Musculoskeletal Injuries in the Pediatric and Adolescent Athlete

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There are approximately 35 million children participating in organized sports in the United States. With this increasing participation, we have seen an overall increase in sports-related injuries in young athletes over the past 20 years. Young athletes suffer both acute and chronic, or overuse, injuries. They are susceptible to many of the same injuries as their adult counterparts, but due to the effects of growth on the musculoskeletal system, they are at risk for injuries to the growth plate, apophysis, and joint surface. Common acute and overuse injuries seen in young athletes are discussed here.

Introduction

Approximately 35 million children aged 5 to 18 years participate in organized sports in the United States [1,2]. The American Academy of Pediatrics supports participation in organized sports for the overall health of children [3]; however, there has been an increase in both acute and overuse injuries in young athletes over the past 20 to 30 years. This is thought to be due to many factors, including the increase in absolute numbers of young athletes, increased intensity of training and competition, participation on multiple teams, and participation at younger ages. The potential effects of injury include not only acute pain and disability, but also the potential for permanent sequelae [4].

There are an estimated 2.6 million emergency department (ED) visits annually in the United States for sports-related injuries in patients aged 5 to 24 years, with the highest percentage occurring in 5- to 14-year-old boys [5]. This is likely an underestimate of the actual number of sports-related injuries, because it can be assumed that many athletes will present to their primary care physician for evaluation or perhaps not seek medical attention at all for minor injuries. The mean age of patients with ED visits for sports-related injuries is approximately 13 years [6,7]. The sports associated with the highest number of visits are basketball, cycling, football, and soccer [5,6]. The types of injury most commonly seen are sprains, contusions, and fractures, with each accounting for 20% to 30% of the injuries [5–7]. Injuries occur to the foot and ankle 20% of the time, and the forearm, wrist, or hand approximately 30% to 35% of the time [6,7]. Sports-related musculoskeletal injuries infrequently result in admission to the hospital [6].

Skeletally immature athletes are unique because of the effects of growth on the musculoskeletal system. They are not only at risk for many of the injuries sustained by adults, but also may suffer injuries to the growth plates, apophyses, and joint surfaces. This article addresses the most common acute and overuse injuries seen in the skeletally immature athlete.

Acute Injuries

Acute trauma in young athletes may result in contusions, strains, sprains, dislocations, or fractures. Athletes who participate in collision sports may suffer contusions of the muscles and soft tissues with hematoma formation. Most of these are mild, self-limiting injuries that resolve with early icing and activity modification, followed by a targeted exercise program to regain strength and flexibility. More significant intramuscular hematomas must be followed closely for the formation of myositis ossificans, which is most common in quadriceps contusions [8]. Strains occur when overload of a muscle results in disruption of the muscle fibers at the muscle-tendon junction. Although most muscle strains resolve completely, chronic pain and inflexibility following hamstring strains is common in adolescents and can lead to a significant amount of disability. Physical therapy to improve flexibility and strength of the hamstring usually results in resolution of symptoms [8]. Young athletes suffer a spectrum of ligament sprains similar to skeletally mature athletes, ranging from a mild stretch to a complete tear. Most mild sprains heal fully within 6 weeks of the injury; however, more significant tears may take up to 5 to 6 months for complete healing or may require surgical repair, such as for a complete anterior cruciate ligament (ACL) tear [8]. Ligament injuries, dislocations, and fractures common to the young athlete are discussed here.

ACL injuries

There has been an overall increased incidence of midsubstance ACL tears in children over the past 20 years, with younger children being more at risk than ever. Increased participation in sports, heightened awareness of the medical community about these injuries, and improved methods for diagnosing ACL injuries in young athletes have all contributed to this rise. In addition, young athletes are participating more and more in competitive high-impact and cutting sports, both of which put the athlete at increased risk of ACL injuries. These injuries are rare before age 11 years, at which time the incidence increases in both boys and girls [9].

Female athletes sustain ACL injuries at rates three to seven times that of their male counterparts [9–13]. The reason for this increased susceptibility is likely multifactorial, including hormonal effects on the ligament, smaller ligament size, smaller intercondylar notch, less strength and conditioning, more inherent flexibility, anatomic alignment differences, and differences in jump-landing mechanics [11,13]. Currently, research and prevention programs are ongoing in an attempt to reduce the risk of ACL injuries in female athletes [11].

ACL injuries usually occur due to deceleration or a change in direction such as when playing cutting sports like soccer, basketball, and football. They can also occur due to hyperextension of the knee while landing a jump. The athlete usually experiences a popping sensation followed by pain, swelling, a sensation of instability, and inability to bear weight. On physical examination, a joint effusion is usually present. A positive Lachman test result is the most sensitive predictor of ACL injury [8].

The association of other intra-articular injuries with ACL tears is well know, with as many as 70% of patients having meniscus tears and 46% having articular cartilage injuries [14]. There is good evidence that delay in treatment of complete tears of the ACL in young athletes puts them at risk for subsequent meniscus tears, joint surface injuries, premature degenerative joint disease, and decline in sports participation [15–18]. The treatment of ACL tears in skeletally immature athletes has been controversial [19,20••], but due to the unsatisfactory outcomes in these patients many experts recommend surgical reconstruction in young patients with evidence of instability due to ACL deficiency [20••].

Lateral ankle sprains

Lateral ankle sprains are among the most common sports-related injuries. The typical mechanism is inversion with the foot in the plantar flexed position resulting in injury to the lateral ankle stabilizers, including the anterior talofibular ligament (ATFL) and the calcaneofibular ligament (CFL). Risk factors for inversion ankle sprain in male athletes include slower running speed, decreased dorsiflexion strength and range of motion, and less balance [21]. On examination there is usually localized swelling and tenderness of the ATFL and CFL. There may be an ankle effusion and marked decrease in range of motion in patients with grade III, or complete, ligament tears. In an attempt to reduce unnecessary radiographs in young patients with inversion ankle injuries, the utility of the Ottawa Ankle Rules in children has been evaluated by several studies. It has been found to have a sensitivity of 83% and a specificity of 50% to predict fractures in children and adolescents [22]. It is therefore recommended that skeletally immature athletes with inversion ankle injuries should have radiographs obtained. Any swelling or tenderness of the lateral malleolus in a child with open growth plates indicates at least a Salter-Harris type I fracture, which should be treated with 3 weeks of immobilization.

Treatment of ankle sprains includes rest, ice, and compression. Cast immobilization is not recommended. Early physical therapy to improve range of motion, strength, and proprioception can improve overall outcome [23]. Although it can be normal for mild pain and swelling to persist up to 6 months after a grade III lateral ankle sprain, other causes such as syndesmotic sprain, joint surface injury, fracture, tendon injury, and osteochondritis dissecans should be considered in the persistently painful sprained ankle [24,25].

Shoulder dislocations

Acute shoulder dislocations are rare in the skeletally immature athlete. The shoulder is the most commonly dislocated large joint in adolescent athletes [26•], who have a spectrum of glenohumeral dysfunction ranging from frank acute dislocation to subacute multidirectional instability. Acute anterior dislocations account for most traumatic dislocations and usually occur due to an indirect force placed on the arm while in abduction and external rotation. This occurs most commonly in basketball and overhead-throwing contact sports. While dislocated, the arm is held abducted and internally rotated, and there is a notable asymmetry of the shoulder contours. There are many well-described methods to successfully reduce a shoulder dislocation [27]. After reduction, a careful examination should be performed to identify injuries to the axillary nerve that may occur 5% to 35% of the time [28]. Radiographs should be obtained to evaluate for associated fractures or Hill-Sachs lesions.

There has been much debate in the literature about the optimal management of young patients with primary anterior shoulder dislocation. High recurrence rates have been well documented to be approximately 65% to 75% in athletes less than 20 years [29•,30,31]. Higher risk of recurrence is associated with male sex, adolescence, and a history of trauma [32]. In one 10-year follow-up study, approximately 35% of young athletes had undergone operative stabilization for recurrent dislocation [30]. Other studies have found a 40% to 50% rate of surgery in young patients within 2 years of initial dislocation [29•,32]. Two prospective studies of young but skeletally

mature patients with primary anterior dislocation showed a statistically significant difference in the rate of recurrent dislocation in patients treated with immediate arthroscopic stabilization versus immobilization and rehabilitation [31,33]. In addition, the study by Kirkley *et al.* [31] showed improved disease-specific quality of life scores in the operatively managed group. Most experts still recommend initial conservative management with a brief period of immobilization followed by rehabilitation to regain range of motion and strength [26•,30]. For athletes involved in contact sports or those with recurrent dislocation, surgical repair is indicated.

Atraumatic multidirectional instability is common in female gymnasts and swimmers. In these patients, episodes of subluxation usually spontaneously reduce. There is often generalized ligament laxity and multidirectional instability of the shoulder on examination. Most of these patients do well with conservative nonoperative management, including rotator cuff strengthening [34].

Patellar dislocations

Dislocation of the patella is most common in the 14- to 18-year-old female athlete. The dislocation occurs laterally in almost all cases. The typical mechanism of injury is a sudden internal rotation of the femur on a fixed foot resulting in forced quadriceps contraction and pulling of the patella laterally. It can also occur due to a direct blow to the medial knee. Most patellar dislocations reduce spontaneously prior to seeking medical attention. Many patients experience a popping sensation and acute hemarthrosis, so this injury can be confused with an ACL tear. The examination, however, reveals tenderness of the peripatellar tissues especially medially, apprehension with lateral movement of the patella (positive patellar apprehension sign), and a stable ACL by Lachman testing. If not spontaneously reduced, the reduction maneuver is quite simple by slowly extending the knee while applying a medially directed force along the lateral patella. Sedation is often necessary for successful reduction.

Although plain radiographs are still considered routine in the initial management of acute patellar dislocations, it has been shown that 68% of osteochondral or chondral injuries confirmed at arthroscopy are missed by this imaging modality [35]. The role of MRI in detecting osteochondral and soft tissue injuries related to patellar dislocation is evolving [36•]. Recurrence rates between 15 and 44% have been described [37,38] following first patellar dislocation, with higher rates associated with younger age at initial dislocation and with anatomic predisposition such as patella alta [38,39]. A decline in sports participation has been seen in as many as half of these patients [37].

Due to the unsatisfactory outcome in many of these patients, optimal treatment of first time patellar dislocation is controversial. Many experts, however, recommend a conservative approach initially [36•,40,41]. After reduction, the knee should be immobilized in the extended position for 2 to 3 weeks [41] and weight bearing as tolerated should be allowed. Early physical therapy to reduce pain and effusion as well as to improve quadriceps strength should be encouraged as long as there are signs of improvement early after the injury. Return to full activity can usually be achieved in 8 to 12 weeks. Early operative intervention should be considered in patients with failure of initial improvement, visible osteochondral fragment on initial radiographs, or recurrent patellar instability [36•].

Fractures

Twenty to 30% of sports-related injuries seen in the ED are due to fractures [5–7]. The average age of sports-related fracture is 12 years and there is a male predominance of nearly 2:1 [6,7,42]. Most sports-related fractures involve the upper extremity, with fractures of the distal radius and ulna (43%) and the fingers (23%) being most common [42]. There is a wide spectrum of sports-related fractures seen in young athletes, but physeal fractures and apophyseal avulsions are unique to children and adolescents and deserve special mention.

The physis, or growth plate, is inherently weaker than the surrounding ligaments. Young children are therefore more likely to suffer a fracture than a sprain, and any young athlete with a significant injury should have radiographs obtained to evaluate for fracture. Any skeletally immature athlete with tenderness and swelling overlying a growth plate, regardless of the radiographic findings, should be considered to have at least a Salter-Harris I fracture and should be immobilized in a cast for 3 weeks. More complex fractures involving the growth plate should be evaluated by an orthopedic surgeon due to the risk of joint surface injury and affected growth.

The apophysis is a secondary ossification center and the site of attachment of a tendon to bone. This can be an area of tension because muscle and tendon growth lags behind bone growth during the preadolescent growth spurt. Chronic traction to this area results in apophysitis, or inflammation of the apophysis, discussed later. A forceful contraction of a muscle can result in an acute avulsion fracture of the apophysis to which it is attached. The most common site of apophyseal avulsion fractures is the pelvis. These occur most frequently at the anterior superior and inferior iliac spines and the ischial tuberosity, the sites of attachment of the sartorius, rectus femoris, and hamstring muscles, respectively. The athlete usually experiences acute pain and a popping sensation during a maximal muscle contraction, such as while running, jumping, or kicking. On examination there is localized tenderness and swelling at the apophysis, limited range of motion, and pain with active contraction of the involved muscle. Radiographs usually confirm the avulsion. The treatment is almost always conservative, including rest, crutches, and antiinflammatory medication. Physical therapy to regain strength and flexibility helps to return the athlete to their sport faster and may decrease the risk of recurrent injury.

Surgical referral is indicated for ischial avulsions with more than 2 cm of displacement [8]. Avulsion fractures also may occur at the tibial tubercle, usually in males nearing skeletal maturity. These may require surgical fixation if there is any more than minimal displacement, otherwise can be managed conservatively with immobilization [43].

Overuse Injuries

Overuse injuries are chronic injuries related to repetitive stress on the musculoskeletal system without sufficient recovery time. This overwhelms normal reparative processes. Overuse injuries in young athletes are often seen with rapid increases in training, such as during sports camps, and in athletes training at consistently high levels. Extrinsic factors that contribute to overuse injuries include hard training surfaces, inappropriate equipment, and poor coaching. Intrinsic factors include extremity malalignment such as excess femoral anteversion and foot pronation, decreased flexibility, and muscle weakness or imbalance. Manifestations of overuse injuries in young athletes include apophysitis, chronic anterior knee pain, stress fractures, and tendonitis.

Tendonitis is seen with much less frequency in young athletes compared to their adult counterparts because the apophysis, or site of attachment of the tendon to bone, is weaker than the tendon itself. Common locations of tendonitis in young athletes include the rotator cuff in throwing athletes and swimmers, the iliopsoas in dancers, and the ankle in dancers, gymnasts, and figure skaters. Apophysitis is due to chronic traction of a tendon at its insertion, resulting in microavulsions at the bone-cartilage junction. This is common during periods of rapid growth in childhood and adolescence. Apophysitis is a self-limiting condition, with symptom resolution occurring with fusion of the secondary ossification center. Treatment for apophysitis and tendonitis is conservative, including activity modification, direct icing of the inflamed area, short-term nonsteroidal anti-inflammatory medications, and physical therapy to improve flexibility and strength. The most common forms of apophysitis, as well as chronic anterior knee pain, are discussed.

Sever's disease

Sever's disease is an apophysitis of the secondary ossification center of the calcaneus due to traction from the gastrocnemius-soleus complex. This condition generally presents at age 9 to 12 years, is more common in boys, and occurs bilaterally in just over 60% of cases [44]. Sever's disease is common in young athletes participating in impact sports, especially those that involve running. The hallmark of the physical examination is pain reproduced with medial and lateral compression of the heel. It is common to find tight heelcords as well. Achilles stretching and the use of viscoelastic heel cups in all shoes are helpful. A recent study by Ogden *et al.* [45] evaluated young patients with persistent heel pain who failed to improve with conservative management. They found bone bruising and edema in the calcaneal metaphysis as well as the apophysis on initial MRI that completely or partially resolved after a 3- to 4-week period of immobilization. These findings suggest that calcaneal stress fracture may be the cause of persistent heel pain in those patients not responding to conservative therapy for Sever's disease, so a period of immobilization may be indicated [45].

Sinding-Larsen-Johansson syndrome

Sinding-Larsen-Johansson syndrome is an apophysitis of the lower pole of the patella due to chronic repetitive traction of the patellar tendon. It occurs most commonly in the prepubescent athlete of 10 to 13 years of age. Repetitive eccentric and decelerative loading of the extensor mechanism, especially in running, jumping and kicking sports, exacerbates symptoms. Patients have localized tenderness of the lower pole of the patella and an otherwise normal examination. The patellar tendon itself is not involved. Extensor mechanism stretching, as well as the above-mentioned conservative measures, may decrease symptoms.

Osgood-Schlatter's disease

Osgood-Schlatter's disease is a traction apophysitis of the secondary ossification center of the tibial tubercle caused by forceful repetitive contractions of the quadriceps. It is most common in the adolescent athlete aged 11 to 15 years, occurs more commonly in boys, and usually occurs unilaterally [13]. This condition is exacerbated by impact and decelerating activities such as running, jumping, and cutting. The hallmark of the physical examination is soft tissue swelling and tenderness of the tibial tubercle. There may also be pain with passive knee flexion or extension against resistance. Extensor mechanism stretching, quadriceps strengthening, and use of a patellar strap may improve symptoms.

Little League elbow

Little League elbow is seen in young throwing athletes, especially pitchers, and is due to traction of the medial structures of the elbow during the acceleration phase of pitching [13]. On examination, there is localized tenderness of the medial epicondyle. The athlete should be removed from throwing until symptoms resolve. Specific therapy includes muscle strengthening and pitch training. Activity modification and adherence to league regulations that limit the number of pitches are beneficial. Athletes with persistent pain, mechanical symptoms such as locking or loss of range of motion, or lateral elbow pain should be evaluated for other throwing-related elbow injuries such as epicondyle avulsion fractures, loose bodies, and osteochondritis dissecans [26•].

Patellofemoral pain syndrome

Patellofemoral pain syndrome (PFPS) is one of the most frequent complaints among adolescent girls [46]. It is char-

acterized by the insidious onset of chronic anterior knee pain not associated with an acute injury or mechanical symptoms such as clicking, locking, or instability. The pain is exacerbated by activities that increase the loading across the patellofemoral joint, including repetitive flexion, jumping, climbing stairs, and sitting for long periods of time. The etiology is felt to be multifactorial with the exact pathologic origin of the pain still unknown. Associated factors include overload of the patellofemoral joint, quadriceps weakness, tight quadriceps and hamstring muscles, abnormal tracking of the patellar extensor mechanism with lateral overload, and anatomic malalignment [46]. The knee examination is often normal, with mild nonspecific peripatellar tenderness or pain with patellar compression being the most common findings.

Treatment for PFPS has classically included physical therapy to strengthen the quadriceps, especially the vastus medialis oblique (VMO) muscle, with the rationale being that the VMO provides medial stabilization of the patella in the trochlear groove. A recent article systematically reviewed the quality of randomized controlled trials for the treatment of PFPS [47••]. Based on the results of studies that met a sufficient level of quality based on four main criteria, the authors concluded that acupuncture, quadriceps strengthening, use of a resistive brace, and the combination of exercises with patellar taping and biofeedback are all treatments that decrease pain and improve function in patients with PFPS. Specific to adolescent female athletes, they felt there was some evidence to support the use of orthotics in patients with excessive foot pronation, In addition, they found no good evidence to support the use of patellar taping or tracking braces alone, modalities, or non-steroidal anti-inflammatory medications in patients with PFPS [47••]. Subsequently, a prospective, randomized, double-blinded, placebo-controlled trial of physical therapy for patellofemoral pain syndrome did find a statistically significant improvement in pain and disability at 6 weeks in the group that received physical therapy, with better outcomes noted in younger patients [48•]. Based on these findings, young patients with PFPS should be started in a rehabilitation program to improve quadriceps strength and lower extremity flexibility. Bracing and orthotics may be recommended in addition to rehabilitation in certain patients.

Conclusions

With the ever-increasing participation of children and adolescents in organized and recreational sports, physicians can expect to see a significant number of both acute and chronic sports-related injuries. An understanding of the unique aspects of the growing musculoskeletal system will provide a framework for treating young injured athletes. Many of the these injuries, such as contusions, muscle strains, lateral ankle sprains, pelvic avulsion fractures, apophysitis, and patellofemoral pain syndrome respond to conservative treatment including activity modification and rehabilitation. Complex fractures involving the growth plate, anterior cruciate ligament tears, and recurrent dislocation of the shoulder and patella warrant surgical evaluation.

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