

# An Epidemiological Comparison of Elbow Injuries Among United States High School Baseball and Softball Players, 2005-2006 Through 2014-2015

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**Background:** Pitching is a common mechanism of injury in baseball, with known risk factors for elbow injuries among adolescent pitchers.

**Hypothesis:** Elbow injury rates and mechanisms will differ between high school baseball and softball players.

**Study Design:** Descriptive epidemiology study.

**Level of Evidence:** Level 3.

**Methods:** Baseball- and softball-related injury data from the 2005-2006 through 2014-2015 academic years were collected from the High School Reporting Information Online (RIO) Internet-based data collection tool. Athlete-exposure (AE) and injury data were collected by certified athletic trainers. Rate ratios (RRs) were calculated comparing injury rates in the 2 populations. Injury proportion ratios (IPRs) comparing elbow injuries in pitchers and nonpitchers were calculated as the proportion of all elbow injuries in pitchers divided by the proportion of all elbow injuries in nonpitchers.

**Results:** A total of 214 elbow injuries in male baseball players occurred over 2,327,774 AEs, for an overall elbow injury rate of 0.92 per 10,000 AEs. A total of 75 elbow injuries were reported in female softball players over 1,731,644 AEs, for an overall rate of 0.43 per 10,000 AEs. The rate of elbow injury was significantly higher for baseball than softball (RR, 2.12; 95% CI, 1.64-2.77). A significantly greater proportion of elbow injuries in baseball were pitching-related compared with those from softball, with 50.2% occurring while pitching in baseball versus 11.0% in softball (IPR, 4.58; 95% CI, 2.35-8.93). If all injuries occurring during pitching were removed from both sports, the difference in elbow injury rate for baseball and softball would no longer be significant (RR, 1.19; 95% CI, 0.88-1.62).

**Conclusion:** The rate of elbow injuries is significantly higher in baseball than softball. This is attributable to differences in rates of pitching-related injuries between these 2 groups.

**Clinical Relevance:** These results demonstrate that overhand pitching increases risk of elbow injury in high school athletes.

**Keywords:** baseball; softball; elbow; High School RIO

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During the 2014-2015 school year, 487,770 US high school students participated in baseball, and 365,528 students participated in fastpitch softball.<sup>1</sup> In a prospective study of high school students, the unadjusted injury rates in baseball and softball were 0.95 and 0.96 per 1000 athlete-exposures (AEs), respectively.<sup>9</sup> Furthermore, arm pain is extremely common in young baseball players, with only 26% of youth baseball players reporting that their arm never hurt while throwing.<sup>12</sup> Overuse injuries in the young throwing athlete are also common, and recently, the rate of surgical intervention as a result of throwing injuries has risen drastically.<sup>8,11</sup> In particular, the number of ulnar collateral ligament reconstructions (“Tommy John surgery”) performed in New York state increased 343% between 2003 and 2014, with the mean patient age at the time of surgery decreasing from 20.5 to 19.1 years.<sup>11</sup> In relation to this, it has recently been shown that more than one-third of Little League baseball players had abnormal preseason magnetic resonance imaging findings of the elbow.<sup>15</sup>

Pitching is a common mechanism of injury in baseball.<sup>5,14</sup> Olsen et al<sup>14</sup> found that adolescent pitchers with injuries to the shoulder and elbow pitched significantly more months per year, games per year, innings per game, pitches per game, pitches per year, and warm-up pitches per game. Athletes in the injured group were also found to be taller and heavier.<sup>14</sup> Other known risk factors include pitching for more than 1 team, pitch velocity, and decrease in 90° abducted internal rotation.<sup>4,17</sup>

In contrast to baseball, softball has a different injury profile, with a greater propensity for lower extremity injuries.<sup>13</sup> Furthermore, among softball injuries that occur as a result of pitching, the majority involve the shoulder.<sup>18</sup> The primary difference between baseball and softball is the style of pitching. In addition to a fundamentally different style of delivery, the distance from the pitching rubber to home plate is 40 feet in high school softball compared with 60 feet in baseball, and a regulation softball has a greater circumference (12 inches) and mass (200 g) compared with a regulation baseball (9 inches and 146 g, respectively).<sup>19</sup> In a review of National Collegiate Athletic Association injury surveillance data, Marshall et al<sup>13</sup> found that in women’s softball, a higher percentage of injuries occurred at the position of base runner and batter than pitcher. However, previous studies have not directly compared the risk of elbow injuries between baseball and softball players at the same level of play to determine whether a true difference in risk exists between sports. The purpose of this study was to describe and compare US high school baseball and softball elbow injury rates and to identify any associated risk factors.

## METHODS

The institutional review board at Nationwide Children’s Hospital in Columbus, Ohio, approved this study. This descriptive epidemiological study retrospectively analyzed sports injury surveillance data, collected using the High School Reporting Information Online (RIO) database, from the 2005-2006 through 2014-2015 academic years. The methodology of High School RIO data collection has been described in depth in previous publications.<sup>16</sup> Briefly, the High School RIO used 2 concurrent

surveillance cohorts during the study period. In the original study cohort, willing participants were categorized into 8 strata based on US census geographic region (Northwest, Midwest, South, and West) and school population (total enrollment ≤1000 or >1000 students). A total of 100 high schools were randomly selected from these 8 strata to report on each of the 9 sports included in the original High School RIO study, including baseball and softball. Beginning in the 2008-2009 academic year, additional schools were recruited and sports were added to the surveillance system (the “convenience sample”). Athletic trainers (ATs) from participating schools logged into High School RIO database weekly to report AE and injury data.

In the High School RIO, each AE represents a single athlete participating in a single practice or competition. To meet the definition of a baseball or softball injury, an incident injury must meet the following 3 criteria: (1) occur as the result of an organized high school baseball or softball practice or competition, (2) require medical attention by an AT or physician, and (3) result in restriction of the athlete’s participation for at least 1 day beyond the date of injury or be a fracture, concussion, heat illness/injury, or dental injury (which are captured regardless of time loss). If more than 1 injury is sustained during a single incident, ATs are asked to report the primary injury based on their expert clinical judgment. However, multiple injuries occurring in different AEs can be reported for the same athlete throughout a season, with the questionnaire asking whether the injury is new or recurrent.

For the purposes of this study, an *elbow injury* is any injury in which the AT selected the elbow as the primary body part injured. Because elbow injuries are relatively rare in baseball and softball, the larger convenience sample of schools reporting baseball data was used in all analyses except the calculation of national estimates, which require using the nationally representative original sample to apply weighting mechanisms. Injuries are weighted based on the inverse probability of the school’s selection into the original sample.<sup>6</sup>

All data were analyzed using SAS software, version 9.4 (SAS Institute) and EpiInfo, version 7 (US Centers for Disease Control and Prevention). Injury rates are calculated as the number of injuries per 10,000 AEs. Rate ratios (RRs) are calculated by dividing the injury rates in 2 populations. Injury proportion ratios (IPRs) comparing elbow injuries in pitchers and nonpitchers, for example, are calculated as the proportion of all pitcher injuries occurring to the elbow divided by the proportion of all nonpitcher injuries occurring to the elbow. RRs and IPRs whose 95% confidence intervals do not include 1.0 are considered statistically significant. The Fisher exact test was used to compare need for surgery in elbow injuries between baseball and softball due to at least 1 cell having an expected frequency of less than 5, with  $P < 0.05$  determining statistical significance.

## RESULTS

### Overall Injury Rates

A total of 214 elbow injuries in male baseball athletes occurred over 2,327,774 AEs, for an overall elbow injury rate of 0.92 per

Table 1. Elbow injury rates in boys' baseball and girls' softball by exposure type, 2005-2006 through 2014-2015<sup>a</sup>

Sport	Elbow Injuries	AEs	Rate per 10,000 AEs	Rate Ratio (95% CI) <sup>b</sup>
Baseball				
Competition	117	815,928	1.43	
Practice	97	1,511,846	0.64	<b>2.24 (1.71-2.93)</b>
Overall	214	2,327,774	0.92	
Softball				
Competition	28	595,067	0.47	
Practice	47	1,136,577	0.41	1.14 (0.71-1.81)
Overall	75	1,731,644	0.43	

AE, athlete-exposure.

<sup>a</sup>Data derived from the High School Reporting Information Online convenience study.

<sup>b</sup>Rate ratio compares competition to practice within each sport. Boldface denotes statistical significance.

10,000 AEs. A total of 75 elbow injuries were reported in female softball athletes over 1,731,644 AEs, for an overall rate of 0.43 per 10,000 AEs. The elbow injury rate was significantly higher in baseball than softball athletes (RR, 2.12; 95% CI, 1.64-2.77), even though overall injury rates (for all body parts) are significantly higher for softball than baseball (1.22 vs 1.01 per 1000 AEs, respectively; RR, 1.21; 95% CI, 1.15-1.29). In addition, injuries to the elbow represented a significantly greater proportion of all baseball injuries (9.2%) than softball injuries (3.6%) (IPR, 2.58; 95% CI, 1.99-3.33). Over the 10-year study period, an estimated 44,429 baseball and 23,710 softball elbow injuries occurred nationally.

Elbow injuries were significantly more likely to occur in competition than practice in baseball (RR, 2.24; 95% CI, 1.71-2.93) (Table 1). However, there was no significant difference in elbow injury rate between practice and competition for softball (RR, 1.14; 95% CI, 0.71-1.81).

### Nature and Severity of Injuries

In baseball players, ligament sprains were the most common injury diagnosis (31.8%), followed by tendinitis (19.0%), contusions (17.1%), and muscle/tendon strains (16.1%). For softball athletes, however, tendinitis was the most common injury diagnosis (30.7%), followed by contusions (22.7%), ligament sprains (18.7%), and muscle/tendon strains (14.7%) (Table 2). A significantly greater proportion of baseball injuries were ligament sprains compared with softball injuries (31.8% vs 18.7%; IPR, 1.70; 95% CI, 1.02-2.84). Tendinitis, on the other hand, represented a greater proportion of softball injuries than baseball injuries (19.0% vs 30.7%; IPR, 0.62; 95% CI, 0.40-0.96).

Baseball injuries tended to be more severe than softball injuries, with 27.9% of baseball injuries resulting in at least 3 weeks of time lost from sport participation compared with 8.2% of softball injuries ( $P < 0.0001$ ) (Table 3). More specifically, 9.3% ( $n = 19$ ) of baseball elbow injuries resulted in medical

disqualification (DQ) for the season, while only 1 softball elbow injury resulted in a DQ (1.3%). Similarly, baseball injuries were more likely to require surgery than softball injuries (6.2% vs 0.0%,  $P = 0.02$ ). Ligament sprains represented 84.6% of baseball elbow injuries requiring surgery, with the other 15.4% coming from a fracture and a muscle strain.

### Injury Circumstances

Circumstances surrounding baseball and softball elbow injuries are presented in Table 2. A significantly greater proportion of baseball elbow injuries were pitching-related compared with softball elbow injuries. This pattern was consistent across all baseball/softball sport-specific variables completed by ATs, including position (injured athlete was a pitcher) (52.9% vs 18.6%; IPR, 2.85; 95% CI, 1.72-4.73), activity (injury happened while pitching) (50.2% vs 11.0%; IPR, 4.58; 95% CI, 2.35-8.93), and mechanism (injury directly resulted from pitching) (44.4% vs 9.7%; IPR, 4.57; 95% CI, 2.22-9.38). The increased rate of elbow injury in baseball compared with softball is largely because of these differences in pitching-related injuries. If all injuries occurring during pitching were removed from both baseball and softball, the difference between elbow injury rates in baseball and softball would no longer be significant (nonpitching RR, 1.19; 95% CI, 0.88-1.62).

## DISCUSSION

In the present study, elbow injuries occurred at a significantly higher rate among US high school baseball players compared with softball players. Additionally, elbow injuries represented a nearly 3-fold higher proportion of all injuries in baseball compared with softball. Injuries were significantly more likely to occur in competition than practice in baseball, while there was no statistical difference for softball. Previous studies using the

Table 2. Nature and circumstances of boys' baseball and girls' softball elbow injuries, 2005-2006 through 2014-2015<sup>a</sup>

	Baseball, n (%)	Softball, n (%)	Injury Proportion Ratio (95% CI) <sup>b</sup>
<b>Diagnosis</b>			
Ligament sprain	67 (31.8)	14 (18.7)	<b>1.70 (1.02-2.84)</b>
Tendinitis	40 (19.0)	23 (30.7)	<b>0.62 (0.40-0.96)</b>
Contusion	36 (17.1)	17 (22.7)	0.75 (0.45-1.26)
Muscle/tendon strain	34 (16.1)	11 (14.7)	1.10 (0.59-2.06)
Other <sup>c</sup>	34 (16.1)	10 (13.3)	1.21 (0.63-2.32)
<b>Injury mechanism</b>			
Pitching	95 (44.4)	7 (9.7)	<b>4.57 (2.22-9.38)</b>
Throwing (not pitching)	41 (19.2)	22 (30.6)	<b>0.63 (0.40-0.98)</b>
NA (ie, overuse, unknown)	23 (10.7)	19 (26.4)	<b>0.42 (0.25-0.73)</b>
Hit by pitch	25 (11.7)	9 (12.5)	0.93 (0.46-1.91)
Other <sup>d</sup>	30 (14.0)	15 (20.8)	0.67 (0.38-1.17)
<b>Activity at time of injury</b>			
Pitching	107 (50.2)	8 (11.0)	<b>4.58 (2.35-8.93)</b>
Throwing (not pitching)	45 (21.1)	35 (48.0)	<b>0.44 (0.31-0.63)</b>
Batting	32 (15.0)	11 (15.1)	1.00 (0.53-1.87)
Fielding	9 (4.2)	5 (6.8)	0.62 (0.21-1.78)
Catching	4 (1.9)	5 (6.8)	<b>0.27 (0.08-0.99)</b>
General play	5 (2.4)	4 (5.5)	0.43 (0.12-1.55)
Other	11 (5.2)	5 (6.8)	0.75 (0.27-2.10)
<b>Position of injured athlete</b>			
Pitcher	110 (52.9)	13 (18.6)	<b>2.85 (1.72-4.73)</b>
Infielder	29 (13.9)	17 (24.3)	<b>0.57 (0.34-0.98)</b>
Outfielder	18 (8.7)	19 (27.1)	<b>0.32 (0.18-0.57)</b>
Batter	28 (13.5)	8 (11.4)	1.18 (0.56-2.46)
Catcher	18 (8.7)	11 (15.7)	0.55 (0.27-1.11)
Other	5 (2.4)	2 (2.9)	0.84 (0.17-4.24)

<sup>a</sup>Data derived from the High School Reporting Information Online convenience study.

<sup>b</sup>Injury proportion ratio compares the proportion of injuries in the selected category in baseball compared with softball. Boldface denotes statistical significance.

<sup>c</sup>Diagnoses representing fewer than 5% of all elbow injuries in both baseball and softball are collapsed into the "Other" category, including lacerations, hyperextensions, inflammation, dislocation, bursitis, stress fracture, subluxation, apophysitis, nerve injuries, and other. Three boys' baseball injuries were excluded due to missing injury diagnosis.

<sup>d</sup>"Other" category includes contact with bat, contact with nonpitched thrown ball, hit by batted ball, contact with walls or bases, contact with another player, and other. Three softball injuries were excluded due to missing mechanism information.

Table 3. Severity of boys' baseball and girls' softball elbow injuries, 2005-2006 through 2014-2015<sup>a</sup>

	Baseball, n (%)	Softball, n (%)	P Value
Need for surgery			
Surgery required	13 (6.2)	0 (0.0)	0.02 <sup>b</sup>
Surgery not required	197 (93.8)	73 (100.0)	
Return to play time			
<1 week	74 (36.8)	45 (61.6)	<0.0001 <sup>c</sup>
1-3 weeks	71 (35.3)	22 (30.1)	
3 weeks or longer <sup>d</sup>	56 (27.9)	6 (8.2)	

<sup>a</sup>Data derived from the High School Reporting Information Online convenience study.

<sup>b</sup>P value calculated using Fisher exact test.

<sup>c</sup>P value calculated using Wilcoxon rank-sum test.

<sup>d</sup>Includes injuries that resulted in time loss over 3 weeks, medical disqualification, the athlete's choosing not to continue, the athlete's being released from team, or the season ending before the athlete returned to activity.

High School RIO database have demonstrated higher injury rates during competition compared with practice.<sup>10,16</sup> The nonsignificant difference in elbow injury rates among softball players likely reflects the overall reduced risk among these athletes.

The mechanics of windmill softball pitching differ from baseball pitching yet still produce significant stress on the throwing arm. In a motion analysis of female fast-pitch throwers, Barrentine et al<sup>3</sup> found that, during the second half of the delivery phase, the elbow reached a maximum extension velocity of 570 deg/s and experienced a maximal compressive force of 70% of body weight. Additionally, the elbow experienced a relatively low varus torque. In fact, the maximal valgus torque was 4% body weight × height. To counteract the large valgus motion experienced in overhead throwing, the elbow must produce a large varus torque. It appears that the biomechanics of overhead throwing are unique and differ from underhand throwing, which may explain the significant difference in injury rates between baseball and softball pitchers.

The difference in elbow injury rate between baseball and softball are pitching related. In baseball, 50.2% of elbow injuries were sustained while pitching compared with 11.0% in softball. The most significant contributing factor likely is the difference in pitching mechanics between baseball and softball. Overhead pitching places a significant amount of stress on the thrower's elbow. In a study using motion analysis on adult pitchers, a maximum varus torque of 64 N·m is generated at the elbow late in the arm-cocking phase of throwing.<sup>7</sup> This value exceeds the maximum torque that the ulnar collateral ligament can withstand, necessitating contributions from the flexor-pronator muscle group. Additionally, during the deceleration phase, the elbow experienced a compression force that reached a peak of 90% of body weight.<sup>7</sup>

By using a large, national injury surveillance program, this study highlights the fact that overhead pitching places the high school athlete at an increased risk for elbow injury. The American Sports Medicine Institute laid out a number of recommendations with the aim of reducing injury.<sup>2</sup> These include closely watching for signs of fatigue, avoiding overhead throwing of any kind for 2 to 3 months per year, pitching more than 100 innings per calendar year, following limits on pitch counts, and prohibiting pitchers from also playing the catcher position. The recommendations also focus on good throwing mechanics. Although the results of this study do not lend any insight into the effects of pitch counts, innings played, or months per year played, it does show that pitchers in particular are at greater risk for injury and suggests that implementation of regulations and close monitoring is prudent. While baseball in particular has higher elbow injury rates than most other sports, it is worth noting that absolute risk of sustaining an elbow injury is relatively small, particularly for softball, in which only 4.3 elbow injuries requiring time loss per 100,000 softball practices or competitions would be expected, given the rates reported.

The limitations of this study should be noted. Only high schools with a National Athletic Trainers' Association-affiliated AT were eligible to be included in this study. Although this limits the generalizability of the data presented, it also ensures a higher level of quality and consistency in data collection. Second, this study only included injuries that resulted in time loss and therefore likely underreports the true injury burden. Third, some of the comparisons in this study were limited in power by the rare nature of these injuries, resulting in a small sample size for comparison using injury proportion ratios. Finally, the RIO data collection tool does not collect data concerning the number of games and innings played, pitch

counts, months per year played, or participation on additional baseball/softball teams outside of high school.

## CONCLUSION

The rate of elbow injuries is significantly higher in baseball than softball. This is attributable to pitching-related injuries.

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