Evaluation of Overuse Injuries in Children and Adolescents

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DIFIORI, J.P. Evaluation of overuse injuries in children and adolescents. *Curr. Sports Med. Rep.*, Vol. 9, No. 6, pp. 372–378, 2010. *With the increasingly competitive nature of many youth sports and with single-sport specialization occurring at young ages, overuse injuries are common among young athletes. Several growth-related factors contribute to the development of overuse injuries in children and adolescents, including the susceptibility of growth cartilage to injury and the adolescent growth spurt. This article will discuss these unique factors and provide an overview of the diagnosis and treatment of overuse injuries in this age group. Specific measures aimed at preventing overuse injuries in young athletes also will be presented.*

INTRODUCTION

In the United States, approximately 25 to 30 million children participate in team sports and likely several million more are involved in individual sports (37). Although little data exist documenting the extent of participation within this population, it is clear that large numbers of children do not limit their sports to a given season and are involved throughout the calendar year. Further, with an increased emphasis on competitive success that seemingly has become widespread at younger and younger ages in youth sports, pressure exists for youth to begin training with greater frequency and intensity than in the past. This, sometimes coupled with parental hopes of securing collegiate scholarships, national team selections, and even professional careers, has led to participation far beyond traditional school-based and community-sponsored programs. Parents may pursue placement of their child (some beginning as young as 5 yr of age) on selective club or travel teams, hire a personal sport coach, enlist a fitness instructor, and enroll their child in a variety of camps. Some parents begin to focus their child on a single sport at a young age in an attempt to improve their chances of being selected for elite teams and to enhance their resumé for college recruiting. It is not unusual for a child specializing in a single sport to be participating on more than one team at a given time. Even children who continue with two or more sports may be involved with more than one team at a time.

This emphasis on year-round training and competition and single-sport specialization sets the stage for overuse injuries to develop. Several issues related to growth and development should be considered when evaluating young athletes with an overuse injury. This article describes an approach to the clinical examination and management, with a focus on the unique growth-related factors that contribute to overuse injury. By understanding these issues, clinicians will be better able to treat these injuries, educate parents, athletes, and coaches, and provide sound recommendations for injury prevention.

DEVELOPMENT OF OVERUSE INJURIES

Anatomic structures that are subjected to repetitive loading during sport participation incur microtrauma. With sufficient recovery between exposures, the tissue (*e.g.*, bone or tendon) can remodel and adapt to the imposed stresses. Overuse injuries develop when repeated mechanical loading exceeds the remodeling capability of the structure under stress. In part, it is the imbalance between loading and recovery over time that can lead to injury. Injury can occur with moderate intensity loading over extended periods when recovery time is not sufficient. Alternatively, injury may develop with repeated high-intensity, short-duration loading even when recovery is planned and provided. From a histopathological standpoint, the tendon model of overuse is perhaps the best studied. Analysis of tendon samples from patients with chronic tendonopathies demonstrates: 1) a loss of collagen continuity, 2) an increase in ground substance

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and vascularity, and 3) an increase in mast cells, fibroblasts, and myofibroblasts. Inflammatory cells are absent (28,35). Thus overuse injuries do not typically involve acute inflammation; in fact, degenerative changes predominate. In tendon, such injuries are more accurately described as tendinosis, rather than tendinitis. Although true tendonopathies are not as common in children as they are in adults, the concept of overuse injuries involving cumulative trauma that alters tissue structure in the absence of inflammation is an important distinction in understanding these injuries and thus in developing sound management strategies.

FACTORS CONTRIBUTING TO OVERUSE INJURY

A number of factors may contribute to the development of overuse injuries. They typically are classified as either intrinsic or extrinsic factors (Table 1). Those that involve the unique characteristics of the immature musculoskeletal system are of particular importance. However, there are relatively few data, especially in children, to clearly substantiate the cause and effect relationship between these purported factors and overuse injury. To this end, this article attempts to cite the available relevant research related to each factor. Although further studies clearly are needed, understanding these potential factors may assist in primary injury prevention, as well as in limiting recurrent injuries.

Skeletal Immaturity and the Adolescent Growth Spurt

There are two important and interconnected growth-related factors to consider: 1) the susceptibility of growth cartilage to injury from repetitive loading and 2) the increased risk for injury associated with the adolescent growth spurt.

In skeletally immature athletes, growth cartilage is present at the articular surface, the physes, and the apophyses. Laboratory studies and clinical observations of injury patterns have shown that growth cartilage is more susceptible to injury than mature bone (2,6,9,12,23). Importantly, injury risk appears to be greatest during the adolescent growth spurt. On a structural basis, Flachsmann and colleagues studied the response to dynamic shear stress of the osteochondral junction in bovines and found that adolescent tissue failed at a significantly lower level of shear stress and required less energy to produce failure than either more immature or mature specimens (23). Related to this, recent studies have shown that a decrease in size-adjusted bone mineral density occurs before the attainment of peak height velocity and correlates with acute fracture incidence (21). In addition, increases in bone strength have been shown to be predicated upon increases in lean tissue mass (26). While such factors clearly play a role in acute bone injuries, they also likely are significant in the development of overuse injuries. For example, chronic wrist pain in young, nonelite gymnasts is significantly more likely to occur during 10–14 yr of age (the expected age range of peak height velocity) than either before or after this age period (18).

In addition, other biomechanical factors enter into the equation. Changes in the length, mass, and moment of inertia of the extremities occur with growth that in turn place increased stress on the muscle-tendon junctions, bone-tendon junctions (apophyses), ligaments, and growth cartilage (25). The increases in strength needed to accommodate these changes that will enable a child or teenager to continue to generate the same limb speed as before the growth spurt may not occur in a uniform pattern. Such imbalances in growth and strength, coupled with the loading imparted by sport training and competition, create a situation conducive to the development of overuse injuries.

TABLE 1. Factors contributing to overuse injury.

Growth-Related Factors
Susceptibility of growth cartilage to repetitive stress
Adolescent growth spurt
Other Intrinsic Factors
Previous injury
Previous level of conditioning
Anatomic factors
Menstrual dysfunction
Psychologic and developmental factors — athlete specific
Extrinsic Factors
Training progression
Equipment/footwear
Sport technique
Psychologic factors — adult and peer influences

[Adapted from DiFiori JP. Overuse injuries in the young athlete. *Phys. Sports Med.* 1999; 27:75–89. Copyright © 1999 JTE Multimedia, LLC. Used with permission.]

Sites of Overuse Injury Involving Growth Cartilage

Articular cartilage

Osteochondritis dissecans (OCD) is a focal articular cartilage lesion that typically occurs at the ankle, knee, or elbow. The etiology is not well understood, but it appears to involve a lack of adequate blood supply to the growth cartilage (33,41). It appears that in some cases repetitive loading may aggravate the existing abnormality of the articular cartilage. Although OCD may be diagnosed in youth presenting with sports-related symptoms, these lesions can occur in the absence of repetitive loading. Thus while OCD is a phenomena of articular cartilage, it may or may not develop specifically due to overuse.

Apophyses

Apophyseal injuries occur at immature tendon-bone attachment sites. The patellar tendon-tibial tubercle apophysis (Osgood-Schlatter disease) and the Achilles tendon-calcaneal apophysis (Sever's disease) are typical examples. As mentioned previously, these sites are exposed to a relative increase in stress during the adolescent growth spurt due to biomechanical factors related to long-bone growth and limb movement. The weakness of the growth cartilage relative to the tendon is a contributing factor in these injuries. Decreased flexibility, thought to create increased traction at the apophyseal insertion of the tendon, also has been proposed previously as a factor

(30). This has been thought to occur as a result of more rapid growth in the long bones, relative to the more slowly lengthening muscle-tendon attachments (30). However, in one study of nearly 1000 high-school students, a relationship between decreased flexibility and growth was not demonstrated (22).

Physis

Overuse injuries also may involve the physis. Such injuries have been described in the proximal humerus, the proximal tibia, and the distal radius in a variety of sports (10,13,14,19,29,34). These injuries appear to occur as a result of diminished metaphyseal perfusion due to repetitive loading. This then inhibits the mineralization of chondrocytes that normally takes place in the zone of provisional calcification. Chondrocyte life is thus extended, and as chondrocytes continue to divide in the zone of proliferation, widening of the physis occurs, which may be seen radiographically or with magnetic resonance imaging (MRI) (27) (Fig.). Partial or complete growth arrest resulting in altered long-bone growth has been reported as a consequence of this form of overuse injury (1,29).

Other Intrinsic Factors

Prior injury

Youth who have developed an overuse injury may have had other injuries in the past. Repeated overuse injury may indicate insufficient rehabilitation of the previous injury or a failure to identify and correct the factors that led to the original injury, including training errors, poor technique, or any of the factors discussed here.

Inadequate conditioning/preparation

Children who have not developed at least some level of strength, endurance, and motor skills may be at increased injury risk as they begin participation in a specific sport. Although there is little data in children, in young women, there is some evidence indicating that poor aerobic fitness is a risk for bone stress injury (36). Activities that promote general fitness may help in preparing a child to begin a sport. Coaches should consider this as they plan their early season sessions, to accommodate children who may need a more fundamental level of training compared with others who have had more experience in the sport.

Anatomic factors

Alignment abnormalities, including pes planus, pes cavus, patellofemoral malalignment, and others, frequently are implicated as risk factors for overuse injury. Excessive ligamentous laxity also may play a role. These factors are difficult to assess since the magnitude of their effect is not appreciated easily in the relatively static office setting. The true cause and effect relationship of malalignment and joint laxity to overuse injury is not clear, as results of prospective studies of both static alignment and dynamic measures vary and do not identify any consistent predictors (40).

Menstrual dysfunction

Menstrual dysfunction, which can be associated with low bone mineral density, has been associated with an increase in the risk of stress fractures in several studies of young adult athletes and military recruits (8,31,32,36).

Developmental level

The concept of sport readiness is a relative one dependent on the child and the sport being considered. In general, practice sessions and competitions should be appropriate not only for a child's physical skills, but also for their stage of cognitive maturation. Young children with more limited attention spans who are distracted easily may not yet be capable of participating in highly structured programs. Programs or parents that do not take into account the child's developmental status may increase the risk for injury and the chance that child will lose interest in the sport if sessions are not geared to their level of understanding and motivation (3).

Extrinsic Factors

Training-related factors

Among risk factors for overuse injury, some of the most consistently identified are those related to training volume (40). Increases in training frequency, duration, or intensity can lead to overuse injury. A failure to incorporate scheduled rest periods within the training program also can be a factor. It is important that the varying physical and emotional maturity levels of children, even within the same age group, are considered when planning training programs. Especially when it comes to training youth, one size does not fit all.

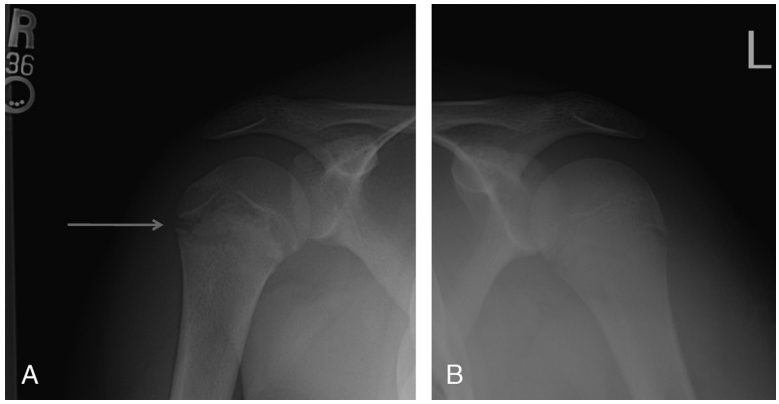

Figure. A 13-yr-old baseball player with right shoulder pain. A. Radiograph of the right shoulder demonstrates widening of the proximal humeral physis. B. Normal left shoulder.

Equipment

Equipment that is worn, not well maintained, or not properly fitted can lead to injury. Footwear that is not appropriate for the activity (*e.g.*, using tennis shoes for distance running) may contribute to injury as well. Running shoes lose their shock-absorbing capacity with prolonged use, which may lead to injury (15,20). Parents and children who are new to a sport and not familiar with the type of equipment needed or the proper fit should seek assistance from coaches or other knowledgeable sources (*e.g.*, Web sites, instructional manuals) on how to choose for their child. For those established in an activity, changes in equipment (*e.g.*, new shoes, new tennis racquet, etc.) should be considered carefully as physical growth, wear, and training needs dictate.

Sport technique

As children grow and progress in their sports, new skills will be undertaken. Mastery of new skills requires some level of repetition. However, if this is being attempted with improper technique, such as poor serving mechanics in tennis, injuries can develop. This can occur either as the new skill is introduced, or later when repetition and training intensity increase, which can then magnify the excessive stress imparted due to faulty technique.

Psychological factors

Many of the factors cited above are affected to a significant extent by adults in a supervisory role. Coaches, parents, and even peers who are unaware or ignore those issues may create an environment in which overuse injuries are more likely to occur. Proper education of parents, coaches, and sport organizations can promote healthy participation that incorporates measures to reduce the risk for overuse injuries (*e.g.*, pitch counts in youth baseball). Parents or coaches should be aware that encouraging excessive levels of participation and competition, such as playing multiple sports at a given time or playing with multiple teams in a single sport in the same season, can lead to both overuse injury and burnout (11).

GENERAL CLINICAL EVALUATION OF THE YOUNG ATHLETE WITH OVERUSE INJURY

History

Many patients with overuse injuries are able to continue to participate in their sport for some time before it interferes with their performance. Because of this, some patients may describe the onset of their injury as the point when it began to affect their training. However, it is important to have the patient describe when he or she first became aware of pain in the involved area. This provides a better sense of the duration of the injury process. Have the patient be as detailed as possible in locating the site of the pain, when the pain occurs relative to their activity, and the way in which the pain affects their participation. Pain that occurs with daily activities or significantly limits or prevents participation signifies a more severe injury, compared with cases in which the pain only occurs later in the activity, allowing training to continue to some degree (Table 2).

When taking the history, it is important not to limit the focus only to the information that will lead to the diagnosis. The clinician also should be thorough in assessing for the training errors and other potential factors that contributed to the development of the injury. The sports the patient is participating in and the extent to which they are involved with those activities should be noted. Are they playing on more than one team at a given time? Are they involved in one sport or multiple? Do they work with a private coach or a personal fitness trainer? Outside of their sport training sessions, do they engage in other cardiovascular conditioning or resistance training? Ask whether a new technique or training method was introduced recently. For example, in the case of a runner with anterior knee pain who has not changed his running program but recently began performing squats or lunges, running may not be the issue. Instead, eliminating or modifying the other activities stressing the patellofemoral joint may be the key intervention.

It is essential to ask how many days of rest the child has from the activity each week, and also how much time away from the activity the child has had over the past 6 to 12 months. Note the type of footwear being used and when it was last replaced. Inquire about any previous injuries and how they were (or were not) treated. In girls, menstrual status should be documented.

As described previously, it is important to review growth and development briefly, specifically noting whether the child is in a period of rapid growth. The mean onset of the adolescent growth spurt in girls is approximately 10 yr of age, with peak height velocity occurring on average at 12 yr. For boys, onset is approximately 12 yr, peaking at 14 yr. If an injury occurs during this time without a clear training error or other identifiable factor, the primary reason may be the musculoskeletal changes associated with increasing growth velocity.

Observing the parent-child interactions in the exam room also is important. Is the child simply sitting there quietly while the parent directs the visit, or is the child answering questions and actively participating? Does the child appear to be interested in the activity? What are the hopes of the parent and child for future participation? Are the expectations

TABLE 2. Symptom-guided grading of overuse injuries.

Injury Severity	Symptom Characteristics
Grade 1	Symptoms occur at the end of the activity, or only at initiation, then diminish.
Grade 2	Symptoms develop during activity, late onset, diminish after activity is completed.
Grade 3	Symptoms develop during activity, early onset and persist during remainder of activity, diminishing after activity has ended.
Grade 4	Symptoms develop during activity and limit training frequency, intensity, or duration.
Grade 5	Symptoms prevent training.

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realistic? Have the parents already sought multiple medical opinions regarding the injury? A child who clearly is self-motivated and has appropriately supportive parents requires a different approach than the disinterested child with over-zealous parents. It also is important to recognize that for children with vague complaints or complaints that vary from one visit to the next, the problem may not be an "injury." Instead, the child may be feeling burned out or has lost interest in the sport.

Physical Exam

The physical examination should attempt to localize the injured tissue as precisely as possible. Carefully palpating the painful area is fundamental. In some cases, recreating the loading pattern is needed to reproduce symptoms. Having the patient hop or run in place, or palpating a muscle or tendon at varying joint angles are examples. At times, having the patient perform some aspect of his or her training in a controlled fashion immediately before the exam is helpful. In addition, all of the structures that affect force dissipation of the injured area should be evaluated, including an assessment of alignment, flexibility, joint laxity, and muscle tone. Both extremities should be compared. This will allow for the identification of intrinsic factors that may have contributed to the injury, such as malalignment, joint instability, or muscle imbalances. For some overuse injuries, it may be difficult to localize or reproduce the pain on examination (*e.g.*, some physeal stress injuries, chronic exertional compartment syndromes). In other cases, what may seem to present as an overuse injury actually may be an underlying problem that is being revealed via the sport activity (*e.g.*, bone or soft tissue tumor).

Diagnostic Studies

Many overuse injuries can be diagnosed and treated initially without the need for diagnostic imaging. In some cases, however, imaging is needed to establish the diagnosis. For suspected stress reactions, physeal injuries, or other bone lesions (OCD), radiographs are helpful. Comparison views can be helpful, especially when evaluating for physeal injuries. Radiographs particularly are important to obtain in cases that do not improve as expected with treatment. These cases create concern for less common diagnoses such as tumors. If plain radiographs are not diagnostic for suspected bone injuries, bone scans, computed tomography (CT), and MRI can be used. The choice of study depends upon the specific case. Bone scans can be used in evaluating suspected extremity stress reactions, and single photon emission computed tomography (SPECT) is especially helpful for spondylolysis. MRI is now used commonly to diagnose stress reactions, including those of the physis. In addition, musculoskeletal ultrasound is being used increasingly to assess overuse injuries, particularly tendonopathies. If exertional compartment syndrome is suspected, compartment pressure testing is needed to confirm the diagnosis. Other studies, such as CT scans, electromyography (EMG) and nerve conduction studies, duplex scans, and magnetic resonance (MR) angiography are considered in selected cases.

TREATMENT

The overall goal of treatment is to promote healing of the injury and to develop strong tissue that will be able to absorb the loading created during sport participation, thus enabling a successful return to participation. How best to achieve this is not well studied. The discussion here represents a general approach that should be modified based upon individual patient characteristics, the specific injury, and any relevant supportive research.

The first step is to protect the injured site by reducing tissue loading. This will decrease the mechanical stress to the injured area, halting the overuse process. Training will need to be modified, although complete rest from the activity may not be necessary. In part, this can be determined based upon the type of injury and the clinical assessment of the injury severity. For example, a stress reaction of the compression side of the femoral neck initially requires protection from all weight-bearing stress to the joint, while a stress reaction of the fibula may be treated with the use of a brace and a reduction in training to allow for some level of continued participation.

For physeal stress injuries, a sufficient period of rest is key. At least 6 wk is needed, and in some injuries the length of time can be on the order of several months. In these cases, repeat radiographs can demonstrate the extent of the healing and can help guide the treatment. Bracing generally is not needed for these injuries unless pain is occurring during routine daily activities.

Other training activities that do not stress the injured site generally can be continued. To offset the overall reduction in training, alternative activities that do not stress the injured tissue can be added. Examples include cycling, swimming, or running in a pool with the use of a flotation vest.

For many patients, pain is alleviated simply by reducing or temporarily eliminating the loading of the injured site. For persisting symptoms, ice or other methods of cold application are helpful. Ice also can be used throughout the treatment period to treat any symptoms that may occur during rehabilitation. Acetaminophen may be used for pain relief if symptoms do not respond to rest and ice. Nonsteroidal anti-inflammatory drugs (NSAID) do not appear to have any benefit in overuse injuries beyond their analgesic properties. Moreover, basic science studies have demonstrated that NSAIDs slow fracture healing (38). Although the clinical relevance of these findings for overuse injuries of the bone (*e.g.*, stress reactions, medial tibial stress syndrome) is not clear, this should be considered when contemplating their use.

Once pain has been addressed and adequate healing is underway, a comprehensive rehabilitation program should be initiated to restore tissue strength and flexibility. Proprioceptive retraining also is an important component of the rehabilitation plan. As strength and flexibility improve, general conditioning and then sport-specific activities are phased in. As the patient progresses and is able to perform sport-specific skills without pain, a full level of training is resumed.

Avoiding Reinjury

In order to avoid a recurring injury, a plan should be developed that addresses the factors that contributed to the injury. This process begins with educating the athlete,

parents, and coaches on the nature of the injury, how it occurred, and specific ways in which it can be avoided in the future. The importance of periods of rest, training modifications, equipment, and technique issues should be part of the consultation. Engaging the athlete and parents in a discussion of short- and long-term expectations should be included at this point if such issues were felt to play a role.

PREVENTION

It generally is believed that the majority of overuse injuries are preventable (5). However, there are little in the way of controlled studies that provide data to guide prevention efforts. With this in mind, some ways in which overuse injuries may be reduced include:

- *Having preparticipation exams*. These may reveal prior injury patterns and can be an opportunity to gauge cognitive and physical maturation and motivation.
- *Ensuring appropriate parental supervision and coaching*. Sport organizations and parents should advocate for workshops to provide coaches with basic education regarding overuse injuries common to their sports and ways in which they can be avoided. Local physicians can be sought to assist in implementing this effort. Children should not be encouraged to "play through" pain or injuries.
- *Recognizing sport readiness*. Coaches and parents should be aware of the variability of cognitive development in young children and how this may affect their sport participation. Expectations and instruction should be geared to this aspect, as well as physical development.
- *Assessing equipment*. As technology evolves, leagues and parents should determine what sort of equipment is appropriate for a given sport and take care that the equipment is fitted properly for youth of varying sizes. Worn or poorly-fitted equipment should be replaced.
- *Avoiding training errors*. Training should focus on general fitness and skill acquisition. While repetition is necessary for skill progression, excessive training volumes should be avoided. Although individual situations vary, the 10% rule — limiting increases in training frequency, intensity, and duration to no more than 10% per week — serves as a general guide (5,11).
- *Delaying single-sport specialization*. Parents should promote sport diversification, especially at younger ages. Allow children to experiment with different activities to develop skills and interest and to prevent burnout. The American Academy of Pediatrics recommends avoiding sport specialization before adolescence (4).
- *Ensuring rest and recovery*. At least 1–2 d of rest each week is essential in providing time for recovery and adaptation to the physical and emotional demands. An additional extended period of time away from sport-specific training and competition is recommended on a yearly basis (11).
- *Avoiding overscheduling*. Parents should be very cautious about having their children competing on more than one team at the same time, especially if by doing so, the child does not have 1 to 2 rest days each week.
- *Monitoring training during the adolescent growth spurt*. It may be appropriate to modify training during this time period because of the increased injury risk associated with the growth-related musculoskeletal changes that occur.

CONCLUSION

Overuse injuries are common in children participating in sports, particularly among the segment who engage in training and competition on a nearly continuous yearly schedule. In addition, growth-related factors create special circumstances that contribute to overuse injuries in this population. Although the diagnosis of many of these injuries can be straightforward, a thorough evaluation to identify the factors that may have contributed to the injury is important in developing a comprehensive rehabilitation program and in avoiding reinjury. A special focus on educating parents, children, and coaches on strategies to prevent overuse injuries is a key aspect of injury management. With careful attention to these issues, young athletes will best be able to recover from injury and enjoy the many benefits of participation in sports and athletic activities.

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