Ulnar Collateral Ligament Injuries in High-School-Aged Athletes

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Background

Medial-sided elbow injuries in young athletes are extremely common, especially in youth and high school baseball players. By high school age, many baseball players have already begun to play for several teams, practice for several hours each day, and play year-round baseball. Shoulder and elbow pain has been reported between 50 and 70% in adolescent baseball players at least some time during the season, more commonly in young pitchers and catchers than position players [1, 2]. Radiographic findings consistent with the phenomenon of "Little League Elbow" such as apophyseal widening, fragmentation, and hypertrophy have been noted in 23–90% of both symptomatic and asymptomatic skeletally immature players [1, 3]. As adolescents reach skeletal maturity, however, their injuries tend to affect the ulnar collateral ligament (UCL) rather than the growth plate or osseous structures.

Since Jobe published his report of UCL reconstruction, or "Tommy John" surgery in 1986, the procedure has become more common among professional, college, and high school athletes [4]. Petty and Andrews noted that over the past two decades, there has been an increasing trend in younger players who require surgery to continue playing. At one institution between the years of 1988 and 1994, 85 UCL reconstructions were performed, and seven (8%) were done on high school players. By contrast, between 1995 and 2003, 609 players underwent UCL reconstruction, and 77 (13%) were high school players. Not only did the overall number of cases increase, but there was also a 50% increase in the proportion of high school players who required surgery [5].

While an increasing number of young athletes have required UCL reconstruction, a disturbing lack of understanding about the injury is still prevalent in the community among players, coaches, and parents. Ahmad et al. administered a questionnaire to assess players', coaches', and parents' perceptions of Tommy John surgery, and found that 30% of coaches and 51% of high school players believed surgery can be performed on uninjured players to enhance performance. Similarly, 28% of players and 20% of coaches believed that performance after surgery would be better than pre-injury, and a significant number of those surveyed underestimated both risk factors for injury and the time frame it would take after surgery to return to play [6]. In this age group, the challenge to inform and educate patients and families about risk factors, prevention, and indications for surgery is paramount.

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Anatomy and Physiology

For athletes with developing musculoskeletal systems, the physis is generally considered to be the most vulnerable link. High-school-age throwers (aged 14–18) compete during various phases of developing skeletal maturity, strength progression, and increasing physical demands of the sport. Throwing, and especially pitching, requires a complex movement that involves the entire body including the legs, core, and entire upper extremity, including the shoulder and elbow. Soft tissue and bony adaptive changes occur during adolescence if a young athlete competes consistently.

Though there is little literature focused on adaptive changes to the elbow, investigators have shown that significant adaptive changes occur in the shoulder in high-school-age athletes. Even younger little-league-age throwers demonstrate differences in the range of motion of their dominant shoulder compared to their nondominant side as a response to the physiologic stresses of throwing. These include an increase in external rotation, reduced internal rotation, and increased inferior laxity in the dominant arm. These changes become more pronounced as the adolescent gets older, particularly during the early high school years (age 13–14), and tend to stay stable once he has reached skeletal maturity [7, 8]. Because there is an increase in external rotation with a complementary decrease in internal rotation, there may be a side-to-side difference in shoulders, but in asymptomatic players, the total arc of motion is usually within 5°. This phenomenon is seen more frequently in pitchers than position players [9]. These changes in range of motion are not only a soft-tissue response to the stress of throwing, but also represent osseous changes including increased retroversion of both the humerus and glenoid in the throwing shoulder compared to the nondominant side [10–13]. Deficits in shoulder range of motion beyond physiologic changes in young pitchers have been linked to increased stress across the elbow during throwing as well as an increased risk for both shoulder and elbow injury [14, 15].

In the elbow, the primary stress of throwing creates a valgus moment on the medial side. In early adolescence, the apophysis of the skeletally immature elbow is particularly vulnerable to these forces. Hang et al. examined 343 little league players in Taiwan, and found that 100% of pitchers and catchers, and 90% of position players demonstrated hypertrophy of the medial apophysis on radiographs. Separation and fragmentation of the medial epicondylar apophysis were also common findings, both in symptomatic and asymptomatic elbows [1]. Before the physis has closed, the UCL is intimately associated with the periosteum, and is less vulnerable to injury than the apophysis. Once the physis has closed, however, the UCL is injured more frequently than the bone [16].

Risk Factors/Prevention

For adolescent and high school athletes, injury prevention is paramount. As these young athletes enter high school, they often compete for multiple teams and for most months out of the year if the climate allows. As they enter puberty, they begin to develop bigger and stronger muscles, and with talent, they throw harder and faster. With these changes, risk factors for UCL injury have been explored.

As throwing and pitching are complex movements involving the entire body, healthy shoulder motion is important to preventing elbow injuries as well. Shanley et al. found that among high school softball and baseball players, those with large mean deficits in internal rotation were at greater risk for shoulder or elbow injury, and that a >25° loss of passive internal rotation was predictive of injury. There was a trend towards total range of motion deficit as a risk for injury, though this was not statistically significant [14]. Among 60 high-school- and college-aged patients with diagnosed UCL tears Garrison et al. found that there was no difference in elbow extension, glenohumeral internal rotation deficit, or horizontal abduction, but those pitchers with UCL tears had less shoulder total range of motion than uninjured players [15].

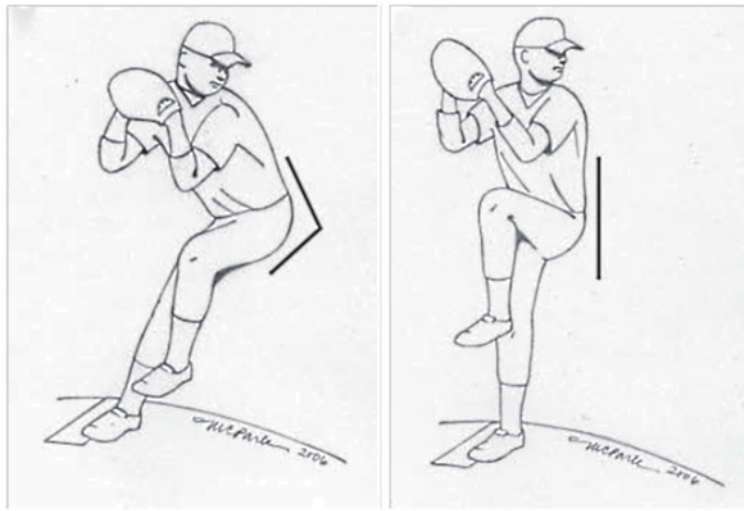

Fig. 23.1. Parameter 1: leading towards home plate with the hips. **a** Correct position defined by the pelvis leading the trunk towards home plate during the early cocking phase. **b** The incorrect position with a vertical torso in the early cocking phase, not leading with the hips. (Reprinted with permission from [17], SAGE publications)

Proper pitching mechanics are important for preventing pitching injury. Davis et al. analyzed five common pitching parameters among pitchers aged 9–18, including (1) leading with hip, (2) early cocking with hand on top of the ball, (3) elbow higher than the hand, (4) shoulder closed (not "opening up" too early), and (5) leading stride foot centered and pointed towards home plate. They found that young pitchers who performed three or more of the above correctly showed lower humeral torque and valgus loads on the elbow than those who did not. Older pitchers tended to follow parameters more correctly than younger ones [17]. Even those children with proper pitching mechanics cannot generate as large torques as adults, and therefore, these must come from increased strength and musculature [18] (Figs. 23.1, 23.2, 23.3 and 23.4).

Pitch type and pitch counts are also important in assessing the risk to a young pitcher. Lyman et al. examined 476 pitchers aged 9–14, and found that the curveball was associated with 52% chance of shoulder pain and the slider with an 86% risk of elbow pain especially in the 13–14 year-old age group [2]. The curveball has been shown to correlate with the highest valgus stress over the elbow with increasing age and strength [18, 19]. Multiple studies have shown a significant correlation between the pitch count and the rate of elbow injuries [2, 20]. Olsen et al. have shown that increased number of months pitching and increased pitch counts per game and per year were all associated with higher risks of injury. Furthermore, those patients who had more frequent starts, participated in showcases, and used more nonsteroidal anti-inflammatory drugs (NSAIDs) during the season had a higher rate of injury. Interestingly, there was no difference in self-rating, stretching, pitch type, or age of the injured players [20].

Pitch velocity has been shown to correlate with stress on the UCL injury. Hurd et al. used high-speed video studies with 3D motion analysis and have shown that the internal elbow adduction moment increases with the increasing pitch velocity in high-school-aged pitchers. Players who are taller and heavier than their age-matched counterparts have a higher rate of injury, suggesting that youth pitchers who are strong and talented enough to pitch with high velocity may be at increased risk for elbow injuries [20, 21]. Furthermore, Fleisig et al. analyzed the pitching

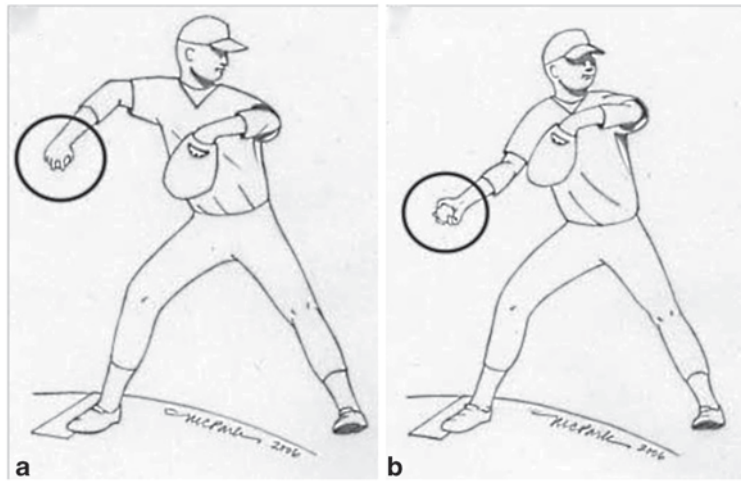

Fig. 23.2 Parameter 2: hand on top position. **a** Correct position defined by the throwing hand on top of the ball with the forearm in pronation as it comes out of the glove. **b** The incorrect position with the hand under the ball with the forearm in supination as it comes out of the glove. (Reprinted with permission from [17], SAGE publications)

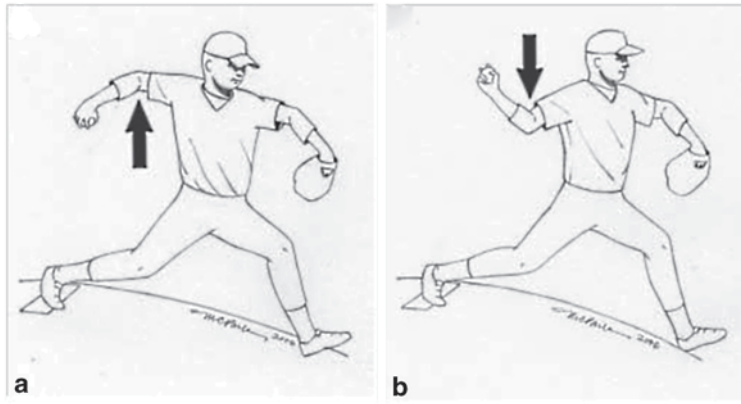

Fig. 23.3 Parameter 3: arm in throwing position. **a** Correct position defined by the elbow reaching maximum height by stride foot contact. **b** Incorrect performance with the elbow below the hand as with stride foot contact. (Reprinted with permission from [17], SAGE publications)

kinematics of youth through professional pitching levels, and found that the greatest elbow torques were in the late cocking and acceleration phase of the pitch, and increased with increasing pitcher level [18]. Many authors have put together safety recommendations for adolescent baseball pitchers [5, 20, 22] (Tables 23.1, 23.2, 23.3).

Evaluation

History

When a high school athlete seeks medical attention for elbow pain, it is usually due to an inability to perform at their prior level. The player will most commonly report a discrete incident in which he felt a pop on the medial side of the elbow, or an episode of "giving way." Symptoms of ulnar nerve irritation may also be present,

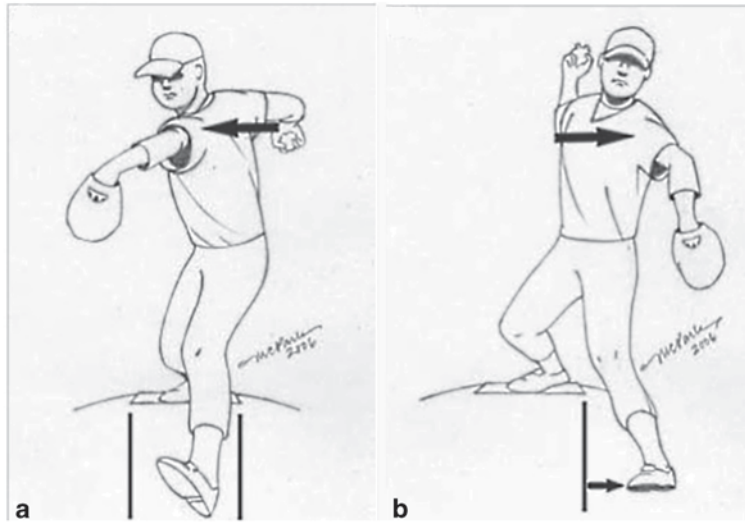

Fig. 23.4 Parameter 4: closed-shoulder position. **a** Correct position defined by the lead shoulder pointing towards home plate at stride foot contact. **b** Incorrect position with the torso facing forward with stride foot contact (opening up too early). Parameter 5: stride foot towards home plate. **a** Correct position defined by the stride foot pointing towards home plate at contact. **b** Incorrect position with the foot not pointed towards home plate. (Reprinted with permission from [17], SAGE publications)

Table 23.1 Recommended maximum number of pitches by age group

Age (years)	Maximum pitches/games	Maximum games/week
8–10	50	2
11–12	65	2
13–14	75	2
15–16	90	2
17–18	105	2

Recommendations were modified with permission from the USA Baseball Medical & Safety Advisory Committee [22]

including an electrical sensation down the arm radiating to the ring and small fingers. This may be the product of hematoma or a subluxing ulnar nerve. Other players may report a more insidious or chronic pain that usually occurs during the late cocking and acceleration phase, and the player may notice that he has lost velocity or accuracy when he throws or pitches.

Physical Examination

The thrower with an acute UCL injury may have swelling and ecchymoses along the medial side of the elbow and forearm. There may be a flexion contracture of the elbow, though this is common with both injured and uninjured throwers and may not be correlated to UCL injury [1]. Tenderness to palpation directly over the UCL distal to the medial epicondyle is the most common finding. The expected amount of elbow laxity even with a complete UCL disruption is only a few millimeters at most, and is thus a very subtle finding.

The most common provocative maneuvers used to evaluate the UCL are the valgus stress test, the milking maneuver, and the moving valgus stress test [23]. In the classic valgus stress test, the examiner stabilizes the humerus and applies a valgus force to the elbow at 30° of flexion. This level of flexion minimizes the bony contribution to stability of the ulnohumeral joint. The milking maneuver may be performed entirely by the patient, in which he supinates the forearm, and bends the elbow past 90°. Using the other hand, he grabs the thumb and pulls downward, producing a valgus force on the elbow. The examiner may then palpate the UCL for instability and pain. The modified milking maneuver is performed by the examiner, in which the examiner pulls the

Table 23.2 Recommended minimum rest after pitching

	Number of pitches			
Age (years)	1 day of rest	2 days of rest	3 days of rest	4 days of rest
8–10	20	35	45	50
11–12	25	35	55	60
13–14	30	35	55	70
15–16	30	40	60	80
17–18	30	40	60	90

Recommendations were modified with permission from the USA Baseball Medical & Safety Advisory Committee [22]

Table 23.3 Age recommended for learning various pitches

Pitch	Age (years)
Fastball	8
Change-up	10
Curveball	14
Knuckleball	15
Slider	16
Forkball	16
Splitter	16
Screwball	17

Recommendations were modified with permission from the USA Baseball Medical & Safety Advisory Committee [22]

thumb down with the patient's elbow in 70° of flexion, producing a valgus force. This position has shown the greatest valgus laxity in a cadaveric model when the UCL is sectioned [23]. With the other hand, the examiner can palpate the medial elbow for subtle laxity. O'Driscoll and associates described the moving valgus stress test, in which the examiner holds the patient's forearm with one hand and the humerus with the other, applying a steady valgus force while flexing and extending the elbow [24]. The athlete will experience pain in the arc from 70° to 120°, with a maximum pain at 90° of flexion, if there is a UCL injury. Advantages of this technique include that it closely mimics the throwing motion, it eliminates shoulder rotation which may confound other exam maneuvers, and pain in the arc of motion is common.

In addition to examining the integrity of the UCL, care must be taken to evaluate the ulnar nerve. Attempting to elicit a Tinel sign along the cubital tunnel, and evaluating the nerve for subluxation during range of motion with gentle palpation will help guide treatment of the nerve. Care must be taken to rule out other injuries, such as flexor-pronator avulsions, medial epicondyle fractures, and loose bodies in the elbow.

Imaging

With plain radiographs, high school athletes in variable phases of skeletal maturity may show variable findings. These may include widening or separation of the medial epicondylar physis, fragmentation of the epicondylar ossification center, or calcification in the substance of the UCL [1]. Occasionally, one may find a sublime tubercle fracture. Though stress radiographs of bilateral elbows may be diagnostic, medial widening tends to be very subtle (only 2–3 mm), and is operator dependent. Furthermore, even in uninjured players, a side-to-side difference in elbow laxity has also been reported, so stress radiographs may be of limited value [25].

Magnetic resonance imaging (MRI) is helpful in diagnosing both UCL injuries as well as injuries to other structures, including findings that may be missed on X-ray [26]. With current high-quality MRI, the UCL may be well visualized in the absence of intraarticular contrast. Sugimoto and associates compared MRIs of the UCL in symptomatic and normal elbows in both skeletally immature and skeletally mature patients [16]. They found that in normal immature elbows, the periosteum was an extension of the UCL, and that the UCL has a different signal from the mature ligaments. In skeletally immature symptomatic elbows, there was segmentation of subchondral bone and resorption of the ossification center, either with or without tear of

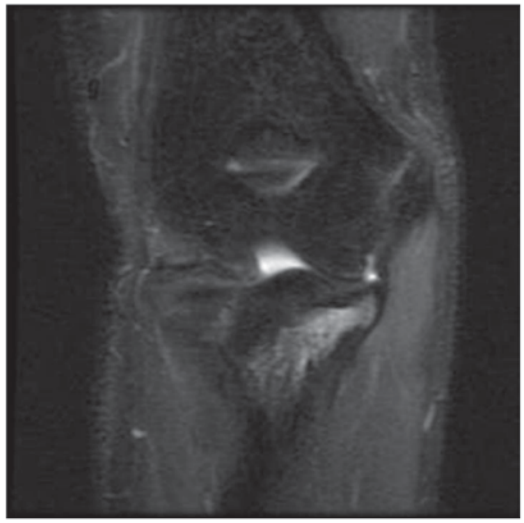

Fig. 23.5 Proton-density sequence MRI of a 15-year-old pitcher and catcher with medial elbow pain. Note that the ulnar collateral ligament is intact, but there is significant bony edema and separation at the medial epicondylar apophysis

the UCL, suggesting apophyseal pathology. In mature elbows, a tear in the UCL was seen more often (Figs. 23.5, 23.6).

One should treat MRI findings with caution, as even in asymptomatic high school pitchers will show some subtle changes on MRI. Wei et al. examined nine skeletally immature players, and found that though MRI was more sensitive than radiographs for abnormalities about the elbow, there were no significant differences between the dominant and nondominant sides [26]. Hurd et al. examined bilateral elbow MRIs of 23 high school pitchers, and found that only 13 % of the players had normal findings, whereas most players had asymmetrical thickening of the anterior band of the UCL, posteromedial subchondral sclerosis, a posteromedial osteophyte, or chondromalacia, and 43 % of the players had multiple of these findings [27]. Therefore, it is important to correlate MRI findings with the physical exam prior to initiating a treatment plan.

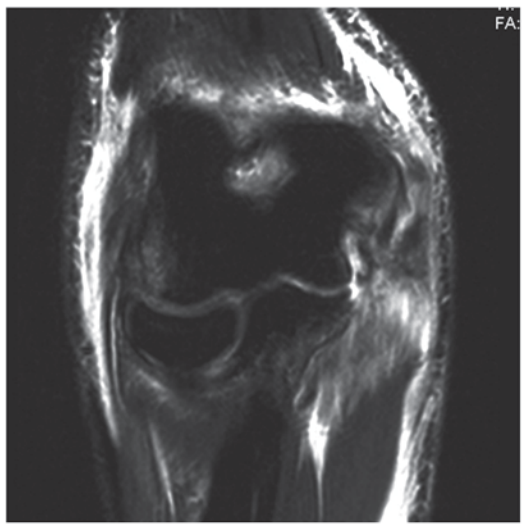

Fig. 23.6 Proton-density sequence MRI of an 18-year-old pitcher with medial elbow pain. Note that the ulnar collateral ligament is completely avulsed from the ulnar attachment (positive "T-sign")

Treatment

Conservative Management

Conservative management of UCL injuries to the elbow consists of several phases, including rest, modalities, strengthening and stretching, and a gradual return to sport-specific activities such as throwing.

A number of rehabilitation programs have been described for overhead throwing athletes, but they all share several common concepts [28–30]. The first phase of rehabilitation aims to improve pain, normalize range of motion and muscle balance, and improve proprioception. This phase involves cessation or modification of throwing in addition to anti-inflammatory medications and therapeutic modalities such as ultrasound, electric stimulation, and ice. Intermediate phases involve progressive strengthening and dynamic stability of the flexors and pronators of the forearm to enhance neuromuscular control, and improve power and endurance for return to sport. Focus should be paid to strengthening the flexor-pronator mass, and particularly the flexor carpi ulnaris and flexor digitorum superficialis, which provide dynamic valgus stability to the throwing elbow [31]. Range of motion, strength, and stability of both the shoulder and elbow joint are essential before returning to the throwing motion.

The final phases of rehabilitation return the player to a slow progressive throwing program and return to competitive throwing while continuing maintenance strength and flexibility drills.

Rettig and colleagues examined 31 throwing athletes with UCL tears initially treated with conservative management. After a period of 3 months rest and rehabilitation, 42% of athletes were able to return to their pre-injury level of competition. These athletes took an average of 24.5 weeks to return to play, with a range of 13–54 weeks. Unfortunately, no risk factors were able to be identified for patients who failed conservative management, including age, acute vs. insidious onset, or length of symptoms prior to treatment [28].

As minimally invasive treatments such as platelet rich plasma and other biologics emerge in the treatment of musculoskeletal disorders, they represent promising adjuncts to nonoperative managements of UCL injuries. Only anecdotal reports exist of the current efficacy of such treatments thus far.

Operative Intervention

When conservative management has failed, many young players will elect surgical treatment as an option to help them return to play. In the high school age group, several options are available for surgical management. Savoie et al. reported a series of 60 young patients with symptomatic UCL tears treated with a primary direct repair of the ligament, either through drill holes or suture anchors. In patients with an average age of 17.2, 93% reported excellent results, and 58 out of 60 athletes were able to return to their previous level of play within 6 months [32]. The authors advocate this alternative approach to reconstruction for young athletes whose ligament tissue quality is excellent, and those who have not experienced the attritional changes from chronic injury.

Traditional reconstruction of the UCL in the high school population is increasingly common. Petty and colleagues retrospectively evaluated outcomes of 27 high school athletes who had undergone reconstruction of the UCL during high school, and found that 74% were able to return to their previous level of play at 11 months, though only 37% of the athletes went on to play in college. Those who stopped playing baseball did so either because of continual pain and dysfunction (7%), or they abandoned baseball for other interests (15%) [5].

Failure of the ligament repair or reconstruction in this population has been reported from 7 to 26%, either early or after return to unrestricted play. Other complications, such as transient ulnar neuropathy is seen in 5–7% of patients either with or without ulnar nerve transposition at the time of surgery.

Rehabilitation

After surgical repair or reconstruction, the elbow should be immobilized for 1 week to allow for soft tissue healing. Active wrist, elbow, and shoulder range of motion should be initialized immediately after removal of the splint. Full range of motion and strengthening exercises may begin at 4–6 weeks, but patients should be cautioned against progressing too quickly, and should avoid valgus stress. After 8–10 weeks, more progressive strengthening may continue, with initiation of plyometric exercises, and continued strengthening of the flexor-pronator mass. A throwing program may begin at 4 months postoperatively, with gradual progression of distance, velocity, and intensity. Shoulder strength, motion, and proper throwing mechanics should be emphasized at this time to prevent re-injury. If there is any return of symptoms, a period of rest and modification of activities is essential, and throwing should not resume until the athlete is pain-free. Strength and flexibility maintenance should continue throughout, and return to competition may resume in at 1 year. Depending on the level of competition, however, some players may take 18 months or more to return to their previous level of play. Young athletes and families must be informed and agreeable to a significant rehabilitation effort prior to return to play.

Summary

In recent years, an increasing number of high-school-aged athletes suffer from elbow UCL injuries. Though conservative management and surgical interventions such as ligament repair or reconstruction may be variably successful in helping young athletes return to play, all require significant time off [5, 28, 32]. In a population of young athletes that may finish their careers at the high school or college level, it is important to counsel patients and families, who may misunderstand the implications of UCL tears [6]. Prevention of injuries to both the shoulder and elbow is paramount in the adolescent and high-school-aged population. Focus should be placed on proper throwing technique and minimizing risk factors such as overuse during the season, year-round throwing, and pitches such as the fast ball and curve ball [2, 5, 17, 18, 20].

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