The Incidence of Shoulder and Elbow Injuries in High School and Collegiate Softball Athletes: A Systematic Review

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Context: Despite increased youth and adolescent participation in fast-pitch softball and the reporting of upper extremity injuries, there remains a relative paucity of research examining shoulder and elbow injuries in high school and collegiate softball athletes.

Objective: To evaluate the reported incidence, setting, and positional factors associated with shoulder and elbow injuries in high school and collegiate fast-pitch softball players.

Data Sources: PubMed, Ovid, Medline, EMBASE, Scopus, Cochrane Central, and Clinicaltrials.gov.

Study Selection: English-language articles reporting the incidence of shoulder and/or elbow injuries occurring in high school or collegiate fast-pitch softball players were included. Biomechanical studies, review articles, abstract only texts, previous systematic reviews, and meta-analyses were excluded.

Study Design: Systematic review.

Level of Evidence: Level 4.

Data Extraction: Two reviewers independently evaluated studies. Data related to the reported incidence of shoulder and elbow injuries, injury setting, position, and rate of return to play after injury were recorded.

Results: A total of 22 studies were identified. In high school athletes, shoulder injury rates ranged from 0.88 to 1.14 per 10,000 athletic exposures (AE), with elbow injury rates ranging from 0.41 to 0.71 per 10,000 AE. In collegiate athletes, reported injury rates ranged from 3.76 to 5.93 per 10,000 AE for shoulder and 1.5 to 3.39 per 10,000 AE for elbow injuries. Shoulder and elbow injuries were reported more commonly during competition in high school athletes, and with greater frequency in the practice setting in collegiate athletes. No association between injury incidence and position was appreciated at either the high school or collegiate level. Most (81%-96%) athletes were able to return to sport within 3 weeks of injury.

Conclusion: The incidence of shoulder and elbow injuries was greater in collegiate softball athletes than in high school athletes.

Keywords: elbow; epidemiology; injury; shoulder; softball

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Fast-pitch softball remains popular among youth and adolescent female players in the United States,[35] with over 1.2 million amateur participants each year.[51] Due to the physical demands inherent to participation in fast-pitch softball, athletes are at risk for injury, with up to 30% of youth athletes reporting softball-related injuries annually.[22] Namely, the biomechanical load placed on the upper-extremity during throwing, especially in pitchers, results in a large proportion of softball-related injuries involving the upper extremity.[5,13,55,56] Early misconceptions regarding the relative "safety" of the windmill pitch have resulted in a paucity of both research and recommendations regarding injury prevention in fast-pitch softball athletes.[4]

Although multiple investigations have examined injury incidence and associated risk factors for the development of upper extremity injuries in adolescent and professional baseball athletes, little data are available for softball athletes.[3,12,37] Despite the adoption of age-specific guidelines limiting the number of pitches, duration of pitching appearances, and mandatory periods of rest in baseball athletes, no such data exist for softball athletes.[6,29,50] Although early literature suggests a similar relationship between pitch volume and injury risk in softball players, few recommendations have been proposed as a means of minimizing injury risk in softball athletes.[39]

Developing a strategy to limit injury risk to the upper extremity first requires a better understanding of the epidemiologic factors associated with injury to the shoulder and elbow in fast-pitch softball athletes. No previous studies have completed a comprehensive systematic review of the literature to detail the incidence of shoulder and elbow injuries in female softball athletes or risks associated with increased injury. As such, the primary purpose of this study was to systematically review the available literature evaluating the incidence, setting, and positional factors associated with shoulder and elbow injuries in high school and collegiate fast-pitch softball athletes, as well as playing time missed due to shoulder or elbow injury in this population. The authors hypothesized that collegiate athletes would possess a higher incidence of both shoulder and elbow injuries when compared with high school athletes, that injuries would occur primarily during game competition, and would be reported more commonly in pitchers than position players.

METHODS

A systematic review was conducted in accordance with 2020 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) and SWiM (Synthesis Without Meta-analysis) guidelines.[8,38] A literature search was conducted in January 2023 by 2 independent authors using PubMed, Ovid, Medline, EMBASE, Scopus, Cochrane Central, and Clinicaltrials.gov from database inception to present. The initial search strategy was created by a medical librarian to identify studies reporting on shoulder and elbow injuries in high school and collegiate fast-pitch softball athletes. The search strategies were established using a combination of standardized terms and keywords, including but not limited to: softball AND (elbow injury OR shoulder injury OR glenohumeral dislocation OR rotator cuff tear OR athletic injury) AND (university OR college OR high school). A narrow search for shoulder and elbow injuries in noncollegiate softball was also performed, to ensure identification of athletes not described as high school or college players. Full electronic search strategies are provided in the Appendix, available in the online version of this article.

The inclusion criteria consisted of studies in the English language or studies with English-language translation, reporting on the incidence of shoulder and/or elbow injuries occurring in high school or collegiate fast-pitch softball players. Exclusion criteria consisted of: studies reporting injuries not involving the shoulder or elbow, studies reporting on injuries in youth or professional softball players, studies failing to specify injuries unique to softball athletes, biomechanical studies, review articles, abstract only texts, as well as previous systematic reviews and meta-analyses. Studies with overlapping patient data were considered separately with inclusion of investigations reporting most recent follow-up.

Two authors independently performed the initial search by screening articles in the following systematic approach: assessment of duplicate articles, content within the article title, content of the abstract, and full-text review. Any disagreements in study selection were discussed and decided with the senior author, during which time no disagreements were encountered. To confirm that no studies were missing from the systematic review, all references cited in the included studies were also reviewed and reconciled.

In studies selected for full-text review meeting inclusion criteria, the following data were extracted by 2 reviewers: level of competition (high school versus collegiate), incidence of injuries to the shoulder and elbow, player position (pitcher versus position-player), injury setting (practice versus game play), as well as the rate and timing of return to play (RTP) after injury. Due to the heterogeneity of methodology and data analysis among the studies, a meta-analysis was not performed and a narrative analysis approach was used.[8] Injury incidence was reported most frequently using injury incidence rates, reported as number of injuries per athlete-exposure (AE). Of the 7 studies directly reporting injury incidence rates[7,27,33,36,42,53] (Bonza, Fields, Yard and Comstock, 2009)(Krajnik, Fogarty, Yard and Dawn, 2010)(Marshall, Hamstra-Wright, Dick, Grove and Agel, 2007) (Oliver, Saper and Drogosz, 2019) (Robinson, Corlette, Collins and Comstock, 2014) (Snyder Valier, Huxel Bliven and Gibson, 2020) (Wasserman, Register-Mihalik and Sauers, 2019) (number of injuries / athlete exposure (AE), 4 reported injury rate per 10,000 AE; therefore, when reported as injury per 1000 AE, injury rates were converted to injury per 10,000 AE for consistency in comparison. With the exception of 2 articles, injury was defined as any pathology occurring directly as a result of softball participation resulting in at least 1 day restriction from athletic participation.[9] Two articles used the National Athletic Treatment, Injury, and Outcomes Network Surveillance Program (NATION-SP) dataset, which included nontime loss (NTL) injuries.[25,49] When these studies were

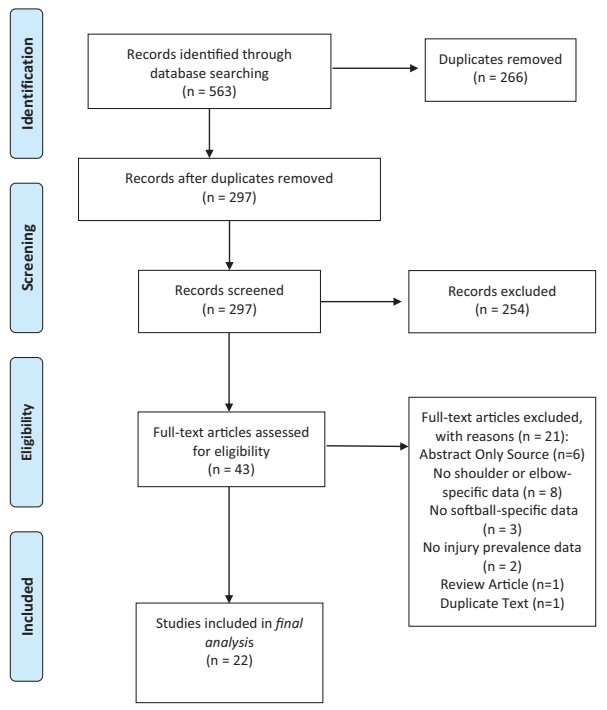

Figure 1. PRISMA flowchart demonstrating the inclusion/exclusion process. PRISMA, preferred reporting items for systematic reviews and meta-analyses.

used in data comparison, only injuries with a minimum of 1 day participation loss were included in the analysis. The reported incidence of injuries to the shoulder and elbow were calculated based on competition level (high school versus collegiate) and setting (practice versus game), as well as athlete position (pitcher versus position-player). Continuous variables were presented as means and standard deviations, while categorical variables were presented as percentages.

The methodological quality of each study was reviewed independently by 2 authors using Joanna Briggs Institute critical appraisal tools (JBI) according to study design.[34] Each appraisal tool includes a list of questions with "yes," "no," "unclear," or "not applicable" based on the study design. Results of the critical appraisal were reported as percentage of questions with a "yes" response. All studies were used regardless of methodological quality.

RESULTS

Study Selection

The initial search identified a total of 563 citations, with a total of 297 unique citations identified after removing duplicate articles (Figure 1). A total of 254 studies were excluded following title and abstract screening, resulting in 43 full text articles eligible for full-text review. The remaining articles were reviewed for inclusion based on predetermined exclusion criteria: abstract-only sources, review articles, and articles lacking shoulder/elbow-specific or softball-specific data. A total of 21 articles were excluded after full-text review, leaving 22 articles initially deemed eligible for inclusion (Table 1).

Study Characteristics

Of the 22 articles included: 4 studies were of level 3 evidence,[40,45,46,48] and the remaining 18 were level 4 evidence.[2,7,11,18,20,21,25,27,28,30,33,36,41,42,44,49,52,53] The studies averaged 90% quality when assessed using JBI critical appraisal evaluations based on study type.[34] Only 1 of the 22 studies was found to score <50% when evaluating the methodologic criteria. Data from the high school Reporting Information Online (RIO) database were used for 7 studies, while the National Collegiate Athletic Association (NCAA)'s Injury Surveillance System (ISS), later renamed the Injury Surveillance Program (ISP), was used for an additional 4 studies. In evaluating injury rates, only NTL injuries from the NATION-SP dataset were included in analysis.

High School Athletes

Shoulder Injuries

The incidence of shoulder injuries in high school softball athletes was reported in 13 studies (Table 2).[7,11,25,27,36,40-42,46,48,49,53] Injury rate was reported in 6 studies,[7,27,36,42,49,53] ranging from 0.88 to 1.14 per 10,000 AE. Shoulder injuries were reported to account for 16.3% to 38% of all injuries in softball athletes in 2 investigations.[40,46] Noncontact injuries accounted for 25.6% to 39% of shoulder injuries, with chronic/overuse injuries comprising 39% to 50.4% of injuries in 2 investigations.[27,36]

Elbow Injuries

The incidence of elbow injuries was reported in 7 articles (Table 3).[18,25,36,46,48,49,53] Injury rate was reported in 3 studies, ranging from 0.41 to 0.71 per 10,000 AE.[36,49,53] Shanley et al[46] and Smith et al[48] observed that elbow injuries accounted for 9.5% and 10% of all injuries sustained over the course of a single season, respectively.

Injury Setting

The rate of shoulder injuries based on injury setting was reported in 5 studies,[7,27,36,42,53] ranging from 0.67 to 1.04 per 10,000 AE in practice versus 1.24 to 1.46 per 10,000 AE during games. Elbow injuries, reported in 2 studies, ranged from 0.41 to 0.64 per 10,000 AE in practice versus 0.42 to 0.84 per 10,000 AE during games.[36,53]

Injuries by Position

Three studies reported injury rates to the shoulder based on player position.[27,36,46] Krajnik et al[27] reported that pitchers, catchers, and first baseman possessed equal proportions of all shoulder injuries over 3 seasons (15% each). Over the course of 12 seasons, Oliver et al[36] observed that infielders composed 36%, and outfielders 24.3%, of shoulder injuries. Shanley et al[46]

Table 1. Characteristics of studies included in analysis

Lead Author (JBI % Yes)	Journal (Year)	Study Design (Level of Evidence)	Study Population	Athletes, AE	Number of Injuries	Time Lost	Injury Setting
Aragon[2] (63%)	*J Athl Train* (2012)	Cross section (4)	Collegiate position players	65 athletes	19 shoulder or elbow	NR	NR
Bonza[7] (100%)	*J Athl Train* (2009)	Case series (4)	High school	254,568 AE	Shoulder 28	<1 week 51.1%	Shoulder practice 0.91/10,000 AE game 1.46/10,000 AE
Darrow[11] (100%)	*Am J Sports Med* (2009)	Case series (4)	High school	254,568 AE	Shoulder 4.089*a*	>21 days	NR
Gooch[18] (38%)	*Sports Health* (2022)	Cross section (4)	High school	28 athletes	Shoulder 11 elbow 11	NR	NR
Hassebrock[20] (100%)	*Orthop J Sports Med* (2019)	Case series (4)	Collegiate	8,250,393 AE	Elbow 1222	<1 day 77.7% <1 week 14.8% 1-3 weeks 3.7% >3 weeks 3.7%	Elbow practice 2.28/10,000 AE competition 1.54/10,000 AE
Hill[21] (75%)	*Sports Health* (2004)	Cross section (4)	Collegiate	181 athletes	Shoulder 41 Elbow 9	NR	NR
Kerr[25] (100%)	*J Athl Train* (2017)	Case series (4)	High school and collegiate	NR	High school Shoulder 135 Arm/elbow 142 College Shoulder 59 Arm/elbow 42	All injuries NTL	NR
Krajnik[27] (100%)	*Pediatrics* (2010)	Case series (4)	High school	399,522 AE	Shoulder 40	<1 week 49% 1-3 weeks 33% >3 weeks 10% 8% unable to RTP	Shoulder practice 55% game 45%
Li[28] (100%)	*Orthop J Sports Med* (2019)	Case Series (4)	Collegiate	NR	Elbow (UCL) 3, National estimate 116	>21 days for 66.6% of injuries	NR
Loosli[30] (71%)	*Am J Sports Med* (1992)	Cross section (4)	Collegiate pitchers	24 athletes	Shoulder 9 Elbow 4	NR	NR

(continued)

Table 1. (continued)

Lead Author (JBI % Yes)	Journal (Year)	Study Design (Level of Evidence)	Study Population	Athletes, AE	Number of Injuries	Time Lost	Injury Setting
Marshall[33] (100%)	*J Athl Train* (2007)	Case series (4)	Collegiate	11,6713 AE	Shoulder 465 Elbow 97	NR	Shoulder practice 318 (68%) game 147 (32%) Elbow practice 72 (74%) game 25 (26%)
Oliver[36] (100%)	*Orthop J Sports Med* (2019)	Case Series (4)	High school	2,095,329 AE	Shoulder 239 Elbow 85	Shoulder <1 week 40.6% 1-3 weeks 40.6% >3 weeks 5.6% 13.2% unable to RTP Elbow <1 week 60% 1-3 weeks 30.6% >3 weeks 2.4% 7% unable to RTP	Shoulder practice 1.04/10,000 AE game 1.33/10,000 AE Elbow practice 0.41/10,000 AE game 0.42/10,000 AE
Powell[40] (63%)	*Am J Sports Med* (2000)	Cohort (3)	High school	5,435 player-seasons	138 (Shoulder/arm)	NR	NR
Rechel[41] (100%)	*J Trauma Acute Care Surg* (2011)	Case series (4)	High school	663,546 AE	2.622*a*	NR	NR
Robinson[42] (100%)	*Pediatrics* (2014)	Case series (4)	High school	911,814 AE	Shoulder 80	<1 week 43.4% 1-3 weeks 39.6% >3 weeks 9.4% 2% unable to RTP	Shoulder practice 0.67/10,000 AE game 1.27/10,000 AE
Sauers[44] (63%)	*J Sport Rehabil* (2011)	Cross section (4)	High school and collegiate pitchers	25 athletes	Shoulder 7 Elbow 5	NR	NR
Shanley[45] (88%)	*Int J Sports Phys Ther* (2012)	Cohort (3)	High school pitchers	12 athletes	2 Shoulder	NR	NR
Shanley[46] (88%)	*J Athl Train* (2011)	Cohort (3)	High school	3760 AE	Shoulder 8 Elbow 2	NR	NR
Smith[48] (75%)	*Sports Health* (2015)	Cohort (3)	High school	98 athletes	Shoulder 12 Elbow 3	NR	NR

(continued)

Table 1. (continued)

Lead Author (JBI % Yes)	Journal (Year)	Study Design (Level of Evidence)	Study Population	Athletes, AE	Number of Injuries	Time Lost	Injury Setting
Snyder Valier[49] (100%)	*J Athl Train* (2020)	Case Series (4)	High school	140,073 AE	Shoulder 150 Elbow 90	Shoulder 89.3% injuries NTL Elbow 93% injuries NTL	NR
Veillard[52] (100%)	*J Athl Train* (2021)	Case series (4)	Collegiate	385,922 AE	Shoulder 229 Elbow 131	NR	Shoulder practice 6.8/10,000 AE[a] game 4.8/10,000 AE[a] Elbow practice 3.9/10,000 AE[a] game 2.8/10,000 AE[a]
Wasserman[53] (100%)	*J Athl Train* (2019)	Case series (4)	High school & collegiate	High school 1,173,722 AE College 579,553 AE	High school Shoulder 66 Elbow 49 College Shoulder 143 Elbow 67	NR	**High school** Shoulder practice 0.9/10,000 AE game 1.2/10,000 AE Elbow practice 0.6/10,000 AE game 0.8/10,000 AE **College** Shoulder practice 2.0/10,000 AE game 3.1/10,000 AE Elbow practice 2.0/10,000 AE game 2.9/10,000 AE

AE, athletic exposures; JBI, Joanna Briggs Institute critical appraisal tools; NR, not reported; NTL, nontime loss; RTP, return to play; UCL, ulnar collateral ligament.
[a]Number of injuries calculated based on reported data.

Table 2. Shoulder injuries in high school softball athletes

Lead Author	Significant Findings
Robinson[42]	Shoulder injury rate 0.9/10,000 AE 87% of all shoulder injuries were new injuries
Wasserman[53]	Shoulder injury rate 1/10,000 AE
Krajnik[27]	Shoulder injury rate 1/10,000 AE 39% overuse injuries 39% noncontact injuries
Bonza[7]	Shoulder injury rate 1.1/10,000 AE
Snyder Valier[49]	Shoulder injury rate 1.1/10,000 AE[a]
Oliver[36]	Shoulder injury rate 1.1/10,000 AE 50.4% chronic/overuse injuries 25.6% noncontact injuries
Gooch[18]	39.2% of pitchers suffered shoulder pain or injury Shoulder pain/injury associated with higher number of pitches per game ($p=0.05$), week ($p=0.03$), and year ($p=0.02$)
Darrow[11]	Shoulder injuries accounted for 8.7% of severe injuries (injuries with >21 days loss of participation)
Rechel[41]	Shoulder injuries accounted for 6.9% of injuries requiring surgery
Shanley[45]	Shoulder injuries accounted for 38% of all injuries
Powell[40]	Shoulder injuries accounted for 16.3% of all injuries
Kerr[25]	Shoulder injuries accounted for 15.3% of all NTL injuries
Smith[48]	Shoulder injuries accounted for 61% of injuries in pitchers 37.5% of pitchers suffered shoulder injuries

AE, athletic exposures; NTL, nontime loss.
[a]Time-loss injuries only.

reported shoulder injuries occurring in 16.7% of pitchers versus 6.6% of position players. When evaluating elbow injuries, Oliver et al[36] observed that outfielders reported 27.5% and infielders 23.8% of elbow injuries, whereas batters and base-runners accounted for 13.8% of all elbow injuries. Shanley et al[46] reported that 2.2% of position players sustained elbow injuries, while no pitchers were reported to sustain any injuries to the elbow.

RTP After Injury

RTP metrics were reported in 8 studies.[7,11,25,27,36,42,48,49] Snyder Valier et al[49] observed that 89.3% of athletes sustaining softball related injuries to the shoulder returned to play in <1 day. Meanwhile, between 40.6% and 48.7% of athletes sustaining shoulder injuries were reported to RTP in <1 week, with 5.6% to 10.2% of athletes returning >3 weeks out from injury.[11,27,36,42] When assessing elbow injuries, Snyder Valier et al[49] reported that 93% of athletes with elbow injuries returned to play in <1 day. Oliver et al[36] compared a breakdown of RTP in athletes with elbow injuries with 60% returning in <1 week and 2.4% returning >3 weeks.

Collegiate Athletes

Shoulder Injuries. The incidence of shoulder injuries in collegiate softball athletes was reported in 5 articles (Table 4).[2,21,30,53] Injury incidence rate was reported in 2 studies ranging from 3.76 to 5.93 per 10,000 AE.[52,53] Veillard et al[52] observed shoulder injuries accounted for 15.1% of all injuries compared with 10.1% observed by Wasserman et al.[53]

Elbow Injuries. The incidence of elbow injuries was reported in 8 articles (Table 5).[2,21,25,28,30,53] The injury incidence rate of elbow injuries was reported in 3 studies, occurring at 1.5 to 3.39 per 10,000 AE.[20,52,53] When specifically evaluating for the occurrence of ulnar collateral ligament injuries, Li et al[28] observed an injury rate of 1.9 per 10,000 AE.

Injury Setting. Shoulder injuries based on injury setting in collegiate athletes were evaluated in 2 studies.[53] The shoulder injuries rate was 4.2 per 10,000 AE in practice versus 3.1 per 10,000 AE during game competition. A total of 66% of shoulder injuries occurred during a practice setting when evaluated by Veillard et al.[52] The same 2 studies analyzed elbow injuries based on setting, with elbow injuries recorded at 2 per 10,000 AE during practice and 2.9 per 10,000 AE during games and 66% of elbow injuries occurring during a practice setting.

Injuries by Position. A single article evaluated combined shoulder and elbow injuries in position-players in collegiate athletes, reporting injuries in 64% of catchers, 37.5% of third basemen and 33.3% of shortstops.[2] Meanwhile, when examining pitchers, Hill et al[21] recorded shoulder injuries in 2.2% and elbow injuries in 0.5% of athletes.

RTP After Injury. RTP timing after elbow injuries was reported in 2 studies, with Hassebrock et al[20] reporting 77.8% of athletes with elbow injuries returned to play within 1 day and 96.3% of athletes returned within 3 weeks. Li et al[28] reported that two-thirds of athlete sustaining UCL injuries returned to play ≥3 weeks after injury. There was no available literature regarding RTP timing after shoulder injury in collegiate athletes.

Combined Studies. Shanley et al[45] evaluated the combined incidence of shoulder and elbow injuries in high school pitchers over a 10-week season, with 16% of athletes sustaining injury. In

Table 3. Elbow injuries in high school softball athletes

Lead Author	Significant Findings
Oliver[36]	Elbow injury rate 0.4/10,000 AE 48.9% overuse injuries 19% noncontact injury
Snyder Valier[49]	Elbow injury rate 0.4/10,000 AE[a]
Wasserman[53]	Elbow injury rate 0.7/10,000 AE
Gooch[18]	39.2% of pitchers suffered elbow pain or injury No difference in elbow pain/injury based on pitch count per game, week, or year
Kerr[25]	Elbow injuries accounted for 16.1% of all NTL injuries
Shanley[46]	Elbow injuries accounted for 9.5% of all injuries 1.9% of athletes suffered elbow injuries
Smith[48]	Elbow injuries accounted for 10% of all injuries

AE, athletic exposures; NTL, nontime loss.
[a]Time-loss injuries only.

Table 4. Shoulder injuries in collegiate athletes

Lead Author	Significant Findings
Veillard[52]	Shoulder injury rate 5.9/10,000 AE[a]
Wasserman[53]	Shoulder injury rate 3.8/10,000 AE
Aragon[2]	25% of athletes suffered shoulder injuries
Loosli[30]	37.5% of pitchers suffered shoulder injuries
Hill[21]	8.9% of pitchers suffered shoulder pain affecting performance 2.2% of pitchers suffered shoulder injuries preventing participation
Kerr[25]	Shoulder injuries accounted for 11.7% of all NTL injuries

AE, athletic exposures; NTL, nontime loss.
[a]Injury rate calculated based on reported data.

Table 5. Elbow injuries in collegiate athletes

Lead Author	Significant Findings
Hassebrock[20]	Elbow injury rate 1.5/10,000 AE
Veillard[52]	Elbow injury rate 3.4/10,000 AE[a]
Wasserman[53]	Elbow injury rate 2.3/10,000 AE
Aragon[2]	7.7% of athletes suffered elbow injuries
Loosli[30]	16.7% of pitchers suffered elbow injuries
Hill[21]	1.1% of pitchers suffered elbow pain affecting performance 0.6% suffered elbow injuries preventing participation.
Kerr[25]	Elbow injuries accounted for 8.3% of all NTL injuries
Li[28]	Rate of UCL injury 1.9/10,000 AE 100% of injuries due to throwing mechanisms 100% treated nonoperatively

AE, athletic exposures; NTL, nontime loss; UCL, ulnar collateral ligament.
[a]Injury rate calculated based on reported data.

their retrospective survey of 25 high school and collegiate pitchers, Sauers et al[44] observed that 68% of athletes reported experiencing a shoulder injury and 20% reported an elbow injury; 60% of survey respondents reported experiencing mild to severe shoulder pain, while 20% reported mild to severe elbow pain at rest.

DISCUSSION

The primary findings from this investigation were that, in high school fast-pitch softball players, the incidence of shoulder injuries was 0.88 to 1.14/10,000 AE, with elbow injuries recorded at a rate of 0.41 to 0.71/10,000 AE. Both shoulder and elbow injury rates were higher in collegiate athletes, with a shoulder injury rate of 3.76 to 5.93/10,000 AE and elbow injury rate of 1.5 to 3.39/10,000 AE in collegiate athletes. Shoulder and elbow injuries were reported more commonly as occurring during game competition when compared with a practice setting in high school athletes; however, collegiate athletes reported injury more frequently in the practice setting. There was no association appreciated when analyzing differences in injury rates by position in either the high school or collegiate setting. Our study noted an increase in injury rates to the shoulder and elbow in collegiate athletes compared with high school athletes. Similar findings have been discussed among baseball athletes.[54] One reason for the increase in injury rate in college athletes may be due to under-reporting at the high school level. With many high school athletes participating in competitive leagues outside of the high school season, there are frequently no formal injury reporting mechanisms with these competitions. In addition,

while national reporting mechanisms exist at the high school level, use of these systems may be limited due to lack of time or resources for school athletic training staff. In addition, studies in windmill pitchers demonstrate increased pain and strength loss associated with fatigue after consecutive days of pitching.[47] The college schedule allows for more frequent team and individual practices and competitions, resulting in increased fatigue with potentially less time for recovery. Therefore, the overall increase in intensity and frequency of activity at the collegiate level may account for the increase in injury rate.

Overall, data from our studies show similarities among shoulder and elbow injury rates in softball and baseball athletes. Comparatively, high school baseball players reported a shoulder injury rate of 1.2 to 1.9/10,000 AE and a 0.8 to 0.86/10,000 AE elbow injury rate.[7,27,43,54] Collegiate baseball players similarly experience increased shoulder and elbow injury rates with rates of 1.8 to 4.02/10,000 AE and 1.8 to 2.44/10,000 AE for shoulder and elbow injuries, respectively.[10,54] Despite reduced shoulder and elbow injury rates compared with baseball players, these injuries account for a substantial proportion of injuries in both the high school (combined 17.6%) and collegiate (combined 22.5%) populations.[53]

Few investigations have examined injury type and severity as a means of addressing potential injury prevention strategies in softball athletes, as have been implemented in baseball athletes.[14,17,19,31] With the support of biomechanical research, pitch count recommendations in baseball players were developed to focus on limiting the number of pitches thrown to decrease overuse injuries to the shoulder and elbow.[1,15,16,32,37] Since there are similar correlations with fatigue and pain/injury in softball pitchers, the American Orthopaedic Society for Sports Medicine (AOSSM) has published pitch count and rest period recommendations for softball athletes, recommending no more than 100 pitches per game or up to 140 pitches per day with 2 days of rest in between outings, when possible.[24] However, there are no studies examining foundations for, compliance with, or the impact of the recommendations on the incidence of shoulder and elbow injuries in softball athletes.[23,26] As such, further studies examining factors that may contribute to shoulder and elbow injury incidence in softball athletes, as well as research determining outcomes after implementation of pitch count recommendation on injury prevention, are necessary.

Limitations of the current systematic review include the use of a single data source reported in multiple studies. Specifically, 7 of the 22 articles sampled the high school RIO database, while 4 of the studies sampled the NCAA's ISP. Although some of the articles were updates of previously reported data over a different time span, many of the articles examined different factors associated with injury such as time-loss or severe injuries. The incidence of shoulder and elbow injuries in high school and collegiate athlete was reported heterogeneously with variable amounts of accompanying data, such as injury setting, position, and time to RTP. Further, specific injuries (ie, rotator cuff, labrum, ulnar collateral ligament, strain, etc) were reported infrequently. Therefore, the authors were unable to evaluate any specific injury type to either the shoulder or elbow, limiting our ability to perform any meaningful statistical analyses based on injury location or based on competition level. Furthermore, the type of throwing motion (underhand versus overhand) leading to injury was also not commonly reported, preventing the authors from determining the true impact of the underhand throwing motion on injury incidence to the shoulder and elbow. The inability to perform any statistical analysis was further limited by the small number of identified articles meeting inclusion/exclusion criteria, as well as the low level of evidence of the included studies, limited primarily to case series.

CONCLUSION

Previous research demonstrates that softball athletes face significant biomechanical loads during overhand and windmill throwing motions. This study demonstrates that the incidence of shoulder and elbow injuries is greater in collegiate fast-pitch softball athletes when compared with high school athletes. Collegiate athletes also reported injuries occurring more frequently in the practice setting. Most athletes are able to return back to sport within 3 weeks of injury.

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