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Overuse and Throwing Injuries in the Skeletally Immature Athlete

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Abstract

Over 25 million children participate in school-sponsored sports, and an additional 20 million participate in extracurricular organized sports. Over the past decade, increased intensity of training, more pressure for success, new opportunities for structured play, and more organized advanced leagues and traveling teams have led to a corresponding increase in overuse injuries in the skeletally immature athlete. Perhaps the classic sports model for overuse injuries of the upper extremity is baseball. Throwing sports contribute to an increased incidence of elbow and shoulder injuries that might be related to intensity of training, throwing mechanics, and poor conditioning, including core strength. Specific areas of concern regarding overuse injuries in young athletes include such diagnoses as little leaguer's shoulder, little leaguer's elbow, osteochondritis dissecans of the elbow, tennis elbow, and distal radial epiphysitis. Ultimately, overuse injuries, and particularly physeal injuries, should be suspected in any young athlete who has pain in the upper extremity. Comparative bilateral radiographs are the rule in workup.

Compared with adult athletes, the skeletally immature athlete has unique issues regarding treatment and injury patterns. Poor technique or mechanics that increase loads across the physis make the skeletally immature developing athlete prone to injury. Coordination and physical skills are dynamically changing. When performed properly and with gradual progression of intensity, strength training for children and adolescents is a safe undertaking.[1] Nonetheless, acute changes in intensity or weight place the growing physis at increased risk of injury. Although the weak link in the young athlete is generally considered to be the physis, muscle-tendon, ligament, and other bone injuries can occur secondary to acute trauma or overuse. Injury to the physis can cause long-term disability, deformity, or shortening. Each potential physeal injury should be evaluated with comparison views of the opposite extremity. The contribution each physis has to total growth and the timing of appearance and closure of the growth plates should also be determined (Figs. 1 and 2).

Acute Injury/Overuse Injury

Acute injuries occur secondary to a single traumatic event or a catastrophic failure of structure. Fractures of the upper extremity are a common injury; the most common site is the distal radius physis, followed by the distal humerus and the fingers[2-4] (Table 1).

An apparently acute injury can occur in the presence of chronic problems or pathologic processes that reduce the young athlete's threshold for injury. If the energy involved in the injury mechanism is not consistent with the severity of the injury in the young athlete, heightened suspicion for an underlying process is warranted. Fortunately, fractures through unicameral bone cysts usually lead to healing of both fracture and cyst and allow for full return to sport (Fig. 3).

Overuse injuries in children imply some activity or demand that resulted in repetitive load and stress to the immature skeleton.[5,6] This scenario may be secondary to stresses that were too great, too frequent, or advanced too quickly. The physis is susceptible to overuse leading to pain, widening, weakened bone strength, and growth abnormalities. Muscle-tendon units may have elevated risk of overuse injuries in the actively growing child because as the bone lengthens, the muscle-tendons have to stretch to keep up. This relative tightness and related poor flexibility place young athletes at increased risk of muscle-tendon strains, avulsion injuries, and muscle tears. Fortunately, chronic tendon breakdown

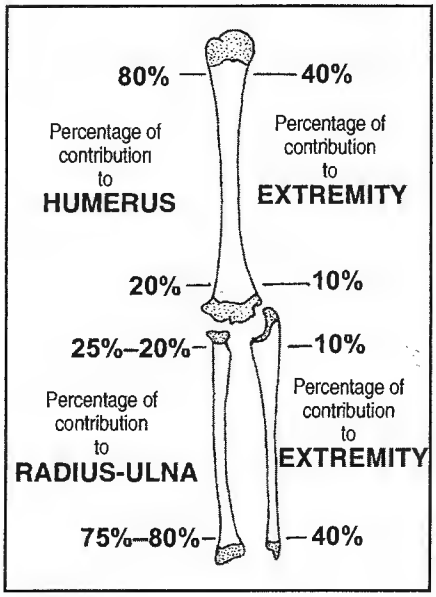

Fig. 1 Percentage of contribution to specific bone is shown on the left, and percentage of contribution to the entire upper extremity is shown on the right.

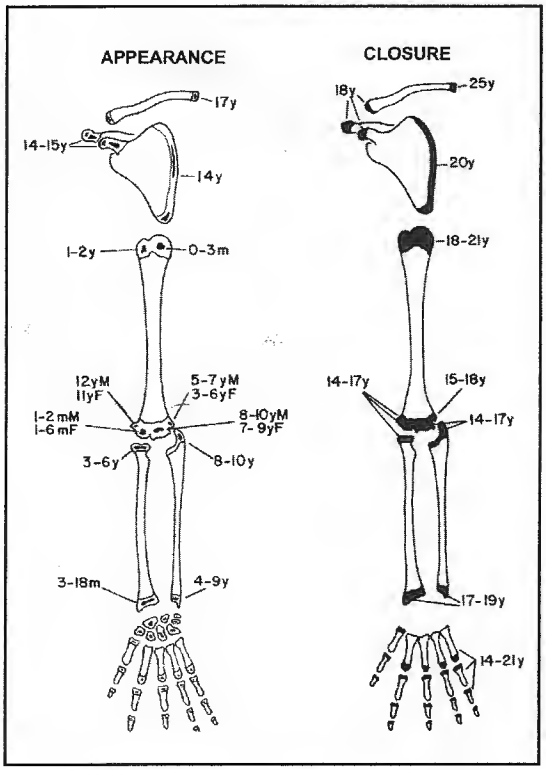

Fig. 2 The times of appearance *(left)* and closure *(right)* of the secondary ossification centers of the upper extremity. y = years, m = months, M = males, F = females.

Table 1
Epiphyseal Fracture Rates: Upper Extremity

	Ogden		Peterson		Neer	
	n	%	n	%	n	%
Distal Radius	197	43.1	98	48.5	1,096	61.5
Distal Humerus	108	23.6	20	9.9	332	18.6
Distal Ulna	13	2.8	12	5.9	136	7.6
Proximal Radius	12	2.6	1	0.5	124	7.0
Proximal Humerus	41	9.0	22	10.9	72	4.0
Phalanges	55	12.0	39	19.3		
Metacarpals	9	2.0	10	5.0		
Proximal Ulna	9	2.0			21	1.2
Proximal Clavicle	8	1.7				
Distal Clavicle	5	1.1				
Total	457	100	232	100	1,781	100

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(tendinosis) occurs less frequently in children than adults because of less repetitive motions. A club-level 50-year-old tennis player would have had many thousands more backhands than a 16- to 18-year-old elite player, which explains the reduced incidence of tennis elbow in the younger age group.

Changes in equipment and rules that target safety have the potential to somewhat reduce the risk of acute traumatic injuries of children in sport. However, the best opportunity to reduce the total number of injuries in youth sports is training in correct technique for the particular sport. In Little League baseball, acute traumatic fractures are commonly related to contact with the ball, a base, or another player rather than throwing. Helmet use and breakaway bases have been proven to reduce injury. Overuse arm pain is very common in young baseball pitchers.[7] Interventions targeted to reduce overuse injuries in young throwers have included limiting the total number of innings allowed per week and total pitch counts. Unfortunately, quality long-term follow-up studies regarding the efficacy of such interventions are unavailable. Further prospective research is needed to evaluate the effect of the safety interventions suggested not only for baseball but for all childhood sports.

The Shoulder

The differential diagnosis of shoulder complaints in the skeletally immature

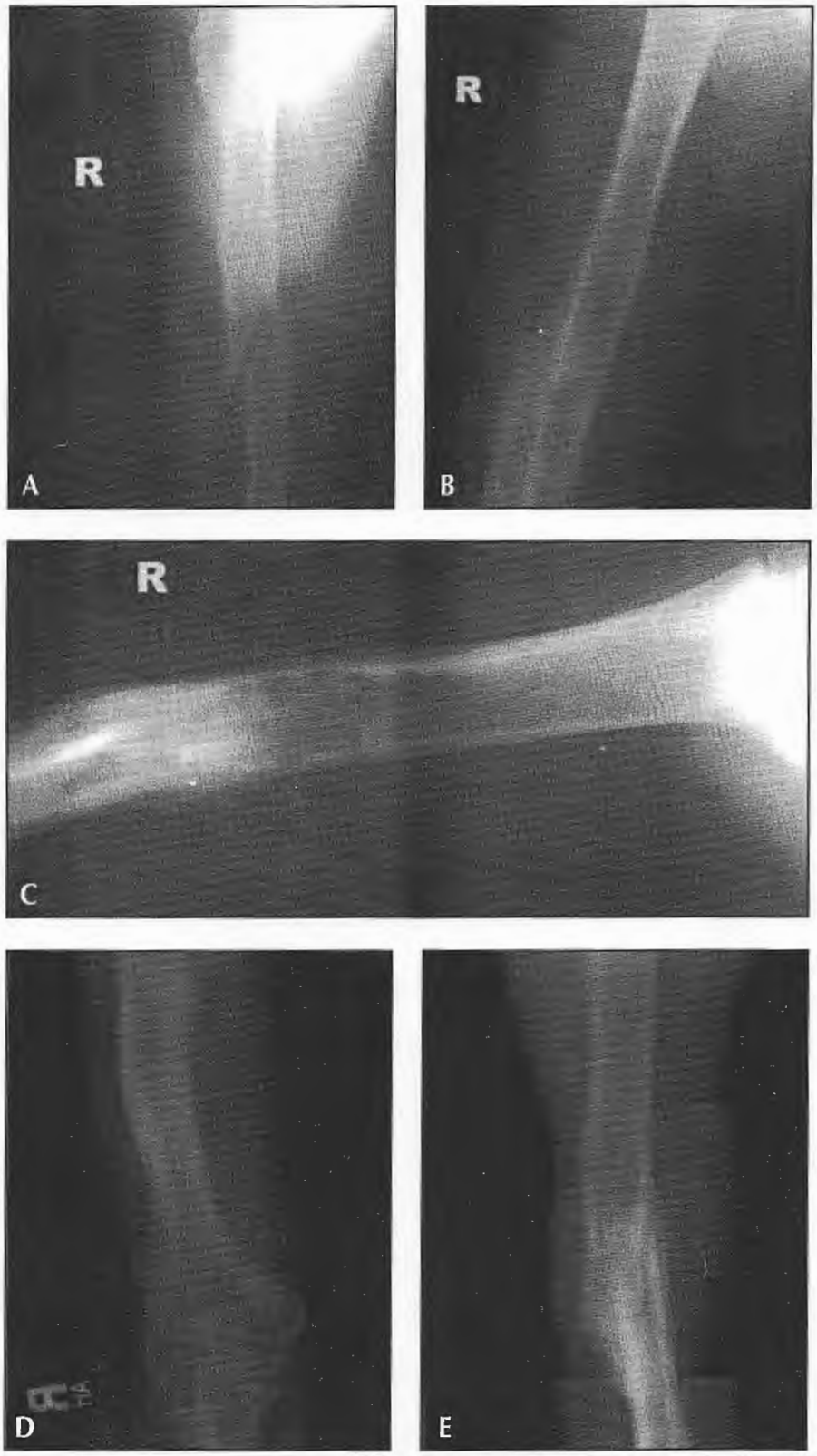

Fig. 3 A, Diaphyseal humerus fracture in an 11-year-old pitcher who felt acute pain in his arm. At 2 months, the unicameral bone cyst can be more clearly seen in the AP (**B**) and lateral (**C**) views. **D** and **E,** Follow-up radiographs show complete healing of the fracture and healing of the cyst.

shoulder includes little leaguer's shoulder (a physeal injury of the proximal humeral physis), osteochondrosis of the proximal humerus, instability, and impingement.[8-11] In general, impingement of the rotator cuff is a disease pattern that occurs secondary to chronic overuse. It is much more common in older athletes because of the higher number of repetitions and stresses to which these athletes' shoulders have been exposed. Young athletes may sustain rotator cuff injuries and strain secondary to repetitive loading or an acute traumatic event; however, signs and symptoms of classic impingement should raise concern about underlying instability. Traumatic injuries such as fractures and dislocations can also occur.[12,13]

Overthrowing the shoulder with associated poor mechanics places increased forces across the anterior capsule and shoulder joint. Children should be taught to throw with proper mechanics, including good foot push-off, solid and strong core stability, and trunk rotation. Proper throwing technique will allow the athlete to achieve the same speed as his or her cohorts without placing pathologic energy demands on the shoulder. Recurrent anterior loads in the cocking phase of throwing have been associated with labral detachments and capsular stretching in older athletes. A young athlete's shoulder is exposed to similar forces and is prone to similar failure if repetitions are too frequent or loads too high. More commonly, however, the weak link in the young thrower's shoulder is the physis and not the capsuloligamentous structures.[14]

Little leaguer's shoulder is a term coined by Dotter[15] in 1995 regarding the relatively common complaint of proximal shoulder pain in Little League pitchers. It is commonly correlated with a stress fracture of the proximal humeral physis. The more innings pitched and greater total number of pitches thrown per week results in an increased risk of arm pain.[16]

Fig. 4 A, Radiograph of a 14-year-old baseball pitcher who developed pain a month prior to radiographs that show stress fracture of the proximal humeral epiphysis. **B,** The opposite side demonstrates the normal undulating proximal humeral epiphyseal plate. **C,** Axillary lateral view of the right shoulder shows the lysis at the metaphysis across the epiphyseal plate suggestive of stress injury.

Overuse and poor technique have also been implicated as contributing causes. The athlete complains of pain over the proximal humerus that is worse with extremes of motion. Direct palpation over the physis is usually very painful. Percussion at the elbow may also exacerbate pain. Onset is usually gradual, although the athlete will occasionally be able to describe a single pitch that brought on the initial complaints of pain. Evaluation should always include comparative imaging studies of the opposite side because subtle physeal widening may easily be missed (Fig. 4).

Treatment is based on the patient's age, symptoms, and amount of displacement or angulation. With over 4 years remaining for expected skeletal growth, angulations of 45° with well over 50% displacement can be expected to remodel. With increasing skeletal maturity or greater deformity, closed reduction and percutaneous pinning may be indicated. Fortunately, most proximal physeal injuries in throwers are subtle with minimal displacement. A sling is used for comfort until symptoms resolve. Early range of motion is allowed but return to sports activity should be delayed for at least 3 to 4 months to prevent recurrence. When the athlete does return to sports activity, progression of intensity and number of pitches should be gradual. A knowledgeable coach should evaluate the athlete's mechanics and throwing style. The parents should be counseled to count the number of pitches and not just the number of innings to reduce the risk of overuse and recurrence.

Proximal humeral osteochondrosis was described by Adams in 1966.[17] It is a rare problem that is in the family of osteochondroses including osteochondritis dissecans of the elbow, Legg-Calvé-Perthes disease of the hip, Sever's disease of the calcaneus, and Osgood-Schlatter's disease of the knee. It is likely a vascular phenomenon, exacerbated by overuse in an athlete, that has some genetic predisposition. Imaging studies will reveal fragmentation of the proximal humeral epiphysis. Treatment for nondisplaced fragments is rest and a reduction of stresses about the shoulder. Throwers should refrain from throwing until symptoms resolve.

Acromioclavicular and sternoclavicular injuries are relatively rare in children, accounting for only 15% of all clavicle injuries and with the medial clavicle injuries accounting for less than 1%. Injuries are usually physeal and not ligamentous. Isolated ligamentous injury is virtually unheard of before age 13 years.[18,19] Treatment is generally conservative to allow the physis to remodel. A sling is usually adequate, although some authors prefer a figure-of-8 swathe. If severe displacement is present, acromioclavicular joint injuries or posterior sternoclavicular dislocations with associated impingement on vital structures should be reduced or (in the case of a posterior sternoclavicular joint fracture/dislocation) converted to an anterior dislocation.

The Elbow

Overuse and throwing injuries about the skeletally immature elbow can be categorized as acute versus chronic or by mechanism of injury. Classification by mechanism of injury is particularly helpful in creating a thorough differential diagnosis to make the most accurate diagnosis (Table 2). Determining the onset and type of injury (acute, chronic, or acute-on-chronic) cannot only guide the expected prognosis but also assist in avoiding missing an underlying factor or cause.[20,21] Further subclassification involving anatomic compartment (medial, lateral, and posterior) will help ensure that associated injury patterns are not missed. A specific diagnosis is important to guide treatment and to better advise the athlete regarding return to play. The term little leaguer's elbow, coined by Brogdon and Crow in 1960,[22] is nonspecific and can account for a myriad of conditions related to the pathologic forces of the immature elbow when throwing. This term should be avoided as a specific diagnosis.

During throwing, compression forces occur laterally, and tensile forces occur medially (Fig. 5, *A*). Tensile forces can cause injuries over the medial, lateral, or posterior aspects of the immature elbow. Medial tension can lead to muscle strains of the flexor muscles, collateral ligament injuries, and avulsions of the medial epicondyle. Lateral tension can lead to muscle strains and tendinosis of the extensor muscles. Posterior tension can lead to avulsion or apophysitis of the olecranon apophysis. Compression forces in throwing or weight bearing, including radial head hypertrophy, radial head fractures, osteochondritis dissecans, and capitellar fractures, have been implicated in causing changes in the lateral compartment of the elbow (Fig. 5, *B*). Posterior compression or impingement can lead to olecranon spurring or loose bodies.

For the skeletally immature throwing athlete, the common injury pattern is a blend of mechanisms called valgus-extension overload. During the cocking and acceleration phases of throwing, the medial structures of the elbow are placed in tension and the lateral structures are placed in compression, potentially leading to injury. In the follow-through phase of throwing, the elbow is locked in extension, leading to stresses on the olecranon, triceps, and olecranon fossa. Laxity in the medial structures, in turn, leads to impaction of the medial border of the olecranon in the olecranon fossa. In addition to these findings, chronic clinical findings can include an increased valgus carrying angle, flexion contractures, pain with throwing, medial epicondyle hypertrophy or fragmentation, and trochlear or olecranon fragmentation.[9,23-26]

Osteochondritis Dissecans

Osteochondritis dissecans, usually seen in patients age 10 to 14 years, is vascular compromise of the capitellum that has been related to repetitive compressive forces. Panner's disease is a similar appearing osteochondrosis that presents in patients age 4 to 8 years.[27] Segmentation of cartilage and subchondral bone is seen on radiographs. Osteochondritis dissecans is more common in males but that

Table 2
Differential Diagnosis of Elbow Injuries of the Immature Skeleton

Medial	
	Acute
	Avulsion fracture medial humeral epicondyle
	Flexor/pronator strain
	Fracture trochlea/distal humerus
	Ulnar collateral ligament sprain
	Ulnar nerve subluxation (Neuritis)
	Chronic
	Fracture medial epicondyle
	Ulnar neuropathy
	Ulnar nerve subluxation
	Medial humeral epicondylitis
	Traction spurs coronoid process
	Valgus extension overload
	Ulnar collateral instability
Lateral	
	Acute
	Osteochondritis dissecans capitellum
	Osteochondral fracture capitellum
	Avulsion fracture lateral humeral epicondyle (Apophysis)
	Fracture capitellum/distal humerus
	Anterior subluxation radial head
	Fracture proximal radius
	Fracture radial head—dislocation radial head
	Chronic
	Lateral humeral epicondylitis
	Radial head hypertrophy/ overdevelopment
	Loose bodies
	Osteochondritis dissecans capitellum
	Osteochondritis radial head
Posterior	
	Acute
	Olecranon fracture
	Olecranon apophysitis
	Olecranon spur with fracture
	Triceps strain
	Olecranon bursitis
	Dislocation
	Chronic
	Olecranon traction apophysitis
	Olecranon spurs
	Loose bodies
	Synovitis
	Posteromedial spurs
	Valgus extension overload
Anterior	
	Acute
	Biceps strain
	Distal physeal humerus fracture
	Chronic
	Loose bodies
	Adhesions
	Synovitis
	Capsular sprain

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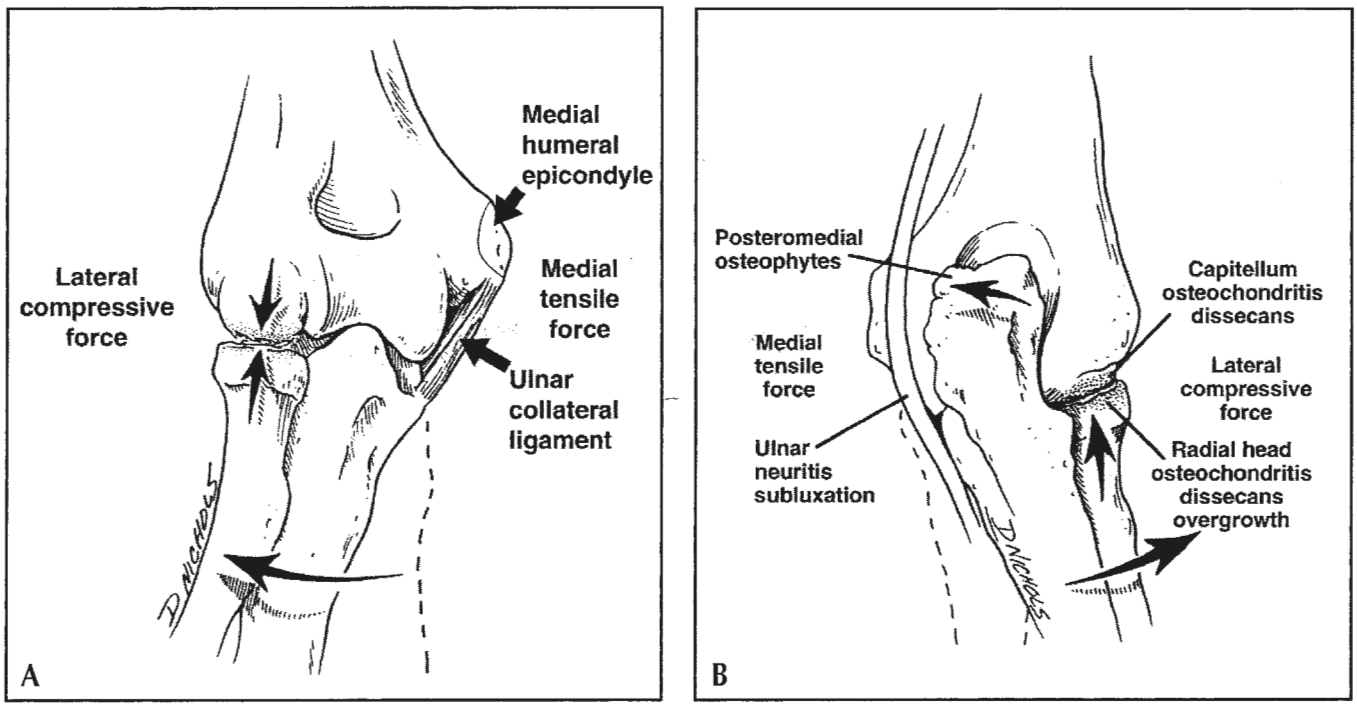

Fig. 5 Forces at the elbow are compression on the lateral side and tension of the medially side. The ulnar collateral ligament attaches lateral to the medial humeral epiphysis. When skeletally immature, medial forces cause medial humeral epicondyle stress fracture rather than ulnar collateral ligament sprain as seen in adults **(A)**. In chronic conditions, as these forces continue, the medial tensile forces result in ulnar neuritis or subluxation, posterior medial osteophytes. Laterally, the compressive forces result in osteochondritis dissecans of the capitellum, radial head overgrowth and joint incongruity **(B)**. (Reproduced with permission from Andrews JR, Zarins B, Wilk KE (eds): *Injuries in Baseball*. Philadelphia, PA, Lippincott-Raven, 1998.)

may be because of demand and total number of boys throwing compared with girls rather than an absolute genetic predisposition. Age is also a factor, and the earlier maturity of females may be relatively protective. Athletes will complain of pain on the lateral aspect of the elbow in 90% of cases. Other symptoms include loss of motion (55% of patients), symptoms of locking (less than 20%), and an acute onset (14%).[28]

Treatment of osteochondritis dissecans and Panner's disease is guided by the age of the patient, radiographic appearance of an unstable fragment, and the presence of loose bodies. Panner's disease is generally self-limited, does not create loose bodies, and rarely causes long-term problems. Treatment for Panner's disease, therefore, is symptomatic. Young athletes with Panner's disease should be restricted from axial stresses and valgus loading of the elbow (no gymnastics and no throwing).

Varying stages of osteochondritis dissecans exist, ranging from cystic changes to unstable but retained fragments to fragmentation and loose bodies. In general, the earlier the presentation the better the prognosis. As patients with osteochondritis dissecans approach maturity, healing potential diminishes and surgery becomes more likely. The presence of loose bodies and elbow locking is a strong indication for arthroscopy and removal of loose bodies. Once floating free, the fragments can rarely be returned to their bed and should be removed. Athletes with fragmentation and loose bodies may present with elbow pain and locking (Fig. 6, *A*). The capitellum should be carefully evaluated as a potential source of other loose fragments or for the presence of exposed subchondral bone that might be treated with marrow stimulation techniques (Fig. 6, *B* and *C*). Locking, as a symptom, is not always present even when loose bodies are present. The most common presenting complaint is pain with a loss of motion, especially extension.

Specific guidelines in treatment of osteochondritis dissecans lesions can be controversial. Fundamentally, the best option is always to save the athlete's native cartilage.[9,21] Cystic changes and stable fragments should be allowed to heal without surgical intervention by reducing axial or valgus stresses until the fragment has healed. Temporary immobilization can reduce symptoms, but long-term immobilization can lead to stiffness. When evidence of healing is delayed or the patient is resistant to conservative treatment, anterograde drilling that does not violate the chondral surface has been suggested to improve circulation to the region.

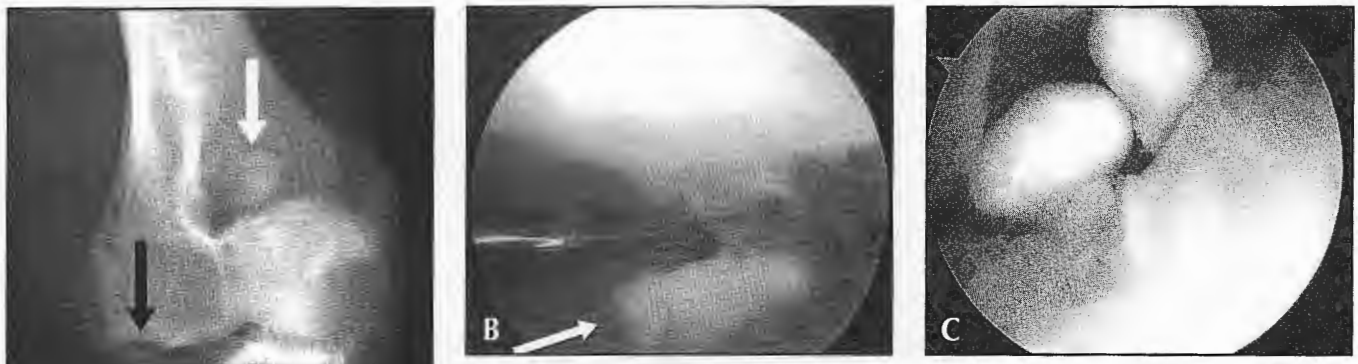

Fig. 6 A, Loose bodies are evident in the olecranon fossa (*white arrow*), and an osteochondritis dissecans lesion is seen at the capitellum (*black arrow*). **B,** Arthroscopic view shows a loose fragment of the capitellum (*arrow*) that required débridement and two loose bodies in the posterior compartment. **C,** Débridement only and no marrow stimulation technique on the capitellum was necessary in this pitcher.

Unstable fragments that remain in their chondral bed can be seen on radiographs and confirmed on MRI as having a fluid line beneath the chondral fragment (Fig. 7). Confirmation of an unstable fragment by MRI should include visualization of an actual chondral defect. Unstable fragments require surgical intervention in an attempt to save the in situ fragment. If the fragment can be elevated, the base is débrided or drilled to encourage a bleeding base for healing. Fixation of the fragment in the past has included anterograde Kirschner wires, small AO screws with subsequent screw removal, and bone pegs. Complications ranging from loss of fixation to fragmentation of the fragment and iatrogenic tibial chondral damage have been described. More recently, headless, variably threaded, metal screws (Accutrac, Acumed, Hillsboro, OR) or Herbert-Whipple screws) can apply some compression at the site and have been used with some success. The fragment must be large enough to tolerate the screw and have a bony component large enough to allow the screw to be recessed but still hold onto the fragment. Current trends of fixation have also included bioabsorbable pins or tacks that reduce or eliminate the need for a second surgery to remove

Fig. 7 A, AP radiograph in this left-hand–dominant baseball pitcher reveals osteochondritis dissecans lesion of the capitellum with open medial humeral epiphysis. MRI scan of coronal **(B)** and sagittal **(C)** views confirm the depth of the lesion and fragmentation of the articular cartilage. **D,** Arthroscopically, the capitellar piece was almost all cartilaginous (*arrow*).

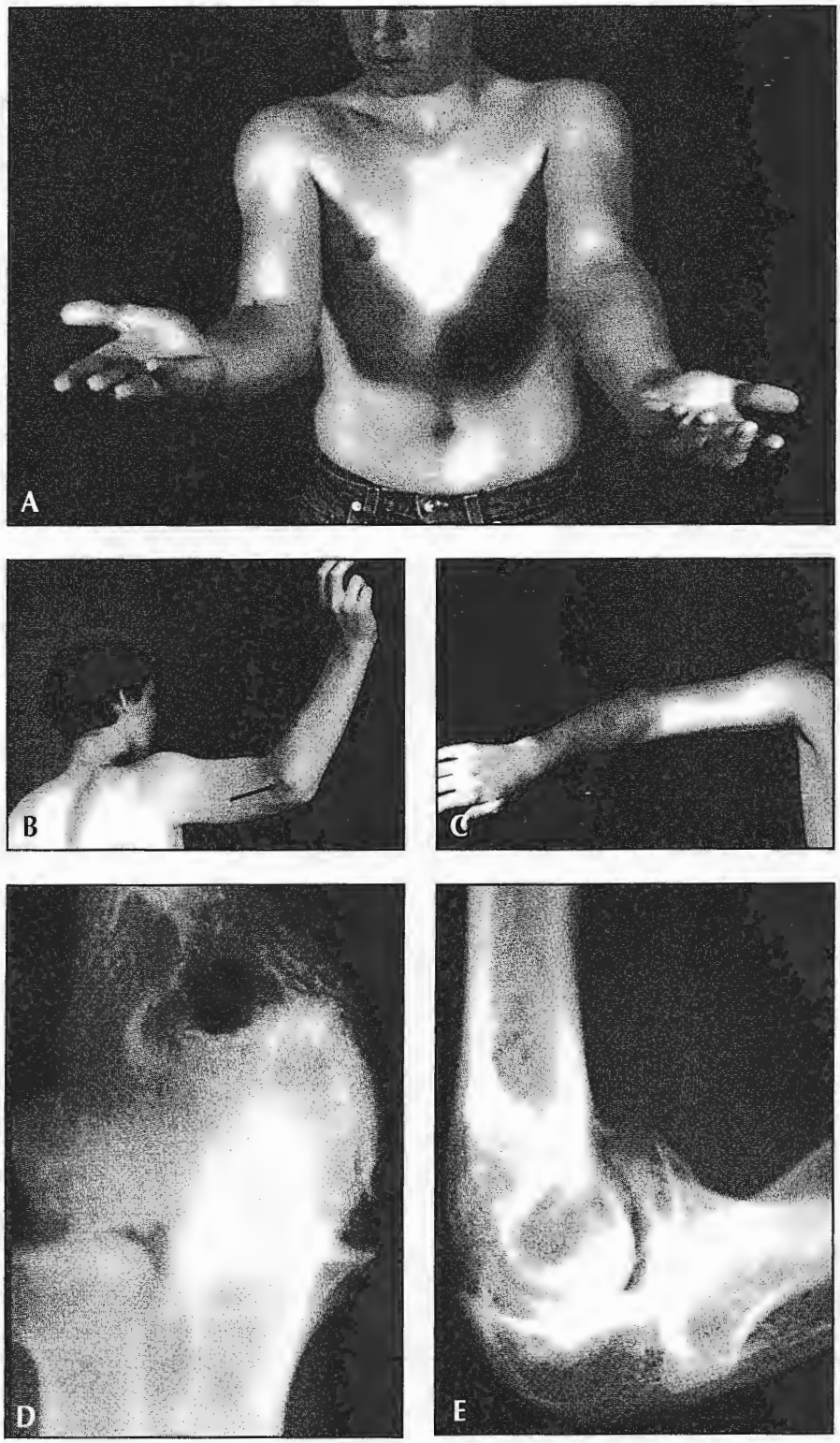

Fig. 8 A former high-school pitcher with painful limited motion of his right elbow, 40° of flexion contracture **(A)** and loss of pronation **(B)**. The radial head is quite prominent (*arrow*) **(C)**. AP lateral radiographs show an irregular capitellum with overgrowth of the radial head **(D)** and spurring of the coronoid anteriorly and joint incongruity **(E)**.

hardware. When the fragment is loose and unsalvageable, the loose piece should be removed. The defect that remains in the capitellum may remodel but many surgeons will drill or marrow-stimulate this region in the hope of covering it with fibrocartilage. Chondral transplants have also been attempted.

The long-term prognosis for displaced osteochondritis dissecans fragments, especially in the older athlete with less than 2 years until skeletal maturity, is guarded. The loose fragments or irregularly shaped capitellum can lead to early arthrosis, stiffness, and dysfunction (Fig. 8). It is in the best interest of the young athlete to be steadfast in restrictions for nondisplaced fragments and aggressive in the treatment of retained stable or unstable fragments to reduce the risk of long-term morbidity.

Medial Epicondylitis and Epicondyle Avulsions

Tension over the medial structures of the elbow can lead to muscle strains, tears of the medial collateral ligament, and avulsion of the medial epicondyle. As stated earlier, the weak link in the skeletally immature athlete is the physis; therefore, medial collateral ligament tears are rare in comparison to adult throwers, and medial epicondyle avulsions are more common in young athletes. Increased risk of medial epicondyle injuries have been correlated with overuse and the total number of pitches an athlete throws per week. An association with a sidearm or curveball throwing technique has also been argued but with less scientific support. Acute trauma can occur; nonetheless, most young athletes can provide a history of medial elbow pain that preceded the ultimate failure. Chronic stresses can lead to chronic changes and hypertrophy (Fig. 9).

Diagnosis is confirmed by localized tenderness, and comparative views of the opposite elbow should always be obtained. Treatment for nondisplaced frac-

tures is symptomatic and may include a short period of immobilization (1 to 3 weeks) followed by early range of motion.[20] Protection against valgus forces and avoidance of resisted flexor strengthening is recommended until symptoms have subsided. As with little leaguer's shoulder, return to throwing should be avoided for 3 months to avoid recurrence; return to sports activity should be slow and progressive. Cross-training focused on core strengthening and stabilization is encouraged throughout the course of treatment. Technique evaluation by a quality pitching coach may also be of benefit to avoid recurrence.

The treatment of displaced fractures is somewhat more controversial.[9] Clearly any fragment that is incarcerated into the joint should be extricated and fixed. Most authors would agree that fragments displaced greater than 1 cm should also be fixed.[29-31] The treatment of minimally displaced fractures is less clear. They may heal with solid bone union but commonly heal with a fibrous union. When fibrous union occurs, high-level throwers, gymnasts, and power lifters may experience chronic pain, weakness, and dysfunction. Therefore, in these select athletes, internal fixation may be the best choice. Perhaps the greatest challenge is identifying the high-level thrower. The determination of surgical intervention in these cases must be made on an individual basis. When a posterior elbow dislocation occurs, some damage to the medial collateral ligament or avulsion of the medial epicondyle invariably occurs. Careful examination should include assessment of neurovascular function and imaging studies before and after reduction and imaging studies to evaluate displaced or intra-articular fragments (Fig. 10).

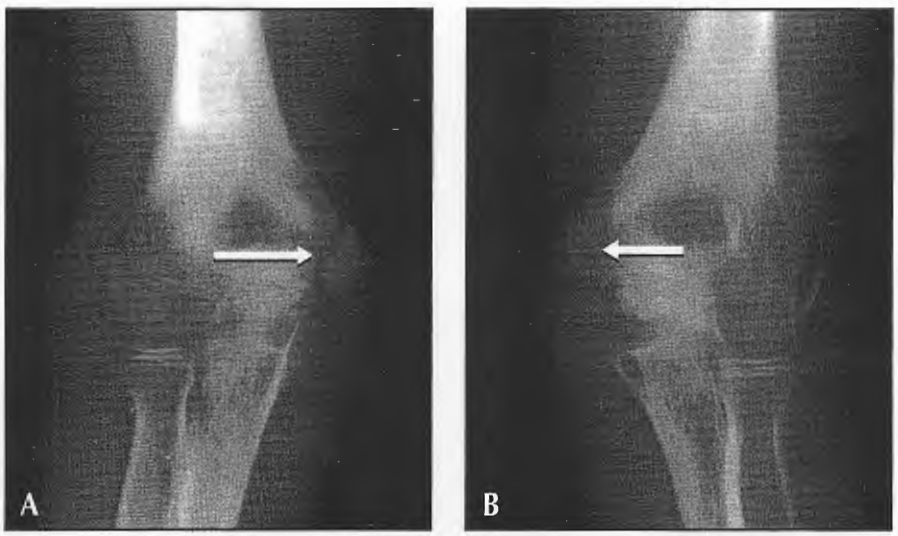

Fig. 9 A, Widening of the medial humeral epicondyle plate and overgrowth are evident in this right elbow (*arrow*). **B,** The nondominant side medial humeral epicondyle is smaller without the radiolucency at the epiphysis (*arrow*).

Tennis Elbow

Tension injuries over the lateral aspect of the elbow occur with the lead hand in hitting sports such as baseball and golf but are most commonly associated with the backhand motion in tennis. While ligamentous injuries are possible, the most common site of pathology is just distal to the lateral epicondyle in the extensor carpi radialis brevis muscle. Pain is exacerbated by extreme wrist flexion with the arm extended and resisted wrist extension. Tennis elbow is more common in adults than children.[32] Over 50% of club-level adult players have had some complaints of lateral elbow pain, whereas fewer than 10% of all boys and girls playing national-level tennis have lateral elbow complaints. Again, tendinosis of the extensor carpi radialis brevis is a problem of chronic overuse, and the young athlete has not yet had enough exposure and repetitions. The incidence of tennis elbow has also been related to grip size (larger being protective), string tension (tighter being worse), racquet size (larger head with bigger sweet spot being protective), and backhand technique (two-fisted being protective).[33]

Treatment is generally symptomatic with rest, ice, deep friction massage, and extensor stretches. Equipment and technique modification may also be helpful in reducing the rate of recurrence. Cross-pressure straps or taping can also be helpful. Nonsteroidal anti-inflammatory drugs should be used cautiously in children. Steroid injections in the skeletally immature athlete should be avoided, and surgical release is rarely if ever necessary or suggested.

Olecranon Apophysitis and Avulsions

Repetitive forceful extension leads to traction along the triceps tendon through the apophysis of the olecranon.[20,21] When the elbow is locked in full extension (follow-through and deceleration phases of throwing), further extension stresses can lead to shear forces across the apophysis. Both tension and shear forces can lead to physeal irritation, widening, or complete failure (avulsion). Like avulsions of the medial epicondyle of the elbow in throwers, complete avulsions in young athletes are associated with overuse and are commonly preceded by a prodrome of achy pain.

Treatment for nondisplaced fractures or olecranon apophysitis is rest, a temporary splint or sling for comfort, and reduction in extension stresses until

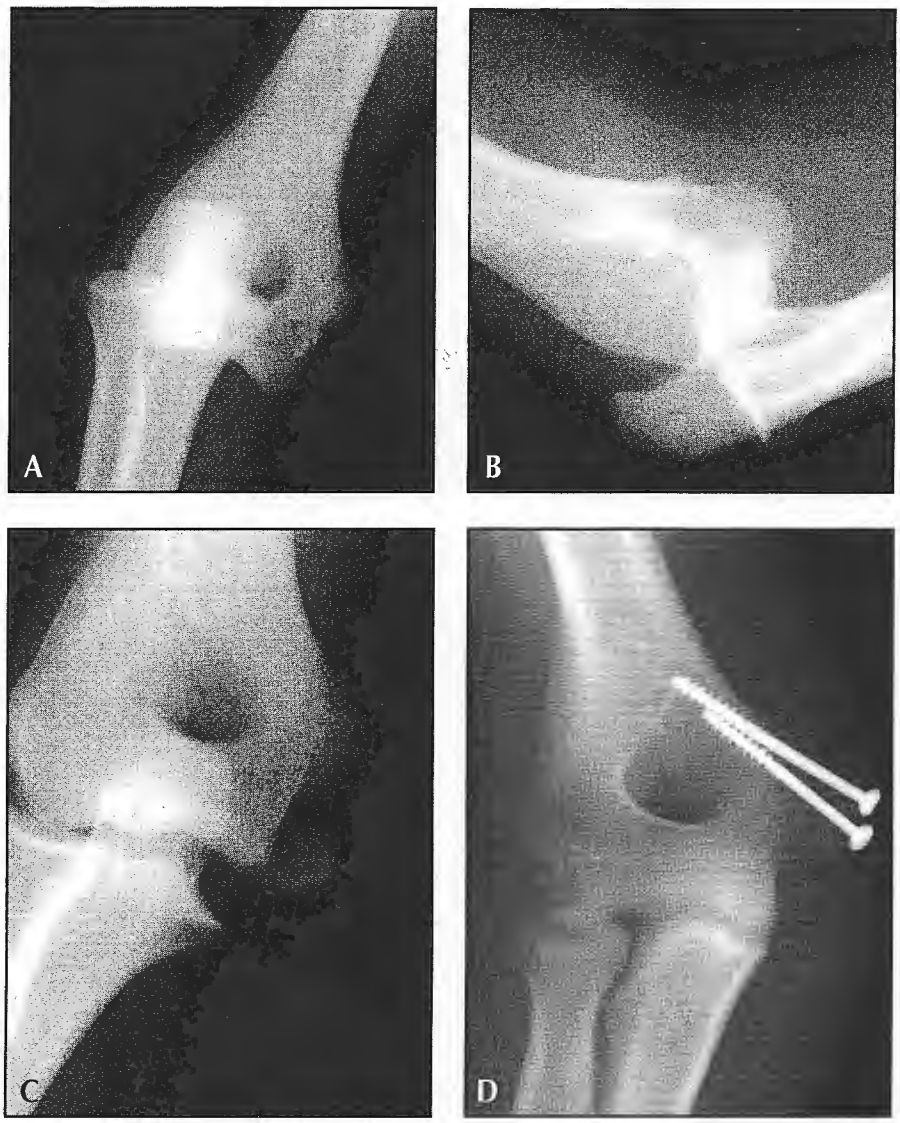

Fig. 10 Posterolateral elbow dislocation occurred in players sliding headfirst into base in AP **(A)** and lateral **(B)** views. **C,** The medial humeral epicondyle displaced fracture is not seen until reduction views. **D,** Open reduction and internal fixation and repair of the capsular injury was performed.

healed. Even after symptoms have resolved, athletes should not return to forceful throwing or upper extremity weight-bearing activities for 2 to 3 months to reduce the risk of recurrence. Displaced fractures imply an extensor mechanism in discontinuity and should be fixed with screws, pins, or tension band technique. Athletes who continue to throw despite an olecranon physeal injury can develop nonunion or resistance to an attempted course of conservative treatment[34,35] (Fig. 11). Surgical fixation can speed healing and time to return to sport.

Olecranon Bursitis and Posterior Olecranon Impingement

If comparative radiographs fail to reveal changes at the olecranon apophysis and the patient has no tenderness over the apophysis, olecranon bursitis or posterior olecranon impingement may be present in young athletes with posterior elbow pain. Olecranon bursitis is usually an obvious diagnosis, with swelling in the soft tissues superficial to the olecranon. The condition is commonly associated with acute or chronic repetitive trauma to the dorsal aspect of the elbow. Radiographs are usually negative but may reveal soft-tissue swelling or calcific densities in the bursa. Treatment is conservative with ice, anti-inflammatory medications, compression wrapping, and elbow pads for return to play. Aspiration and steroid injection have been recommended prior to the need for bursectomy in resistant cases. Any injections or surgeries attempted in this area should be done with caution because of the elevated risk of infection. Perioperative antibiotics are recommended for all surgical bursectomies.

If careful inspection of the radiographs reveals intra-articular loose bodies in the posterior compartment of the elbow or spurs on the medial border of the olecranon, the working diagnosis is likely posterior olecranon impingement. Athletes will generally present with a loss of full extension and pain with forced extension. A locking sensation is good evidence of an intra-articular loose body. Initial treatment begins with optimization of full extension. The presence of intra-articular loose bodies is a good indication for an elbow arthroscopy and removal of the loose bodies. The medial olecranon spur can be débrided at the same time. The prognosis after a simple arthroscopic débridement is guarded. The presence of posterior olecranon spurring and loose bodies is generally a secondary sign of valgus-extension overload. The integrity of the medial collateral ligament should be assessed with physical examination, stress radiographs, and possibly CT or MRI with contrast. Although young throwing athletes may experience improvement with arthroscopic débridement, they are unlikely to return to com-

petitive throwing unless all components of pathology are addressed.

The Forearm, Wrist, and Hand

Although the classic upper extremity regions of concern for the skeletally immature athlete involve the shoulder and elbow, injuries related to overuse and throwing can also affect the forearm, wrist, and hand. Overuse problems of the forearm are rare in children and uncommon in throwing athletes. Activities such as gymnastics that demand weight bearing on the upper extremities are more prone to forearm complaints. Chronic exertional compartment syndrome of the forearm has been reported in skeletally mature collegiate gymnasts but not in children. Stress fractures and stress injuries to the radius and ulna have presented as forearm splints in skeletally mature and immature athletes. Radiographs are commonly negative, but bone scans may reveal diffuse or focal bone changes consistent with periostitis or stress fracture, respectively. Treatment is always conservative, beginning with reduced stresses and loading. Some athletes have returned to competition early with forearm splinting. Nonsteroidal anti-inflammatory agents are discouraged because they may impede the progress of bone healing. As is the case for all stress fractures, the presence of eating disorders is a possibility, and the athlete should be screened with an evaluation of nutrition and energy balance.

Fig. 11 Continued olecranon pain in this pitcher was caused by olecranon nonunion of the apophysis (*arrows*) as seen in AP **(A)** and lateral **(B)** views. The same views (**C** and **D**) show the result of open reduction and internal fixation with tension band wiring and screw placement.

The most common overuse injury at the level of the distal radius and wrist in young athletes is distal radius epiphysitis.[36-38] Pain on the dorsal aspect of the wrist with extension and weight bearing is the major complaint. Comparative radiographs will reveal an asymmetric widening of the distal radial physis. Continued stresses could lead to permanent deformity, radial shortening, and an ulnar positive wrist. These are nondisplaced fractures, and surgery is never necessary. Treatment is based on reduction of stresses. When the athlete is asymptomatic, a gradual progressive return to sport may begin; taping or bracing of the wrist will protect against the extremes of dorsiflexion.

Less common injuries about the wrist in young athletes include carpal tunnel syndrome, Kienböck's disease (lunatomalacia), and tears of the triangular fibrocartilaginous complex.[39] Only two cases of a purely ligamentous wrist injury in skeletally immature athletes have been reported. Physeal injuries or carpal stress fractures are more common. The most common carpal bone injured in all athletes is the scaphoid, and this injury should be suspected in athletes with wrist pain, reduced flexibility, and pain in the anatomic snuff box. Even when radiographs are negative, temporary immobilization is recommended until bone scans or repeat radiographs at 2 weeks are negative. Injuries to the metacarpal and phalanges in young athletes are frequently physeal. Comparison should be made to adjacent physis and to the opposite hand.

Summary

Overuse and throwing injuries that occur in the skeletally immature athlete can

lead to long-term disability and deformity. Therefore, it is imperative to encourage prevention when possible and early recognition of all injuries to prevent progression to a more serious stage. Early recognition can be aided by a high index of suspicion and a dedication to perform complete evaluations, which should always include radiographs of the contralateral side for the skeletally immature patient.

Young athletes usually want to continue sports participation and may play through pain to please their parents, coaches, or peers. Education of athletes, coaches, and parents that pain in young athletes is a key symptom that should not be ignored is important. These athletes can be protected from progression or more serious injury by early clinical evaluation, appropriate radiographs, accurate diagnosis, and tailored care and rehabilitation programs. Fortunately, for a majority of overuse and throwing injuries in the skeletal immature athlete, conservative treatment, thorough rehabilitation, and gradual progressive retraining and reconditioning will allow a full and safe return to sport.

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