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Review article

Sports injuries of the foot and ankle in the adolescent athlete

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Abstract

As adolescent athletes place increasing demands on their bodies, injuries in this population are frequent and becoming more common. Overuse injuries, rather than acute traumatic events, comprise the majority of injuries in adolescents. These injuries, as in adults, are a result of poor form, poor habits, and poor training patterns. In addition, anatomic variations in the hind-foot, mid-foot, and forefoot may predispose an athlete to specific injuries. Prevention of these injuries and early intervention by an orthopaedist can decrease the athlete's time lost to injuries and potential long-term adverse effects. The objective in this paper is to review common sports-related injuries of the foot and ankle in the adolescent athlete, with particular attention paid to overuse injuries in terms of contributing factors, prevention and treatment. **Keywords:** foot, ankle, sports injuries, adolescent, overuse

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Introduction

As adolescent athletics has become more competitive and training programs have become more intense, the number of injuries to young athletes has increased [1,2]. The most common contributing sports are football, soccer, baseball, basket ball, rugby, tennis, running and gymnastics [2]. The adolescent population has an increased risk for injury when compared to the adult population, principally due to overuse injuries of the developing skeleton. This article reviews common adolescent sports injuries of the foot and ankle, particularly those secondary to overuse in terms of causes, prevention and treatment.

General considerations

The demands and expectations on an adolescent athlete make them prone to injuries, particularly overuse injuries [1,3,4]. The term overuse is commonly attributed to chronic injuries secondary to high levels of physiological stress without sufficient recovery time [4]. The factors responsible for overuse injuries can be defined under two broad categories, intrinsic and extrinsic factors. The intrinsic factors include anatomic considerations, gender, development, and growth considerations. The extrinsic factors include technique, training and recovery regimens, shoe wear and playing surfaces.

Intrinsic factors

Anatomic alignment

Certain anatomic variants can make adolescent athletes predisposed to certain injuries. Adolescent athletes with a cavovarus foot are often prone to lateral foot injuries, including stress fractures of the fifth metatarsal and ankle sprains [1]. Adolescents who present with painful planus or flatfeet must be carefully evaluated for tarsal coalition, tight gastroc-soleus muscle tendon, or peroneal muscle spasm. Tarsal coalition is present in just over 1% of the adolescent population and must be ruled out in an adolescent athlete presenting with a “chronic ankle sprain” not responding to conventional therapy [5] (Figure 1). A common finding in tarsal coalition is decreased subtalar motion which predisposes to recurrent ankle sprains. Orthotics may provide relief for these patients when combined with a vigorous physical therapy regimen or, in some cases, surgical correction may be necessary.

A

B

Figures 1A and 1B: Plain radiograph (A) and MRI (B) demonstrating tarsal coalition (talocalcaneal)

A common problem in adolescent runners is excessive forefoot pronation which makes athletes susceptible to mid-foot pain, plantar fascitis, and stress fractures [4,6].

Anatomic variations in forefoot metatarsal length may also contribute to overuse injuries. In adolescents with a long second metatarsal (Morton's foot), the second metatarsal is predisposed to stress fractures (Figure 2) and Freiberg's infraction (Figure 3) [7]

Figure 2

Figure 3

Figure 2: 2nd metatarsal stress fracture with early stress reaction
Figure 3: Freiberg's infraction of 2nd metatarsal head

Development and growth considerations

The variability of anatomic development during the adolescent years impacts performance and injury significantly. Adolescent runners are prone to muscular imbalance secondary to repetitive training and asynchronous muscle growth. A common combination seen in adolescent runners includes strong quadriceps, a strong gastroc-soleus complex, and a weak hamstring muscle group. Whilst uncommon this combination can increase the risk of Achilles tendon rupture, calcaneal apophysitis (Figure 4), hamstring strain, and hamstring avulsion [8,9]. Traction apophysitis can also be seen at the base of the fifth metatarsal (Figure 5).

Figure 4: Sever's apophysitis of calcaneus

Figure 5: Traction apophysitis of 5th metatarsal base

Extrinsic factors

Footwear

Footwear plays an important role in the biomechanics surrounding injuries and overuse syndrome in adolescents. The materials used to manufacture shoes provide differing densities that create either a cushioned flexible sole or a motion control shoe that controls pronation in flat footed athletes via a stiffer sole. Wear patterns on the heel indicate if an adolescent pronates or supinates while running. Those with pronated feet should use a contemporary sports shoe with a rigid shank, whereas those runners who have a supinated foot should be fitted with a more flexible shoe. More importantly, significant wear patterns indicate that a shoe no longer provides adequate support and should be changed. Ideally, athletic shoes should be changed four times a year for an athlete running greater than 113km (70 miles) per week.

Inappropriate shoe and sock wear can lead to blisters and nail problems. A running sock provides stability, decreases friction between layers, and dissipates moisture in an attempt to decrease blistering and discomfort. It provides a buffer between the impact of the shoe and the foot during the stance phase of the running cycle. Running socks should be replaced at regular intervals to maintain their efficiency. Blisters should be drained with a sterile needle and dressed with non-slip tape. Moleskin or an alternate cushioned material should be used in the shoe until the blister has resolved.

Adolescent track athletes often wear spiked running shoes. Currently, six 9mm spikes are the standard for synthetic track shoes. Care should be taken in the fitting of the shoe to insure that a spike does not screw into the shoe directly under the sesamoid bone of the first ray. This direct pressure can cause sesamoiditis or neurapraxia of Joplin's nerve. For long-distance running events, a rigid heel counter is required to control heel strike. Athletes with pronated feet can increase hind-foot stability with the use of a flared heel shoe.

Running surfaces

Natural grass provides excellent shock absorption, with little torque. However, athletes running on natural grass are susceptible to slipping on uneven terrain, which can cause ankle and subtler sprains.

Synthetic surfaces have less shock absorption and increased torque when compared to natural grass. However, as a result of the decreased give and increased torque of the surface, turf toe type injuries are more common and the severity of sprains is increased. Synthetic surfaces are predictable and provide greater traction than natural surfaces. Athletes training on road surfaces must be careful to avoid the same cant when running on the road to avoid unilateral foot overload. Running on the opposite side of the road on alternate days can reduce the risks of overload.

Training patterns

In both adolescent and adult athletes, poor form, poor habits, and poor training patterns contribute to overuse injuries. In general, sudden changes in intensity, frequency, and duration of training have a linear correlation with the number of overuse injuries. Physeal injuries have been found to be more common with increased levels of training. Despite this, however, no correlation has been shown between increased training and permanent physical damage resulting in growth arrest or angular deformities [4].

Injuries about the ankle

Os trigonum syndrome

The os trigonum is an accessory bone that develops from a secondary ossification centre at the posterior aspect of the talus. Radiographically it can be seen as a separate ossicle or prominence of the talus, Stieda's process. In general, symptoms result from impingement of soft tissues between the ossicle and the posterior aspect of the tibia when the ankle is in plantar flexion. This problem often results from the repetitive trauma of the cross country runner's training on hills and ballet dancer's chronic use of the "en pointe" position [5] (Figure 6). Most cases of os trigonum syndrome can be diagnosed from a careful history, physical examination, and plain radiograph. Occasionally, a magnetic resonance imaging (MRI) scan may be required to rule out a fracture of the Stieda's process in the skeletally immature patient. Initial treatment consists of rest, anti-inflammatory medication, and behaviour modification. The patients are placed in a cam-walker boot for a period of one week in the acute phase. This is followed by gradual return to activity with training modification, specifically restriction from hill work. In cases with continued pain refractory to conservative management, the ossicle can be surgically resected.

Figure 6: Posterior os trigonum impingement syndrome in the en pointe position

Osteochondral lesions of the talus (OCD)

Osteochondral lesions of the talus are common in adolescent athletes. They may result from an inversion injury or may arise 'de novo' from microcirculatory impairment [10]. Often they are asymptomatic and found as an incidental finding on a plain radiograph or MRI (Figure 7). When symptomatic, patients present with diffuse ankle pain, swelling, and occasional locking or catching in the joint secondary to loose fragments. In the adolescent athlete with persistent pain following an ankle sprain, careful attention must be directed to rule out an OCD lesion.

Figure 7

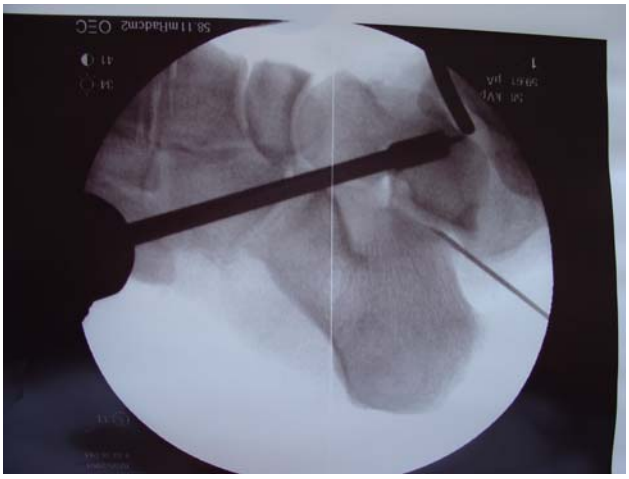

Figure 8

Figure 7: MRI evidence of an osteochondral lesion
Figure 8:. Intra-operative radiograph showing retrograde drilling of an OCD

Treatment of OCD lesions depends on the grade of lesion and the patient's symptoms. In general, asymptomatic cysts with intact cartilage can be observed. In symptomatic patients with intact cartilage, retrograde drilling can stimulate neovascularisation and bone formation within the cyst without disrupting the overlying cartilage (Figure 8). When the cartilage is loose or partially attached, ante-grade drilling can promote fibro-cartilage scarring within the defect. In larger lesions osteochondral plugs or autografts may be required to provide satisfactory relief of symptoms [11,12].

Ankle sprains

Ankle sprains are the most common sports-related injury of the foot and ankle. The anterior talofibular ligament (ATFL) and the calcaneofibular ligament (CFL) are the most commonly injured ligaments in the ankle [1,3,4]. Although less prevalent, high ankle sprains bring significant morbidity if missed. Distinguishing these injuries is essential as they require an extended period of strict immobilisation. ATFL and CFL injuries present with pain and swelling at the anterolateral and/or lateral aspects of the ankle.
Treatment is based on a triple phase rehabilitation programme. The initial phase includes rest, ice, and elevation. After 2-3 days the athlete is encouraged to commence weight-bearing in an air cast or sports brace as can be tolerated. The second phase of treatment includes range of motion exercises with peroneal muscle strengthening. Following the restoration of mechanical stability, functional instability can persist. The third phase of treatment addresses this functional deficit and begins 10-14 days following the injury. At that time, the patient begins proprioceptive- and balance training which is critical in the prevention further injury and chronic sprains. Over 90% of patients return to full activity following the rehabilitation protocol.

For those who have persistent instability despite the triple phase rehabilitation programme, surgical procedures can reconstruct the damaged structures and stabilise the ankle. These procedures can be broadly categorised as anatomic procedures or check rein procedures. The Brostrom-Gould procedure is an anatomic reconstruction of the ATFL using the inferior extensor retinaculum to augment the construct. Results of this lateral ankle stabilisation procedure have been uniformly excellent [13,14,15]. Several check rein procedures have been described using both the peroneus brevis and allograft materials. These procedures should be reserved for patients in whom the ATFL is completely destroyed or in athletes that place great physiologic loads on the ankle. The check rein procedures can provide excellent functional outcomes. However, there are some concerns that normal kinematics may be lost [14]. Due to this concern, the current authors favour an anatomic reconstruction in the adolescent patient.

Injuries about the hind-foot

Calcaneal apophysitis

The vertically-oriented epiphysis of the posterior calcaneus is susceptible to shear forces from the strong gastrocsoleus complex. This condition generally presents from ages 8-12 years and is more common in males, particularly in runners and sports involving repetitive jumping [2]. The aetiology of this entity may be related to poor shock absorption in the adolescent foot, which results in excess force around the heel [8,9]. Adolescents may be predisposed to this condition due to inherent biomechanical conditions (forefoot varus, pes cavus, or pes planus) or reduced flexibility secondary to growth spurt limitations [8]. Symptoms usually involve pain and tenderness over the Achilles apophysis during or right after running.

Radiographs may show sclerosis and fragmentation of the apophysis; however, this is not required for a diagnosis (Figure 4). Radiographs are important to identify other potential causes of symptoms, including calcaneal stress fractures. Treatment consists of stretching, ice, massage, and activity modification. A 1.25cm visco heel cup or a .6cm heel lift, should be worn in both shoes to reduce Achilles tendon stretch. If symptoms persist, a fibreglass cast can be applied for 6 weeks to reduce the constant motion causing the inflammation. As Sever's disease is self-limiting, there is rarely a role for surgical intervention.

Achilles peritendonitis and tendonitis

Inflammation of the Achilles tendon and peritenon are part of the same continuum of disease in the adolescent athlete. Caused by a tight gastrocsoleus complex, both have a similar clinical presentation. The symptoms of Achilles tendon inflammation can be felt as a bulbous swelling that moves on moment at the ankle. In contradistinction, tendon sheath inflammation is characterised by more diffuse appearance of swelling that does not move on ranging the ankle joint.

Treatment for both conditions is based on breaking the cycle of inflammation and addressing the underlying cause. A cam-walker boot is prescribed for 23 hours a day for two weeks and the patient is prescribed non-steroidal anti-inflammatory (NSAIDs) medication. The cam-walker boot should have a 1.25cm heel raise to reduce the resting tension in the Achilles tendon complex. In some adolescent athletes it may be advisable to use a fibreglass cast for 2 weeks to ensure compliance with the protocol. Once the cycle of inflammation has been broken, physical therapy can be used to stretch the tight gastrocsoleus complex.

Retrocalcaneal bursitis

Inflammation of the retrocalcaneal bursa is caused by repetitive motion of the Achilles tendon over the posterosuperior aspect of the calcaneus and/or pressure of the heel counter. Dorsiflexion of the ankle precipitates the pain. Radiographs often identify an anatomic cause for this inflammation, a hatchet-shaped prominence on the posterior calcaneus called a Haglund's lesion. The presence of this prominence is confirmed with a Fowler and Philip's angle of greater than 75°. Treatment is directed at reducing inflammation with ice, protective padding, soft heel counters, and anti-inflammatory medication. Surgical resection is rarely indicated in adolescents before physeal closure [16].

Plantar fascitis

Repetitive loading of the plantar fascia can cause medial arch strain. In adolescents, this is often more distal than at the location of plantar fascitis found in adults. Patients should be carefully examined to rule out other causes of plantar pain, including medial plantar nerve compression.

Plantar fascitis is often associated with a cavus or pronated foot [1]. As such, treatment should initially be directed toward running shoe modifications that increase shock absorption. This is supplemented by a physical therapy programme that includes deep tissue massage, tibialis anterior strengthening, gastroc-soleus stretching and occasional anti-inflammatory medication. Steroid injection should be used sparingly and as a last resort in difficult cases. Ultrasound guided injections can define the area of inflammation more clearly and limit the risk of inadvertent plantar fascia rupture.

Injuries about the mid-foot

Kohler's disease

Kohler's disease, idiopathic osteonecrosis of the navicular bone, is a self limiting process associated with repetitive trauma to the developing epiphysis. Athletes present with tenderness and swelling over the navicular bone after activity. Although the naviculum is the last tarsal bone to ossify, this condition usually presents before the age of 10 years and is significantly less common in adolescents. Males are more commonly affected than females [17,18].

Treatment is directed towards immobilisation and rest in a cam-walker boot for a period of 6 weeks followed by a wedge arch support orthotic. Normal navicular architecture, as evidenced by radiographs, can take up to a year to return. Long-term results are excellent and athletes are expected to return to normal activities within 3 months. Failure to treat this entity expeditiously, however, can result in a poor outcome that may require Chopart joint fusion [7,18].

Accessory navicular bone

Approximately 20% of the population has an accessory navicular bone [19]. Athletes may develop symptoms following repetitive trauma as seen in running and cutting-type activities. Patients typically present with pain over the medial forefoot and a prominence over the naviculum. The prominence may swell with activity and pain at this location will be increased with forceful inversion of the foot.

Radiographically this condition may be best visualised on a reverse oblique view where an ossification centre can be identified lateral, proximal, and plantar to the naviculum. Accessory navicular bones have been divided into three types. Type I represents a true sesamoid bone within the tibialis posterior tendon and is usually asymptomatic. Type II represents a cartilaginous synchrondosis between the main body of the navicular and the accessory bone. This is the most common type and is often symptomatic secondary to repetitive trauma and overuse. Type III represents an ossification of a Type II lesion. Type III lesions are not usually symptomatic, but may cause discomfort with tight-fitting sneakers. This can easily be corrected with appropriate footwear modifications that relieve the pressure over the prominence.

Treatment of Type II accessory navicular conditions is aimed at relieving the immediate inflammatory response with rest and anti-inflammatory medication. A cam-walker boot or cast is used for 3-6 weeks to immobilize the inflamed area. Once the acute phase has resolved, a medial longitudinal arch support can be worn to prevent pronation and tibialis posterior muscle spasm. In cases that are recalcitrant to conservative therapy, the accessory bone can be resected with reattachment of the tendon (Kidner procedure) [21].

Stress fracture of the navicular

Stress fractures occur as a result of a mechanical overload. Under normal loading conditions, bone balances osteoclastic bone resorption and osteoblastic bone proliferation to maintain the structural integrity of bone. In overuse injuries, bone resorption exceeds the proliferative process resulting in net loss of bone and increased risk of fracture [7].

Stress fractures of the navicular are common in adolescent athletes. Traditionally it has been more common in males; however, the incidence in female athletes is increasing. The fracture is typically seen in the middle third of the navicular, where blood supply is poorest. It progresses from proximal to distal in the sagittal plane, perpendicular to the long axis of the bone [17].

The clinician must have a high index of suspicion in order to make the correct diagnosis promptly. Patients usually present with a vague history of dorso-medial foot pain that is exacerbated by running and sprinting. Athletes with certain anatomic variants are predisposed to stress fractures of the navicular, including a tight gastrocsoleus complex, limited subtalar motion, and a Morton's type foot with a relatively long second ray. The common effect of each of these anatomic variants is increased biomechanical loads through the navicular and thus an increasing risk of injury. Since the diagnosis can be difficult using conventional radiographs, multi-planar CT images are preferred for imaging. Early stress fractures may be demonstrated on MRI by marrow oedema [18].

Activity restriction in a cam-walker boot or cast for 4-6 weeks is the initial treatment. This can be augmented with a bone stimulator. In cases that do not show adequate resolution of symptoms with immobilisation, internal fixation can provide excellent outcomes [17].

Compression of medial plantar nerve (Jogger's nerve)

The medial plantar nerve can become compressed as it travels through the Master Knot of Henry. This neurapraxia causes symptoms of pain along the medial aspect of the foot radiating to the great toe and occasionally to the ankle. Patients with forefoot abduction, heel valgus, or overpronation have increased risk of this compression. In addition, shoe wear with high medial arches can compress the nerve and exacerbate the condition. Symptoms may be reproduced clinically by everting the heel or asking the patient to stand on the balls of their feet. A Tinel's nerve compression test is usually positive.

Treatment is directed at footwear modifications that alleviate the nerve compression and include the use of a longitudinal arch support that limits pronation. The vast majority of patients respond well to conservative treatment options; however, refractory cases may require surgical release. After surgery, the athlete can usually resume training in 6 weeks.

Injuries about the forefoot

Metatarsal stress fractures

In the adolescent athlete a rapid increase in the duration and intensity of activity running predisposes the metatarsals to physiologic overload. The second metatarsal is the most vulnerable to overload followed by the third, first, fourth, and fifth metatarsals, respectively. Diaphyseal and neck stress fractures most commonly occur in the second and third metatarsals. Fractures of the fifth metatarsal often involve the base of the bone.

Patients complain of pain 2-3 weeks following the onset of an increase in training. Initially the pain is related only to strenuous activity, but as the fracture progresses it can be present with normal weight bearing. Clinically, patients' symptoms may be reproduced with dorsiflexion of the involved ray. Radiographs are of marginal value in the first 2 weeks after a diaphyseal injury. Stress fractures in cancellous bone can take up to 24 weeks to be visible radiographically [20] (Figure 2).

Treatment is directed at reducing the patient's activity level to encourage bone proliferation and consolidation. A cam-walker boot is used for some patients, but most can manage in a comfortable shoe. After 3-4 weeks, consolidation of the injured bone is usually complete. Training is then initiated at gradual increases in duration and frequency. Forefoot overload from a tight gastrocsoleus complex should be addressed with physical therapy. In cases of delayed union or non-union, a metabolic bone evaluation should be performed and the patient may benefit from a bone stimulator.

Fifth metatarsal stress fractures require a more prolonged treatment course. These fractures occur in the metadiaphysis of the fifth metatarsal about 1.5 cm from the base. They do not involve the base of the fifth metatarsal as it articulates with the fourth metatarsal, in contradistinction to the Jones fracture. The insufficiency fractures of the fifth metatarsal require 6 weeks of immobilisation in a non-weight-bearing cast. Occasionally, elite athletes will initially be treated with screw fixation to facilitate an early return to activity. The screw should remain in situ, for as long as the athlete is competing [21].

Freiberg's infraction

Osteochondrosis of the metatarsal head represents an avascular event in the metatarsal epiphysis. Initially thought to result from an acute traumatic event, Freiberg's infraction is now thought to be caused by repetitive micro-trauma resulting in stress fractures through the metatarsal head [22]. A Morton's type foot, with a long second or third ray, can predispose the athlete to repetitive loading on the metatarsal heads when running or jumping (Figure 3). It most commonly is found in the second ray. Over 75% of cases are seen in females over the age of 13 years [22].

Symptoms include pain and swelling over the second or third metatarsal head that worsens with activity and weight-bearing. Motion in the metatarsal phalangeal joint is restricted. Radiographs demonstrate osteosclerosis during the initial stages of the disease. Later in the process, osteolysis and collapse can be seen radiographically.

Conservative management of symptoms includes a stiff-soled post-operative shoe with a metatarsal pad. For advanced stage disease, cast immobilisation may be required for up to 12 weeks. For patients with persistent symptoms, a dorsal closing wedge osteotomy can be performed with the expectation of satisfactory outcomes [23].

Turf toe

Turf toe is a sprain of the plantar capsule and the supporting structures of the first metatarsophalangeal joint. The mechanism can be hyper dorsi- or plantar-flexion of the joint. The turf toe is more common on artificial running surfaces than on natural turf and is therefore more prevalent in American Footballer players. Patients complain of pain over the first metatarsophalangeal joint with dorsiflexion. Care should be taken to rule out concomitant injury to the collateral ligaments and the sesamoid bones. Plain radiographs are useful in evaluating the position of the sesamoid bones. MRI can help diagnose the injury, confirm the severity of the injury, and identify chondral injuries.

Treatment is largely conservative with 3 weeks immobilization in a post-operative shoe. In more severe grades of ligamentous laxity, a short leg cast with the toe at 10° of plantar flexion is used to take the resting tension off the plantar structures. Surgery is restricted to patients that do not respond to the conservative protocol and those cases with associated osteochondral injury. In general, turf toe has disappointing outcomes with most series reporting just over half of patients being satisfied with outcome [1,3,22].

Sesamoid fractures and sesamoiditis

The sesamoid bones are intratendonous structures that improve the biomechanical advantage of the flexor tendon to the great toe. When the athlete is running, forces greater than four times body weight are transmitted through these small bones. Patients with sesamoid fractures and sesamoiditis complain of pain over the sesamoid bones, particularly on toe push off. Plain radiographs can demonstrate a fracture. However, since up to 30% of sesamoids are bi-partite or multi-partite, MRI is a more useful modality to make a definitive diagnosis.

Treatment consists of rest, anti-inflammatory medication, and a stiff-soled shoe. The toe should be taped in a slightly flexed position and a doughnut or J-pad can be used to distribute weight away from the sesamoid bones. Surgical resection of a fractured sesamoid is only required in cases of non-union or osteonecrosis. The fibular sesamoid is removed through a dorsal first web space incision and the tibial sesamoid is removed through a medial incision with care to avoid the plantar cutaneous nerve or nerve to the abductor hallucis.

Hallux rigidus

Repetitive trauma to the first metatarsophalangeal joint causes proliferation of bone that prevents adequate dorsiflexion of the great toe. Hallux rigidus is not common in adolescents as it is principally a degenerative process. Despite that, however, hallux rigidus can occur as a result of a traumatic event and be associated with an osteochondral defect in the adolescent population [24, 25]. Some authors suggest that overloading the first ray is the primary cause of this entity, either from repetitive micro-trauma or from a single traumatic episode. Therefore anatomic variants that contribute to this overload may contribute to the development of hallux rigidus, including metatarsus primavarus, pes planus, foot pronation, and a long slender foot [24]. However, there is no consensus that these conditions place the adolescent athlete at greater risk.

Patients with hallux rigidus complain of restricted motion and pain in toe off when walking or running. Plain radiographs provide evidence of dorsal and medial bone proliferation. In the adolescent, an MRI is required to rule out osteochondral lesions in the first metatarsophalangeal joint. Since the process is usually degenerative in an adult, an MRI is not required in the older athlete with these symptoms.

Treatment consists of a carbon fibre orthosis or a rocker bottom shoe. Most adolescent athletes, however, are unable to tolerate the orthosis and a simple cheilectomy is usually advocated. In cases of discrete osteochondral lesions, drilling of the subchondral bone can provide a fibrocartilagenous repair [24,25].

Summary

Adolescent injuries to the foot and ankle are common and becoming even more frequent as these athletes place increasing demands on the growing body. Many extrinsic factors, including shoe wear, running surfaces and equipment, can be modified to accommodate the varying stages of the developing runner. Coaches should modify training regimens to facilitate the various factors inherent to developing athletes. Although no data currently shows long-term repercussions to overuse injuries in adolescents, it is reasonable to protect against this possibility by preventing these injuries. Prevention is best achieved by assessing the adolescent's physical development, skills, and fitness prior to the training season. Since development is extremely variable at adolescence, age-specific training is of marginal benefit. Training should be tailored to the individual athlete, taking into account their strengths and weaknesses. It is only by injury prevention and recognition that an adolescent's safe participation in competitive athletics can be insured without undue risk to their future wellbeing.

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References

1. Chambers HG. Ankle and foot disorders in skeletally immature athletes. Orthopedic Clinic North America 2003; 34: 445-459.
2. Lord J, Winell J. Overuse injuries in pediatric athletes. Curr Opin Pediatr 2004;16(1):47-50.
3. Adirim TA, Cheng TL. Overview of injuries in the young athlete. Sports Medicine 2003; 33: 75-81.
4. Hogan KA, Gross RH. Overuse injuries in pediatric athletes. Orthopedic Clinic North America 2003; 34: 405-415.
5. Krivicas Lisa S. Injury clinic. Sports Medicine 1997; 24: 131-146.
6. Barr KP, Harrast MA. Evidence-based treatment of foot and ankle injuries in runners. Phys Med Rehabil Clin N Am 2005;16: 779-799.
7. Pentecost RL. Fatigue, insufficiency and pathological fractures. Journal of the American Medical Association 1964; 187: 1001.
8. Crosby LA, McMullen ST. Heel pain in an active adolescent: Consider calcaneal apophysitis. Physician and Sportsmedicine 1993; 21: 89-91.
9. Michelli LJ, Ireland ML. Prevention and management of calcaneal apophysitis in children: An overuse syndrome. Journal of Pediatric Orthopedics 1987; 7:34-38.
10. Hughes JA, Cook JV, Churchill MA, et al. Juvenile osteochondritis dissecans: A five year review of the natural history using clinical and MRI evaluation. Pediatric Radiology 2003; 3:3410-3417.
11. Benthien RA, Sullivan RJ, Aronow MS. Adolescent osteochondral lesion of the talus, ankle arthroscopy in pediatric patients. Foot and Ankle Clinic 2002: 7; 651-667.
12. Robinson DE, Winson IG, Harries WJ, et al. Arthroscopic treatment of osteochondral lesions of the talus. Journal of Bone and Joint Surgery 2003; 85B: 989-993.
13. Hamilton WG, Thompson FM, Snow SW. The modified Brostrom procedure for lateral ankle instability. Journal of Foot and Ankle Surgery 1993; 14: 1-7.
14. Tohyama H, Beynnon BD, Pope MH, et al. Laxity and flexibility of the ankle following reconstruction with the Chrisman-Snook procedure. Journal of Orthopedic Res 1997; 15: 707-711.
15. Letts M, Davidson D, Mukhtar I. Surgical management of chronic lateral ankle instability in adolescents. Journal of Pediatric Orthopedics 2003; 23: 392-397.
16. Reinherz RP, Smith BA, Henning KE. Understanding the pathologic Haglund's deformity. Journal of Foot Surgery 1990; 29: 432-435.
17. Torg JS, Pavlov H, Cooley LH. Stress fracture of the Tarsal Navicular. Journal of Bone and Joint surgery 1982; 64A: 700-712.
18. Pavlov H, Freiberger RH. Tarsal Navicular Stress Fracture: Radiographic evaluation. Radiology 1983; 148: 641-645.
19. Bennett GI, Weiner DS, Leighley B. Surgical treatment of the accessory tarsal navicular. Journal of Pediatric Orthopedics 1990; 10: 445-449.
20. Santi M, Sartoris DJ. Diagnostic imaging approach to stress fractures of the foot. Journal of Foot Surgery 1991; 30: 85-97.
21. Torg JS, Balduni FC, Zelko RR, et al. Fractures of the base of the fifth metatarsal distal to the

tuberosity: Classification and guidelines for non-surgical and surgical management. Journal of Bone and Joint Surgery 1984; 66A: 209-214.
22. Clanton TO, Butler JE, Eggert A. Injuries to the metatarsophalangeal joints in athletes. Journal of Foot and Ankle 1986; 7: 162-168.
23. Kuo-Hua, Chia-Her, Lee-Chyr Lin. Surgery for symptomatic Freiberg's disease. Acta Orthopedic Scandinavia 1999; 70: 483-486.
24. Mann RA, Coughlin MJ, DuVries HL. Hallux rigidus: A review of the literature and a method of treatment. Clinical Orthopedics 1979; 142: 57-62.
25. Thomas AP, Dwyer NS. Osteochondral defects of the first metatarsal head in adolescence: A stage in the development of hallux rigidus. Journal of Pediatric Orthopedics 1989; 9: 236-239.

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