Ankle and Foot: Foot Abnormalities and Pathologies

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Children and adolescents start sports at earlier ages and with higher intensity. In the USA, more than half of people between 8 and 16 years old are engaged in some kind of sport during the school years [1]. In Italy, 22 % of children between 6 and 10 years of age play sport for less than one hour in the week, and at 13 years of age, 51 % of boys and 34 % of girls are engaged in some kind of sport. Foot and ankle abnormalities are common in children under 10 years old and may result in impairment while starting a sports activity. Pathologies that can affect young athlete include flatfoot, tarsal coalition, cavus foot, juvenile hallux valgus, ankle impingement, os trigonum, Haglund's disease, and osteochondroses [2].

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19.1 Flatfoot

Flatfoot is a common disorder characterized by morphological reduction in plantar arch and valgus hind foot. Functionally, the subtalar joint does not alternate the physiologic movements of pronation during the stance phase and supination during the propulsive phase. A state of persistent or prevailing pronation is instead maintained during gait with consequent loss of propulsive efficacy and overload of ipsilateral foot joints.

Flatfoot may be an isolated pathology or part of a larger clinical entity like collagen disorders, generalized ligamentous laxity, genetic conditions, and neuromuscular abnormalities. As reported by Harris [3], pediatric flatfoot can be divided into flexible and rigid categories, symptomatic and asymptomatic. Most flatfeet are flexible physiologic and asymptomatic. Rigid flatfoot is often associated with underlying pathology as congenital vertical talus or tarsal coalition and is characterized by a deformity non-reducible manually.

At 10 years of age, children with flatfoot are 4 % but only 10 % of these have a functional flatfoot which needs treatments in order to reduce pain and prevent disability in adulthood like hallux valgus, metatarsalgia, Morton's neuroma, and posterior tibialis tendon dysfunction.

The diagnosis of flexible flatfoot is based on clinical and radiographic examinations.

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The young patient is usually referred to orthopedic control because of foot morphology and discomfort during activity.

The most common symptoms are pain in foot sole and medial hind foot, leg and knee with prevalence in girls and in patients with increased BMI [4]. Increased heel valgus at rest more or less reducible during the tiptoe standing test, footprint enlargement at rest and during the Jack test, restriction of dorsiflexion of the ankle joint after manual correction of the deformity are evident during examination.

Radiographs of the flexible flatfoot are not necessary for diagnosis, but they may be helpful in case of uncharacteristic pain, decreased flexibility, and for surgical planning.

Weight-bearing anteroposterior (AP) and lateral views are generally sufficient to evaluate the flexible flatfoot. The lateral radiograph reveals alteration in talocalcaneal and intermetatarsal angle and Meary's line interruption. Meary's line is formed by the lines drawn through the mid-axis of the talus and the mid-axis of the first metatarsal on a standing lateral radiograph.

Though there is no disadvantage in sport performance originating from flexible flatfoot and no significant correlations between the arch height and motor skills [5], about 1/3 patients with flatfeet have complain during sports practice, and in a large part of patients, the sport practice is limited to swimming or lower impact activities [4].

From 4 to 6 years of age, a conservative treatment is indicated: stretching exercises and insoles. From 6 to 8 years of age, orthoses loose their corrective function. So that it is advisable to permit the young athlete every activity without insoles in order to understand if the foot is somehow symptomatic deserving further treatment.

Eight to twelve years is considered the most suitable age if surgical correction is needed. The aim of surgical treatment is to restore the normal relationship between the talus and calcaneus through either arthroereisis, osteotomy, or arthrodesis. Arthroereisis is the principal option for children since permits a foot correction without osteotomies nor arthrodesis, relying basically on skeletal growth [6]. Arthroereisis is performed by inserting a screw (calcaneo-stop) into calcaneus or an endorthesis into sinus tarsi in order to correct the subtalar pronation and permit a remodeling of the foot over time. A major improvement in the technique has been given by the introduction of bioreabsorbable materials for the implants, such as poly-L-lactic acid (PLLA), which are degraded in 4 years without the need of a second surgery for device removal [7] (Fig. 19.1).

Achilles tendon lengthening may be performed subcutaneously as an associated procedure to arthroereisis if 90° dorsiflexion of the foot is not obtained once the valgus of the hind foot is corrected. Other accessory procedures include medial procedure for prominent navicular bone or accessory navicular. During this procedure, the accessory navicular is removed, or the prominent navicular is tangentially resected and the tibialis posterior is sutured back in place having care to restore the correct tension.

Grice extra-articular subtalar arthrodesis is considered to be a valid surgical method which improves foot alignment in patients with severe ligamentous laxity and can achieve significant correction. This procedure relies on a bone autograft inserted into the sinus tarsi to create an "extra-articular arthrodesis" and thus correcting the valgus hind foot [8].

If the skeletal maturity is reached, calcaneal osteotomy is to be preferred. This procedure consists in an oblique osteotomy of the posterior calcaneus in which the posterior fragment is displaced medially to correct the apparent heel valgus. This procedure does not actually correct the malalignment of the subtalar joint, but merely creates a compensating deformity to improve the valgus angulation of the heel [9].

19.2 Tarsal Coalition

Tarsal coalition is a congenital union of two or more tarsal bone fibrous, cartilaginous, or osseous in nature which is cause of a rigid flatfoot deformity.

Fig. 19.1 Weight-bearing lateral and dorsoplantar X-ray view of foot in 11-year-old boy, *pre*- and *post*-surgery. Before subtalar arthroereisis with bioreabsorbable implant, Meary's line is interrupted. After surgery, Meary's line is continued and foot is corrected

Synostosis affects 1 % of population and is believed to result from a failure of embryonic mesenchymal differentiation and segmentation. Talocalcaneal and calcaneonavicular synostoses are the most common coalitions and in 50 % of cases are bilateral, while calcaneocuboid and talonavicular are rare [10].

Symptoms are not always evident in children, and in adults tarsal coalition may become symptomatic after trauma. The onset of symptoms usually coincides with the ossification of the coalition that limits the residual subtalar motion.

Clinically, the degree of deformity is variable, and pain may range from vague and insidious at sinus tarsi or below lateral malleolus during physical activity, to persistent pain. Limitation of inversion–eversion movement of the subtalar joint and/or midtarsal is evident. A history of frequent ankle sprain may be reported.

Standard RX projections united to oblique are the first step for the diagnosis of synostosis, in particular for the calcaneonavicular coalition but may not be diriment.

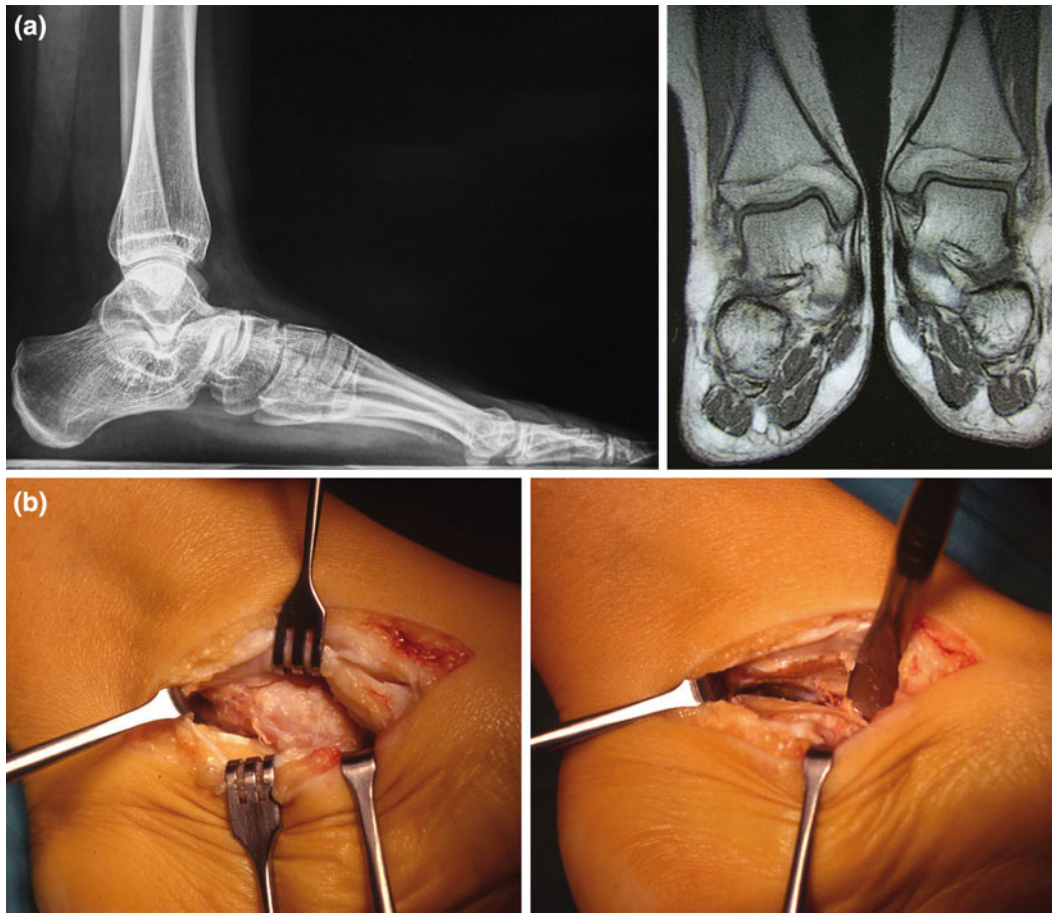

Fig. 19.2 **a** Weight-bearing lateral X-ray view of *left* foot in a 10-year-old girl with rigid flatfeet. RMN view shows bilateral talocalcaneal coalition. **b** Intraoperative views of talocalcaneal coalition and its excision

Full-length, weight-bearing anteroposterior and lateral radiographs of the foot may show signs of coalition. Lateral X-ray may show the "anteater nose" sign (extensions of the anterior process of the calcaneus toward its junction with the navicular) in the presence of calcaneonavicular coalition or "C" sign (continuous circular density formed by the outline of the talar dome and the inferior outline of the sustentaculum tali) in the presence of talocalcaneal coalition. This last coalition is most commonly found at the middle facet [11].

A 45° medial oblique view is useful for identifying calcaneonavicular coalition.

CT or MRI is usually necessary to confirm the diagnosis: both are excellent in recognizing the coalition compared to radiography and allow to describe size and location of the lesion (Fig. 19.2a).

As larger parts of coalition are asymptomatic, a conservative treatment may be effective, using orthoses with shell and medial heel wedge, a cast in severe cases with peroneal spasm [12].

If the coalition results in a recurrent symptomatic flatfoot, surgery is required.

Surgical treatment depends on the type of coalition and the status of joint.

Talocalcaneal coalitions, in skeletally immature individuals, are usually managed by coalition excision (Fig. 19.2b). Subtalar arthroereisis by implanting a bioreabsorbable device after removal of the tarsal coalition, in the same surgical session, is an effective procedure for restoring the alignment of the hind foot and

prevents coalition recurrence. In patients reached skeletal maturity, or when the conditions of the subtalar joint are too compromised, due to coalition size or arthritis, arthrodesis is to be performed [11].

Calcaneonavicular coalitions are also managed by coalition resection. However, a high rate of coalition recurrence and progressive radiographic evidence of transverse tarsal joint arthrosis have been reported. Some form of interposition is recommended in literature at the site of resection, and the most commonly used is extensor digitorum brevis muscle [12, 13]. Otherwise, also in this type of coalition, an arthroereisis by a reabsorbable device is capable to correct the deformity and have a positive impact on the recurrence, which if eventually happens, will happen in a good foot position with reduced or no impairment.

19.3 Cavus Foot

Cavus foot is a complex deformity that can be morphologically defined as a dorsiflexed and varus hind foot, a plantar flexed forefoot, and subsequent elevation of the plantar arch in weight bearing.

The difference in height between the forefoot and the hind foot and the persistent supination of the foot during gait are primarily responsible for functional consequences that produce instability, soft tissue overloading, stretching, adaptive secondary joint positions, and footwear problems [14].

The incidence in population is 1/1000 and from clinical observation is common in population who plays sports. The deformity tends to develop by growth after the three years of age.

The etiology of the deformity can be generally divided into 5 major groups: neuromuscular, congenital, post-traumatic, idiopathic, and miscellaneous [15].

The neuromuscular disorders that can lead to pes cavus are varied and include Charcot–Marie–Tooth disease, Duchenne's muscular dystrophy, poliomyelitis, and cerebral palsy.

Typical congenital cavus foot deformities are the residual of club foot, arthrogryposis or less frequently, the presence of tarsal coalition, and they are quite rare. Traumatic etiologies can include fractures, tendon lesions, or foot and leg compartmental syndrome.

In the miscellaneous group, we can include a number of endocrine, rheumatic, or iatrogenic problems, such as excessive lengthening or failed repair of Achilles tendon rupture [16].

Idiopathic cavus foot can be functionally defined as a foot in a persistent or prevalent state of supination.

Based on the location of deformity, cavus foot can be divided into anterior, posterior, and cavovarus. Anterior cavus foot is characterized by flexion of forefoot, posterior cavus foot from the vertical heel, and cavovarus is a result of these two conditions together. In detail, the cavovarus foot is a three-dimensional deformity characterized by the fixed cavus deformity of the first ray with internal rotation of the foot, varus deviation of the heel, and forefoot pronation [17].

During the cycle of gait, cavus foot keeps a state of prevalent supination in correspondence of the subtalar joint.

The site of the deformity (forefoot or hind foot) and the persistent supination of the foot are responsible for functional consequences and the extremely variety of clinical presentation of this deformity. Frequent symptomatologies are ankle instability, soft tissue overloading, anterior impingement, toes deformity, plantar fasciitis, Achilles tendinopathies, and plantar hyperkeratosis leading to footwear difficulties.

Depending on the degree of deformity and reducibility of the deformity itself, sports activity is more or less impaired. Because running requires the foot to accept 2.5 times the body weight at heel strike, the cavovarus deformity causes less stress dissipation and increases lack of shock absorption. So, runners with a cavus foot configuration can have additional problems such as plantar fasciitis, metatarsalgia, stress fracture, tendinitis, medial longitudinal arch pain ankle instability, and recurrent sprain [18].

At RX, lateral view is characterized by accentuation of the arch and the angle of arc decreased.

The choice among available surgical procedures is dictated by the age of the patient, the flexibility, and cause of the deformity.

Conservative treatment consists of stretching exercises and insoles.

Surgical treatment has to be carefully planned case by case and may consist of soft tissues and bony procedures. Among soft tissue procedures are widely used Steindler's plantar fasciotomy and Achilles tendon lengthening. Among bony procedures, is to be noticed the Jones procedure, in association or not with first metatarsus osteotomy, consists in transposition of the tendon of the flexor hallucis longus on the first metatarsus to facilitate dorsiflexion of the first metatarsal and correct deformity cock-up of metatarsophalangeal joint. Other tendon transpositions include tibialis anterior, tibialis posterior, and long hallux extensor in patients with muscular or neurological deficit [19].

Bony procedures are usually performed in mature feet because soft tissue procedures do not provide a complete correction of the deformity. Calcaneal osteotomy, tarsectomy, subtalar arthrodesis, midtarsal arthrodesis, and interphalangeal arthrodesis are among the different arthrodeses used.

19.4 Juvenile Hallux Valgus

Juvenile hallux valgus deformity is described as valgus deviation of the great toe proximal phalanx and varus deviation of the great toe metatarsal, occurring in patients who are skeletally immature. The incidence, etiology, risk factors, and natural history of juvenile hallux valgus (JHV) have not been completely defined. The strong preponderance of girls with JHV (surgical series report 84–100 % girls) and the presence of a positive family history in most cases (72 %) suggest a hereditary component to the etiology of JHV [20].

Etiology includes also ligamentous laxity, forefoot deformities, including lesser toes deformity or hind foot deformities such as flatfoot which is a strong predisposing condition.

In sportive people, hallux valgus may be correlated with hyperextension, acute luxation or subluxation of the first metatarsophalangeal joint, or chronic condition of overuse like flatfoot with increment of stress acting on the hallux, squatting, and abduction stress. Athletes most frequently involved in hallux valgus are dancers, fencers, and American football, soccer, and golf players [19].

With respect to the adult hallux valgus, in younger, the deviation is less pronounced and the medial eminence is smaller. The large part of patients is asymptomatic, and the hallux valgus is often an incidental finding but sometimes it can be painful, exacerbated with shoe wear. The probability of progression of deformity is assumed because of remaining skeletal growth but is not actually known because no study to date has documented the progression of JHV without treatment. At radiographs, it is possible to measure intermetatarsal angle, hallux valgus angle, proximal metatarsal articular angle, and metatarsal length ratio.

The first approach of treatment is conservative with comfortable shoes, orthotics, bunion pads, and physical therapy. Usually, the advice is to postpone surgical correction until skeletal maturity to minimize the risk of recurrent deformity. If pain persists, surgery becomes necessary. Although several techniques have been described to correct this deformity in adults, limitations exist for adolescents because of the presence of open growth plates and high recurrence rates. Procedures include soft tissue balancing or skeletal realignment.

Distal first metatarsal osteotomy fixed with Kirschner wire (SERI) is a valid technique for realignment of the hallux valgus without interesting of growth cartilage (Fig. 19.3) and can be associated with Akin procedure if interphalangeal deformity is also present or in

Fig. 19.3 Weight-bearing dorsoplantar X-ray view of foot in 10-year-old girl, *pre-* and *post*-distal first metatarsal osteotomy

hypermetric toe. Other techniques include lateral hemiepiphysiodesis of the great toe metatarsal physis, Chevron osteotomy for mild deformities, distal soft tissue procedure with proximal first metatarsal osteotomy for moderate and severe deformities with MTP subluxation, and double osteotomy (extra-articular correction) for moderate and severe deformities with an increased distal metatarsal articular angle [20].

19.5 Ankle Impingement

Ankle impingement is infrequent in children and still is one of the most common causes of chronic ankle pain in young athlete. It is the result of a conflict between bony or soft tissue structures during the normal range of motion of the ankle. The etiology and the pathologic anatomy are heterogeneous.

19.5.1 Anterior Ankle Impingement

Can be bony or soft tissue related. It appears as an anterior pain exacerbated by forced dorsiflexion.

An anterior bony impingement may be present in dancers or soccer players which perform repetitive movements in dorsiflexion, with compression and damage of the anterior capsular structures and joints. Dancers try to compensate by overpronating, leading to other injuries [21].

A soft tissue impingement generally occurs as a result of synovitis or capsulitis: It develops as a consequence of inversion ankle sprain or repetitive microtrauma. In young gymnasts, it may occur as result of repeated extreme dorsiflexion under load.

On examination, it is possible to find pain and tenderness to palpation in the anterior region of the ankle, exacerbated by the simultaneous movement of dorsiflexion. The Achilles tendon can be shortened.

A bony impingement instead is a rare occurrence in younger's, since is related to an early stage of arthritis. Still, professional athletes may be affected by bony impingement even at young age.

Plain ankle X-rays can show the bony impingement, while MRI is capable to evidentiate also the soft tissue and cartilage pathology being usually diagnostic.

Conservative treatment includes rest, heel lifts, ice, non-steroidal anti-inflammatory, and stretching exercises.

In case of conservative treatment failure, arthroscopic excision of the lesion with a partial synovectomy is indicated [22]. Surgical treatment should be followed by stretching exercises to prevent recurrence.

A "meniscoid lesion" can occur due to repeated ankle sprain: In these cases, a meniscus-like reactive fibrous tissue may develop between the fibula and the talus and because of pain. The young sportive patient presents pain and swelling on the anterior aspect of the fibula, sometimes with a snap when testing inversion stability. The diagnosis is completed by MRI. The arthroscopic treatment of the lesion is usually resolving [23].

Hypertrophy of the distal anterior talofibular ligament is another cause of pain impingement related. Usually, it is a result of repeated trauma. Clinically, the young complains pain on the syndesmosis, dramatically increased by forced dorsiflexion. It is necessary to exclude an osteochondritis dissecans with MRI. The treatment, also in this case, is arthroscopic and provides for the debridement of the lesion.

19.5.2 Posterior Ankle Impingement

Posterior impingement of the ankle [24] is a common syndrome consisting in posterior ankle pain exacerbated by forced plantarflexion. Bony structures involved in posterior bony impingement of the ankle lie in the tibiocalcaneal interval: these structures are the posterior tibial malleolus, the posterolateral talar process (Stieda's process), the os trigonum, the posterior subtalar joint, and the posterior process of the calcaneus.

Posterior ankle impingement is more frequent in athletes participating in sports involving repeated plantarflexion with compressing the posterior structures of the ankle [23, 25], especially in young female dancers , ice skaters, soccer players, or gymnasts.

On physical examination, patient has pain in palpation of the posterior ankle, dramatically increased with forced plantarflexion. Plain radiographs of the ankle, possibly with oblique views, may be taken to check for a bone etiology (i.e., os trigonum) [23]. Soft tissue etiology includes flexor hallux long irritation, thickened or invaginated posterior capsule, synovitis, and posterior impingement by anomalous muscles [25].

19.6 Os Trigonum

The posterior region of the talus often shows a core of separate ossification that appears at 8–10 years of age in females and 11–13 years in males. Fusion usually occurs one year after its appearance [24], but if fusion does not occur, os trigonum is formed. Approximately 10 % of the general population presents os trigonum, often unilateral [24, 26], and usually, it is asymptomatic. Os trigonum can be congenital or acquired. The congenital one appears when separation of the nucleus of ossification of the lateral tubercle of the talus is maintained, secondary to microtrauma during growth. It is acquired when it occurs secondary to a fracture of the posterolateral process unconsolidated [24].

In some cases, it may become symptomatic in young athletes who engaged in forced plantarflexion, as dancers, gymnasts, and soccer players [24, 26–28].

Clinical presentation usually consists in pain in the posterolateral side of the ankle, behind the peroneal tendons [24], exacerbated by forced plantarflexion. An anteromedial pain can be

associated if tendinitis of the flexor hallucis longus occurs [24, 27].

Radiographic diagnosis includes standard X-rays and lateral projection in plantarflexion.

Differential diagnosis should exclude Achilles tendonitis, flexor hallucis longus, and peroneal tendinitis.

Conservative treatment consists in rest, anti-inflammatory, discharge of plantarflexion, orthopedics cast, and infiltrative therapy [24, 27]. However, symptoms often recur when the subject returns to play sports, especially in dancers. In these cases, surgical treatment (endoscopic and open) is indicated to remove os trigonum. The open lateral approach is considered safer, and the medial approach may be indicated in case of concomitant tendinitis of the flexor hallucis longus.

19.7 Haglund's Disease

Haglund's disease is an alteration of the morphology of the calcaneus, described for the first time in 1928 by Patrick Haglund and characterized by the prominence of the posterosuperior margin of the calcaneal tuberosity [29].

Haglund's disease is not rare in adolescent females due to the use of rigid rear shoes, while in sport it is more frequent in young males and female runners, ice skaters, and soccer players.

On physical examination, the prominence is usually located to the lateral side of the heel.

Sometimes it can be observed an associated retrocalcaneal bursitis or Achilles tendonitis with thickening of the overlying skin and may be associated with varus hind foot.

Goal of the treatments is to reduce friction between shoe and prominence by padding the prominence and using a higher heel to download the region.

Conservative treatment also includes physical therapy and stretching of the Achilles tendon in association with non-steroidal anti-inflammatory. If the problem persists, open or endoscopic resection of the lesion is indicated [29].

19.8 Osteochondrosis of the Foot

Osteochondrosis is defined as deviations from the normal process of bone growth, non-inflammatory, or infectious. They appear as an abnormal ossification process, accompanied by a specific set of symptoms [30] in order to differentiate from normal variants of ossification.

In foot, the following diseases occur:

1. Sever's disease or osteochondrosis of the calcaneus
2. Kohler's disease or osteochondrosis of the tarsal navicular
3. Freiberg's disease or osteochondrosis of the head of the second metatarsal or Kohler's disease II
4. Iselin's disease or osteochondrosis of the base of the fifth metatarsal

The cause is still under investigation. However, it is believed that vascular disorders in combination with repeated microtrauma are at the base of the pathology. Hereditary and endocrine theories have also been proposed. Males are most frequently affected.

The main feature is an alteration degenerative–necrotic core of epiphyseal ossification followed by reparative processes that may hesitate in an anatomical deformity.

In the foot, the role of biomechanical factors as pathogenetic elements or aggravation is important: Forces that develop on the plantar structures are related both to load and direct reaction of the ground and to the tension that develops through tendons and ligaments on apophysis.

High stresses are transferred to foot's different bone structures, during gait or running, according to the performance helix breech: The calcaneal region will be severely stressed in the initial phase of step (heel strike), and thereafter at the end of the contact phase, the scaphoid is stressed while occurs the pronation of the subtalar joint. Finally shortly before the transfer of weight on the first finger, this is concentrated in a combination of vertical and horizontal forces on the condyle of the second metatarsal.

Sports increase quality and quantity of stress over structures, so it is possible to highlight the connection between sports and osteochondrosis in foot.

1. *Sever's disease (osteochondrosis of lower posterior calcaneal apophysis)*

Sever's disease is an avascular necrosis interesting calcaneal apophysis with pain in the posterior surface of the calcaneus [31] (Fig. 19.4). It is a non-articular osteochondrosis in the tendon insertions, particularly exposed to trauma: The region is subjected to damaging stresses resulting from contact with the ground directly and indirectly by the action of the Achilles tendon and plantar band.

Among the various osteochondrosis of the foot Sever's disease is the one that is more directly connected to sport. It affects mainly robust males engaged in sports as football, basketball, mini-rugby usually aged between 7 and 10 years. The higher prevalence is found among 8–9 years.

It occurs both bilaterally and unilaterally, and length difference should be evaluated in order to justify asymmetrical stresses. In 61 % of cases, this osteochondrosis is bilateral [32].

Fig. 19.4 Lateral X-ray view of foot shows osteochondrosis of lower posterior calcaneal apophysis in Sever's disease

Onset of the disorder is influenced by pronated foot and gastrocnemius–soleus complex retraction.

It presents with pain in the heel region usually without clinical local signs and may be accompanied by pain at the insertion of Achilles tendon.

At X-rays, secondary ossification center of the heel makes its appearance in the back around 8 years and undergoes fusion to 14 years [30]. In children between 9 and 11 years old, it is possible to detect a thickened apophysis, sometimes interrupted with or without fragmentation [33]. However, this isolated X-ray aspect is not to be considered specific because it is very common in the development of the calcaneal apophysis.

With ultrasound investigation, it is possible to find an inflammatory, edematous framework of insertion of Achilles and peritendinous tissues.

Treatment is conservative: rest and abstention from sport, discharge heel, and heel soft silicone are indicated. In the acute phase, treatment includes ice and anti-inflammatory therapy and is useful to avoid walking bare feet and stretching of the triceps surae until it becomes asymptomatic [34]. In the long term, it is important to reduce stress controlling the weight.

This osteochondrosis usually solves after a maximum of 8–12 months, depending on the subject and observation of prescriptions. Recurrence of symptoms may occur in subjects which do not suspend the activities or that start again early.

2. *Kohler's disease (osteochondrosis of the tarsal navicular)*

Kohler's disease is an idiopathic ischemic necrosis of the tarsal navicular [35] (Fig. 19.5). It was reported by Kohler (1908) as a thickening and flattening of the bone seen radiographically. Kohler later described the osteochondrosis of the second metatarsal; therefore, the pathology of the scaphoid is also defined Kohler's disease I. It is more frequent in males than females with a ratio of 6:1, and sport is not considered an etiological cause but a cause of aggravation. An etiological factor as a traumatic episode was found in 50 % of cases and is bilateral in 30 %.

Fig. 19.5 Oblique X-ray view and MRI view show injury to the scaphoid in Kohler's disease

Scaphoid is last bone of the tarsus to appear, and its ossification is late [33]. The process normally is completed between the 4th and 5th year.

The age of greatest incidence of the disease is between 3 and 8 years, coinciding with that of the proximal femoral epiphysis involvement. As tarsal navicular is positioned at the apex of arch, it is supposed to be strongly stressed when it was still in cartilage phase.

Frequently, Kohler's disease is associated with flatfoot, and clinically, it shows antalgic lameness, swelling, and medial edema [36].

Radiographic diagnosis is simple: It presents a thickening and thinning of the core of scaphoid. X-rays may be non-diriment in case of young children, when the core is not yet present. The densification of the nucleus is followed by fragmentation, and generally, it is followed by an almost normal bone morphology. Nevertheless, in rare cases, it may remain a flattening of the scaphoid with osteophytosis of talonavicular joint.

The treatment is conservative: reduction in weights, abstention from sports, orthoses with plantar support of the medial longitudinal arch for unloading the medial arch and for the pronation control. In severe cases, a plaster cast is needed in order to reduce recovery time [36].

The healing process is completed in 9–12 months, and recovery is faster in children.

Sport must be suspended in the acute phase except for swimming and may be resumed gradually in association with the use of orthotics.

3. *Freiberg's disease (osteochondrosis of the head of the second metatarsal)*

Also referred to as Kohler disease II, Freiberg's disease is an avascular necrosis of second metatarsal epiphysis.

The osteochondrosis of the head of the second metatarsal is due to a suffering of the epiphyseal nucleus, which affects therefore the metatarsophalangeal joint. Described by Freiberg in 1914 [37] can occur more rarely at the level of the third, fourth, or fifth metatarsal.

Usually, it occurs in childhood or adolescence around 13 years old and often regard females, in particular girls who practice dance or volleyball. The suffering epiphyseal develops in response to a solicitation of the metatarsal head which, during growth, changes its mechanical properties.

The joint is stressed in the propulsive phase of the step, and the disease appears to be related to sports repeated traumatism that is developed, especially in the presence of flatfoot and insufficiency of the first metatarsal [34].

Clinically, Freiberg's disease is characterized by unilateral pain in correspondence with the metatarsal head.

At X-ray examination, the metatarsal head shows a progression from osteosclerosis to osteolysis with a lacunar appearance and a dome-shaped deformity of the head. In the joints, a lesion of the cartilage or subchondral bone appears.

Conservative treatment provides for rest and use of orthotic plantar to control the pronation with bar or olive for unloading metatarsal. In severe forms, it is appropriate to use a cast.

In adulthood may manifest osteoarthritis of the second metatarsal joint with typical deformity in the shape of Burmese pagoda. Surgical treatment is indicated in these cases for joint debridement, removal of any residual lost body up to resection of the head or osteochondral transplantation [38].

4. *Iselin's disease (osteochondrosis of the base of the fifth metatarsal)*

Iselin's disease is an apofisite caused by traction on the tuberosity of the fifth metatarsal, and it is very rare. It occurs in late childhood–adolescence in subjects who play sports [39].

The secondary ossification center appears as a small shell-shaped oblique at the level of the tuberosity, which is part of the tendon of the peroneus brevis. The nucleus appears late in an average of 9 years in females and 12 years in males and ends its maturation at 11 and 14 years, respectively.

Patients affect by Iselin's disease are usually athletes involved in sports that include running and jumping, and generally, there is a real trauma. The movement in eversion against resistance generally evokes pain. The differential diagnosis should be placed with fracture of the base of the fifth metatarsal. The oblique X-ray is the one that best shows the apophyses.

Treatment is conservative and includes immobilization in the acute phase, no weight bearing, and then stretching and strengthening of the peroneal muscles [39].

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