

[Athletic Training]



Prevention of Elbow Injuries in Youth Baseball Pitchers

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Context: Although baseball is a relatively safe sport, numerous reports suggest a rapid rise in elbow injury rate among youth baseball pitchers.

Evidence Acquisition: PubMed was searched for epidemiologic, biomechanical, and clinical studies of elbow injuries in baseball (keywords: “youth OR adolescent” AND baseball AND pitching AND “ulnar collateral ligament OR elbow”; published January 2000 – April 2012). Studies with relevance to youth baseball pitchers were reviewed. Relevant references from these articles were also retrieved and reviewed. Original data, insight, and recommendations were added.

Results: The majority of baseball elbow injuries are noncontact injuries to the dominant arm resulting from repetitive pitching. Five percent of youth pitchers suffer a serious elbow or shoulder injury (requiring surgery or retirement from baseball) within 10 years. The risk factor with the strongest correlation to injury is amount of pitching. Specifically, increased pitches per game, innings pitched per season, and months pitched per year are all associated with increased risk of elbow injury. Pitching while fatigued and pitching for concurrent teams are also associated with increased risk. Pitchers who also play catcher have an increased injury risk, perhaps due to the quantity of throws playing catcher adds to the athlete’s arm. Another risk factor is poor pitching biomechanics. Improper biomechanics may increase the torque and force produced about the elbow during each pitch. Although throwing breaking pitches at a young age has been suggested as a risk factor, existing clinical, epidemiologic, and biomechanical data do not support this claim.

Conclusions: Some elbow injuries to youth baseball pitchers can be prevented with safety rules, recommendations, education, and common sense. Scientific and medical organizations have published safety rules and recommendations, with emphasis on prevention of overuse and pitching while fatigued.

Strength-of-Recommendation Taxonomy (SORT): A

Keywords: pitcher; pitch count; ulnar collateral ligament; Tommy John surgery; curveball

Every year in the United States, approximately 15 million children and adults play organized baseball.⁴⁵ This includes 5.7 million children in eighth grade or lower, representing 17% of all children participating in baseball.⁴⁵ Although the rate of elbow injuries is relatively low, the total number of such injuries is significant due to the high number of participants. The majority of baseball elbow injuries are noncontact injuries to the dominant arm resulting from repetitive pitching.^{11,30} Of extra concern is the apparent rise in elbow injuries to youth baseball pitchers, which has been featured in countless stories on television, radio, print, and online media. While no national database exists documenting the total number of elbow surgeries in baseball pitchers, the experience at the Andrews Sports Medicine and Orthopaedic Center supports the belief of increased rates of elbow injuries to youth pitchers (Table 1). In 2010, the American

Orthopaedic Society for Sports Medicine began 2 multicenter youth baseball studies exploring elbow and shoulder problems in young pitchers.⁴ The first study is a community-based project surveying overuse injuries and potential risk factors in youth baseball pitchers. The second is a clinic-based study of youth baseball pitchers seeking medical care at sports medicine clinics. These multicenter studies will determine the prevalence of youth pitching injuries. Recently, the American Sports Medicine Institute (ASMI) published results of a prospective longitudinal study of 481 youth pitchers (aged 9 to 14 years).¹² Each participant was a healthy, active pitcher at the onset of the study and was followed until he no longer played organized baseball or for 10 years (whichever happened first). The incidence of serious elbow or shoulder injury for pitchers was 5% (serious injury was defined as requiring surgery or retirement from baseball).

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Table 1. Ulnar collateral ligament reconstructions (Andrews Sports Medicine and Orthopaedic Center).

Year	Total (No.)	Youth and High School	
		No.	%
1994	6	0	0
1995	21	2	10
1996	31	1	3
1997	23	1	4
1998	43	5	12
1999	65	12	18
2000	93	17	18
2001	93	17	18
2002	110	19	17
2003	172	45	26
2004	174	35	20
2005	153	42	27
2006	140	36	26
2007	125	38	30
2008	103	33	32
2009	121	34	28
2010	131	41	31
Total	1607	374	23

QUANTITY OF PITCHING

The risk factor with the strongest correlation to injury is amount of pitching.³⁸ Olsen et al showed this in their retrospective study of 140 adolescent baseball pitchers (14 to 20 years old).³⁸ The participants were divided into 2 groups, 95 pitchers previously operated on for an elbow or shoulder injury from pitching and a control group of 45 active pitchers with no history of pitching injury. While there was no difference in age between the groups, the injured group self-reported pitching more months per year, innings per game, and pitches per game. Multivariable logistic regression revealed that averaging more than 80 pitches per game almost quadrupled the chance of surgery (odds ratio = 3.83) and pitching competitively more than 8 months per year increased the odds of surgery by fivefold (odds ratio = 5.05). Most alarming was the finding that a pitcher who regularly pitched with his arm fatigued was 36 times as likely to be in the surgery group (odds ratio = 36.18). Recent prospective studies have also identified overuse as the principle risk factor for pitching injury.¹⁵ In the 10-year ASMI study, pitching more than 100 competition innings in a calendar year more than tripled the risk of serious elbow or shoulder injury (odds ratio = 3.5).¹⁵ A study by the University of North Carolina followed Little

League (n = 410), high school (n = 293), and college (n = 629) pitchers for multiple years.^{28,41} Little League and high school pitchers who also pitched for travel teams or showcases had increased risk of elbow injuries (Table 2).

Thus, results from recent prospective studies point to increased amount of pitching in organized baseball as the main culprit for the apparent increase in elbow injuries in young pitchers. Previous generations of young baseball pitchers had passion for playing baseball, parents who pushed them, and temptation to throw breaking pitches, but they did not have the opportunity to play extensive schedules. In previous generations, kids would pitch for their youth league team or school team, perhaps playing 20 scheduled games per year. Today's young baseball player can play for a local league or his school but also can play for a travel team. In fact, nearly one quarter of all Little League pitchers also pitch for travel teams.⁴¹ The prospective studies show that it is not uncommon for youth pitchers to play 70 games or more per calendar year, often playing more than 8 consecutive months.^{15,41} The rapid rise in elbow injuries in young pitchers corresponds with the extended competitive baseball of recent times. "More" is not always "better," and the prospective data strongly correlate extensive pitching with risk of elbow injury.

Table 2. Epidemiologic studies of injuries in young baseball pitchers.

Study	Participants	Questionnaire	Outcome	Risk Factors Related to Injury Outcome
Olsen et al ³⁸	95 pitchers (aged 14-20 years) with elbow or shoulder surgery history 45 pitchers (aged 14-20 years) with no injury history	Retrospective	Elbow or shoulder surgery	Regularly pitched with arm fatigued (36.18 odds ratio) More than 8 months per year of competitive pitching (5.05 odds ratio) Greater than 80 pitches per game (3.83 odds ratio) Fastball velocity greater than 85mph (2.58 odds ratio)
Fleisig et al ¹⁵	481 pitchers (aged 9-14 years at onset of study)	Prospective, annually for 10 years	Elbow or shoulder surgery and/or retired from baseball because of injury	Pitched more than 100 innings in at least one year (3.5 odds ratio) Played catcher in addition to pitcher (2.7 odds ratio)
Register-Mihalik et al ⁴²	409 Little League (LL) pitchers (aged 9-12 years) 293 high school (HS) pitchers	Retrospective, past 12 months	Elbow pain	Participated in showcase (χ^2 , LL = 7.91) Participated in concurrent leagues (χ^2 , HS = 5.34) Participated in travel ball (χ^2 , LL = 4.86)

Another way to examine the effect of pitching more is to compare pitchers from cold and warm climates. The premise is that young athletes in warm climates have opportunities to play organized baseball for more months each year. Data from Kaplan et al support this premise.²⁵ The 50 healthy high school-age pitchers in their study from cold-weather climates averaged 6 months of “pitching activities” per year, whereas the 50 pitchers from warm-weather climates average 9 months per year. While they did not test differences in elbow characteristics, the study found that dominant shoulder range of motion was greater in the warm-weather athletes while dominant shoulder external rotation strength was greater in the cold-weather athletes. They concluded that more pitching and range of motion and strength adaptations may make warm-weather pitchers more susceptible to throwing-related injuries. If this is true, then it may be more difficult for pitchers from warm weather to reach the highest levels of baseball than those from cold weather.

To investigate this possibility, we looked at the place of birth of all major league players on active rosters at the end of the 2010 season.³² The players were separated into warm and cold weather, based on the state they were born in, with players born outside the United States omitted from the analysis. Warm-weather states were those starting high school baseball season in February. California was divided into Northern (cold weather) and Southern (warm weather) California. The players were also separated into pitchers and hitters. Even though place of birth may not completely correlate with amount of baseball played during childhood, the data did show an interesting trend. The percentage of major league hitters born in the warm-weather states was 63%. If overuse in warm-weather climates was not a risk factor for pitching injuries, the percentage of pitchers from warm-weather states should also be approximately 63%. However, the percentage of major league pitchers born in the warm-weather states was only 56%.

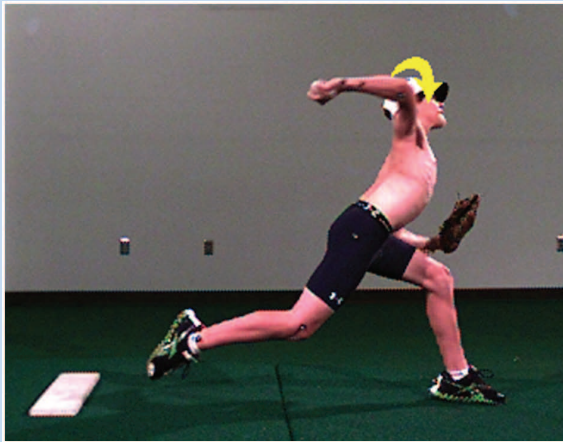


Figure 1. Maximum elbow varus torque.

BIOMECHANICS OF PITCHING

In the kinetic chain of events, a pitcher rotates his pelvis and then upper trunk to face the target while the abducted arm externally rotates at the shoulder.^{16,17} Peak values of shoulder internal rotation torque and elbow varus torque are produced near the time of maximum external rotation to decelerate shoulder external rotation, prevent elbow valgus opening, and initiate shoulder internal rotation (Figure 1).[‡] Tension in the ulnar collateral ligament (UCL) absorbs about half the maximum varus torque in this position.¹⁶ Repetitive pitching can lead to partial or complete tear of the UCL.^{9,10,31,38,39,44} Although younger pitchers produce significantly less torque than adults, youth pitchers have more compliant connective tissue, open epiphyses, and underdeveloped muscles. Thus, repetitive pitching can lead to bony avulsion at a growth plate near the origin or insertion of the anterior bundle of the UCL.^{9,13,22} Elbow varus torque is generated not only by tension in the medial elbow but also by compression on the lateral elbow. Compression between the radial head and humeral capitellum can lead to osteochondritis dissecans, osteochondral chip fractures, or avascular necrosis.^{9,22,31,39} From the arm-cocked position, the elbow rapidly extends, and the shoulder rapidly internally rotates. The combination of elbow varus torque and elbow extension can cause impingement in the posteromedial elbow.¹⁶ Repetitive pitching can result in osteophytes, loose bodies, or chondromalacia at the posteromedial tip of the olecranon.^{9,22,31,39}

Previous research has shown similar motions and timing between youth and adult pitchers but with increased elbow and shoulder velocities, forces, and torques at higher levels.¹⁷ Pitchers at the youth level also have greater inconsistency in their biomechanics from pitch to pitch.¹⁹ Like an adult pitcher, the young pitcher swings his arms apart and up during the leg stride.^{13,26,37,43} At the time of front foot contact, the throwing

shoulder is abducted about 90°, and the elbow is flexed about 80°. ^{13,26,37,43} Elbow flexion at the time of maximum shoulder external rotation varies greatly among studies, reportedly from 57° to 100°. ^{13,26,37,43} From this cocked position, elbow flexion and shoulder internal rotation are initiated. Peak elbow extension velocity of approximately 2000 degrees per second is achieved shortly before ball release. ^{13,26,37} Improper pitching mechanics can lead to increased elbow varus torque and consequently increased risk of elbow injury. ²³ Specific technique flaws associated with increased varus torque include hand under the ball during the stride phase, ¹² late arm rotation (measured as insufficient shoulder external rotation at the instant of front foot contact), ¹⁴ excessive shoulder external rotation, ^{1,43} excessive elbow flexion, ¹ and improper shoulder abduction and trunk tilt. ³³ Correcting flaws in pitching mechanics can reduce the stress on the elbow, reduce the stress on the shoulder, and/or increase ball velocity. Improving biomechanics can increase a pitcher's chance of staying healthy and succeeding.

PITCH TYPE

For generations, experts have pointed to curveballs as a source of pain and injury in youth baseball pitchers. The theory is that to spin a ball to cause a break, the pitcher must put his arm in a position that increases strain on the elbow. Because youth pitchers are skeletally immature, the growth plates at the origin and insertion of the UCL cannot safely withstand such increased strain. ⁴⁷ Many experts over the years have recommended that boys avoid throwing curveballs until they are old enough to shave, an approximate indicator of puberty and skeletal maturity.

A series of biomechanical studies have compared fastball and curveball motions, forces, and torques. Dun et al¹³ tested 29 volunteer youth pitchers (11 to 14 years old) who threw fastball, changeup, and curveball pitches. There was no screening of curveball “good” or “bad” mechanics. All who threw fastballs, changeups, and curveballs were included. As expected, the curveball had greater forearm supination than the fastball. However, elbow varus torque was significantly *less* in the curveball (31.6 ± 15.2 Nm) than in the fastball (34.8 ± 15.4 Nm). Nissen et al³⁶ studied high school pitchers (14 to 18 years) and also found significantly less varus torque in the curveball (54.1 ± 16.1 Nm) than fastball (59.6 ± 16.3 Nm). Fleisig et al²⁰ evaluated collegiate pitchers and found no significant difference in varus torque between fastballs and curveballs. Previous cadaveric research has shown that supination does not affect tension in the UCL during elbow varus torque.⁴⁰

Several retrospective and prospective studies have examined the relationship between throwing curveballs at a young age and elbow pain or injury. In a retrospective study of young pitchers (14 to 20 years old), Olsen et al³⁸ found no difference between the elbow surgery group ($n = 66$) and the healthy control group ($n = 45$) regarding the age they began throwing breaking pitches (13.3 ± 2.3 years vs 12.9 ± 1.4 years). Likewise,

[‡]References 1, 13, 16-18, 20, 21, 26, 33, 36, 37, 42, 43.

the 10-year prospective study by ASMI found no difference between the surgery group ($n = 25$) and the successful, healthy outcomes group ($n = 143$) in terms of age and throwing curveballs (13.4 ± 1.6 years vs 13.5 ± 1.6 years).¹⁵ Pitchers who threw curveballs before 13 years old were no more likely to be injured than pitchers who began after 13 years ($P = 0.41$). The University of North Carolina prospective study also found no evidence that throwing breaking pitches at an early age was an injury risk factor.²⁸

OTHER FACTORS

Youth baseball pitchers also play other positions. Even if a young player specializes as a pitcher, pitch count rules and inning limits have made it harder to pitch all of the time. The pitcher-catcher combination in particular has been suggested as a risk factor. Repetitive pitching may create microscopic tears in the elbow or shoulder that need rest to recover. The quantity of throws by a catcher may add to the cumulative load inhibiting recovery. Data from the ASMI 10-year longitudinal study support this theory. A pitcher who also played catcher was 2.7 times more likely to suffer a serious injury than a pitcher who did not also catch. However, this trend was not statistically significant ($P = 0.09$) due to limited sample size of the pitcher-catcher group ($n = 35$).¹⁵

Other potential risk factors are physical conditioning, nutrition, hydration, and playing environment. Young children often have less coordination and skill than older players.^{2,19} The focus for young players should be to develop physical fitness, athleticism, knowledge of baseball, and enjoyment of the game. Strength and physical conditioning programs for younger players should be aimed at developing general fitness and athleticism, with concentration on functional strength for pitching added for the more advanced athletes. Nutrition and hydration are important for general health as well as for recovery from pitching.^{3,7,8} Outdoor temperature and humidity are also factors for player health and risk of injury.^{2,3}

A potential risk factor for youth pitchers is physical maturity. If children are bigger, faster, and stronger because they developed early physically, they are usually overrepresented in key sports positions such as baseball pitcher.^{24,34} Overuse may be particularly risky for early developers. Muscles of young athletes develop secondary to growth spurts. Strong muscles with open growth plates may increase the risk of physeal plate injuries in a young pitcher's elbow or shoulder.²⁷

INJURY PREVENTION

USA Baseball, Little League Baseball, Baseball Canada, ASMI, the American Orthopaedic Society for Sports Medicine, and the American Academy of Pediatrics have published or implemented guidelines and rules for prevention of youth pitching injuries.^{2,5,6,29,35,46} Most of the focus has been correctly placed on awareness and prevention of overuse. Furthermore, although research has been unable to prove an association between youth curveballs and elbow injury, many

organizations and leading clinicians believe this is a risk factor and discourage curveballs before skeletal maturity.

RECOMMENDED GUIDELINES

1. Watch and respond to signs of fatigue (eg, decreased ball velocity, decreased accuracy, upright trunk during pitching, dropped elbow during pitching, or increased time between pitches). If a youth pitcher complains of fatigue or looks fatigued, rest is recommended.⁵
2. No overhead throwing of any kind for at least 2 to 3 months per year (4 months is preferred). No competitive baseball pitching for at least 4 months per year.
3. Do not pitch more than 100 innings in games in any calendar year.
4. Follow limits for pitch counts and days rest.
5. Avoid pitching on multiple teams with overlapping seasons.
6. Learn good throwing mechanics as soon as possible. The first steps should be (1) basic throwing, (2) fastball pitching, (3) changeup pitching.
7. Avoid using radar guns.
8. A pitcher should not also be a catcher for his team. The pitcher-catcher combination results in many throws and may increase the risk of injury.
9. If a pitcher complains of pain in his elbow or shoulder, discontinue pitching until evaluated by a sports medicine physician.
10. Inspire youth pitchers to have fun playing baseball and other sports. Participation and enjoyment of various physical activities will increase the youth's athleticism and interest in sports.

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