Sideline Management From Head to Toe of the Skeletally Immature Athlete

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Abstract
Many articles have been written on specific injury patterns and types of injuries that occur in sports, but few have addressed sideline management with a specific focus on the injuries affecting skeletally immature athletes. This article will review the most common injuries that can occur with the skeletally immature athlete from head to toe in comparison to a skeletally mature or adult athlete. It will address also how to approach these injuries from a sideline and sports medicine perspective, thus providing insight for health care professionals to evaluate and treat young athletes that could allow them to return to sports safely.

Introduction
In the history of medicine, children were treated often as small adults. As knowledge has increased, physicians have learned that this is far from the truth. In the care of young athletes, these differences in treatment are amplified even more. As children develop and grow, changes in muscle, ligament, and bone structure result in differences from adult injury patterns that commonly present on the sidelines and in clinics and emergency rooms. In the immature athlete, the apophysis is the weakest and most commonly injured area of the bone (4,19,32). For example, repetitive-use injuries that may cause tendonitis in a teenager result in apophysitis in a younger athlete. Shoulder pain in a skeletally mature patient can be attributed to instability or a labral injury, whereas a higher level of suspicion should be held for Salter Harris I injury in skeletally immature individuals. Children also commonly have difficulty localizing pain, which makes it imperative for a health care professional to examine the joints above and below the injured joint (19). For example, knee pain in a skeletally mature athlete is localized usually to a variety of structures in and around the knee; however, knee pain in a skeletally immature athlete may be radiating pain from the hip, e.g., Legg-Calves-Perthes (LCP) disease or a slipped capital femoral epiphysis (SCFE). With over 41 million children in competitive sports and approximately 20.6 million of them sustaining an injury every year, the ability to access quickly and triage harmless injuries from the more severe injuries is vital to health care professionals (29). Typically most skeletally immature athletes’ injuries are minor and nonlife or limb-threatening; however, the evaluation and management of these injuries should not be taken lightly.

This article is intended to help health care professionals gain an awareness of the types of injuries that commonly affect the skeletally immature athlete in order to evaluate an athlete on the sideline effectively and allow these athletes to return to activity safely. Even though sprains, strains, and contusions can occur frequently, fractures are more common and should be higher on a provider’s differential diagnosis when initially evaluating any injured skeletally immature athlete as compared to the skeletally mature athlete (19,32). In addition, providers should be always aware of the red flag symptoms (e.g., night pain, fever, weight loss, morning stiffness, and night sweats), especially in the event of a possible injury. Red flag symptoms could indicate that a more serious condition exists, such as infection, malignancy, or rheumatologic condition (19). Most young athletes’ musculoskeletal injuries improve with rest and rarely require narcotic pain medication after the acute injury phase of 1 to 2 wk. The ordering of simple blood tests, such as sedimentary rate (ESR), C-reactive protein (CRP), and complete blood count, can be very helpful in ruling out dangerous infections and/or rheumatologic conditions (19). A skeletally immature athlete is less likely to continue playing with a significant injury than an adolescent or adult; however, continued participation or use of a limb should not preclude a provider of suspecting a more serious injury, such as a fracture (34). The young athlete also may be encouraged or pressured to “get back in the game” from parents or volunteer coaches who may lack formal training in youth fitness and first aid. For example, a skeletally immature athlete that falls on an outstretched hand and subsequently complains of pain and inability to use the arm is more likely to have a fracture through the growth plate (e.g., nondisplaced Salter Harris type I fracture) than a soft tissue sprain even with normal-appearing x-rays. As regards...
sideline management, assessing joint or limb function is vital in determining if an athlete can return safely to play. An injured athlete, regardless of age or level competition, should be able to perform all the necessary functions of his or her position prior to returning that day; e.g., a soccer player after injuring his or her ankle must be able to run, jump, kick, and change directions prior to returning to play. A final point to remember in the clinic setting, comparison radiologic x-rays are important in the evaluation of any skeletally immature injured child (32).

Head and Neck

One of the most recent highly published and much debated topics in sports injuries focuses on concussions. This is an endemic problem to all sports and is increasing only in relevance and importance in the sports medicine community. It is estimated that between 1.6 and 3.8 million sports-related concussions occur every year in the United States (17). Currently most of the studies related to concussions are focused on adolescents (high school) and adults, while few studies address concussions in young athletes less than 14 years old and their immature brains (6,16). It is well known that high school athletes take longer to recover than adults, and it is assumed that these issues should be amplified in young athletes (6,16,31). However this may not be the case; one article recently published that examined neuropsychological and neurophysiological assessments comparing children (9 to 12 years), adolescents (13 to 16 years), and adults (>18 years) discovered that adolescents are still the most vulnerable and sensitive to concussions as compared to children and adults (16). Even with the increase in research, the long-term effects and proper lengths of recovery from concussions are still mostly unknown in all athletes and, specifically, young athletes who are less than 14 years old (16).

The physiology of concussions in both young and adult populations is complex and significantly different. Overall the immature brain does not respond well to concussions. New studies show that an immature brain is more susceptible to injury and not protective as previously hypothesized (12,31). Thankfully due to many biomechanical factors, such as cerebral blood volume, level of myelination, and skull geometry, the immature brain requires increase force and energy to produce cerebral injury. Typically young athletes are smaller in size and strength, which in turn produces less force and lowers the risk of cerebral injury (31). However these younger athletes also have less neck and shoulder musculature than adults, which has been proven to help in the prevention of concussions in adults (31). Another study has shown that even though the amount of force to produce concussions occurs less frequently in youth sports as compared to high school and collegiate levels, this force still occurs quite often (17). Finally the existence or nonexistence of second-impact syndrome may not be clear, but one of the clear risk factors for severe brain injury is well known — the immaturity of a person’s brain (31,33).

Since the passing of the initial concussion legislation under the Zackery Lystedt Law in Washington State in May 2009 and the 40+ states now with similar legislation, as well as high profile athletes dying from possible concussion-related effects, sideline concussion management has become more noticeable and important (15). In most of these states, any athlete who is suspected of having a concussion or concussion-like symptoms during a game or practice must be removed immediately from that practice or game and cannot return until cleared by a licensed health care provider and placed through a return-to-play protocol. However many of the state laws are restricted to state affiliated schools only and often are not covered under junior and youth leagues. Moreover many youth league games and practices are not covered by any health care-trained professionals. Even among health care providers, treatment and management of concussions can vary dramatically (8). Therefore more universal awareness and teaching of the appropriate coaches and health care professionals are needed, yet there is no clear universal protocol for young athletes. After reviewing the literature, most sideline assessment tools have not been proven in the evaluation of young athletes (<14 years old) (16). Tools, such as the standardized concussion assessment tool (SCAT/SCAT2), neurocognitive tests (ImPACT), and balance error scoring system (BESS), have been shown to be effective in the sideline evaluation of adolescents and adults, but not in the younger athletes, which emphasizes the importance of more education and baseline testing for younger athletes (16). The overall theme for sideline management in the skeletally immature athlete should be conservative, when in doubt, protect the brain from further injury, and evaluate for the more acutely life-threatening brain injuries, such as subdural and epidural hematomas, subarachnoid hemorrhages, and cerebral edema.

Determining if a serious intracranial injury exists and/or when to order brain imaging can be extremely difficult, especially in pediatrics. Many imaging rules regarding minor brain injury in children have been studied, but there is no consensus. In one recent study from Canada, the CATCH rule (a clinical decision rule for the use of computed tomography in children with minor head injury) seems to be promising (37). According to this study, the four high-risk symptoms requiring neurological intervention were 1) Glasgow Coma Scale score <15 at 2 h after injury, 2) suspected open or depressed skull fracture, 3) history of worsening headache, and 4) irritability on examination (37). The three medium-risk symptoms for brain injury on computed tomography (CT scan were 5) any sign of basal skull fracture (e.g., hemotympanum, “raccoon” eyes, otorrhea or rhinorrhea of the cerebrospinal fluid, and Battle’s sign); 6) large, boggy hematoma of the scalp; and 7) dangerous mechanism of injury (e.g., motor vehicle crash, fall from elevation ≥3 ft ≥91 cm) or five stairs, and fall from bicycle with no helmet (37). If one or more of the four high-risk symptoms existed, the test was 100.0% sensitive and 70.2% specific for determining the need of neurological intervention. If any of the four high-risk and/or three medium-risk symptoms existed, the test was 98.1% sensitive and 50.1% specific for determining a CT-visible brain injury and the rule would require that 51.9% of children with minor head injury would undergo a CT scan (37). The three CT-visible brain injuries that were missed by the rule required no specific treatment, and the patients had no neurological sequelae (37). Even with the CATCH rule, a large number of children had an unnecessary and potential dangerous test. In addition, this rule did not specifically
address sports-related trauma or concussions. If this rule was applied universally to sports-related head trauma, it can be assumed that majority of athletes would need a CT scan simply by having at least one of the medium-risk symptoms, i.e., the dangerous mechanism of injury. However despite the dangerous mechanisms and forces observed with sports-related head injuries, the vast majority of athletes with concussions does not require any imaging and does not have serious intracranial pathology (27).

Finally when evaluating young athletes for concussions, a health care provider should always be aware of other potential injuries besides brain injury. Skull fractures, facial fractures, and cervical spine injuries can occur also from similar forces associated with concussions, especially in the pediatric population (1,31,40). In one study, one-third of pediatric patients with facial fractures were diagnosed concurrently with a concussion (1). Similarly neck injuries and pain commonly are associated with concussions (31). As regards neck pain, there are many different injury patterns to keep in mind when evaluating the young athlete with a possible cervical spine injury. These differences are related to proportionally larger skulls, incomplete ossification centers, different vertebral configuration, and ligamentous laxity (40). The younger children (8 years old or younger) tend to have higher level cervical spine injuries (C2–3) as compared to the older children and adults (C5–6) (40). In addition, the children less than 8 years old can have devastating spinal injuries without an associated fracture, i.e., transient vertebral displacement (40). Therefore evaluating for cervical spine injuries is very important, even though these injuries are rare; these injuries have high mortality rates and neurological deficit rates (40). On the sideline, young athletes with any complaints of neck pain need to be evaluated thoroughly and transported immediately with C-spine immobilization if any suspicion of fracture and/or spinal cord injury exists.

Thoracic and Lumbar Spine

Back pain in the skeletally immature athlete cannot be ignored or dismissed. Athletes may present with many variety of symptoms, e.g., mild pain, feeling tired when sitting or standing for long periods, or there can be acute onset of pain that makes children irritable and/or refuse to move (41,43). Muscle strains are as common in the young as in the old and can be severe, but typically these resolve on their own in short periods of time, while bony issues will persist and need to be diagnosed accurately so corrective action can be taken.

Preparticipation physicals can be the first line in dealing with back issues. On inspection, assess for the curvature of the spine. Scoliosis is assessed best by having the patient perform forward flexion at the hips. There may be a notable S or C curve to the normally straight spine, tilt of the pelvis, or one shoulder that remains higher than the other (41). The amount of curvature then can be assessed further with x-ray. It is more common in girls and may be exacerbated by growth spurts (41). The best screening is performed in girls at ages 10 and 12 years and boys at ages 13 or 14 years (44). In this same patient flexed position, viewing from the side can assess for Scheuermann’s disease, which typically has an onset between ages 10 and 12 years (7). On examination, a rigid humpback deformity that does not correct with back extension is indicative of Scheuermann’s disease (5,7). This can be evaluated further with x-rays. Both scoliosis and Scheuermann’s disease can be asymptomatic in many children. However early recognition even in the asymptomatic child can lead to better outcomes in preventing deformities before a child reaches skeletal maturity (7).

In evaluating a young athlete with persistent pain even as short as a week, in one or both paraspinous regions, a diagnosis of spondylosis or spondylolisthesis should be considered first until adequately ruled out. The pain typically presents in the L4–S1 region and is worse with extension or hyperextension as opposed to muscular issues that are aggravated by flexion, rotation, and lateral bend (38,43). Spondylosis typically does not present usually with radiologic symptoms that may be seen in an athlete with herniated disc or traumatic spine fracture. This injury is most common in young athletes who participate in repetitive back extension activities such as gymnasts, volleyball hitters, football linemen, and kickers (38,43). It may be visible on oblique lumbar x-rays, but if negative and there is a high degree of suspicion still, a bone scan with single-photon-emission computed tomography (SPECT) images or magnetic resonance imaging (MRI) is indicated. The early detection and appropriate treatment of spondylosis can increase the likelihood of complete healing and return to play without recurrent or persistent pain (38). In addition to stress fractures, rarer, traumatic fractures, such as Salter Harris, compression, and burst fractures, can occur and should be considered in a skeletally immature athlete that has an acute onset of back pain while playing sports, falling, or being involved in a motor vehicle accident (13).

Although rare, diskitis should be considered in young athletes with severe back pain in the lumbar or thoracic region that occurs with any movement and may or may not be associated with fever and other systemic symptoms. Diskitis typically occurs in children under the age of 10 and is the result of staphylococcus, viruses, or other inflammatory conditions (7). Perceived injuries and lack of fever can be misleading; however the severity of pain should be the largest red flag. MRI, ESR, and CRP are keys to the diagnosis (7).

Shoulder

Shoulder injuries are very common in sports. The shoulder injury patterns in the skeletally immature athletes differ significantly from adults. As observed in all joints, the history of injured athlete is vital to understanding and diagnosing shoulder injuries on the sideline. The mechanism and the timing of the injury are the two most helpful history points to determine.

Acute shoulder injuries can vary in all ages, but fractures are the most likely diagnosis in the skeletally immature athlete (11). The most common shoulder fractures are clavicle fractures, followed by proximal humeral fractures, then scapular fractures. Scapular fractures and ligamentous injuries, such as acromioclavicular or sternoclavicular separations, can occur but are rare in the skeletally immature athlete. The most common shoulder injury in the skeletally immature athlete is anterior glenohumeral dislocations (11,32). As in adults, sideline management of these
injuries is similar — suspected athletes with fractures and primary shoulder dislocations should be removed immediately from the event. Nearly 100% of skeletally immature athletes that have experienced a traumatic anterior glenohumeral dislocation will have a recurrent dislocation (32). Primary reduction of shoulder dislocations may be attempted in the appropriate setting depending on the experience of the provider; however without x-rays, especially in the skeletally immature athlete, further injury could be significant if the diagnosis of dislocation is made in error (e.g., misdiagnosing a displaced proximal Salter Harris fracture of the humerus).

Chronic shoulder injuries are also very common, especially in throwing athletes. The most common injury is epiphysiolysis of the proximal humerus caused by repetitive microtrauma from overhead activity, also known as little leaguer shoulder (11). Any young athlete with chronic shoulder pain that worsens with throwing evaluated on the sideline should be considered to have this injury. Definitive diagnosis must be confirmed with radiographs and compared to the nonaffected side (11,32). Since the proximal humerus has excellent remodeling ability, healing complications are rare if a period of 2 to 3 months of rest is observed (11). Shoulder impingement and rotator cuff tendinosis, although not as common, can occur in the pediatric athlete and thrower (11,32). This is caused commonly by chronic anterior and/or multidirection instability (11). Common adult injuries, such as rotator cuff tears and isolated labral tears, are uncommon in the skeletally immature athlete that has not dislocated their shoulder (11).

Elbow
Similar to shoulder injuries, elbow injuries can be evaluated by the timing and mechanism of injury. When evaluating acute elbow injuries in the skeletally immature athletes, fractures should be considered first. Supracondylar fractures are the most common fractures in the pediatric population, followed by condylar fractures (28). Medial epicondylar avulsion fractures may be seen in the skeletally immature thrower as well. Any pediatric thrower with acutely painful medial elbow pain should be examined for this type of fracture. During a sideline evaluation, any athletes with swelling and decreased range of motion or strength should be suspected of having an elbow fracture. These athletes should be withheld from that practice or game until definitive evaluation with an x-ray is performed. As in most injuries to the joints and bones in the skeletally immature athlete, comparison radiographs of the unaffected side are essential (32).

Chronic elbow injuries can occur frequently in the pediatric elbow, especially in throwers and gymnasts. The most common injury seen in throwers is medial apophysitis, also known as little leaguer elbow. Due to the repetitive valgus stresses and tension overload of the medial structures, the medial epicondyle apophysis is the weakest link (11). Sideline recognition of this problem is important. Most athletes with little leaguer elbow complain of medial elbow pain with throwing. The athletes may or may not have swelling but are tender over the medial epicondyle. These athletes should be removed from the game or practice and advised to stop throwing until properly evaluated with x-rays. While many studies and guidelines have been written to prevent shoulder and elbow injuries by limiting pitch counts on the skeletally immature athlete, so far, these efforts clearly have not made a significant difference (24,58). This same injury pattern that occurs in the skeletally mature thrower usually results in a tear of the ulnar collateral ligament in the elbow (11). Another condition to understand when evaluating chronic elbow pain is osteochondritis dissecans (OCD) of the capitellum. OCD of the capitellum usually presents in boys, 13 years or older, with dull and poorly localized elbow pain that increases with sports (11). These athletes also may have swelling and difficulty extending their elbow. Locking or catching symptoms may exist if loose bodies are present. This condition differs from Panner’s disease, an acute self-limiting osteochondrosis of the entire capitellar ossific nucleus that typically occurs in younger boys (ages 5 to 10 years) (11). Unlike athletes with an OCD of the capitellum, patients with Panner’s disease rarely have any residual deformity or late sequelae (11,52).

Wrist and Hand
Wrist and hand pain can be very challenging to evaluate on the sideline, but an understanding of the most common injuries can be helpful. Fractures of the wrist and hand are the most common injuries that occur in the skeletally immature athlete. Distal radius fractures with and without epiphyseal involvement are the most common fractures observed in the wrist (20,21). Swelling, deformity, bony tenderness, and function are the keys to sideline evaluation of both wrist and hand injuries. In the wrist, having a high suspicion for scaphoid fractures always should be a priority in the evaluation of any injured athlete. Scaphoid fractures are the most commonly missed fractures in all clinical settings (20). Any skeletally immature athlete with a suspected wrist fracture should be splinted and removed from the game until further imaging is performed. Triangular fibrocartilage complex (TFCC) injuries usually occur in the setting of a distal radius fracture in the skeletally immature athlete. However many of the TFCC injuries in the younger athletes are asymptomatic and rarely require surgical repair or excision (20). In particular, gymnasts have a higher risk for developing TFCC injuries (20). Distal radial apophysitis also has been shown to be a common injury in gymnasts. This injury occurs due to the repetitive impact forces on the wrists. Athletes present with chronic pain, swelling, and stiffness. If untreated, this may lead to premature closure of the radius, which can cause stiffness, pain, and permanent deformity (21).

Hand pain and injuries are also complex in the setting of sideline injury evaluation and management. Many athletes can continue playing frequently during the same competition after sustaining a serious hand injury. The most important aspect to remember when assessing hand injuries is determining functionality (57). For example, a spiral metacarpal fracture can appear minimally displaced on examination and radiographically but clinically can cause debilitating rotational issues for hand function if not properly reduced and treated. Another common injury seen in young athletes is skier’s or gamekeeper’s thumb, which usually involves a Salter Harris type 3 fracture at that base of the ulnar side of the proximal phalanx of the thumb. If
this fracture is displaced significantly, surgery is required often to prevent or correct a Stener lesion (57). Other liga-
mentous type injuries, such as mallet and jersey finger, can occur also but usually involve a bony avulsion frac-
ture as well. Dislocations can occur also frequently in the hand. Most common dislocations occur at the proximal interphalangeal (PIP) joint due to hyperextension injury (55).
As long as no significantly displaced fracture has occurred, these PIP dislocations, once reduced, can heal easily with buddy taping and minimal restriction of activity. Metacar-
pophalangeal dislocations are usually more complex and involve volar cartilage plate injuries and/or significant art-
ticular fractures that often require surgical fixation (55). Therefore tendon function evaluation and testing for liga-
ment laxity in the hand and fingers are imperative whether on the sideline or in the clinic.

Hip and Pelvis

Hip pain can be difficult to evaluate for any patient, but even more so in the skeletally immature athlete with the number of growth plates that exist in the hip and pelvis. On the sideline, determining if the hip pain is a simple contu-
sion, hip pointer or apophysitis that will resolve without complication, or a hip injury that is more serious and may potentially cause long-term disability is a priority. Athletes, parents, or coaches may dismiss hip pain as a simple groin strain that actually represents an avulsion fracture or a worse injury, such as a stress fracture or an SCFE.
Young athletes commonly can injure or complain of pain over the iliac crest, which is the most prominent bony structure in the pelvis that has several muscle attachments. In the setting of trauma or direct blow to this area, also known as a hip pointer, with an athlete that can bear weight fully, a reasonable approach is to treat this pain initially with ice, nonsteroidal anti-inflammatories (NSAIDs), and relative rest (4). If the pain does not resolve in a few days or is worsened by specific motions associated with muscle contraction, further imaging for avulsion fracture or apophysitis would be indicated. Differentiating between avulsion fractures and apophysitis can be challenging. The key difference is usually in the mechanism of injury — an avulsion fracture typically occurs from one single injury (e.g., a football player who feels a pop with immediate pain during a quick sprint or change in direction), whereas apophys-
ysis usually has an insidious onset (4). Hip apophysitis most commonly affects children between the ages of 14 to 18 years in the areas of the anterior superior and inferior iliac spine and the iliac crest (4). Because the muscles that attach in the hip and pelvis are used for flexion of the hip and rotation of the trunk, hip apophysitis are more promi-
nent in sprinters, soccer players, dancers, and ice hockey players, especially in athletes with tight hamstrings and hip flexors. There may be tenderness and even swelling over the area of the apophysitis similarly to an athlete with a hip pointer, but pain will be reproduced with muscle con-
traction and a widened apophysis will be noted on x-ray (4). Comparing x-rays of the affected side to the unaffected side is key to diagnosing this alignment.

Another radiographically dependent diagnosis in the hip and pelvis is an avulsion fracture, which can appear similar to apophysitis on x-ray. These types of fractures typi-
cally result from high-energy eccentric muscle contractions and therefore can be confused with acute muscle strains (4). Similar to muscle strains, there is pain with active and pas-
sive muscle stretching as well as palpation over the area of attachment. In immature athletes, the weakest link is the bone and not the muscle (4). Understanding this difference is important because an avulsion fracture, unlike a sprain, often requires the patient to be non-weight bearing to heal. The most common sites for avulsion fractures are at the hamstring attachment to the ischial tuberosity or at the rectus femoris attachment on the anterior inferior iliac spine (35). In evaluating an athlete on the sideline, weight-bearing ability and/or the ability to play their position without significant pain or limp should influence decision making on the same-day return to play.

While not specifically sports related, SCFE, LCP disease, and transient or toxic synovitis may be brought to the at-
tention of the sports medicine provider on the sidelines following minor trauma or as a persistent pain in younger athletes. All of these conditions may present with acute onset of a limp or pain in the hip, thigh, or even knee, es-
pecially early in presentation (14,56). SCFE and LCP present more commonly in boys. Common age ranges for toxic synovitis, LCP, and SCFE are 3 to 6, 4 to 8, and 10 to 17 years, respectively (14,42,56). SCFE commonly can (20% of the time) occur bilaterally; it is more common in African American boys and overweight children (14). Diag-
nosis typically can be made on x-ray with displacement of the femoral head on the neck in SCFE or flattening or frag-
mentation of the femoral head in LCP (14). X-rays and blood work in toxic synovitis are unremarkable. Typically toxic synovitis is a diagnosis of exclusion, but a history of recent viral illness is usually common (42). While toxic synovi-
tis will resolve with rest and NSAIDS, SCFE and LCP re-
quire emergent referral to an orthopedic surgeon (5,42,56).

Knee

In sports, the knee injury is one of the more feared inju-
ries among athletes secondary to the loss of play time due to high-grade ligament sprains, fractures, and meniscal tears. While these types of injuries are significant in teenagers, younger athletes generally have less disabling problems such as Osgood–Schlatter disease, Sinding–Larsen–Johansson disease, patellar subluxation, and patellofemoral pain syn-
drome (PFS). Even though most knee injuries in the ske-
etally immature athletes have better prognosis, several conditions exist that should be recognized early in order to prevent long-term pain or disability, e.g., SCFE and osteochondral defects (OCD) (10,14,47,56).

Pain with jumping or bending and tenderness above or below the patella may lead to fear of a tear of the patellar or quadiceps tendon or avulsion fracture. While tendon ruptures and avulsion fractures are possible with explosive eccentric load activities, the more likely diagnosis is repeti-
tive stress at the apophysis. Osgood–Schlatter disease is apophysitis that is located where the patellar tendon inserts on the tibial tubercle, while Sinding–Larsen–Johansson is apophysitis where the patellar tendon originates at the in-
ferior pole patella (18). A most important sideline man-
gagement goal is confirming that tendon rupture or avulsion fracture has not occurred. Apophysitis may have small
amount of localized swelling, but a joint effusion will not be present. In addition, with apophysitis, the knee extensor mechanism (the athlete will be able to perform a straight leg raise) will remain intact and the athletes will be able to continue walking without severe pain or limp (18).

A similarly benign condition is PFS. These patients are more likely to be girls who participate in running, dancing, and jumping sports. The pain is located usually in the anterior portion of the knee and is aggravated by repetitive knee flexion, e.g., using stairs and performing deep squats and lunges (18). The pain inside or in the medial aspect of the knee may cause concern for a meniscal tear; however, in children and adolescents, having a weaker vastus medialis and abnormal patellar tracking is the more likely etiology (18). This pain is not associated with persistent swelling or other mechanical symptoms, such as locking and instability. Therefore a more serious knee injury should be considered always when a young athlete presents acutely or chronically with significant swelling or effusion.

Swelling and acute pain associated with a pop requires further investigation and is most likely secondary to an acute anterior cruciate ligament (ACL) tear. While not as prevalent as in adults, it is estimated that 50% of children with hemarthrosis have an ACL tear (49). ACL avulsion fractures off the tibial spine are more common in children than the usually isolated midsubstance ACL injuries seen in adults. ACL avulsion fractures if minimally displaced even can be treated nonsurgically in most cases (25). The second most common of hemarthrosis is patellar subluxation or dislocation (53). Patellar subluxation may lead to recurrent episodes or have associated patellar fractures or OCD lesions (53).

Chronic or persistent swelling that does not resolve or that occurs intermittently is abnormal even when subtle. After the initial injury passes, chronic knee pain in children may be thought to be simply one of the apophysitis or “growing pains” mentioned earlier. Children that continue to have swelling, pain, and decreased range of motion need to be evaluated for an OCD lesion. The most common site for an OCD lesion is the lateral aspect of the medial femoral condyle and is often visible on plain radiographs (10). However an MRI can be helpful for OCD lesion staging and should always be considered in evaluation of any child with persistent knee swelling with a negative x-ray (47). Detecting OCD lesions is very important for prognosis. The majority of OCD lesions can be treated successfully nonoperatively in the skeletally immature athletes with wide-open physes as compared to OCD lesions in skeletally mature athletes that usually need to be treated operatively and have less favorable outcomes (47). Therefore, from a sideline perspective, any acute or chronic effusion of the knee should be managed with removal of the athlete from practice or game followed by appropriate evaluation and imaging.

**Leg and Lower Leg**

Any active and healthy child will inevitably have bumps and bruises on their legs, but there are instances when these aches and pains can be more. Simple muscle cramps and pain can appear benign, but could be related to a more serious condition, e.g., compartment syndrome. An uncomplicated hematoma can become a heterotopic ossification, and chronic ache or pain could be a stress fracture, not just a simple muscle strain.

Sports medicine physicians commonly treat cramps, often on a daily basis. This can be the sign of overexertion, dehydration, or possibly electrolyte issues. Younger children are particularly prone to dehydration due to a larger surface area to body ratio and different thermoregulatory response to exercise than adults. They often simply do not know how to replace properly their fluids (50). Since children may lack the motivation to properly intake enough fluids, coaches and parents need to assure that young athletes receive appropriate hydration during and after exercise (45). Furthermore health care providers need to educate coaches and parents about this critical issue. While most hydration-related issues can be addressed easily on the sideline, recurrent cramps or pain out of proportion should be evaluated by further testing. For example, compartment pressure testing, creatine kinase levels, kidney function tests, and myoglobin can help to determine the amount of damage to the muscles and the extent of dehydration (2).

The diagnosis can be as simple as an athlete consistently not hydrating sufficiently during physical activity or a more complex diagnosis such as a genetic myopathy. With cramping and severe pain associated with numbness, weakness, or skin changes in the legs, acute compartment syndrome also needs to be considered (39, 50).

A small percentage of muscle contusions (9% to 17%) can progress to myositis ossificans (48). The athlete may present with a hardening area in the muscle 4 to 7 wk after an initial injury (48). While this development of heterotopic bone usually can be visualized on x-ray and treated with rest, aggressive physical therapy, and NSAIDs, it is important to differentiate these lesions from more worrisome conditions such as sarcoma (48).

Athletes training at moderate to high levels of intensity may experience occasional episodes of pain and soreness; however, if their pain increases, persists even at rest, and/or limits their activity, a more significant injury must be considered, such as a stress fracture. Most common stress fractures occur in the tibia (50%), followed by the metatarsals at 25% (51). In children, the proximal third of the anterior tibia is the most common location of stress fractures. The anterior cortex of tibia stress fractures is considered high risk, along with femoral neck stress fractures (48). These areas typically have a delayed diagnosis and frequently result in less favorable outcomes (26). While older athletes may develop stress fractures as a result of over training, younger athletes can have similar injury patterns due to increasing demands while advancing to higher levels of sports and/or improper training techniques. When evaluating a young athlete, it is also important to remember that x-rays can be negative up to 50% of the time; therefore an MRI or bone scan with SPECT images is warranted when a stress fracture is suspected (26).

**Foot and Ankle**

Most coaches and parents could accurately guess that the most common sports injury in children is an ankle sprain, but many other conditions can masquerade with this same presentation (22). The foot and ankle account for a
large majority of lost playing time in athletes. There are several different areas of the ankle and foot, and each area can have many diagnoses; however the most common injuries will be reviewed. Remembering the key to any same-day return to play or sideline assessment of an injured young athlete is determining if the athlete can perform his normal athletic function while not increasing his risk for further injury.

Pain in the malleolar region (lateral or medial) in an athlete that is able to walk off the field would most likely be a sprain of the anterior talofibular, anterior tibialis, or deltoid ligaments in a skeletally mature individual. In a younger athlete, apophyseal injuries are far more common and usually limit the ability of the athlete to fully bear weight and perform his athletic functions. Also medial ankle pain in a skeletally immature athlete is far more worrisome than lateral ankle pain (30). In the lateral foot, Jones’ fractures and avulsion fractures, also known as dancer’s fractures, of the proximal fifth metatarsal commonly occur. These fractures typically occur when the foot is forced into inversion while the foot is plantar flexed (51). Differentiating between an avulsion fracture and Jones’ fractures is important and can be challenging. Jones’ fractures occur at the base of the fifth metatarsal at the metaphyseal–diaphyseal junction, while avulsion fractures are more transverse and proximal in the fifth metatarsal (51). Many Jones’ fractures have delayed healing due to poor vascular supply and require surgical fixation (51). In children (9 to 14 years old), an apophysis also exists at the fifth metatarsal tuberosity and could be mistaken for a fracture. However if the pain is more chronic in nature and has an insidious onset, proximal fifth metatarsal apophysitis (Iselin’s disease) also could be considered (51). Comparison radiographs also can be extremely helpful.

In skeletally mature patients, posterior ankle and/or heel pain is most likely Achilles’ tendonitis or plantar fasciitis, especially in those athletes that are involved in explosive or jumping activities. While treated similarly, this pain in young athletes is due to the repetitive stress at the calcaneal apophysis known as Sever’s disease (5,30). When pain is deeper in the ankle and swelling persists for more than 4 wk or mechanical symptoms exist, a work up for an OCD lesion is recommended. The most common location for an OCD lesion in the foot and ankle is the talar dome (30). As previously described in the elbow and knee, these OCD lesions can be treated successfully nonsurgically in the skeletally immature athlete.

Pain in the midfoot of skeletally mature athletes can result from a variety of alignments including improperly fitted shoes and degenerative changes. However fractures, particularly stress fractures, should be high on the differential when evaluating skeletally immature athletes. Metatarsal stress fractures are common in both children and adults and account for 25% of all stress fractures (46). Athletes, particularly dancers and runners with an increase in their training, typically present with pain and swelling over the second or third metatarsals. It is also important to pay attention to the fifth metatarsal because stress fractures in this area are prone to nonunion (30). While stress fractures can affect any age, when younger athletes present with midfoot pain, Freiberg’s infraction or Kohler’s disease also should be in the differential. Freiberg’s infraction is characterized by disordered ossification of the second metatarsal head and is more prevalent in adolescent girls who complain of pain in the ball of the foot that progresses gradually (5,23). Kohler’s disease is more common in boys and is seen in children 3 to 5 years old who present with night foot pain that is usually unilateral. Radiographs demonstrate navicular sclerosis, flattening, and fragmentation of unknown etiology (5,36). Eventually both can be seen on x-ray as the flattening of the metatarsal head or the degeneration and fragmentation of the navicular bone (36). Unlike the previous mentioned midfoot pains, more mature patients with sudden pain after trauma in the midfoot and inability to bear weight require further evaluation for a Lisfranc fracture–dislocation. While these fractures–dislocations account for less than 1% of all fractures, they can have significant morbidity if not treated properly and usually require surgery (9). In addition, the great toe can be a tremendous source of pain, especially seen in catchers, runners, dancers, and gymnasts. Although acute fractures can occur, the constant forces on the great toe usually lead to sesamoiditis or a sesamoid stress fracture (3).

Conclusion

Evaluating the skeletally immature athlete is far different from evaluating the skeletally mature adolescent or adult. As is the case for most of sideline medicine, very little data are available, especially as regards the younger athlete. More research is warranted on enhancing and providing sideline management for skeletally immature athlete in the community-based youth leagues. Specifically developing future strategies for overuse injury prevention is needed, because these injuries account for up to 50% of pediatric sports injuries and over 50% of those injuries may be preventable (54). However with the understanding of the available research and the biomechanical differences between pediatrics and adults, a thorough approach to evaluating sideline injuries in the skeletally immature athlete is possible to allow for a safe and effective return to sports.

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References
