Ankle injuries in the growing skeleton

A review of the recent literature

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ABSTRACT

تنشأ إصابة الكاحل بوتيرة كبيرة بين الأطفال وذلك على الرغم من أن التشخيص نادراً ما يكون واضحاً. وتُمارس الرياضات الجماعية وخصوصاً كرة القدم على نطاق واسع ولا سيما بين الرياضيين السعوديين، إلا أنه هناك القليل من التثقيف حول التدابير المتعلقة بظروف اللعب واتخاذ خطوات وقائية مثل الأحذية المناسبة، والإحماء، وغيرها. وعادة ما تكون التعقيدات المحتملة المصاحبة لإصابات الهيكل العظمي البالغ وكذلك غير البالغ والتي تتضمن الفصال العظمي الناجم عن الإصابة، والتيبس المفصلي، والحثل العَرَضي المعاكس، بالإضافة إلى الحالات المتعرضة للإصابات الجسدية والتي تتضمن تباين طول الساق، والتشوهات الزاويّة أو أن تكون كلتاهما. إن معرفة هذه الإصابات بالإضافة إلى الفرق بين البنية الهيكلية عند الأطفال والبنية الهيكلية لدى البالغين ضروري للعلاج الفعّال لتلك الإصابات الشائعة. وتعتبر هذه المقالة جامعة بين علم التشريح وعلم الوظائف والفيزياء، والجهات التشخيصية، والتكهّن بالمسببات، وطرق العلاج، والتحليل والتركيز، والمعلومات المنشورة في الأبحاث العلمية حول إصابات الكاحل في الهيكل العظمي المتنامي والتي تعدّ حاسمة لعلاج تلك الإصابات.

Ankle injuries arise with significant frequency in the pediatric population, although diagnosis is rarely straightforward. Contact sports, such as football are widely practiced in Saudi athletes, little is carried out to educate them of measures regarding playing conditions and prophylactic steps like foot wear, warming up, and similarly. The usual potential complications associated with trauma to mature skeleton, as well as immature selection includes post-traumatic arthritis, stiffness, reflex sympathetic dystrophy, as well as those seen with physeal damage including leg length discrepancy, angular deformities, or a combination. Knowledge of these injuries, as well as the differences between children and adult skeleton is essential for proper and effective management of these common injuries. This article is a review of anatomy, physiology of physis, diagnostic modalities, prognosis, treatment methods and analyzing, and highlighting data from the published literature regarding ankle injuries in growing skeleton, which is crucial to manage these injuries.

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The increasing number of activity lead to musculoskeletal injuries among adolescents and young adults is considered a true public health burden.[1-3] Acute injuries of the ankle are among the most common injuries of the musculo-skeletal system.[4] It has been estimated that one ankle sprain occurs per 10,000 people each day in Western countries.[5] In sport, the incidence is even higher.[6-9] Many adolescents initiate year round training and specialization in their sports at a very early age. The ankle was found to be the most common location of injury in 24 of the 70 sports studied.[10] Three-quarters of ankle injuries contain the lateral ligamentous complex, comprised of the anterior talofibular ligament (ATFL), the calcaneofibular ligament (CFL), and the posterior talofibular ligament (PTFL).[6] Ankle sprain was the major ankle injury in 33 of 43 sports, especially in Australian football, field hockey, handball, orienteering, scooter, and squash.[10] Epidemiological studies also showed that high school athletes have established ankle sprains to be the most prevalent soccer injury among boys (16%) and girls (20%).[11] The incidence of ankle injuries and ankle sprains was high in court games and team sports, such as rugby, soccer, volleyball, handball, basketball, American football, Australian football, Gaelic football, tennis, netball, lacrosse and field hockey.[10] Moreover, the incidence of ankle injury was also high in gymnastics, orienteering, dancing, and skiing. In general, the incidence of ankle injury in competitive games was higher than in other sports.[10] In addition, 22% of sports injuries reported to emergency rooms were ankle injuries, among which sprain was the most common type of injury followed by fracture (the ratio of sprain to fracture is 8:1).[12] The incidence of ankle sprain and fracture has been reported to be 600-700 and 107-187 per 100000 person years, respectively in the general population.[13] Injuries in children may affect both growing bone and soft tissues and may result in damage of the growth mechanisms.[14] Although most injuries involving physes might resolve with treatment and rest, there is substantial evidence of subsequent lifelong growth disturbances and deformities.[14] There was a special concern regarding the pattern of injuries which exclusively limited to ankle region in different scenarios like sports injuries particularly football, and everyday common incidents like sprains.[15] The reason for this review is to provide awareness to the general public about these injuries and their sequel, especially in Saudi Arabia. It is of great concern that the general public, emergency room (ER) physicians, and even orthopedic physicians who are not trained in the specialty of foot and ankle, are largely uninformed on the difference in growth pattern and development characteristics of children and adults and they usually lack the information about the sequel of these injuries in immature skeleton. In sports especially football is commonly played and crazed in Saudi Arabia, in spite of this there is no governing body to educate the masses and young athletes to educate them and take corrective measures on proper playing conditions such as proper footwear, warming up before the activity, and so forth. This literature review was carried out in order to obtain an insight into the prevalence and incidence of soft tissue and growth plate injuries in growing skeleton. This article is a review of anatomy, physiology of the physis as well as analyzing and highlighting the data published regarding ankle injuries in growing skeleton, which is crucial to manage these injuries.

Developing skeleton and injuries. The process of longitudinal growth occurs at the epiphyseal plate, a thin layer of cartilage entrapped among epiphyseal and metaphyseal bones, at the distal ends of the long bones.[16] These areas of high metabolic activity characterize relatively weak points for the growing child, mostly during periods of accelerated growth. Conversely, the ligaments and tendons are proportionally stronger, accounting for markedly dissimilar injury patterns in the growing child compared with those seen in adults.[17] Substantial acute traumatic events frequently result in fracture at the physis, or avulsion of the apophysis, in a child, leaving the ligaments intact.[18] While acute traumatic ligament injuries can be seen in children, these injuries are typically not severe.[19] Repetitive forces applied to the developing skeleton involving the bones results in a variety of problems especially articular cartilage and apophyses. Microtrauma causes osteochondral lesions and apophysitis. The growing skeletons of children can be injured more frequently than the mature skeletons of adults for the reason of porosity of the bones and the long bones are further weakened by the epiphysial plates at their proximal and distal ends. Children skeleton are naturally more flexible than adults; but flexibility often varies during skeletal growth.[20]

Anatomy and pathophysiology of the growth plate. Bone, like all other tissues and organs of the body, grow to their adult size and also undergo constant remodeling and turnover. The surrounding mechanical environment affects both the modeling and remodeling of the bone.[21] The pediatric skeleton differs from that of an adult in the bones are more elastic and they contain growth plates (physes). Physeal injuries affect the growth plates of children and adolescents.[22] During pediatric ankle trauma, the force is transmitted directly to the most fragile metaphyseal tibial area.[23] These anatomical features of the adolescent ankle predispose a fracture and generally lead to a fracture displacement in the metaphyseal area. The stability of the ankle is due to bony configuration of the ankle mortise, ligamentous structures, capsule, syndesmosis, and the crossing tendons.[24]

Traction and pressure are the types of epiphyses establish in the extremities. Traction epiphyses (or apophyses) are located at the site of attachment of muscle tendons to bone and are subjected primarily to tensile forces.[24] The apophysis of the tibial tubercle delivers an example of traction apophysis. The apophyses involve to bone shape but not to longitudinal growth.[24] The acute or chronic injuries affecting traction growth plates are not generally related to disruption of longitudinal bone growth. Among overuse injuries, apophyseal injuries, such as Osgood-Schlatter's Disease, Sever's Disease, and Sindig-Larsen-Johansson Syndrome, are exclusive to the young athlete which could be the major reasons for discomfort and time lost from training.[24] These injuries happen at secondary centers of growth, termed apophyses, and are manifested by inflammation at the insertion site of a major tendon into the immature bony prominence. The pressure epiphyses are situated at the end of long bones and are subjected to compressive forces. The classical examples for pressure epiphyses are the distal femur and proximal tibia.[24]

The growth plate is situated among the epiphysis and metaphysis and is vital for endochondral ossification.[25] In contrast to apophysis, injury to pressure epiphyses and their related growth plates can disturb the growth disturbance.[24] In the zone of growth, the germinal cells are attached to the epiphysis and have a blood supply from the epiphyseal artery.[24,26] Longitudinal growth is accomplished by the proliferation of these cells. The zone of growth is the main concern with any fracture relating the growth plate, as damage of the cells in this zone may have long term concerns for normal growth patterns. The subsequently functional area is the zone of cartilage "the maturation zone". Abundant extracellular matrix is formed in this zone, primarily between columns.[24,27] The extracellular matrix exhibits cell mediated biomechanical changes and hence calcifies. As they hypertrophy, the cells align in vertical columns and are eventually replaced by osteoblasts. The junction of the calcified and the uncalcified hypertrophic cells are the places where fractures occur commonly as it is structurally the weakest portion of the growth plate.[24,27] In the zone of cartilage "the transformation zone", the cartilaginous matrix is penetrated through metaphyseal vessels, which break down the transverse cartilaginous septa, permitting invasion of mature cell columns. The cartilage and the bone are remodeled, removed and replaced by a more mature, secondary spongiosa, and hence, no remnants of the cartilaginous precursor would exist.[24,27]

Injury characteristics and risk factors. In children and young adult growth plate is a hyaline cartilage plate at each end of long bone in metaphysis which is replaced by an epiphyseal line in adults.[14,26,28] In children growth plate and area around is weaker than ligaments and tendons, and bones and soft tissue are elastic and have tendency to heal very rapidly.[14,26,28] Children have imbalance in strength, flexibility to adopt different types of environment and also the different and adapting biomechanical properties of bone.[14] Recent studies have shown clearly that low intensity training can stimulate bone growth and vice versa of high intensity training.[14,29-30]

In immature bones high energy injuries to growth plate cause progressive and sometimes leading to permanent deformities leading to dysfunction.[31,32] Injuries to growth plate causes angular deformities causing dysfunctional biomechanics leg length discrepancies and all these leading to significant and severe disabilities.[31-34] In the literature risk factors have been identified which are associated with increased incidence of injury to immature bones. During growing period of bones as they are growing faster than soft tissues they have less amount of flexibility and this leads to trauma especially if there is lack of stretching prior to sport activity.[35-40]

The ankle carries more weight per unit area than any other joint in the body.[41,42] Injuries can either occur acutely such as fractures and sprains, or occur gradually, such as stress fracture, osteochondritisdissecans (OCD), apophysitis or tendinopathies.[43] Seventy-five percent of all ankle injuries are ankle ligament injuries, with 85% of those ankle sprains produced by inversion trauma.[42] The majorities of injuries are minor in nature and require a short period of rest and analgesia prior to graduated rehabilitation.[44] Overuse injuries give a more insidious onset of symptoms that are typically related to sport activities[45] depending on the anatomical locations. Younger population may present purely with reduced performance or a limp. Exact identification of the anatomical area injured is usuallydifficult.[14]

The severity of injuries spans broadly from sprains and contusions to death, and certain types of injury occur more commonly in specific sports.[14] Fortunately, the vast majorities of sports injuries are minor in nature and do not require major medical care. Serious sports accidents in youth, such as brain or spinal cord damage lesions of the heart or submersions leading to invalidity or death, are rare.[44]

Vulnerability of injury. Physical injuries can yield irreversible damage to the growing cells, resulting growth disruption. Compared to adult articular cartilage, growth plate cartilage is low resistant to stress.[46] It is also less resistant than adjacent bone to shear and tensile forces. Therefore, when disruptive forces are applied to an extremity, failure can arise through the physis. Further, the physis may be 2-5 times weaker than the surrounding fibrous tissue.[47] Due to these reasons, injury mechanisms in an adult may result in a comprehensive tear of a ligament or in a joint dislocation may yield a separation of the growth plate in a child.

The susceptibility of the growth place to injury appears pronounced during the period of rapid growth.[46,48]

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Researches on the development of physeal cartilage in animals have indicated a decrease in the physeal strength during puberty.[48] These results are similar among human as well. An increased rate of growth is accompanied by structural changes that result in a thicker and more fragile plate. In addition, during the pubescent growth spurt, bone mineralization may lag behind bone linear growth, causing the bone temporarily more porous and vulnerable to injury. Studies on the incidence of physeal injuries in humans indicated an increased incidence of fractures during pubescence and the highest fracture rate probably happening at the time of peak height velocity.[49]

It has been suggested that the growth spurt may also raise the susceptibility to growth plate injury by causing an increase in musclotendinos tightness on the joints and an accompanying loss of flexibility. However, this concept is debatable. Longitudinal growth occurs primarily in the long bones of the extremities, and the musclotendinous units elongate in response to this change. This may generate a temporary disparity between muscle-tendon and bone lengths. If an excessive muscular stress is applied, a musclotendinos imbalance is produced that may predispose to injury.[50] The joint, particularly the growth cartilage, is the weakest link in this assembly, it is believed that the risk of injury may be aggravated at this location during the growth spurt.[50]

Acute physical injury. The widely used system in defining physeal injuries was developed by Salter and Harris.[51] Type I Salter and Harris injury indicates a complete separation of the epiphysis from the metaphysis. The germinal cells of the growth place remain feasible and placed at the separated epiphysis and the calcified layer remains with the metaphysic. The type II is a common extensive physeal injury, fractures through the physis, with metaphyseal fragment referred as the Thurston Holland sign, it usually has an excellent prognosis. The type III is an intra-articular extension in which fractures are through the physis and epiphysis.[51] It usually has good prognosis but has the potential for intra-articular deformity; may require open reduction and internal fixation (ORIF). In type IV, the fracture is through the epiphysis, physis, and thereby generating a complete split, prognosis is good but unstable; and fragment requires ORIF. The type V is a comparatively infrequent injury, there is a crush injury to the physis thereby prognosis is poor with growth arrest.

Prognosis for types I and II fractures is worthy if the germinal cells persist with the epiphysis, and circulation is unchanged. On the other hand, these injuries are not as safe as believed,[52] and can be linked with the risk of growth problems. Type III injuries have a valuable prognosis if the blood supply in the parted portion of the epiphysis is still intact and if the fracture is not

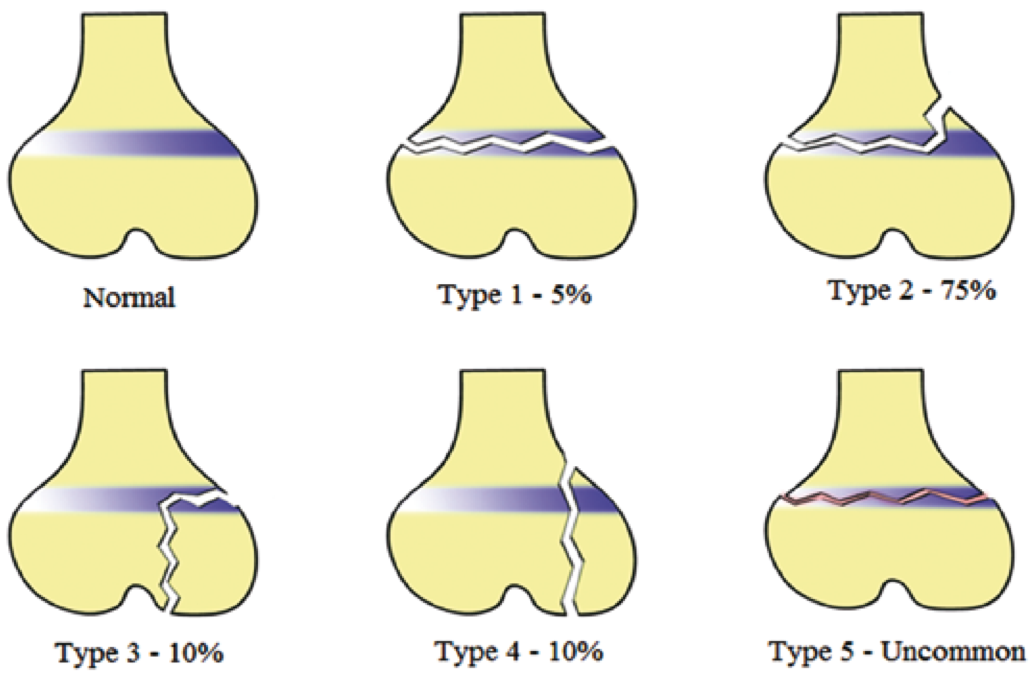

Figure 1 - A diagram of Salter Harris classification of epiphyseal fractures.

displaced. Sometimes surgery is required to restore the joint surface to normal. In type IV injuries, surgery is required to restore the normal anatomy and to realign the growth plate and usually thease injuries have a poor prognosis (**Figure 1**).

There are numerous studies on acute physeal injuries affecting young athletes. These injuries were incurred in a variety of sports, particularly football.[24] In a study,[53] the injury outcome was generally good with growth disturbance described in only 8 of 50 cases; however, the length of follow up was short-term or not reported in some cases. Most of the athletes were advanced in age (13-17 years), limiting the amount of growth disturbance possible.[54] The problem here is that all data is encompassing the western side of the world and there is no data, or case reports referring to Middle East or Saudi Arabia.

Common injuries about the ankle. The twisting injuries causing fracture in adults produce a different injury pattern in the growing skeleton.[55] In general, ankle fractures in children are minimally displaced. Nevertheless, they may require open reduction and internal fixation when involving the articular surface. Ankle fractures are generally caused by major violence and frequently results in epiphyseal injury. The most common fractures of the ankle following twisting trauma are type 1 or 2 Salter-Harris injuries.[56] With an open distal fibular epiphysis, these fractures are frequently reduced spontaneously leaving only swelling and tenderness over the epiphysis with normal radiographs. Stress radiographs, however, may reveal the underlying pathology, and according to the age of the patient, internal fixation should be considered.

Tillaux-Chaput lesions are Salter-Harris type 3 where internal fixation may need to be considered. These fractures happen in young and athletic individuals near to the end of puberty, due to the positioning of the growth plate, the direction of ossification from posteromedial to anterolateral and the mechanism of injury.[24]

Stress fractures. Stress fractures are not easily diagnosed and are usually multifactorial like disarrange biomechanical misalignment in lower extremity. They are also associated with diet, hormonal status, and osteoporosis. Technetium-scan (Tc scan), MRI or CT scan are usually helpful for diagnosis; plan radiograph are usually not helpful before 2-3 weeks and treatment is usually with immobilization and activity restriction.[44,57-59]

Calcenial apophysitis. The sever's lesion along with well-localized, activity-related pain at the tip of the heel and fragmentation of the calcaneal apophysis were seen on radiographs. Sever's lesion may occur from intensive training and improper footwear. Some authors consider sever's lesion to be a form of stress fracture.[60,61]

Figure 2 - A MRI example of sprain.

Soft tissue injuries: a) Tendinopathy. Tendinopathy is a pervasive overuse injury of the lower extremity and frequent pervasive forms of tendinopathy that occur in the lower limb. Achilles tendinopathy can be the effect of excessive eccentric weight bearing while tibialis anterior tendinopathy can be due to direct pressure in skates or ski boots.[62] Fractional rest and strapping are adequate in most of the patients. Complete immobilization can leads to musculoskeletal atrophy. Few children are getting benefit from physiotherapy, particularly stretching, and occasionally from peritendinous injections. Surgery has a partial role and is rarely indicated.[62]

b) Ankle sprains. In general population, the ankle sprains are common and can result in prolonged disablement.[63] It is one of the most common injury sustained during sporting activities. Three-quarters of ankle injuries take in the lateral ligamentous complex, comprised of the ATFL, CFL, PTFL.[6] Lateral ankle ligamentous injuries are rare in children with open physis, increases with age, and are seen with considerable frequency in late childhood and adolescence.[64-65] In athletes with ligamentous laxity, recurrent sprains may lead to ligament attenuation and instability, and if this instability is hindering the everyday activity, reconstruction is indicated if conservative measures fail. Ankle sprains are more common in patients with weak and deconditioned peroneal muscles and pescavovarus deformity[64,66,67] (**Figure 2**).

Nonunion of osteochondral fractures of the distal fibula: This can be easily missed and relatively unknown entity of problem, which is considered a major cause of chronic painful ankle instability in growing skeleton. It is usually associated with multiple inversion injuries with recurrent pain and instability which almost always fail to respond to conservative treatment and usually need advanced imaging and operative treatment.[68]

Injuries to the chondral surface: Injuries to the chondral surface of ankle in the growing skeleton generally occur in demanding sports, and in children with inappropriate shoe wear during sports.[69] These injuries are usually missed and the major reason of delay in returning back to sports after what seems to be a minor injury to the ankle. Advanced secondary joint damage could be prevented if this injury is suspected earlier and investigated.[69]

Chronic injury to physis. Number of clinical reports showed that sport training, of long duration and high intensity may produce growth disturbance in the epiphysis. This injury appears to occur through repetitive micro trauma, which alters metaphyseal perfusion and consequently interferes with the mineralization of the hypertrophied chondrocytes in the zone of provisional calcification.[70]

Jaramillo et al[71] stated that the hypertrophic zone continue to broaden because of continuous growth in germinal and proliferative zones. There is a huge epiphyseal and metaphyseal blood supply and they are usually undisturbed, this widening of hypertrophic zone is usually temporary. However, if the blood supply is disturbed, ischemia of hypertrophic zone ensured and leads to ischemic osseous necrosis which leads eventually to deformity. This ischemic insult may be confiding to a small segment or generalized leading to asymmetric growth or a complete shutdown of growth in the growth plate[24] (**Figures 3A and 3B**).

Conditions for concern. The acute growth plate injuries take place in sport and may account for 30% of injuries.[24] However, the proportion of physeal injuries is less, ranging from 1-12% of injuries conditional on the sport being involved.[72,73] Although 71-75% of sport related growth plate fractures were related with growth disturbance, the proportion of those with poor prognosis is probably much less, ranging from 0-37%.[74,75]

Type 1 and type 2 Salter-Harris acute growth plate injuries are not as innocuous as originally defined and may occasionally be related with localized growth plate closure and osseous bridging.[52,76] There are many reports of stress related physeal trauma disturbing young athletes in a variety of sports, including baseball, long distance running, football, basketball, soccer, rugby, gymnastics, tennis, and cricket. While most of these stress related conditions resolved without growth complication during short term follow up, there are nonetheless many reports of stress related premature partial or complete physeal closure.[77,78] Researchers reported numerous changes subsequent to sports related stress injury to the distal femoral and/or proximal tibia physes among rugby and tennis players.[79,80] It is of great concern that several coaches of children and youth sports, although enthusiastic are largely uninformed about peculiar growth and development characteristics of children and youth and are also unaware of the appropriate care and preventive measures of athletic epiphyseal trauma.

Techniques to prevent injuries. Prevention of injuries mainly sports injuries should be a priority for parents, coaches and children themselves. Protection (helmet, padding) is mandatory for some activities. Proper education and preparation are necessary for all sports activities.[81-83] Training and skill development should be individualized to minimize the risk of acute and stress connected physeal and extraphyseal injuries. In specific, coaches should reduce training loads and delay skill progressions for young athletes experiencing periods

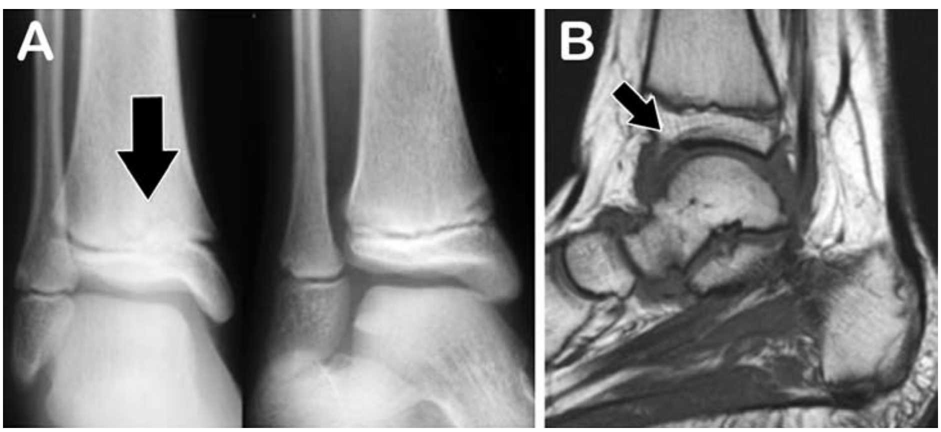

Figure 3 - An MRI scan showing **A)** premature closure of tibial physis. **B)** A chronic epiphyseal injury with signs of premature closure.

of rapid growth.[81-83] Careful measurement of height at 3 months interval will provide coaches with data to estimate growth rate. Height measurements should be taken at the same time of the day (preferably in the morning) and should not be taken after a workout.[70] Coaches should avoid excessive repetitive movements that may result in overuse injury. Emphasis should be on quality of workouts instead of high training volume.[84,85]

Young athletes should have periodic physical examination so that stress related epiphyseal and other overuse injuries can be diagnosed as early as possible. Amendments, made to the training program should be taken to assist in the recovery process. When indicated, radiographs of symptomatic physis areas should be carried oute to rule out stress changes. Although evidence on injury prevention is deficient, physical conditioning may help to reduce both acute and chronic musculoskeletal injuries.[86,87] Trained athletic personnel should supervise injury rehabilitation and return to practice.[24] Periodization of training can help to reduce stress related physeal injuries and prevent overtraining. This practice involves the systematic cycling of training loads for a set periods of time with well-defined rest periods.[24] The recommendations for acute epiphyseal fractures involving a joint are that the child should not participate in contact sports for at least 4-6 months to prevent re-injury.[24,50] Long term follow up is usually necessary to monitor the child's recuperation and growth. Assessment includes x-ray examination of matching limbs at 3-6 month periods for at least 2 years.[24] For collision sports, a non-invasive measure for grouping young athletes has been proposed. There should be a nationwide awareness program to educate the masses about the proper playing and proper environment to play.[88]

Diagnostic modalities. Standard ankle radiographs can be performed on the basis of Ottawa Ankle Rules after an acute ankle injury to evaluate suspected lesions.[11,89] These injuries in children needs carefull evaluation with history, and examination, keeping in mind all the possibilities of occult soft tissue injuries and fractures which can be easily missed with the diagnosis of sprains and usually resulting disabled in deformities.[90] In some cases, the ankle injuries in growing skeleton need advanced investigations like ultrasound and MRI. Stress radiography or arthroscopic, all are recommended to make an accurate diagnosis.[91-94] Among radiographically negative ankle and wrist injuries, ultrasound can be used as an adjunct to radiography in clinically suspicious cases.[95] Although MRI offers superior soft tissue contrast resolution,[96] both conventional radiography and MRI are useful in the diagnosis of epiphyseal and physeal injury. It helps in detection of occult fractures; however, it may alter Salter Harris staging and consequently change the line of management of patient.[97] Sonography has been shown to be effective in the diagnosis of musculoskeletal pathology, and its use is increasing.[98,99] It is a valuable tool for examining the tendons of the ankle joints.[100] Rupture of the ATFL can be diagnosed with a sensitivity of 96-100% using arthrography. For anatomical reasons the PTFL, sensitivity decreases to 75%.[5]

Magnetic resonance imaging of the knee and ankle is playing an increasingly important role in the detection, diagnosis and prognosis of these injuries and their associated complications and is increasingly seen as the modality of choice for evaluating ligamentous injuries of the knee and ankle. A sensitivity and specificity of up to 93%[101,102] to 96%[103] and 89%[101] to 98%[102,103] respectively are reported for the diagnosis of anterior cruciate ligament (ACL) injuries with MRI. Lateral ligamentous complex injuries of the ankle are also well visualized on MRI, with a sensitivity of 74% and specificity of 100%,[102,104] among other ligamentous injuries.

Prognosis and treatment. Ankle injuries experiencing a significant cost to both the individual and society.[105] In order to evaluate the effectiveness of therapeutic interventions and to manage these injuries, it is important to have recovery awareness training course after an acute lateral ankle injury and to assess potential factors for non-recovery and re-sprains.[106] There is a general census that a minor injury to the lateral ligament complex recovers quickly with non-operative management with excellent prognosis,[5] Several studies indicated that 20-40% failure following non-operative functional treatment for acute lateral ligament disruption of the ankle.[107] A recent study shows that non-operative functional treatment only and functional treatment after primary surgical repair presented similar results after acute lateral ankle sprain, but functional treatment only had an approximately 10% failure rate and a slower return to full activity.[107] However, there is still controversy about the good treatment for severe ankle sprains. Functional treatment includes a short period of activity restriction, taping, bandage, or an ankle brace, followed by early weight-bearing.[108] Exercises for range of motion, and neuromuscular training of the ankle, should begin as early as possible. Initial treatment is control of pain, swelling, and maintenance of range of motion as much as possible.[108] The application of ice after ankle sprain is accepted generally.[105,109] Nevertheless, the long-term effects of cryotherapy and the effect on the tissue repair are not known.[109] The non-steroidal anti-inflammatory drugs (NSAID) leads to a significant reduction in pain at short-term follow up. Other treatments such as laser therapy,[110] ultrasound,[111,112] electrotherapy,[113,114] homeopathic therapy,[115,116] hyperbaric oxygen therapy,[117] prolotherapy, platelet rich plasma,[118-120] and hyaluronic acid[120] or topical nitroglycerin injection[121] were not effective, and have insufficient evidence to prove their benefit in the treatment of acute ankle injuries.

A recent systematic review revealed that the clinical course of conventionally treated acute ankle sprains at one year follow-up was 5-33% of the patients that experienced pain and instability, 34% informed at least one re-sprain, and 15-64% stated that they had not recovered fully from their initial injury.[106] These injuries have large societal effect, and considering the commonly poor clinical course, the optimal treatment and rehabilitation protocols has yet not established. The overall prognosis for different ankle injuries in developing skeleton is good if diagnosed and classified properly. The treating doctor should be aware of the differences in adult and pediatric pathophysiology of trauma and classification of trauma to physis which is Salter-Harris classification, classify the patient and treat accordingly. Failure to abide by the rules results in complications, which have to be treated accordingly, and these complications can never have full functional recovery.[23,122]

Prognosis of Salter-Harris type I and II injuries have excellent prognosis and usually treated with short leg walking cast for 6 weeks and then gradually full weight bearing.[123] Salter- Harris III, IV the prognosis is good but they have a potential for intra articular deformity, and they are anatomically unstable, so they usually require open reduction and internal fixation or close reduction and percutaneous pinning.[122-124] The complications usually are angular deformities bony bridges, key length deformities, rotational deformities, vascular Necrosis and later on degenerative joint disease. Salter- Harris V have poor prognosis even with surgical intervention and usually end up with growth arrest.[124] Salter- Harris VI have good prognosis but can end up in angular deformities.[124,125]

Treatment of complications especially growth arrest. Physeal bars or bridges result from growth plate injuries that arrest a part of physis and leave the uninjured physis to grow normally, this end up in angular growth and deformity. The surgical option for this deformity is physeal bridge resection with interposition of a fat graft or artificial material but is reserved for patients with over 2 cm of growth remaining and less than 50% of physeal involvement. If the physis is involved more than 50% it should be treated with ipsilateral completion of the arrest and contralateral epiphysiodesis or ipsilateral limb lengthening.[126,127]

Challenges for future research. Prospective cohort studies should contain analytical as well as descriptive components, so that possible risk factors and viable preventive procedures can also be determined. Studies need to include as many relevant risk factors as possible in order to account for the multivariate nature of ankle injuries. A risk factor of particular interest is whether periods or rapid growth related to an increased risk of injury and accordingly whether training programs planned to decrease the training loads during these periods may also reduce risk of injury. Further research studies that test the effectiveness of pre-participation musculoskeletal screening are also recommended. It is only through concerted combined efforts that best results can be succeeded. The research team should include the coach, athletic trainer, and sports injuries physicians including orthopedic surgeons, emergency room physicians, and epidemiologist, who interact in a very dynamic manner. In addition, it is important to highlight that each effort should be made by the research team to launch an open and trusting dialogue with young athletes and their parents. It is only after that, an adequate database can be established.

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