Abstract

This article describes a variety of elbow injuries often seen in young, throwing athletes. Understandings of normal skeletal development, as well as the biomechanics of throwing, provide a basis on which to evaluate, diagnose and manage ‘little league elbow’. With emphasis on an anatomically-based differential diagnosis, the pathologic forces placed upon the young thrower’s elbow, and the subsequent injury patterns, are reviewed.

Medial side injuries are the most common and relate to chronic forces of valgus overload produced during the early and late cocking phases of throwing. The majority of this force is placed on the medial epicondyle and produces age-dependent injury patterns, such as apophysitis in childhood and epicondylar avulsion fractures in the more mature athlete. With repetitive valgus overload, lateral side injuries such as Panner’s disease and osteochondritis dissecans of the capitellum and radial head become more apparent. These injuries relate to the compressive forces produced by the late cocking and early acceleration phases of throwing. Finally, posterior injury patterns consistent with olecranon apophysitis and posteromedial impingement, as well as flexion and capsular contracture, can be seen.

The key in the treatment of ‘little league elbow’ is prevention and this responsibility lies not only with the evaluating or team physician, but also with the coach, trainer, parents and officials. Proper throwing mechanics must be emphasised at an early age, and the determinants of elbow injury among young pitchers better understood. Early recognition and proper treatment of such injuries will then prevent later sequelae or functional disability.
With the increasing participation and competitive level of today’s youth sports, more adolescent and paediatric athletes are being evaluated for sports-related injuries. Injury patterns unique to the growing child, and specific to the skeletally immature elbow, have become more apparent and better understood. In 1960, Brogden and Crow coined the term ‘little league elbow’ to describe a medial epicondyle fracture seen in an adolescent pitcher. Today, such a term encompasses a wide range of injury patterns that are not only unique to the immature upper extremity, but also to the specific demands posed by certain sporting activities.

The developing elbow is particularly vulnerable to injury in the paediatric, throwing athlete. Each year, over 2 million children participate in Little League activities. In 1976, little league surveys based in Houston (TX) and Eugene (OR) demonstrated symptomatic elbow pain in 17–20% of all little league throwers. A more recent study found a 26% frequency of elbow pain in 9–12-year-old baseball players. Acute, macrotraumatic injuries such as fractures, dislocations, or avulsions are often seen. More common, however, are the so-called ‘overuse’ injuries such as apophysitis, osteochondritis dissecans (OCD) and physeal growth disturbances. These injuries are the result of repetitive and excessive forces placed on the vulnerable areas of the growing athlete’s elbow.

This article describes a variety of elbow injuries often seen in young, throwing athletes. An understanding of normal skeletal development, as well as the biomechanics of throwing, provides a basis on which to evaluate, diagnose, and manage ‘little league elbow’. An anatomically-based differential diagnosis is provided and individually discussed.

1. Evaluation

Injury patterns unique to the immature elbow are dependent on the stage of elbow development, as well as sport-specific demands. The apophysis is particularly vulnerable in the paediatric athlete and a source of many acute, macrotraumatic and repetitive, microtraumatic injuries. Similar to such overuse injuries as ‘Sever’s disease’ of the calcaneal tuberosity and ‘Osgood Schlatter disease’ of the tibial tubercle, apophysitis involving the medial epicondyle and the olecranon can be seen in the paediatric, throwing athlete. In addition to the physeal and apophyseal cartilage, articular and epiphyseal cartilage is also vulnerable: OCD is a condition seen secondary to repetitive microtrauma to the immature elbow. An understanding of normal elbow development becomes essential in the evaluation of these injuries.

Six secondary centres of ossification are present in the developing elbow, each with a predictable ossification rate throughout childhood. An orderly appearance of ossification begins at the capitellum at 1–2 years of age. This is followed by the radial epiphysis (2–4 years), the medial epicondylar epiphysis (5–6 years), the trochlea (8–10 years), the olecranon (~10 years) and finally the lateral epicondylar epiphysis at ~12 years. Fusion of the common epiphysis is usually seen between 14 and 16 years of age, often earlier in females than males. The medial epicondylar epiphysis is usually the last centre to fuse around 15–16 years of age. And although these centres generally appear as single bony foci, two or more foci at each centre can sometimes appear during early development.

Careful radiographic evaluation and the use of certain radiographic parameters will then allow the evaluating physician to better understand the underlying injury pattern. Measurement of the anterior capitellar inclination, anterior humeral line, anterior coronoid line, and ‘Baumann’s angle’ are reproducible methods of assessing elbow injury and alignment. Radiographs of the contralateral elbow can help to determine if a certain radiographic appearance is an age-related development, a normal variant, or true pathology. Variations in density, position, or fragment size may be subtle findings suggestive of repetitive stress, injury or fracture (figure 1).

Also essential to the treating physician is an understanding of the biomechanics of throwing, common to many sports. The throwing mechanism, especially that seen in pitching, has been well
documented in the literature, as have the tremendous forces produced by this mechanism.[1,10-12] Pitching occurs through 6 main stages. Stage one entails windup, stage two and three comprise early and late cocking, respectively. Stage four comprises acceleration and ends at release of the ball, leading to stage five: deceleration. Stage six entails follow-through. Each stage of throwing produces a unique force upon certain areas of the elbow, thus accounting for the multiple variety of injuries often seen with ‘little league elbow’. For example, both the early and late cocking phase place not only a significant distraction force on the medial aspect of the elbow, but also place a compressive load on the lateral, radiocapitellar articulation. Late cocking can also produce a shear force within the olecranon fossa. In addition, acceleration can produce the well-documented lateral extension overload, thus producing a tension force to the lateral ligaments and lateral epicondyle. With follow-through, hyperextension stress to the anterior capsule and olecranon fossa is present. It is these specific mechanisms that provide the basis for understanding an anatomic-based differential diagnosis for elbow pain in the paediatric thrower. One must keep in mind, however, that the paediatric thrower is different from a high-level, competitive and mature athlete: improper mechanics often produce a dissimilar cocking phase and follow-through in the younger athlete.

2. Differential Diagnosis

The differential diagnosis of ‘little league elbow’ encompasses a group of related injury patterns, which are the result of repetitive and recurrent microtrauma to specific and vulnerable areas of the immature elbow (table I). Medial side injuries are the most common[6-8] and relate to chronic tension forces of valgus overload placed primarily at the medial epicondyle. The medial epicondyle apophysis is the weakest structure on the medial side of the elbow; thus, the majority of pathology seen early relates to apophysitis and fragmentation. With fusion of the secondary centre and increasing muscle strength in the older athlete, avulsion fractures of the medial epicondyle and medial collateral ligament become more common. Isolated ulnar collateral ligament injuries are uncom-
mon in the growing child, seen primarily once maturity has been reached in mid-to-late adolescence. With repetitive valgus overload, lateral side injuries become more apparent. These injuries relate to the compressive forces placed on the lateral elbow joint during the late cocking and early acceleration phases of throwing. Some shear forces are seen during follow-through. Nonetheless, pathologic changes in the capitellum and radius are the most common. Injuries to the extensor origin and lateral extension overload are less frequently seen in the young athlete.

Posterior injuries are also uncommon in young throwers, but the incidence increases with age. Pathologic forces in the form of shear act mainly at the olecranon apophysis. Impingement of the olecranon into the olecranon fossa during the acceleration phase can lead to the formation of posteromedial osteophytes, loose bodies, or chondromalacia.[11] Finally, anterior pathology can result in flexion contracture of the elbow.

3. History and Physical Exam

Appropriate evaluation begins with an extensive history and physical exam. There are several key features of the history that are important for the evaluating physician to remember. Patient’s age, both skeletal and chronological, is important because many of the possible injury patterns are age-dependent. During childhood, medial elbow pain is usually secondary to micro-injury at the apophysis or ossification centre of the medial epicondyle. In contrast, valgus overload during adolescence more commonly produces complete or partial avulsion fractures of the medial epicondyle. Once the medial epicondyle fuses during young adulthood, injuries to the musculotendinous and/or ligamentous complex predominate. Family history can also be important as a positive history of osteochondrosis can increase the likelihood of similar problems or variations in normal osteochondral development.

Pain is the most common presenting complaint and the chronicity or duration of pain must be assessed. An acute onset of symptoms is more suggestive of an avulsion type injury, whereas longstanding pain may signal a chronic, overuse type phenomenon. Location of pain will lead the evaluating physician through the appropriate differential diagnosis. In addition, questions regarding player position, intensity of play, number and type of pitches thrown per game or season, frequency of pitching, and the amount of play time or games missed due to injury should be asked. Previous treatment modalities, as well as the social dynamics between player, parent and coach, must also be evaluated.

Physical exam begins with the inspection of both elbows, assessing for overall alignment and carrying angle of the upper extremities. The presence of swelling, atrophy, or hypertrophy should be identified. Range of motion should be tested and

Table I. Differential diagnosis of ‘little league elbow’

<table>
<thead>
<tr>
<th>Medial</th>
<th>Lateral</th>
<th>Posterior</th>
<th>Anterior</th>
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<tr>
<td>Medial epicondyle</td>
<td>Capitellum</td>
<td>Olecranon</td>
<td>Flexion contracture</td>
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<tr>
<td>apophysitis</td>
<td>osteochondrosis</td>
<td>apophysitis/osteochondrosis</td>
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<td>avulsion fracture</td>
<td>(Panner’s disease)</td>
<td>avulsion fracture/lack of apophyseal fusion</td>
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<td>fragmentation</td>
<td>osteochondritis</td>
<td>posteromedial impingement/osteophytes</td>
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<td>growth disturbance</td>
<td>dissecs (OCD)</td>
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<td>delayed ossification</td>
<td>traumatic osteochondral fracture</td>
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<td>accelerated growth</td>
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<td>Radial head</td>
<td>Olecranon</td>
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<td>Common flexor origin</td>
<td>deformation</td>
<td>apophysitis/osteochondrosis</td>
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<td>Ulnar nerve neuritis</td>
<td>Lateral extension overload</td>
<td>avulsion fracture/lack of apophyseal fusion</td>
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documented, comparing flexion, extension, pronation and supination to the contralateral, non-painful elbow. Palpation of all bony protuberances, including the medial epicondyle, the radiocapitellar joint and the posterior olecranon apophysis, may reveal tenderness and true pathology. Elbow stability is also evaluated, ideally testing the lateral ligamentous structures with a varus stress applied to an internally rotated, pronated arm, and medial structures via a valgus stress applied to an externally rotated, supinated arm with the elbow flexed ~25°. General evaluation of the neck, ipsilateral shoulder and wrist is also important, as well as a complete neurological assessment, specifically the ulnar nerve.

Following a complete history and physical exam, routine radiographic evaluation in the form of anteroposterior, lateral and oblique views is indicated. As stated previously, contralateral elbow films are invaluable in differentiating true pathology from normal or slightly variable development. Stress radiographs may aid in the evaluation of underlying instability. Magnetic resonance imaging (MRI) is often indicated to evaluate the displacement of fractures, delineate the extent of OCD or identify the presence of loose bodies within the joint. MRI can also be diagnostic for medial collateral ligament avulsions or isolated disruptions. Rarely, ultrasound or a three-phase bone scan can be helpful to identify certain overuse injuries.

4. Medial Side Injuries

On the medial side of the immature elbow, tension secondary to valgus stress is the main pathologic force. The majority of this force is placed on the region of the medial epicondyle, producing varying patterns of injury (figure 2). As stated, these injuries are age dependent: in childhood, the apophysis is the weakest structure and thus especially vulnerable to injury. With maturity, avulsion fractures are common, followed by ligamentous injury and stress to the flexor-pronator mass once skeletal maturity is reached. Regardless, most patients present with medial-sided elbow pain. Throwers often complain of decreased ability to throw hard or far distances. Patients usually present with point tenderness, often with a localized effusion, and may have a flexion contracture of up to 15°.

Medial epicondyle apophysitis is a typical overuse syndrome seen in young athletes. Such athletes are still learning proper throwing mechanics, thus exposing the elbow to abnormal, and excessive forces while often times throwing unlimited numbers of pitches at full effort. Radiographs can reveal slight widening of the apophysis and/or fragmentation of the epicondyle ossification centre. With chronicity, accelerated growth and gradual deformity of the epicondyle can be seen. In addition, changes in the radiocapitellar joint may signal long-standing disease and pathologic compression overload laterally.

The treatment of apophysitis is one of rest. This comprises a short period of 4–6 weeks when patients are asked to stop or decrease the level, duration, and amount of throwing. Pitchers are put through a position change, to first base or designated hitter, allowing continued participation but decreased stress to the elbow. Nonsteroidal anti-inflammatory medication and ice can also help. Immobilisation is used only if symptoms are severe. In general, once symptoms have abated the patient may resume via a progressive strengthening and throwing programme, on average 6–8 weeks from onset. If symptoms return, complete cessation of play for the season is indicated.10

Acute, macrotraumatic avulsion fractures of the medial epicondyle occur secondary to a substantial and immediate valgus stress applied to the elbow. Some reports suggest that up to 30–50% of these injuries are associated with an elbow dislocation.9 It is these injuries which may present with incarceration of the fracture fragment within the joint. Some investigators believe this to be the only absolute indication for open reduction and internal fixation of this fracture.9,13 The amount of fracture displacement determines the treatment. Displacement is determined by those structures that remain attached to the fragment and thus provide a deforming force. Wood and Tullos14 catego-
rised these fractures into two types. Type I fractures occur in young children and present with a large, often rotated, fragment due to the attached anterior oblique band of the ulnar collateral ligament complex. Type II fractures occur in the adolescent with a smaller fracture fragment secondary to the avulsion of a flexor tendon attachment, leaving the ligamentous attachments intact. Neverthe-

less, significant controversy exists with regard to the treatment of such injuries.

Conservative treatment is universally agreed upon for nondisplaced or minimally displaced fractures. These may be seen radiographically as a loss of parallelism between the smooth sclerotic margins of the physis or via an increased width of radiolucency at the physis. Treatment entails a

Fig. 2. Injury patterns of the medial epicondyle. Images reveal the varying patterns of injury occurring at the medial epicondyle. From apophysitis (a) to a displaced fracture requiring open reduction with internal fixation via two screws (b) and (c). Finally to fragmentation of the medial epicondyle (d) and, as seen on the final lateral image, a displaced, intra-articular fragment requiring prompt treatment (e).
short period of immobilisation for comfort and emphasises early range of motion, beginning at 1–2 weeks post injury. Patients should avoid early, aggressive passive range of motion, rather limiting their activity to active range of motion only. Patients are able to begin throwing at ~6 weeks or upon radiographic evidence of fracture union. The main complication of non-operative treatment is stiffness, thus making early motion imperative.

Disagreement over the amount of displacement indicative of open reduction with internal fixation (ORIF) results from studies which suggest that subsequent non-union, or the amount of fracture displacement does not influence outcome. In a recent retrospective review of 42 patients, Farsetti et al. concluded that nonsurgical treatment of medial epicondyle fractures displaced >5mm produced similar long-term results to those treated surgically. All patients treated in a long-arm cast showed no signs of instability and no effect secondary to non-union was found.

In contrast, numerous authors have produced good results with operative treatment for displaced fractures. Many advocate uniform operative treatment for those fractures with over 2mm of displacement. Others feel that if instability is present, especially in a high-level athlete, then ORIF is indicated regardless of displacement. A gravity stress radiograph can be used to assess for subtle instability. Regardless of indication, if fixation is undertaken it must be done in a way that allows for early range of motion. In young children, smooth pins are used to preserve the apophysis. With adolescents and large enough fragments, screw fixation is ideal. For small, comminuted fragments with instability and a positive stress test, fragment excision and reattachment of the ligamentous complex is indicated.

5. Lateral Side Injuries

The main pathologic force on the lateral side of the elbow is one of compression, primarily during the late cocking phase as well as the acceleration phase of throwing. In addition, deceleration during follow-through may produce shear forces across the radiocapitellar joint. It is this region where subsequent pathology produces the lateral-sided elbow pain present in young athletes. OCD of the capitellum is the most common clinical presentation. Less commonly, OCD of the radial head may be present. Overuse injuries to the lateral epicondyle and/or extensor origin are rare and are seen in the older, skeletally mature patient.

Osteochondrosis of the capitellum, so-called ‘Panner’s disease’, is the most common cause of chronic lateral elbow pain in the young athlete under 10 years of age. It must, however, be differentiated from OCD. Panner’s disease is a self-limited condition of the capitellum, often presenting with a dull, activity-related pain which quickly resolves with decreased activity. Minimal effusion and flexion contracture may also be associated. On radiographs, fragmentation of a globally involved capitellar epiphysis is seen. A treatment of rest and activity restriction leads to a gradual resolution of symptoms and a relatively benign natural history. Regeneration and ossification of the epiphysis is eventually seen on radiographs, with no residual deformity, joint collapse or late sequelae.

In contrast, OCD of the capitellum is the leading cause of permanent elbow disability in adolescent athletes. Unlike Panner’s disease, OCD represents a focal lesion in the capitellar subchondral bone, often with a well-demarcated island of involvement and collapse. An insidious onset of dull, activity-related, and poorly localised pain may precede other more severe symptoms such as locking, decreased motion, and flexion contracture >15°. MRI or a computerised axial tomography (CAT) scan complement radiographic evaluation in order to determine the size of the lesion, the condition of the articular cartilage and radial head, as well as the presence of loose bodies.

Treatment of capitellar OCD is somewhat controversial but begins with staging of the lesion. Both arthroscopic and radiographic classification systems are available. In general, stage I lesions are intact, focal subchondral lesions with no evidence of articular cartilage involvement (figure 3). Stage II lesions show fracture or fissur-
ing of the articular cartilage with or without partial detachment of the lesion. Stage III lesions represent completely detached loose body formation. Once classified, available treatment options are determined.

Stage I lesions are initially treated with rest and symptomatic splinting if needed. Once symptoms have decreased, active range of motion is begun and the elbow is protected until radiographic confirmation of revascularization or healing.\[21\] If symptoms persist over 8–12 weeks and the lesion demarcates on MRI, arthroscopic or open subchondral drilling is indicated.\[3\] The treating physician must keep in mind that not all OCD is the same; rather, juvenile OCD in those with open physes has the potential to heal unlike that seen in the older population. Treatment of stage II lesions is somewhat controversial. With articular cartilage involvement, one must first determine the size and stability of the lesion. Often this requires arthroscopy as well as an MRI. For large, hinged lesions, open or arthroscopically-aided in situ fixation via screws, K wires, or bioabsorbable pins has been promoted by many surgeons.\[2-4,10\] For smaller stage II or stage III lesions, excision of the lesion, open or arthroscopic debridement of the previous attachment, as well as some form of chondral resurfacing is indicated: either chondroplasty, microfracture, or drilling techniques.\[2,10,22\] Some advocate reattachment of stage III lesions\[23\] but numerous studies have found no evidence that this is successful, at least in the chronic setting.\[22,24\] This is more than likely related to a mismatch of size and shape between an often rounded and smooth-edged loose body with a sclerotic subchondral bed which has filled with fibrous tissue. Fixation of an acute, traumatic osteochondral fracture has a better prognosis with some of today’s fixation techniques. Nevertheless, studies advocate a treatment protocol aimed to encourage healing of the OCD lesion,\[25\] thus preventing such long-term sequelae as residual deformity, loose body formation, and early degenerative disease.

**Fig. 3.** Capitellar osteochondritis dissecans. (a) Anteroposterior radiograph of the elbow revealing a well-demarcated subchondral lesion of the capitellum. (b) The magnetic resonance image demonstrates a stage I lesion with an intact articular surface.
With chronic and repetitive microtrauma to the lateral side of the elbow, deformity of the radial head can also be seen. Acute macrotrauma can result in an epiphyseal or physeal fracture, and OCD of the radial head has been described, although it is much less common. Patients often present with pain, loss of pronation/supination and mechanical symptoms related to loose body or osteophyte formation. Treatment entails the removal of loose bodies, the burring down of osteophytes and, for severe disease, radial head excision.

6. Posterior Injuries

Injury to the posterior elbow is primarily due to the main pathologic force of shear present during both the acceleration and deceleration phases of throwing. The main site of injury is to the olecranon apophysis. This results in apophysitis during childhood, avulsion fracture in the adolescent, and extension overload with posteromedial osteophyte formation at the olecranon tip of the young adult.

Apophysitis usually presents as localised tenderness, pain with elbow extension and radiographs that reveal widening of the apophysis. Contra-lateral elbow radiographs help to confirm the diagnosis. Patients are treated with 3–4 weeks of rest from throwing, an associated position change, and immobilisation if needed. Physical therapy for gentle range of motion exercises, as well as a flexibility and strengthening programme may be helpful immediately. Most athletes are able to return to throwing after 6 weeks, when normal strength and motion have returned.

Acute, nondisplaced avulsion fractures of the apophysis are treated with casting. If displaced more than 2mm, open reduction and internal fixation is indicated (figure 4). Residual pain may be due to loose body formation or non-union, both indicative of surgical treatment. In young adults, posterior and/or posteromedial osteophytes may

Fig. 4. (a) Lateral elbow radiograph revealing a displaced avulsion fracture of the apophysis requiring (b) open reduction with internal fixation via the tension band technique.
lead to pain with elbow extension secondary to im-
ingement.[11] If present, open vs arthroscopic os-
teophyte excision is indicated.

7. Anterior Injuries

Anterior pathology presents as a flexion contracture to the elbow. This is the result of repetitive tension overload during follow-through. Such a contracture may, however, result secondarily from pathology to the medial or lateral side of the elbow as previously discussed. In addition, osteochondrosis of the trochlea has been reported and may present with a flexion contracture between 15–30°.[26,27]

If an isolated flexion contracture is present, conservative treatment is the rule. Aggressive therapy and stretching is usually all that is needed. Operative contracture release is indicated for only the severe cases with contractures over 30° and/or functional disability.

8. Prevention

The key in the treatment of ‘little league elbow’ is prevention and this responsibility is widespread. The evaluating or team physician, the coach and team trainer, parents, and officials are all important components. Emphasis must be placed on pre-season conditioning, proper throwing mechanics, and proper ‘warm-up’ exercises. The determinants of elbow injury among youth pitchers are not well understood.[6,28] Andrews and Fleischig[29] described three main contributors to a young pitcher’s ability to stay healthy: pitching mechanics, pitch type and pitch volume. As the amount of force placed upon the player’s elbow increases with the level of play in which he or she is involved,[30] the risk of injury therefore increases as well. Proper throwing and pitching mechanics must be emphasised at an early age to help reduce this risk.

Controversy regarding the frequency of pitching and number of pitches thrown does exist. Some studies suggest no relationship between average number of pitches thrown per inning and elbow pain.[6,8] However, in a recent prospective study[8] of 298 youth baseball players, arm fatigue and >600 pitches thrown per season were found to be risk factors for elbow pain. Older players who pitched in non-league, recreational baseball were at higher risk, thought to be due to higher pitch counts. Overall, every ten pitches thrown per ball game equated to a 6% increased risk of elbow pain.[8] Little League, Inc. guidelines relate to the number of innings pitched per week: <6 innings/week for the 9–12 year age group and <9 per week for those between 13–15 years of age. Some authors have emphasised the number of actual pitches thrown both in practice and in games: <75 pitches/game, <600 pitches/season.[8] Nevertheless, no suggestions found in the literature today are evidence-based. In addition, no research among youth pitchers comparing the effect of pitch types has been conclusive. While some studies suggest that certain pitch types are more prone to produce injury,[31] other studies have shown a protective effect of the change-up pitch[8] in older pitchers.

Clearly, the issue is multi-factorial; not only is the cumulative amount of pitches thrown important, but also the type of pitches thrown, the position played, and perhaps most importantly, the technique and subsequent position of the elbow at ball release.

9. Conclusion

In conclusion, early recognition and prevention is the key to treating those injuries entailed in so-called ‘little league elbow’. The prevention of later sequelae or functional disability is based on such recognition. Often, rest or activity modification is the key to treatment, followed by a gradual return to sport. Too often, young athletes are treated like high-level, adult athletes and told to ‘play through the pain’ or ‘throw the pain out’. Educating coaches, parents and officials so that they recognise these injuries will allow early and appropriate treatment. The evaluating physician must keep in mind the anatomic-based differential diagnosis, understand normal elbow development and the throwing mechanism to accurately diagnose and treat such injuries.
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