Title

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Journal

Current Reviews in Musculoskeletal Medicine, 17(4)

ISSN

1935-973X

Authors

Feeley, Brian
Feeley, Sonali
Chambers, Caitlin

Publication Date

2024-04-01

DOI

10.1007/s12178-024-09886-y

Peer reviewed

Current Reviews in Musculoskeletal Medicine (2024) 17:110–116
https://doi.org/10.1007/s12178-024-09886-y

Fastpitch Softball Injuries: Epidemiology, Biomechanics, and Injury Prevention

Brian T. Feeley[1] · Sonali E. Feeley[1] · Caitlin C. Chambers[2]

Accepted: 19 January 2024 / Published online: 12 February 2024

Abstract

Purpose of Review Fastpitch softball is one of the most popular sports among youth and high school female athletes. Despite some similarities to baseball, key differences between the two sports result in different injury patterns, and there is comparatively less literature describing injury epidemiology in fastpitch softball. The purpose of this review is to describe the epidemiology, biomechanics, and injury prevention efforts in regards to fastpitch softball injury with a particular focus on underhand pitching.

Recent Findings The injury rate in softball is relatively low and extended time loss injuries in particular are uncommon. Lower extremity injuries are more common overall in softball, but pitchers more often suffer upper extremity injury. Pitchers account for a relatively small proportion of all injuries recorded, but represent a similarly small subset of team rosters, with most teams carrying only a few pitchers in total. The underhand pitching motion exerts significant glenohumeral distractive forces and high stress across the biceps-labrum complex. Core and lower extremity strengthening play an important role in injury prevention for softball pitchers and position players. Fatigue and number of games pitched are tied to increased strength deficiencies and pain in fastpitch softball pitchers, yet pitch count limits are not employed in any major fastpitch softball leagues.

Summary While overall injury incidence is low in fastpitch softball players, the potential for overuse injury in pitchers in particular is noteworthy and not nearly as scrutinized as within the baseball community. Critical longitudinal tracking of softball injuries at varying levels of play would be helpful to better understand the sport's injury risk. There are currently no formal pitch count limits enforced in a majority of fastpitch softball leagues. Core and lower extremity strengthening, pre-season conditioning, and monitoring of pitchers for signs of fatigue may be helpful in injury prevention.

Keywords Softball injury · Pitching injury · Female athlete · Fastpitch softball

Introduction

Softball is the 3rd most common high school and college women's sport, and there has been a growing number of club athletes playing fastpitch softball. Recent data suggests that over 2 million female athletes play fastpitch softball, ranking it only behind soccer and basketball in popularity for female athletes. Despite this popularity, there is a relative paucity of data describing the incidence, mechanisms, and outcomes of softball-related injuries. Indeed, while most of the literature focuses on baseball injury, particularly among pitchers, injury data from athletic trainer databases suggest that the overall injury rate in softball is comparable to or exceeds baseball injury rates [1, 2•].

Softball is similar to baseball in many respects, but key differences between the games result in different injury patterns, making the copious injury data for baseball relatively non-transferable to softball. Pertinent dissimilarities between baseball and softball are outlined in Table 1. The primary visible distinction is differences in throwing mechanics, with the windmill pitch employed in softball, and an overhand throwing pitch in baseball. Injury rates between these have been well described and the windmill pitch will be described in more detail later in this review [3–5]. Despite the slower pitch speed in softball, the shorter pitching and base distances result in a need for quicker reaction time on the part of the batter and fielder. Additionally, the prevalence of bunting and slap hitting in softball result in third and first

✉ Caitlin C. Chambers
cchamber@umn.edu

[1] Department of Orthopedic Surgery, University of California, San Francisco, CA, USA

[2] Department of Orthopedic Surgery, University of Minnesota, Minneapolis, MN, USA

Table 1 Pertinent elements of softball and baseball

		Softball	Baseball
Athletes		Predominantly female	Predominantly male
Equipment	Ball	12 inch circumference 6.25–7 oz (for players 12 +)	9.25 circumference 5.25 oz
	Bat	Metal or composite 34 in max length 2.25 in max barrel diameter 31.5 oz max weight	Metal, composite, or wooden 36 in max length (42 in wooden) 2.625 in max barrel diameter (2.75 in wooden) Max weight = length – 3 (i.e. 34 in bat < 31 oz)
Field Layout	Infield	All dirt 60 ft bases	Dirt and grass 90 ft bases
	Outfield	Fence ~ 220 feet	Fence ~ 400 feet
Pitching	Mound Location	40 ft (< 12 y/o) 43 ft (> 12 y/o) Not elevated	46 ft – 60.5 ft 6–10 in elevated
	Mechanics	Underhand windmill motion	Overhand motion
	Ball trajectory	Tends to rise	Tends to drop
	Fastball speed	70 + mph	100 + mph
	Mound-plate reaction time	0.35 s (70 mph fastball)	0.38 s (100 mph fastball)
	Injury Risk	Less risk of surgical injury from pitching [6]	Higher risk of surgical injury from pitching
Game play	Runner Leadoff	At pitcher ball release	Before pitch
	Innings	7	9

basemen often playing 15 ft or more in front of their 60-ft base as compared to these respective positions in baseball who typically line up behind their 90-ft base. As such, the risk for injury from direct impact of a batted ball in softball is worthy of increased consideration. While the throwing motions are the same for fielders in baseball and softball, there are differences in the musculoskeletal system between male and female athletes that may also result in small but significant differences in injury risk [1].

Epidemiology of Softball Injuries

Several studies have evaluated the epidemiology of softball injuries over the last 20 years utilizing databases from local and national samples to evaluate collegiate, high school and youth softball injury rates.

Collegiate Softball Injuries

A comprehensive analysis of injury in collegiate softball players was undertaken by Marshall et al. in 2007, utilizing the NCAA Injury Surveillance System to categorize the time of injury, type of injury, and the mechanism of injury within NCAA softball athletes [2•]. Overall in-game injury rate was 4.30 per 1000 athlete-exposures (AEs), while practice injury rates were 2.67 per 1000 AEs, with practice injuries occurring more than twice as often in the pre-season compared to in-season practice setting. Lower extremity injuries were more common than upper extremity injuries in both the game and practice setting. The most common diagnoses reported in practice were ankle sprain, knee internal derangement, concussion, thigh muscle–tendon strain, and lower leg contusion, while in games were ankle sprain, thigh muscle–tendon strain, shoulder muscle–tendon strain, knee internal derangement, and shoulder tendinitis. Twenty-seven percent of in-game and 55.0% of practice injuries were non-contact. Sliding accounted for 23.0% of game injuries, and contact with a batted ball resulted in 11.2% of all game injuries, most commonly affecting pitchers and third basemen. Softball pitchers accounted for 11% of injuries seen in this study. Time loss injuries were uncommon, with 22% of all injuries resulting in loss of 10 or more days.

High School Softball Injuries

Oliver et al. obtained data from the National High School Sports-Related Injury Surveillance System, which captures data from a diverse sample of US high schools [7•]. They specifically examined injuries that occurred in the shoulder and elbow of softball players. Overall, the injury rate was relatively low, with shoulder and elbow injury rates of 1.14 per 10,000 AEs and 0.41 per 10,000 AEs, respectively. Shoulder injuries were more commonly recorded during games than practices, while elbow injuries occurred at similar frequency in practice and games. Overuse injury was

responsible for 60.8% of injuries in pitchers and 49.2% of position players. The most common shoulder diagnoses were muscular strain (30.6%), tendinitis (23.5%), and subluxation (8.8%), and dominant elbow diagnoses were tendinitis (32.9%), contusion (23.5%), and ligament sprain (17.7%). A majority of athletes were able to return to play within 3 weeks (93%). While only 16.7% of the shoulder and 17.5% of the elbow injuries were attributed to pitchers, since most teams carry only two or three pitchers maximum, these numbers represent a relatively high proportion of pitchers affected by shoulder and elbow injuries.

Youth Softball Injuries

Farooqi et al. evaluated the epidemiology of pediatric baseball and softball injuries using the National Electronic Injury Surveillance System from 2010 to 2019 [5]. They translated this data to extrapolate the national estimate of injury incidence over that time. In comparison to baseball, softball had overall lower number of injuries although injury rate could not be extrapolated from this database given lack of athletic exposure event data. Other studies have shown that injury rates are higher in softball compared to baseball [8]. Farooqi et al. found that as compared to baseball, softball had a higher proportion of lower extremity injuries (31.72% versus 19.22%), similar proportion of upper extremity injuries (32.61% vs 33.04%), and lower proportion of head/neck/face injury (30.15% vs 40.80%) [9]. Softball had a 50% higher incidence of sprain/strain. Baseball athletes more commonly had contact injuries (49% vs 40%, $p < 0.01$) and saw more severe injuries involving throwing (0.9% vs 0.2%, $p < 0.01$) than in softball.

In a prospective cohort study, Smith and colleagues evaluated 98 youth athletes (48 pitchers, 50 position players) for a single fastpitch softball season [10]. There were 49 reported injuries in 43 athletes during this single-season study. A majority of the non-pitching injuries involved the lower extremity (61.3%) or back (25.8%), while 72.2% of pitching injuries involved the upper extremity. Of the 48 pitchers in this study, 18 (38%) suffered an injury directly attributable to pitching, with a large majority of these pitching injuries (78%) occurring within the first 6 weeks of the season. While a majority of injuries in position players resulted in less than 2 weeks of time lost, 50% of pitchers missed more than 2 weeks of the season, with 4 pitchers suffering season-ending injuries. These findings are particularly given that most teams carry a limited number of pitchers. Carrying more pitchers and improving the early season conditioning program would appear to be means of limiting the risk of pitching related injury in these athletes [11].

Biomechanics of Windmill Pitching

The normal sequence of windmill softball pitching delivery (Fig. 1) differs considerably from that of baseball pitching, with the phases of the windmill pitch divided into windup, stride, delivery, and follow through [12••]. Maffet et al. performed the most comprehensive description of muscle activation during the windmill pitch, using surface EMG to evaluate peak muscle forces [13]. During windup, the supraspinatus serves to maintain humeral head centralization within the glenoid cavity, with the infraspinatus abducting and externally rotating the shoulder and the anterior deltoid flexing the arm. In the stride phase, the teres minor takes over external rotation from the infraspinatus at higher shoulder flexion angles, and the posterior deltoid abducts the shoulder. In the delivery, the subscapularis, pectoralis major, and serratus anterior adduct, internally rotate, and stabilize the scapula, respectively. The kinematics of pitching, in particular factors such as trunk motion (flexion/extension,

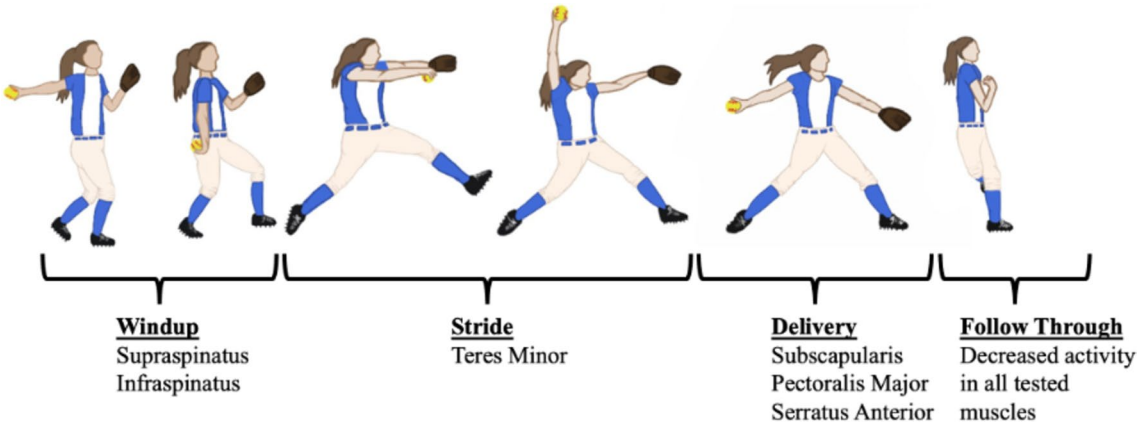

Fig. 1 Phases of softball pitching with peak muscle activations as described by Maffet et al. [13]; EMG testing inclusive of anterior and posterior deltoid, pectoralis major, serratus anterior, supraspinatus, infraspinatus, teres minor, and subscapularis

lateral flexion, rotation), stride length, center of mass, and elbow flexion differ between fastpitch pitch types, which typically include fastball, drop ball, rise ball, curveball, and changeup [14, 15]. Thus, pitchers' typical pitch type preferences may also play a role in muscular activation and fatigue or injury patterns.

While there is a plethora of data on overhead throwing mechanics, there is relatively little information on the biomechanics of windmill pitching. Barrentine et al. published the first study evaluating the biomechanics of the upper extremity in 8 collegiate softball pitchers [12••]. They found that there were distraction stresses of 70-98% of body weight across the shoulder and elbow, and report that the biceps labrum complex is at considerable risk of overuse injury in softball pitching. Werner et al. performed similar studies in Olympic softball pitchers as well as youth pitchers and found that these forces were similar across all levels of competition [16, 17].

The biceps complex deserves special attention when discussing windmill pitching due to the high levels of activation throughout the pitch [18]. Compared to overhead throwing, the biceps is both more active overall, and active through a larger proportion of the throwing cycle in the windmill pitch compared to overhead pitching. Importantly, activation of the biceps actually increases throughout the phases of pitching until follow through, but even then remains higher than at any point during overhead throwing. Oliver et al. found that the greatest biceps forces were from late windup (12 o'clock) to ball release [19, 20]. Thus, the biceps-labrum complex appears to be more important and more at risk for injury in the softball pitch.

Pitching Injuries

Studies looking at softball injuries by position have shown that pitching is the responsible mechanism for 6% of all collegiate softball injuries [2•] and 36.7% of all youth softball injuries [10]. While these numbers may seem underwhelming at first glance, it is worth noting that most softball teams have only two to three pitchers, making these athletes proportionately more affected by injury than their position player teammates. In fact, a study by Loosli et al. found that 83.3% of pitchers from 8 elite NCAA teams reported at least one injury in a single season. Of the injuries in these pitchers, 42.3% resulted in time loss, with upper extremity diagnoses responsible for 81.8% of the time-loss injuries [21].

Hill et al. performed the most comprehensive study regarding the epidemiology of injury in softball pitchers [22]. Among 131 reported injuries in pitchers, 36 were described as acute, 92 were chronic/overuse, and 3 were unspecified. Of the total injuries, 80 were directly from pitching, with 33 that were shoulder-related and 16 related to the lower back. Among the injured softball pitchers, 109 took nonsteroidal anti-inflammatory drugs, 140 used modalities, 11 received surgery, and 95 saw additional specialists. The authors concluded that softball pitchers are at risk for injury, with 72.8% of surveyed softball pitchers being injured during the 2001 to 2002 years.

The rate of re-injury to the shoulder seems to be high in pitchers as well. Rauh et al. reported that there was a 2- to threefold risk of reinjury to the shoulder within one season in high school softball, suggesting potential training errors or lack of effective rest periods [6]. Studies of both collegiate and youth softball injuries have found that pitchers are more likely to have injuries resulting in substantial (> 2–3 weeks) time loss [2•, 7•].

Core Strengthening, Performance, and Injury Risk Prevention

There has been an increased emphasis across sports on the importance of core strength and stability both for performance and injury risk reduction. Many core-strengthening programs focus on open-kinetic chain exercises to improve performance. Closed-kinetic chain exercsies require fixing the terminal segment or providing it with considerable resistance, such as the hands pushing against the ground during the push-up. Open-kinetic chain exercises (OKCEs) either do not fix the terminal segment or allow the terminal segment to move freely without external resistance, such as the hands moving a weighted barbell against gravity during the bench press. Prokopy et al. evaluated upper extremity core strengthening through closed vs open chain exercises in 14 division 1 softball players [23]. Closed-kinetic chain exercises (CKCEs) led to both improvements in strength (similar to open chain) but also improvements in performance and pitch velocity. Interestingly, upper body CKCEs also led to improved lower body kinematics, with improve single leg squat balance compared to open-chain exercise athletes.

Lower extremity strengthening has also been shown to be important in mitigating injury risk and improving performance. Several studies in baseball have shown that improving core stability lowers injury risk and improves performance [24–29]. Oliver et al. (2011) evaluated 10 softball pitchers with an average age of 17 [30]. They found that ground reaction force and braking velocity increased with pitch velocity, and that pitch velocity increased with push-leg gluteus medius and maximus activation. Guido et al. found similar kinematics and ground reaction forces in youth pitchers, and concluded that stride leg exercises that reduce forces across the anterior knee would reduce injury risk [31]. In catchers, both ipsilateral and contralateral gluteal muscles were important in maintaining lumbopelvic stability [32]. The authors concluded that these core stabilizers have

a central role in maintaining pelvic stability, and catchers in particular should incorporate strengthening of the lumbopelvic hip complex into their training regimen including concentric and eccentric gluteal exercises to assist in upper extremity injury prevention.

Fatigue and Softball Injuries

Two important areas cause softball to be at higher risk for fatigue-related injuries—the weekend 'tournament style' of club softball in the youth and adolescent softball fastpitch leagues, and the paucity of pitchers. The culture of softball is such that typically the best pitcher on a high school team will pitch most, if not all, of the games in a season. Shanely et al. found that half of softball pitchers threw in 60% or more of their games [1]. Softball teams thus usually carry a lesser proportion of softball pitchers on their rosters than do their baseball counterparts, resulting in more innings pitched per athlete. This leads to a single pitcher often throwing more than 300 in-game pitches over the course of a day and up to 1500 pitches in as little as 3 days over the course of a weekend tournament [17].

Even over the course of a single game, fatigue leads to characteristic changes in the pitching technique. Downs et al. performed a simulated game with 32 youth softball pitchers. Less trunk rotation toward the pitching arm side was found at the start of the motion (defined as when the pitching arm was at 90° of forward flexion) and the top of the backswing in last inning compared to the first. Pitch velocity increased slightly from 39.74 ± 4.44 in the first inning to 40.49 ± 4.30 mph in the last inning. The authors found that as pitch number increased over the course of the simulated game, stride length at the start of the pitching motion significantly increased, center of mass (COM) at the start of the pitching motion was statistically more positioned towards the stride leg, and trunk flexion from top of backswing, ball release, and follow-through significantly decreased. These results indicate that players may increase stride length and shift their COM towards the stride leg as fatigue sets in. Decreased trunk flexion could be a result of poor trunk control and strength in youth athletes. These markers also allow for coaches to watch for key aspects of the pitching motion to understand when their youth pitchers begin to fatigue.

Over the course of a game and season, fatigue leads to an increase in pain and deficiencies in strength. Yang et al. followed a group of softball players through a season [33]. They found reduced dominant arm strength after pitching in a single game and after an 8-week season. This group also reported that the number of games pitched over an 8-week season significantly affected pregame shoulder pain and strength. Pitching 10 or more games resulted in added pain and strength deficiencies, indicating a cumulative fatigue effect with increased pitching time over the season. Corben et al. similarly found that significant fatigue results in reduced bilateral strength throughout the entire kinetic chain after pitching one game [34]. Similarly, Skillington et al. showed that there was decreased dominant upper extremity strength over multiple days of pitching, indicating that cumulative fatigue occurs over consecutive days of pitching [35].

Pitch Count Limits

Despite the effects of fatigue on muscle strength and function, there are no current limitations on softball pitch counts as are seen within baseball. Preliminary youth baseball pitch count recommendations were based on survey responses from 28 orthopedic surgeons and baseball coaches, reported by Andrews et al. in 1996 and instituted by Little League Baseball in 2006 [11, 36].The gravity of these recommendations was cemented by a 1998 analysis of 172 youth baseball pitchers demonstrating that the risk of injury in a game increased 20% for each inning pitched, and 10% for every 10 pitches thrown [37••] As described above, softball teams usually carry a lesser proportion of softball pitchers on their rosters than do baseball teams, which results in more innings of softball pitched per athlete. Although there is no clear data regarding pitch counts for softball at this time, the Stop Sports Injuries guidelines from the American Orthopaedic Society for Sports Medicine recommend a limitation on softball pitch counts which resemble the maximum pitch counts by youth baseball [38].These softball pitch counts, however, are recommendations and do not reflect actual restrictions in a majority of leagues. Unlike baseball where increased pitch counts and innings pitched lead to a higher likelihood of pain, injury, and retirement (citations needed), the evidence is not as clear in softball. Further research on this topic would be helpful in understanding whether similar pitch count limits are advisable in fastpitch softball.

Conclusions

Overall injury incidence in fastpitch softball is quite low and often mild in severity. Across all positions, lower extremity injury is more common in softball but for pitchers, upper extremity injuries dominate. Pitchers represent a relatively small proportion of softball injuries, but reflect a similarly small subset of team rosters. While surgical and significant time-loss injuries are uncommon, pitchers are more likely to have time-loss injuries and the rate of same-season re-injury in softball pitchers is concerning. Given the small number of pitchers listed on the average softball team's roster, appropriate periods of rest may not be achievable with a smaller bullpen, prompting premature return from injury. The underhand

pitching motion exerts significant glenohumeral distractive forces and high stress across the biceps-labrum complex. The biceps and superior labrum may therefore be at particular risk for overuse injury in softball pitchers, although there is a paucity of data clinically examining this theory.

The best means of preventing injury in softball players appears to be core and lower extremity strengthening, preseason conditioning, and recognition of signs of fatigue. With number of games pitched and fatigue shown to have a direct tie to strength deficiencies, the athlete's eccentric control and protective strength may suffer as fatigue sets in.

Improved longitudinal tracking and assessment of softball injuries at varying levels of play would be helpful to garner a better understanding the sport's associated injury risk. While a majority of fastpitch softball leagues do not enforce and pitch count limits, further research is warranted in regards to any tie between pitch count and injury in softball pitchers to determine whether stricter enforcement limits may be advisable. At this time, in the absence of formal pitch count limits, the responsibility for injury prevention falls to athletes and coaches. Focusing on multisport conditioning and participation in multiple sports throughout adolescence likely has important health benefits in youth and adult athletes alike [39, 40].

Author Contributions All authors contributed to writing the main manuscript text and S.F. prepared Fig. 1. All authors reviewed the manuscript.

Data Availability No datasets were generated or analysed during the current study.

Declarations

Competing Interests The authors declare no competing interests.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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- • Of importance
- •• Of major importance

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