The American Journal of Sports Medicine

Ulnar Collateral Ligament Reconstruction in High School Baseball Players : Clinical Results and Injury Risk Factors

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Published by:

$SAGE

On behalf of:

AOSSM

American Orthopaedic Society for Sports Medicine

Ulnar Collateral Ligament Reconstruction in High School Baseball Players

Clinical Results and Injury Risk Factors

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Background: The incidence of ulnar collateral ligament injury has increased in baseball, especially at the high school level.

Hypothesis: Ulnar collateral ligament injury in high school baseball players is associated with overuse, high-velocity throwing, early throwing of breaking pitches, and improper warm-ups.

Study Design: Retrospective cohort study.

Methods: Follow-up physical examination and questionnaire data were collected at an average of 35 months after ulnar collateral ligament reconstruction from 27 former high school baseball players. Six potential risk factors were evaluated: year-round throwing, seasonal overuse, event overuse, throwing velocity more than 80 mph, throwing breaking pitches before age 14, and inadequate warm-ups.

Results: Overall, 74% returned to baseball at the same or higher level. Patients averaged 3 potential risk factors, and 85% demonstrated at least one overuse category. Of the pitchers, the average self-reported fastball velocity was 83 mph, and 67% threw breaking pitches before age 14.

Conclusions: The success rate of ulnar collateral ligament reconstruction in high school baseball players is nearly equal to that in more mature groups of throwers. Overuse of the throwing arm and throwing breaking pitches at an early age may be related to their injuries. Special attention should be paid to elite-level teenage pitchers who throw with high velocity.

Keywords: pitcher; overuse; curveball; velocity; elbow

Injury to the ulnar collateral ligament (UCL) of the elbow causes significant disability in the throwing athlete. The most significant symptom is medial elbow pain. It is occasionally accompanied by ulnar nerve paresthesias. Throwers usually notice a decrement in their velocity and/or control.[2,3] In high school baseball, most UCL injuries become apparent in a single throw, in which a popping or tearing sensation in the elbow is accompanied by immediate medial elbow pain. The microtrauma leading up to this injury, however, is usually accumulated over a season or more. Evidence of this microtrauma can often be seen on radiographs that show healed avulsion fractures of the sublime tubercle of the ulna or ossification within the UCL.[11]

We have seen, based on experience at our institution, a dramatic increase in baseball players who require UCL surgery. Most alarming is the fact that there has been a 50% increase in the proportion of surgeries performed on high school players. Between 1988 and 1994, the senior author (JRA) performed UCL reconstruction or repair on 85 baseball players.[3] Of this group, 8% (7/85) were high school players. Between 1995 and mid-2003, the senior author performed UCL reconstruction or repair on 609 baseball players, of whom 13% (77/609) were high school players.

Many of these injured high school baseball players describe regimens that include year-round throwing, with bullpen work or long-toss programs throughout the off-season. Others describe excessive throwing during the regular season, a playoff, or a showcase event.

The authors hypothesize that the increased frequency of UCL injury in high school baseball players (ages 15-19 years) may be due to an excessive amount of competitive throwing, throwing breaking pitches, high fastball velocity, or inadequate warm-ups.

MATERIALS AND METHODS

Patient Population

Between 1995 and 2000, 31 UCL reconstructions on the elbows of high school baseball players were performed at our institution. Twenty-seven of the players were available for follow-up evaluation at a point at which it could be determined whether they would return to baseball at the same or higher level. All were male athletes between the ages of 15.9 and 19.0 years at the time of surgery. The mean age was 17.4 years. There were 7 left-handed throwers. Eleven percent (3/27) were catchers; the rest were pitchers. Sixty-three percent (17/27) of patients experienced sudden onset of symptoms—a popping sensation followed by pain in the medial elbow. Of these, 18% (3/17) had a prior history of medial elbow pain that had resolved. The other 33% (10/27) of patients developed debilitating medial elbow pain over the course of weeks to months. Seventy percent (7/10) of these patients with insidious onset had symptoms of medial elbow pain for more than a year before seeking surgical intervention. Ten percent (1/10) had been treated remotely for a stress fracture of the olecranon.

Pain with throwing, usually worst in the arm-cocking phase,[7] was the most significant symptom in all (27/27) patients. Seventy percent (16/23) reported a significant decrease in velocity or control after the injury. Twenty-six percent (7/27) reported preoperative ulnar nerve paresthesias.

Seventy-eight percent (21/27) of the patients had undergone conservative therapy for more than 6 weeks before UCL reconstruction. Twenty-two percent (6/27) of the reconstructions were performed within 6 weeks of the injury—3 of these were early reconstructions. No patients had prior elbow surgery.

Clinical Evaluation

Preoperative physical examination was performed on all patients in the clinic, and physical examination was performed again when the patients were under anesthesia. In the clinic setting, 14% (3/21) had gross (2+ or greater) valgus laxity in near extension. Only 4% (1/25) had loss of flexion and/or extension greater than 5°. Fourteen percent (3/21) of patients had pain with forced terminal extension of the elbow (valgus extension overload sign). Thirty-six percent (8/22) of patients had a Tinel sign over the ulnar groove. None had motor deficits in the affected extremity. The most significant physical examination finding was pain with a valgus force placed across the joint in the arc of motion between 60° and 120° of elbow flexion (positive dynamic valgus stress test). This sign was present in all (27/27) operative candidates.

Patients were seen routinely at 6 and 12 weeks postoperatively. They were seen again in our clinic or contacted by phone before resuming competitive throwing. Final follow-ups were conducted at a mean of 35 months postoperatively (range, 18-75 months). Thorough interviews were conducted with the patient and a guardian who was most

TABLE 1
Recommended Maximum Number of Pitches[a]

Age, y	Maximum Pitches per Game	Maximum Games per Week
8-10	50	2
11-12	65	2
13-14	75	2
15-16	90	2
17-18	105	2

[a]Recommendations were modified with permission from the USA Baseball Medical & Safety Advisory Committee.[1]

TABLE 2
Recommended Minimum Rest After Pitching[a]

Age, y	Number of Pitches			
	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

[a]Recommendations were modified with permission from the USA Baseball Medical & Safety Advisory Committee.[1]

TABLE 3
Age to Learn Types of Pitches[a]

Pitch	Age, y
Fastball	8
Change-up	10
Curveball	14
Knuckleball	15
Slider	16[b]
Forkball	16[b]
Splitter	16[b]
Screwball	17[b]

[a]Reprinted with permission from the USA Baseball Medical & Safety Advisory Committee.[1]
[b]These ages reflect results from a survey by the USA Baseball Medical & Safety Advisory Committee. The authors of the current study believe that these pitches should not be thrown before the player is 18 years old.

familiar with his throwing history, during which any presumed risk factors were explored and documented.

The follow-up interview included questions on 6 presumed risk factors for UCL injury derived from the recommendations of the USA Baseball Medical & Safety Advisory Committee, as described in Tables 1, 2, and 3. Three overuse categories were defined: year-round throwing, seasonal overuse, and event overuse. *Year-round throwing* was defined as less than 2 full months of rest
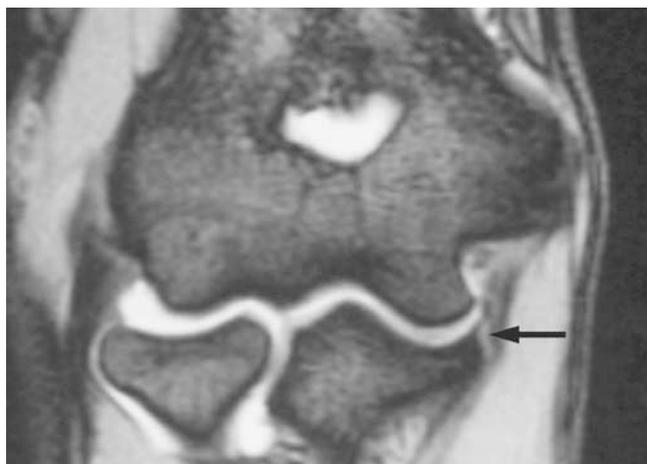
Figure 1. MRI of distal disruption of the ulnar collateral ligament at its insertion on the ulna (T-sign).
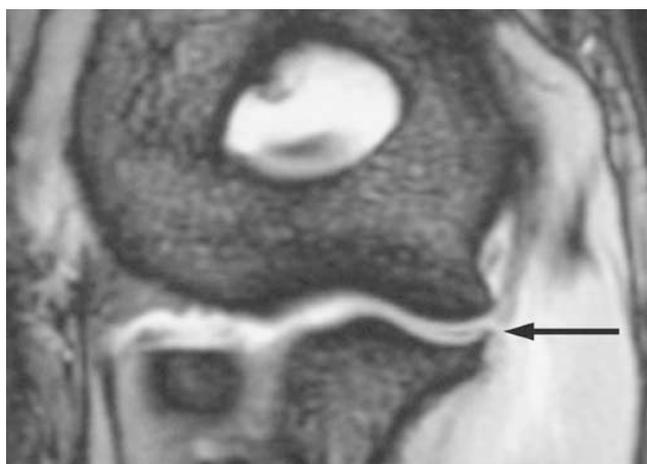

Figure 2. MRI of complete disruption of the ulnar collateral ligament.

from throwing per year. *Seasonal overuse* was defined as routinely violating the modified USA Baseball Medical & Safety Advisory Committtee recommendations for maximum pitch counts or minimum rest, as described in Tables 1 and 2. *Event overuse* was defined as a short episode of extreme overuse, such as starting as pitcher on back-to-back days, making an excessive number of throws to second base as a catcher during a showcase for scouts, or some other event in which common throwing guidelines were grossly violated. The remaining 3 presumed risk factors were throwing breaking pitches before age 14 (Table 3), having inadequate warm-ups before pitching, and having a fastball velocity of more than 80 mph.

Radiograph Studies

All patients were evaluated for UCL injury with MRI. All but one (26/27) of these MRIs showed positive findings within the ligament, including distal disruption of the

TABLE 4
Findings From the Radiographs

Patient	Finding
SS	Large sublime tubercle avulsion and >2-mm stress opening[a]
RM	Small sublime tubercle avulsion fracture
CP	Very small sublime tubercle avulsion fracture
MD	>3-mm stress opening[a]
TD	>2-mm stress opening[a]
CE	Sublime tubercle avulsion fracture
JK	Posterior compartment degenerative joint disease, loose body, 1-mm stress opening[a]
BB	Normal
ZH	Sublime tubercle avulsion fracture
TM	>1-mm stress opening[a]
BH	Mild trochlear degenerative joint disease, 1-mm stress opening[a]
WW	>1-mm stress opening[a]
DD	Large sublime tubercle avulsion fracture and proximal ossification in ligament
TC	Normal
BS	2-mm stress opening[a]
JC	Old medial epicondyle avulsion at ulnar collateral ligament origin, 3-mm stress opening[a]
MK	>2-mm stress opening[a]
BP	2-mm stress opening[a]
JB	4-mm stress opening, posterior olecranon osteophyte/erosion
MB	Normal
BM	>3-mm stress opening[a]
TM	Normal
LH	Normal
SW	Normal
PA	Proximal ulnar collateral ligament ossicles, 3-mm stress opening[a]
AH	Unfused olecranon apophysis, 4-mm stress opening[a]
JD	2-mm stress opening[a]

[a]Indicates side-to-side difference on stress views.

UCL insertion or "T-sign" (Figure 1), signal disruption in the proximal UCL, frank disruption of the ligament (Figure 2), and bony avulsion. All elbows were evaluated with plain radiographs that included anteroposterior, lateral, oblique, olecranon, and stress views in 30° of flexion with a 15-kPa valgus load applied. Findings based on these radiographs are described in Table 4. Notably, 33% (9/27) had bony abnormalities within the ligament, including sublime tubercle avulsion fractures, proximal ossifications within the ligament, or medial epicondylar avulsion fracture at the origin of the UCL (Figures 3, 4, and 5).

Operative Treatment

A UCL reconstruction on the elbows of these 27 patients was performed at a mean of 6 months after injury. The ipsilateral palmaris longus was used preferentially for the graft. If none were available, either the contralateral palmaris longus or gracilis tendon was used. Table 5 shows the distribution of grafts used. A concomitant ulnar nerve transposition was performed on all patients. Posteromedial

Figure 3. Radiograph of avulsion fracture of the sublime tubercle.

Figure 4. Radiograph of proximal ossifications within the ulnar collateral ligament.

Figure 5. Radiograph of remote medial epicondylar avulsion at the ulnar collateral ligament origin.

TABLE 5
Grafts Used for Ulnar Collateral
Ligament Reconstruction

Type of Graft	Number
Palmaris longus–ipsilateral	19
Palmaris longus–contralateral	2
Gracilis-contralateral	5
Gracilis-ipsilateral	1
Plantaris	0

olecranon osteophytes were excised in 15% (4/27) of the patients through arthrotomy during the reconstruction. All procedures were performed under the direction of one surgeon (JRA). Examination under anesthesia revealed that 38% (8/21) had 2+ or greater UCL laxity, and none had a significant flexion contracture. At the time of surgery, it was noted that 43% (10/23) had complete disruption of the UCL.

The technique for the reconstruction was performed as previously described,[3] with the following changes: the ulnar nerve was retracted posteriorly throughout the case, except when opening the posterior band of the UCL to excise posterior olecranon osteophytes. The flexor carpi ulnaris fascia was split superficially, followed by blunt separation of the muscle fibers in line with their course to expose the ulnar nerve distal to the joint. No muscle fibers were transected. Once the UCL was exposed, the overlying muscular origins were gently elevated anteriorly and posteriorly only as much as was necessary to drill the tunnels in the sublime tubercle. A single small Hohmann retractor was placed anteriorly at the coronoid process, and retraction of this Hohmann retractor was minimized to prevent injury to the median nerve. Ulnar nerve transposition was performed routinely on all patients and with only a single fascial sling from the pronator fascia. A 9/64-in drill bit was used to drill the osseous tunnels if the graft was the palmaris longus; a 5/32-in bit was used if the graft was the gracilis.

Complications

Seven percent (2/27) of patients had transient ulnar nerve paresthesias that eventually resolved; 4% (1/27) had a saphenous nerve sensory deficit owing to injury while harvesting the gracilis tendon. There were no infections or postoperative motor deficits.

RESULTS

Success or failure of the procedure was determined by whether the patient returned to baseball at the same level or higher. Seventy-four percent (20/27) of the baseball players returned to competition at or above their previous levels. The average time to return to competition was 11 months. Thirty-seven percent (10/27) went on to play base-

TABLE 6
Representation of the Baseball Season of the Cohort

Day of the Month

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
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- Time off throwing
- Competitive season
- Off-season throwing programs
- High school pre-season practice and conditioning
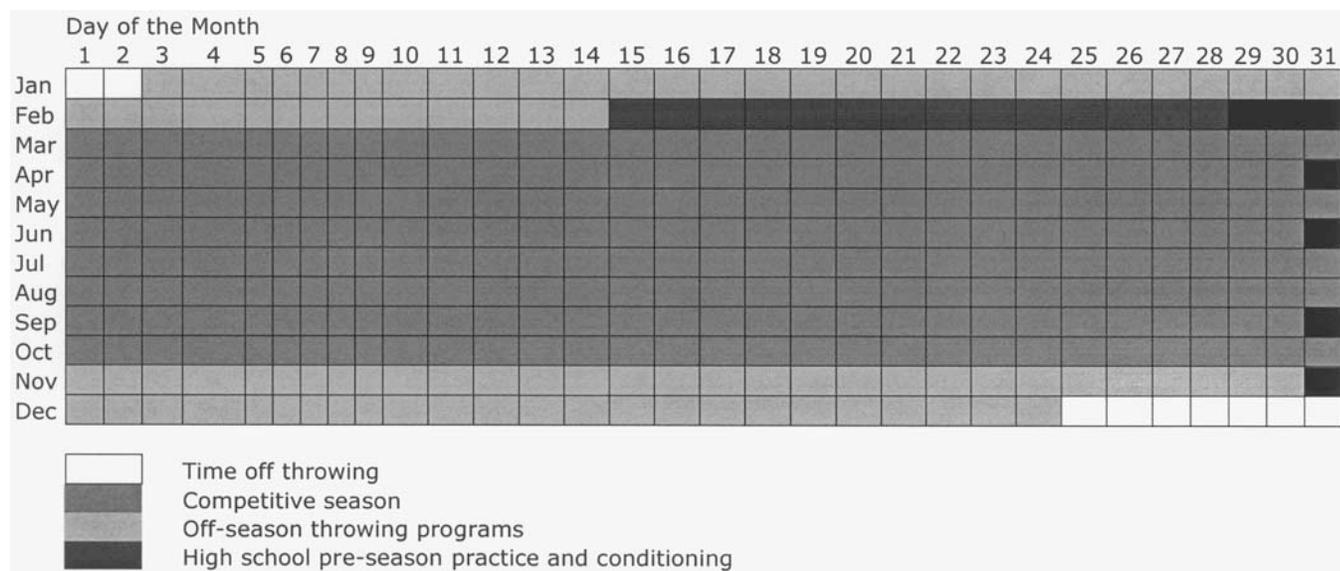
ball in college. Another player plans to do so after graduating high school.

There was a 26% (7/27) failure rate. Only 7% (2/27) retired from baseball because of continual pain in their elbows with throwing. Fifteen percent (4/27) abandoned their rehabilitation and lost interest in baseball owing to graduation from high school or pursuit of other interests. One patient had a successful recovery and was practicing with his college baseball team, about to start the season, when he sustained a grade III acromioclavicular joint separation on his dominant side while wrestling with a roommate; this player had not recovered from his latest injury at the time of latest follow-up.

There was a 74% (20/27) success rate. Thirty-seven percent (11/27) are currently playing baseball in high school or college. Thirty percent (8/27) of patients with successful surgeries have retired from competitive baseball after an average of 1.6 seasons after their reconstructions. In retrospect, all patients (27/27) would choose to have the surgery again.

A telephone follow-up survey was completed by 96% (26/27) of the patients. These baseball players had a mean of 3.1 presumed risk factors for UCL injury in their throwing histories. Eighty-five percent (22/26) were involved with at least one overuse category. Sixty-nine percent (18/26) were involved with year-round throwing, 62% (16/26) in seasonal overuse, and 42% (11/26) in event overuse. Two thirds (16/24) began throwing curveballs before age 14. Twenty-three percent (6/26) threw without adequate warm-ups. The average self-reported maximum throwing velocity was 83 mph (range, 70-93 mph), with 72% (7/25) of this group throwing more than 80 mph. Overall, only 1 injured player had none of the 6 presumed risk factors for UCL injury.

DISCUSSION

The clinical results of UCL reconstruction in high school athletes are roughly equal to those in collegiate and professional baseball players.[3] Most of these patients are able to continue their baseball careers and enjoy a high level of satisfaction with the results of their procedures.

Nonetheless, the utility of reconstructions in this group may be lower than in the professional and collegiate ranks.[2] Most of these athletes were injured in their junior or senior years of high school, making development for college or amateur careers difficult and limiting their opportunities to play baseball after recovery. Many went on to pitch for a single season or less after their reconstructions—some for as few as 1 or 2 games—before retiring because of graduation from high school or a lack of college or professional opportunities.

Nearly all these athletes had multiple risk factors for UCL injury—the number one risk factor being, simply, overuse of one type or another. The average number of months per year these patients played competitive baseball was 8.0 (spring, summer, and fall seasons). Beyond this, they threw a regular schedule of long toss or bullpens in the off-season (Table 6). They also found themselves in situations in which they were enticed to throw too much to win playoffs and tournaments, or to display their capabilities to scouts. Parents and coaches were often tempted to allow this to occur because of the player's talents—a "natural curveball" or remarkable velocity. They were also often late to intervene, reducing the amount of throwing done by these athletes only after significant symptoms were present. Only 52% (13/25) of these injured players thought that their coaches were careful about preventing throwing injuries.

The patients in this study reported an unusually high average velocity (83 mph), with some stating that they pitched as fast as 93 mph. High velocity compounds the risk of UCL injury. For example, a study of college pitchers showed that elbow varus torque increased from 44 N·m to 54 N·m when ball velocity increased from 73 mph to 79 mph.[8] It is estimated that one half of throwing varus torque is distributed through the UCL,[5] so increasing ball velocity from 73 mph to 79 mph theoretically increases the torque in the UCL from approximately 22 N·m to 27 N·m. Cadaveric sectioning studies have shown that the UCL can withstand approximately 32 N·m of force before failure[4,10]; therefore, as ball velocity reaches 80 mph and above, the load on the UCL may approach its limit.

The fact that none of these injured throwers had an elbow flexion contracture greater than 5° is notable. Flexion contractures are common in elite-level pitchers and do not cause performance deficits until they are greater than 25°.[6] This flexion contracture is an adaptive change due to hypertrophy of soft tissue and osseous structures in the posterior elbow, and it is postulated that these changes are protective of the UCL. The absence of this adaptive change may have put these throwers at increased risk of UCL injury.

The overuse-type throwing habits seen in these pitchers induce substantial, repeated microtrauma to the static restraints of the throwing elbow, without offering adequate time for healing.[9,12] Accumulation of this microtrauma leads to a cumulative overload of the UCL. As a result, this tissue becomes weakened and prone to catastrophic failure. This process is exacerbated by high pitch velocity, the throwing of breaking pitches, and inadequate warm-ups.

Surgical indications for UCL reconstruction in the high school baseball player are different from those in the collegiate or professional player. The decision to proceed with surgery is more complex in this younger age group. Athletes in their teenage years tend to have more significant symptoms and complaints related to a given level of identified abnormal indications. This is to say that in the authors' experience, young athletes complain of more pain and disability from a given injury than do more tenured or professional athletes. The reasons for this are unclear, but it confounds the decision-making process.

These young athletes are also better able to heal injuries than the older athlete, so conservative treatment has a higher chance of being effective. But prolonged attempts at conservative therapy also result in lengthy absences from competition and loss of opportunities to develop in the sport. Also, most of these athletes could recover with nonsurgical treatment, allowing effective participation in baseball at a position other than pitcher or catcher. This option has been unpopular in the authors' practice, but it must be discussed with the patient and family.

Radiograph studies are helpful in making the surgical decision. The presence of sublime tubercle avulsion fractures,[13] proximal ossicles within the ligament, or grossly positive stress views (Figure 6) reduce the likelihood of the success of conservative treatment, making reconstruction a more logical course.
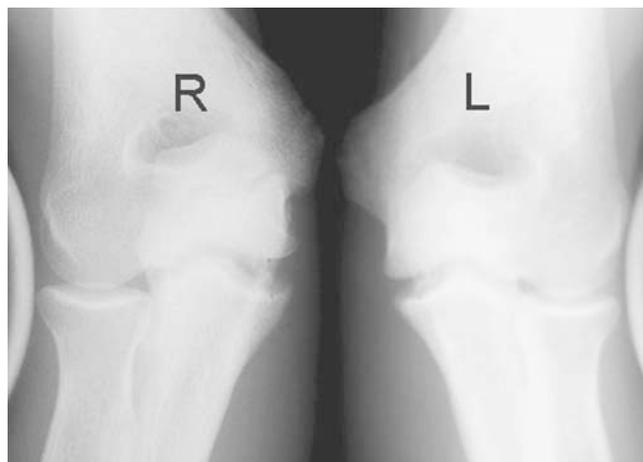

Figure 6. Stress radiographs showing gross increase in medial opening (right [R] elbow) versus uninvolved side (left [L] elbow) at 15 kPa of valgus force.

Finally, the talent and career prospects of many of these patients are undeclared and largely unknown. Regardless of their injuries, they may lack the talent to have the opportunity to play baseball in college or the professional leagues. These injuries also tended to occur toward the end of high school, leaving little time to recover from UCL reconstruction and to win or keep a spot on a college or minor league team. Five pitchers in this study failed to return to baseball for reasons such as these.

A weakness of this study was the lack of data on the throwing habits, histories, and velocities of uninjured high school baseball players, which could be used for statistical comparison. A comparison between high school pitchers with and without UCL injuries could build on this study and previous epidemiologic studies of youth pitchers.[9]

The authors believe that more attention needs to be paid to prevention of serious elbow injury in the young thrower. Parents and coaches need to pay special attention to those at greatest risk—usually the best throwers on the team or in the community. The following are the authors' recommendations for reducing the risk of significant elbow injury in the young thrower:

1. Coaches and parents of young baseball players should be educated on the risks of overuse. They should follow the modified USA Baseball Medical & Safety Advisory Committee guidelines on pitch counts, innings thrown, and minimum rest, which are described in Tables 1 and 2.
2. Coaches and parents should be especially careful with young throwing athletes with the highest velocities and recognition as the team's or community's "best" or "star" pitcher.
3. The young throwing athlete should take a 2- to 3-month rest from all throwing each year, doing shoulder and elbow exercises during this period, to offer the static restraints of the elbow a chance to

heal from the microtrauma caused by competitive throwing.

4. The young pitcher should be wary of pitching back-to-back days or overthrowing at crucial portions of the season, especially in tournaments, playoffs, or showcases in which such overuse is tempting. Catchers should also be wary of making repeated, maximum-effort throws during practice and should follow pitching guidelines for these types of throws.

5. The young thrower should avoid throwing the curveball before age 14 and follow the guidelines in Table 3 for timing development of other breaking pitches.

6. Throwing athletes should always perform an adequate warm-up before any competitive throwing.

ACKNOWLEDGMENT

REFERENCES

1. Andrews JR, Fleisig G. USA Baseball News Medical & Safety Advisory Committee special report: how many pitches should I allow my child to throw? *USA Baseball News.* April 1996:5.
2. Andrews JR, Timmerman L. Outcome of elbow surgery in professional baseball players. *Am J Sports Med.* 1995;23:407-413.
3. Azar F, Andrews JR, Wilk K, et al. Operative treatment of ulnar collateral ligament injuries of the elbow in athletes. *Am J Sports Med.* 2000;28:16-23.
4. Dillman CJ, Smutz P, Werner S, et al. Valgus extension overload in baseball pitching [abstract]. *Med Sci Sports Exerc.* 1991;23(suppl 4):S135.
5. Fleisig G, Andrews JR, Dillman C, et al. Kinetics of baseball pitching with implications about injury mechanisms. *Am J Sports Med.* 1995;23:223-239.
6. Fleisig G, Barrentine S, Zheng N, et al. Kinematic and kinetic comparison of baseball pitching among various levels of development. *J Biomech.* 1999;32:1371-1375.
7. Fleisig G, Dillman C, Andrews JR. Biomechanics of the shoulder during throwing. In: Andrews JR, Wild K, eds. *The Athlete's Shoulder.* New York, NY: Churchill Livingstone; 1994:355-368.
8. Fleisig G, Zheng N, Barrentine S, et al. Kinematic and kinetic comparison of full-effort and partial-effort baseball pitching. Paper presented at: 20th Annual Meeting of the American Society of Biomechanics; October 17-19, 1996; Atlanta, Ga.
9. Lyman S, Fleisig G, Andrews JR, et al. Effect of pitch type, pitch count, and pitching mechanics on risk of elbow and shoulder pain in youth baseball. *Am J Sports Med.* 2002;30:463-468.
10. Morrey BF, An K-N. Articular and ligamentous contributions to the stability of the elbow joint. *Am J Sports Med.* 1983;11:315-319.
11. Mulligan S, Schwartz M, Broussard M, et al. Heterotopic calcification and tears of the ulnar collateral ligament: radiographic and MR imaging findings. AJR *Am J Roentgenol.* 2000;175:1099-1102.
12. Oberlander MA, Chisar MA, Campbell B. Epidemiology of shoulder injuries in throwing and overhead athletes. *Sports Med Arthrosc Rev.* 2000;8:115-123.
13. Salvo JP, Rizio L, Uribe JW, et al. Avulsion fracture of the ulnar sublime tubercle in overhead throwing athletes. *Am J Sports Med.* 2002;30:426-431.