, become symptomatic. To date, there is no evidence that preventive treatment with orthoses or other shoe inserts will prevent the development of symptomatic FF in the future. [26]. Among personal cases, many practitioners had patients with AFFF treated with orthoses or had the opportunity to wear special, custom-made footwear, which recovered from the amplitude of the arch and did not evolve into SFF. However, such findings have no statistical relevance.

B). FF without evolutionary potential.

This type of foot is shaped between the ages of 1 and 2, after the child starts walking, and is painless. It stays that way throughout life. There are elder people over 60, with flatfoot since childhood, who never had any pain and led a normal life, some of them also with athletic performances. Currently, the diagnosis of this type of flatfoot can be carried out only after a long period, in the teenage period or adulthood. The only diagnostic criterion is pain- free evolution. The prevalence of this form of FF is unknown. In this context, the definition of the FF remains evasive [34].

Until the diagnosis is established, it enters the transient FF group. Paraclinical examinations should establish the etiopathogenic diagnosis of this form.

C) Rigid FF (RFF)

It is usually painful. The plantar vault does not appear in the digitigrade position. Usually, patients with rigid FF withdraw from school sports. As they age, children with progressive, flexible, or painful flexible FF may develop rigid feet.

In adults and especially in the elderly, the condition can worsen, and the plantar arches can collapse. The foot is known as a rigid foot, and has no plantar arch, even when the foot is raised. Rigid flatfoot diminishes the quality of life [35]. Acquired flatfoot is usually considered to be caused by posterior tibial tendon failure [9].

Congenital RFF occurs at birth and is given by vertical talus and tarsal synchondrosis. Spontaneous evolution is followed by pain and changes in shape incompatible with the wearing of shoes.

A rigid flatfoot is often associated with a tarsal coalition or a vertical talus [36].

Vertical talus is treated by cast immobilization and physical therapy followed by surgery.

Tarsal coalitions are fibrous or cartilaginous connections between the talus and the calcaneus, or between the calcaneus and the navicular and occur during intrauterine development. In evolution, synostoses appear that amplify the rigidity of the foot. Walking becomes painful and the fibular muscles contract and refract.

Neglected RFF are undiagnosed or untreated feet and are secondary to feet with evolutionary potential, flexible or painful and flexible. They are much rarer than congenital rigid FF.

Neurological and myopathic RFF is found in cerebral palsy, poliomyelitis, peripheral neuropathy, Duchenne muscular dystrophy, etc. In these conditions, the deformity of the foot appears more frequently as a FVF.

Rigid flatfoot due to neuro-muscular causes is characterized by limited mobility of the subtalar joints. It is non-physiological, associated with pain and has a serious pathology. The vast majority of children with cerebral palsy have rigid flat feet.

Treatment

Non-surgical treatment. To alleviate the symptoms and to avoid their aggravation and structural changes in the bones, muscles, ligaments and tendons, the podiatric and kinetotherapeutic assessment provides important details for the treatment.

The etiopathogenesis of the flat foot is certainly multifactorial, interdependent with bones, ligaments, muscles and comorbidities [4]. As such, to be effective, non-surgical treatment should be eclectic, simultaneous and long-term. It includes orthotic, physical and sports therapy.

Orthotic treatment is long-lasting, and the effects appear in the long run. If the treatment consists only in orthopaedic shoes for 3 years, no positive effects are achieved, that can be proved radiologically [21]. There are no studies showing the ineffectiveness of non-surgical treatment methods performed simultaneously.

The footwear should be well adapted to the contour of the foot and have a plantar support. It often happens that the footwear is inadequate and causes some discomfort or even disrupts the formation of the plantar arch.

Not all shoes are adapted to the configuration of the foot. The adapted sole can be a good support for the arches of the foot. If applied correctly, after a podometric study, the foot placed in reverse position provides normal support. This reduces the pressure on the medial plantar arch, reduces or alleviates the pain and prevents the evolution towards the rigid shape of the flatfoot or FVF. When the pressure exerted on the medial mesotarsus and Socolescu interline is excessive, for various reasons, the effects of the treatment appear after 2-3 evaluations, every 2 years.

The supporting of the medial margin of the tibialis posterior in tendinitis adapts the footwear and has the role of reducing the pressure exerted on the posterior tibial tendon in the one-side support phase.

A podiatrist will be able to recommend suitable soles or orthotics for your foot and direct you to the best store for the right footwear, given that some types of footwear are inappropriate.

Sports therapy is useful in boosting the intrinsic and extrinsic forces that act to develop the plantar arch, maintain it, or restore balance and reconfigure the plantar arch. The stimulation of the muscles forming the plantar band is of great importance (Fig. 8). Karate, gymnastics and swimming are the key sports that, along with orthotic treatment, restore the plantar arch after the age of 4.

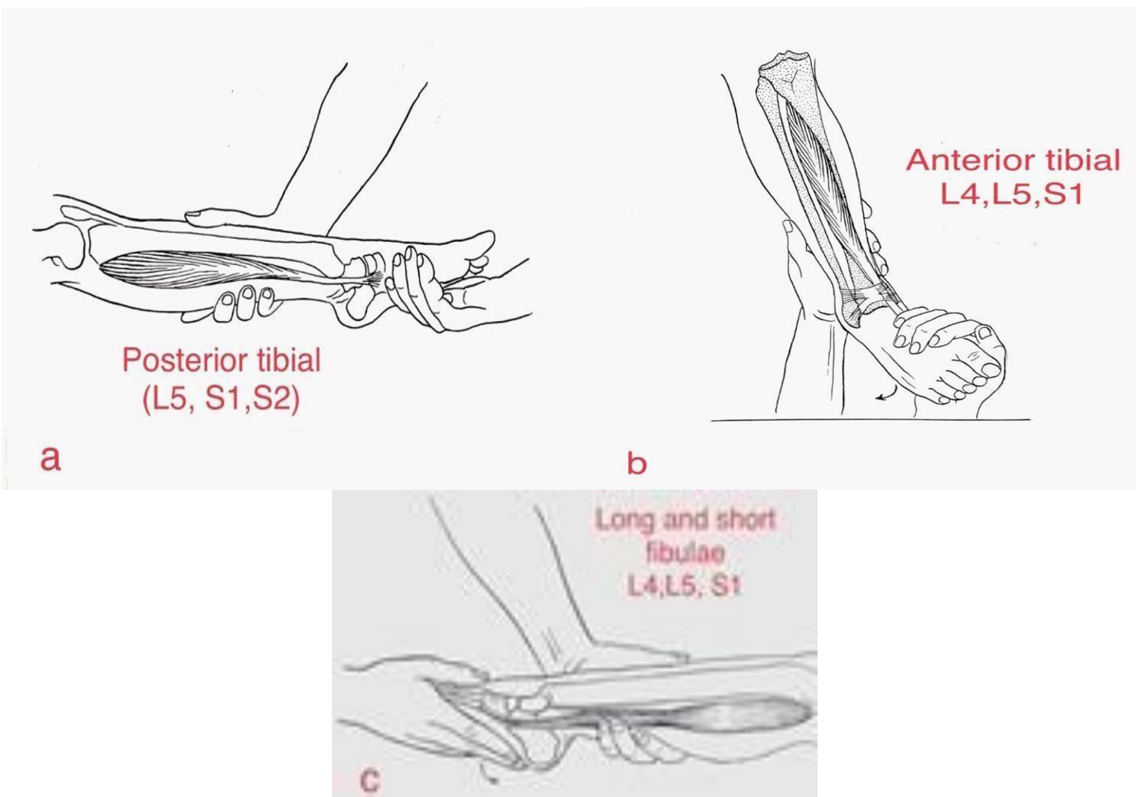


Fig. 8 Selective passive and active stimulation of the extrinsic muscles forming the plantar band:
a) the tibialis posterior, counter-pressure exercises for the flexion and supination of the hindfoot
b) tibialis anterior, counter-pressure exercises for the extension and supination of the forefoot
c) fibularis longus and brevis, exercises for the flexion and pronation of the foot.

Relief from sports activities in symptomatic FF aims to avoid physical exertion until symptoms are reduced or disappear.

Surgical treatment is indicated for rigid FF and symptomatic FF with severe static and dynamic discomfort. These forms of FF with surgical indication come from undiagnosed or neglected FF, or bone malformations.

Obesity, which is less common in children and teenagers, variably induces FF and the deformity improves or disappears if the patient loses weight and returns to normal weight. If pain is present, it disappears when the weight returns to normal.

Synchrondrosis and synostosis of the tarsus induce a painful and deformed flat foot. The operation consists of excision of the chondral or bone bridges and application of wax on the remaining surfaces or fatty cell tissue, to avoid recurrence, but the recurrence rate remains high [37].

A deformed FF, with bone malformations, requires other additional interventions: medial translational osteotomy, elongation of the calcaneus after the Mosca procedure, Coton osteotomy or, if the rigidity of the protarsul is present, subtalar arthroereisis [38].

In order to avoid recurrences or other operations, greater safety is provided by the restoration of the plantar vault on the calcaneo-metatarsal 1 splint, which ensures the healing of the foot in the correct position.

Surgical correction of a rigid flat foot may include excision of a cuneonavicular coalition or a talocalcaneal coalition, osteotomy, or the elongation of the lateral column [9].

Patients with symptomatic flexible FF, who fail to improve or heal after non-surgical treatment and cannot have normal daily activities, are recommended surgical intervention. The quality of life is poor and surgical interventions are indicated, to improve health. The best results are obtained by interventions conceptualized by Mosca, calcaneal osteotomies (Dwyer type) and vault reconstruction (screws, biovitroceramics, bioresorbable implants from poly-I lactic acid) for arthroereisis. These interventions prevent the appearance of the valgus in the subtalar joint and restore the talus from the flexion position.

Other procedures that can be applied are the elongation (Evens conceptualized by Mosca), calcaneus osteotomisis (type Dwyer) and the reconstruction of the medial plantar voult on the calcaneo-metatarsal 1 lamellar splint. (Burnei).

The reconstruction of the plantar arch offers safety in the repositioning of the plantar arch and is performed extra-articular, open, minimally invasive or arthroscopic (fig. 9). It is indicated in rigid flatfoot, symptomatically flexible flatfoot and severe FVF in: cerebral palsy, neglected forms of the flatfoot and flat valgus foot, congenital malformations of the protarsus and arthrogryposis. The treatment of neuromuscular flatfoot differs from the treatment of idiopathic and flexible feet [4]. The best results are obtained by implanting a screw in the tarsal sinus or by reconstructing the plantar arch on the calcaneo-metatarsal 1 splint.

Fig. 9 Neglected bilateral rigid FVF, in a 13-year-old boy.

a) Collapsed plantar arch and reversed forefoot; toes 1 and 2 facing medially.

b) Digitigrade position slightly sketched, and the sole does not restore the plantar arch.

c) The axes of the talus and calcaneus are interrupted due to the reversion of the forefoot.

d) Profile radiography after surgery: elongation of the Achilles tendon, talo-calcaneal arthroereisis with autogenous graft and reconstruction of the plantar arch on the calcaneus-metatarsal lamellar 1 splint.

e) Clinical appearance after surgery: the plantar arch is restored and the forefoot is in normal position, compared with the opposite one.

Flat Valgus Foot

This deformity is a distinct entity clearly differentiated from flatfoot or pes valgus.

Structurally, there are changes in both feet, in addition to other disruptions. Changes in the medial radius of the flatfoot are present. The medial radius of the protarsus and mesotarsus is pronated: the head of the talus is flexed if the Achilles tendon is contracted and retracted. In pes valgus, the head of the talus is also adducted, making the biomechanics of the tibiotalar joint even more difficult. The lateral radius, whole in flatfoot, shows the raised calcaneus and the abducted cuboid. The metatarsus no longer has a plantar arch, is flattened and raised; the dorsal face of metatarsal 1 looks medially, partially or totally.

In adults, it is characterized by medial rotation and flexion of the talus, eversion of the calcaneus, collapse of the medial arch and abduction of the forefoot.

In terms of evolution, FVF could come from a flatfoot or FVF with evolutionary potential.

The clinical examination is edifying. The axis of the calf forms an open lateral angle of less than 170 degrees with the axis of the hindfoot. Heel eversion, or posterior valgus is a normal position in young children. It is corrected by one degree every 12 months and becomes vertical at the age of 7. The average posterior angle of the foot in children between 6 and 16 is 4°, from 0 to 9 ° valgus [29][30].

Static and gait highlight the valgus position of the foot and the absence of the plantar vault. Podiatry, CT and MRI certify the diagnosis. The presence of the FVF at a young age involves detailed evaluations to establish the diagnosis of underlying diseases: syndromic disease, cerebral palsy, cerebrospinal malformations, arthrogryposis, etc.

Valgus flatfoot also has a clinical form with no evolutionary potential, like flatfoot. The similarities with flatfoot are predominant, which is why they are presented together in many studies and articles.

The treatment aims at correcting the essential changes; restoration of the plantar arch, calcaneus varus and flexion of the protarsus. Such changes are in the forefront. It is preferable that these interventions be performed surgically, at the same time.

The equinus given by the flexion of the protarsus is treated by different methods of elongating the Achilles tendon; in fact, it relaxes the tendon forcing the traction on the calcaneus and gives the possibility for the other interventions to reposition the Chopart interline.

The deviation of the calcaneus in moderate and severe forms of painful flexible FVF is treated by Grice-type arthroereisis, which remains effective for several reasons, with Maxwell-Brancheau-type screws, Gianini implants, biointegrable or bioresorbable materials. In addition to arthroereisis, Dwyer-type heel osteotomies are also used.

In rigid FVF, the elongation of the Achilles tendon and arthroereisis associate with the reconstruction of the medial radius on the calcaneo-metatarsal 1 splint.

References

1.Bonnel M, Bonnin F, Canovas M, Chamoun M, Bouysset. Anatomy of the foot and ankle. Bone and Joint Disorders of the Foot and Ankle. 1998; 1-14

2.Riga I Th. Practical Anatomy Vol. 1 Part 1. Live Anatomy: Skeleton; 1971: 529-82

3.Lowe W, Chaitow L. Orthopedic Massage (Second Edition), 2009; 6: 77-115

4. Carr JB, Yang S and Lather LA. Pediatric Pes Planus: A State-of-the-Art Review. Pediatrics. 2016; 137 (3): e20151230;

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

6.Harris EJ, Vanore JV, Thomas JL, et al. Diagnosis and treatment of pediatric flatfoot. J Foot Ankle Surg. 2004;43(6):341–73

7.Stavlas P, Grivas TB, Michas C, Vasiliadis E and Polyzois V. The Evolution of Foot Morphology in Children Between 6 and 17 Years of Age: A Cross-Sectional Study Based on Footprints in a Mediterranean Population. The Journal of Foot and Ankle Surgery 2005 ; 44 (6) : 424-8

8.Pita-Fernández S, Cristina González-MartínC et al. Validity of Footprint Analysis to Determine Flatfoot Using Clinical Diagnosis as the Gold Standard in a Random Sample Aged 40 Years and Older. Journal of Epidemiology 2015; 25 (2) 148-54

9.Parvizi J, Gregory K. Kim GK and Associate Editor. High Yield Orthopaedics. Saunders/ Elsevier 2010; 88: 183-4

10.Morley AJ. Knock-knee in children. BMJ. 1957;2(5051):976–9

11.Staheli LT, Chew DE, Corbet M. The longitudinal arch. A survey of eight hundred and eighty-two feet in normal children and adults. J Bone Joint Surg Am. 1987;69(3):426–9

12.Edinger J, Fisher M. Atlas of Orthoses and Assistive Devices (Fifth Edition). Elsevier 2019; 30: 303-12

13.Agarwal A, Lalchandani R. Osteochondritis of Intermediate Cuneiform with Delayed Appearance Ossification Centre of Navicular Bone-A Rarity Article. The Journal of Foot and Ankle Surgery (Asia Pacific) 2018 ; 5(2):77-9

14.García-Mata S. Avascular necrosis of the intermediate cuneiform bone in a child: a very rare cause of limp in a child. A variant of the normality? Journal of Pediatric Orthopaedics B 2013 ; 22 : 255-8

15.Kose O, Demiralp B, Oto M, Sehirlioglu A. An unusual cause of foot pain in a child:osteochondrosis of the intermediate cuneiform. J Foot Ankle Surg 2009;48: 474-6.

16.Dowling AM, Steele JR, Baur LA (2001) Does obesity influence foot structure and plantar pressure paterns in prepubescent children? Int J Obes Relat Metab Disord. 2001; 25: 845– 52.

17.Mickle KJ, Steele JR, Munro BJ. The Feet of Overweight and Obese Young Children: Are They Flat or Fat?. Obesity 2012 ; 14 (11) : htps://doi.org/10.1038/oby.2006.227

18.Sachithanandam V, Joseph B. The influence of footwear on the prevalence of flat foot. A survey of 1846 skeletally mature persons. J Bone Joint Surg Br. 1995;77:254–7.

19.Rao UB, Joseph B. The influence of footwear on the prevalence of flat foot. A survey of 2300 children. J Bone Joint Surg Br. 1992;74:525–7

20.Gould N, Moreland M, Alvarez R, Trevino S, Fenwick J. Development of the child‟s arch. Foot Ankle. 1989;9:241–5

21. Wenger DR, Mauldin D, Speck G, Morgan D, Lieber RL. Corrective shoes and inserts as treatment for flexible flatfoot in infants and children. J Bone Joint Surg Am. 1989;71: 800–10
22. Jones BH,Thacker SB,Gilchrist J, Kimsey Jr. CD, Sosin D. Prevention of Lower Extremity Stress Fractures in Athletes and Soldiers: A Systematic Review. Epidemiologic Reviews. 2002 ; 24 (2): 228–47
23. Harris EJ. The Natural History and Pathophysiology of Flexible Flatfoot. Clinics in Podiatric Medicine and Surgery. 27 (1): 1–23
24. Harris EJ. The Natural History and Pathophysiology of Flexible Flatfoot. Clinics in Podiatric Medicine and Surgery. 27 (1): 1–23
25. Tudor A, Ruzic L,Sestan B, Sirola L, Prpić T. "Flat-Footedness Is Not a Disadvantage for Athletic Performance in Children Aged 11 to 15 Years" lPediatrics 2009 ; 123 (3): e386–e92
26. Hintermann B, Nigg BM. "Pronation in Runners: Implications for Injuries". Sports Medicine. 1998 ; 26 (3): 169–76.
27. Kraft D, Zippin J. Baxter's the Foot and Ankle in Sport (Second Edition), 2008; 23: 535- 46
28. Bleck EE, Berzins UJ. Conservative management of pes valgus with plantar flexed talus, flexible. Clin Orthop Relat Res. 1977;122:85–94
29. Bordelon RL. Correction of hypermobile flatfoot in children by molded insert. Foot Ankle. 1980;1(3):143-50
30. Bok SK, Kim BO, Lim JH, Ahn SY. Effects of custom-made rigid foot orthosis on pes planus in children over 6 years old. Ann Rehabil Med. 2014;38(3):369–75
31. Kosashvili Y, Fridman T, Backstein D, Safir O, Bar Ziv Y. The correlation between pes planus and anterior knee or intermitent low back pain. Foot Ankle Int. 2008 ; 29 (9) : 910–13 32.
32. Ruello O. "Walking and Running Shoe". EC Orthopaedics 2016 ; 2 (6) : 206-17. Atik A and Ozyurek S. Flexible flatfoot. North Clin Istanb. 2014; 1(1): 57–64
33. Evans A. The Pocket Podiatry Guide: Pediatrics. Churchill Livingstone 2010; 6: 107-37
34. Pita-Fernández S, Gonzalesz-Martin C, Alonei-Tajes F, Seoane-Pillado T, Perthes-Diaz S, Perez-Garsia S, Seijo-Bestilleiro R and Balboua-Barreiro V. Flat Foot in a Random Population and its Impact on Quality of Life and Functionality. J Clin Diagn Res. 2017 ; 11(4): 22–7.
35. Brosky Jr. JA, Balazsy JE.Orthopaedic Physical Therapy Secrets (Third Edition), 2017; 75: 581-6
36. Shuyuan L, Mark S M. Excizion of a Middle Facet Tarsal Coalition. Jbjs Essential Surgical Techniques. 2020 ; 10 (1) : e0114
37. Li S, Myerson MS. Excision of a Middle Facet Tarsal Coalition. JBJS Essential Surgical Techniques. 2020 ; 10 (1) : e 01114
38. K.C. Chen, C.J. Yeh, Li-Chen Tung, J.F. Yang, S.F. Yang, C.H. Wang – Relevant factors influencing flatfoot in preschool-aged children. Eur J Pediatr 2011;170(7):931-6.
39. Cass AD, C.A. Camasta CA. Review of Tarsal Coalition and Pes Planovalgus: Clinical Examination, Diagnostic Imaging, and Surgical Planning. 2010 J Foot Ankle Surg 2010;49(3):274-93

