Do Professional Baseball Players With a Higher Valgus Carrying Angle Have an Increased Risk of Shoulder and Elbow Injuries?

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Background: There are many risk factors for shoulder and elbow injuries in professional baseball pitchers. The elbow carrying angle has not been studied as a potential risk factor.

Purpose/Hypothesis: The aim of this study was to determine whether elbow carrying angle is a risk factor for shoulder or elbow injuries in professional baseball pitchers. We hypothesized that pitchers with a higher elbow carrying angle would be less likely to sustain an injury during the season than pitchers with a lower elbow carrying angle.

Study Design: Cohort study; Level of evidence, 2.

Methods: All professional pitchers for a single baseball club during the 2018 season had the carrying angle of both elbows measured at spring training by a single examiner. The pitchers were followed prospectively throughout the season. Shoulder and elbow injuries were recorded prospectively.

Results: A total of 52 pitchers (21 [40%] Major League Baseball and 31 [60%] Minor League Baseball) were included. During the season, 23 (44%) pitchers became injured. The mean carrying angle in the throwing arm was 12.5° ± 4.2° versus 9.9° ± 2.8° in the nonthrowing arm (P < .001). Comparing the injured and noninjured groups, there were no differences in level of play (P = .870), throwing hand dominance (P = .683), batting hand dominance (P = .554), throwing-side carrying angle (P = .373), nonthrowing-side carrying angle (P = .773), or side-to-side difference in carrying angle (P = .481).

Conclusion: The elbow carrying angle was not associated with an injury risk during a single season in professional baseball pitchers.

Keywords: Major League Baseball (MLB); elbow; injury prevention; carrying angle; pitcher; shoulder

Shoulder and elbow injury rates in baseball pitchers of all levels have been increasing over the past decade.4,15,17 While several risk factors for an injury have been identified and prevention programs implemented, these injury rates have yet to level off. Currently identified risk factors for an injury in baseball pitchers include high pitch counts, pitch velocity, overall pitching workload, pitching year round, pitching while fatigued, geographic location, loss of shoulder motion (including forward flexion, internal rotation, and total arc of motion), loss of hip motion, elbow torque, and others.6 Unfortunately, as injury rates continue to rise, there are likely other risk factors that have not been identified.

The elbow joint is a complex hinge joint that is made up of 3 distinct articulations.33 The valgus carrying angle, the angle between a line drawn down the axis of the arm and down the axis of the forearm, is between 11° and 16° (higher in females than males).11 This allows the forearm and wrist to clear the hips during gait. Baseball pitchers generate more valgus stress on the medial elbow during the pitching motion than the ulnar collateral ligament (UCL) can withstand alone.29-31,35 Bony and other soft tissue/muscular restraints, specifically the wrist flexors and forearm pronators, help to protect...
the UCL. Recent evidence has shown that contraction of the wrist and finger flexors helps to compress the medial side of the elbow when valgus stress is applied. A smaller elbow carrying angle may create an obligate increase in torque across the UCL for the same ball velocity, but this factor has not been studied as it relates to the injury risk in baseball pitchers, specifically professional baseball pitchers.

The purpose of this study was to determine if a professional baseball pitcher’s elbow valgus carrying angle is a risk factor for injuries. A secondary aim was to compare side-to-side differences in the elbow carrying angle between a pitcher’s throwing and nonthrowing elbows to determine if a difference existed. We hypothesized that pitchers with a higher valgus carrying angle would be less likely to sustain an injury during the season than pitchers with a lower valgus carrying angle. We also hypothesized that the carrying angle would be greater in the throwing elbow than the nonthrowing elbow. The thought process behind the hypothesis was that the elbow has to achieve a certain amount of valgus to generate enough torque and energy to throw a baseball at high speeds. Hence, if the player is starting with more elbow valgus, he has less of a distance to go to achieve the appropriate valgus and therefore would stress his ligament to a lesser degree.

METHODS

Institutional review board approval was obtained before initiating this study. All professional baseball pitchers who played for a single baseball club at the start of the 2018 season and were available for an examination at spring training were eligible for inclusion. Inclusion criteria were healthy male (currently not injured) professional (Major League Baseball [MLB] and Minor League Baseball [MiLB]) pitchers. Players were excluded if they were injured at the time that the measurements were taken or if they refused to participate. Participation was voluntary. At spring training, on 2 consecutive days, the elbow valgus carrying angle was measured in both the dominant and nondominant elbows of all included pitchers by 1 author (B.J.E.). No pitcher refused to participate. The examiner was not blinded to arm dominance.

The measurements were taken with the players supine, the elbow in full extension, and the hand completely supinated. As has been previously described, when measuring the carrying angle (Figure 1), the goniometer was oriented such that the center of the instrument was positioned on the cross line of the bicep’s tendon and the interepicondyle axis. The distal arm of the goniometer was aligned with the center of the wrist, and the proximal arm was aligned with the center of the arm. All pitchers were measured in the same position, with the same equipment, by the same examiner (B.J.E.). Players were evaluated prospectively throughout the season, and injury data were recorded. For the purpose of this study, an injury was defined as any condition that placed the pitcher on the disabled list, causing him to miss time. Upper extremity (shoulder, elbow, forearm, etc) injuries were recorded and documented for all players.

Figure 1. The goniometer and setup for the measurements. The hand is completely supinated, the elbow is in full extension, the distal limb of the goniometer is centered on the wrist, and the proximal end of the goniometer is centered on the humeral shaft.
 Statistical Analysis

Descriptive statistics were calculated and examined for spurious values. Continuous variables were evaluated for normality using the Kolmogorov-Smirnov test. Based on the results of this test, nonparametric tests were used. Categorical variables were compared between the injured and noninjured groups using the chi-square or Fisher exact tests, as appropriate depending on subsample sizes. Continuous variables were compared between the injured and noninjured groups using the Mann-Whitney U test. To compare throwing and nonthrowing arms, we used the related-samples Wilcoxon signed-rank test. An additional post hoc power analysis was conducted using this test based on the observed effect size. *P* values < .05 were considered significant. All analyses were conducted in Excel 16 (Microsoft), SPSS 25 (IBM), and G*Power 3.20

RESULTS

A total of 52 pitchers were included, of whom 21 (40%) were MLB pitchers and 31 (60%) were MiLB pitchers. This included 42 (81%) who threw right-handed and 41 (79%) who batted right-handed. During the season, 23 (44%) sustained an upper extremity injury of the dominant arm, causing them to spend time on the disabled list. These injuries included shoulder impingement (6 pitchers, all successfully treated nonoperatively), UCL tears (5 pitchers, of whom 4 underwent UCL reconstruction [UCLR] and 1 was successfully treated nonoperatively with platelet-rich plasma and rehabilitation), proximal biceps tendinitis (5 pitchers, all successfully treated nonoperatively), labral tears (2 pitchers, both treated with surgical labral repair), elbow stiffness (2 pitchers, both successfully treated nonoperatively), forearm strain (2 pitchers, both successfully treated nonoperatively), and a symptomatic Bennett lesion (1 pitcher, treated with an injection). The mean carrying angle in the throwing arm was 12.5° ± 4.2° and in the nonthrowing arm was 9.9° ± 2.8°, which was significantly different between arms (mean difference, 2.6° [95% CI, 1.6-3.6]; *P* < .001).

Comparing the injured and noninjured groups, there were no differences in level of play (*P* = .870), throwing hand dominance (*P* = .683), batting hand dominance (*P* = .554), throwing-side carrying angle (*P* = .373), nonthrowing-side carrying angle (*P* = .773), or side-to-side difference in carrying angle (*P* = .481) (Table 1). A post hoc power analysis was conducted using the utilized statistical tests and observed mean values in the injured and noninjured groups for throwing-side carrying angle, which revealed an effect size of 0.26. With α set at .05 and β set at 0.8, 482 pitchers would be required to show a difference, should one exist. This group size exceeds the number of MLB pitchers.

**DISCUSSION**

Shoulder and elbow injuries in professional baseball players have been on the rise in the past 10 years. While several studies have examined modifiable risk factors for these injuries, there have been limited data on nonmodifiable risk factors. Contrary to our hypothesis, this study found no correlation between the elbow carrying angle and the risk of shoulder or elbow injuries in professional baseball players.

There has been a recent push to identify risk factors for shoulder and elbow injuries in overhead athletes, as the rates of these injuries have continued to rise.5,8,18 Camp et al5 evaluated all MLB players who missed at least 1 day of play between 2011 and 2016 using the MLB Health and Injury Tracking System (HITS). They found 49,955 injuries (45,123 were non–season ending), resulting in 722,176 days out of play, 39% of which involved the upper extremity. Their study identified the scope of the issue facing MLB players. Several studies have been conducted to isolate specific risk factors for shoulder and elbow injuries in professional baseball players. Chalmers et al8 evaluated all professional pitchers who underwent UCLR between 2007 and 2015 to determine if pitch velocity was a risk factor for UCL injuries. The authors collected data on pitch count, pitch type (fastball, curveball, etc), and pitch velocity on all MLB players and compared those pitchers who underwent UCLR with pitchers who did not require UCLR. The authors found that peak pitch velocity and mean pitch velocity were significantly higher in the pitchers who required UCLR compared with those who did not. Similar studies evaluating potential modifiable risk factors for an injury have been performed in professional as well as high school and college-aged pitchers and have found pitch count, number of innings pitched per season, pitching while fatigued, shoulder motion, hip motion, pitching complete games, and other variables to be risk factors for an injury.6,7,13,19,21,22,36,37

While these studies have reported modifiable risk factors, there are also several risk factors that are nonmodifiable. Pitcher age, for example, is a nonmodifiable risk factor that has been shown to increase a player’s risk for sustaining a UCL tear.8 Another nonmodifiable risk factor that has been associated with shoulder and elbow injuries in high-level baseball pitchers is pitcher height, as taller players are more likely to sustain an injury...
than shorter pitchers. While there are several nonmodifiable risk factors that have been associated with an injury, there are others, such as handedness, that have not been found to increase a pitcher’s risk for injuries; right-handed throwers are no more likely to sustain an injury than left-handed throwers. It is important to identify all possible risk factors, both modifiable and nonmodifiable, so that a pitcher can properly train and adequately prepare himself for each outing. For example, if a pitcher has several nonmodifiable risk factors for sustaining a shoulder or elbow injury, he may need more time between starts or to have reduced workloads than pitchers without any nonmodifiable risk factors so as to avoid injuries.

This study evaluated the potential nonmodifiable risk factor of a pitcher’s elbow carrying angle. This valgus angle allows the arm to swing freely without hitting the leg. To generate a forceful pitch, a significant amount of stress is placed across the shoulder and elbow. The elbow experiences valgus stress of approximately 64 Nm with every pitch. As the pitching motion is part of the kinetic chain, this stress can increase if the scapula is not in its proper position. It is unclear if a change in the valgus carrying angle of the elbow increases, decreases, or has no effect on the stress seen by the shoulder and/or medial elbow during pitching.

We found a side-to-side difference in the valgus carrying angle between the dominant and nondominant elbows of pitchers. The increase in the valgus carrying angle of the dominant elbow could be an adaptive change secondary to lateral physeal growth arrest, chronic tension on the medial elbow, wear and/or compression of radiocapitellar articular cartilage, or for other reasons. Another possible cause is a small amount of medial laxity at rest causing an apparent increase in elbow valgus, as the medial structures are slightly looser than the lateral ones from overuse. No longitudinal studies in youth pitchers have been conducted to understand when this difference in the valgus carrying angle develops, so it is difficult to determine the cause. Future longitudinal studies are necessary to follow youth pitchers from adolescence through college to evaluate the progression of the elbow carrying angle over time so as to provide a better understanding of how this variable affects pitchers.

We did not see a correlation between the elbow carrying angle and shoulder and elbow injuries in professional baseball pitchers. One possible reason for the lack of correlation is that pitchers have adapted to their anatomy. This allows them to compensate for any anatomic abnormalities during the pitch. Further studies comparing pitchers with a history of specific shoulder and elbow procedures (UCLR, labral repair, etc) to controls may be warranted. However, it may be that there is no set amount of valgus that the elbow needs to achieve to throw a baseball at a high velocity, so the amount of elbow valgus in pitchers may be arbitrary. This study was underpowered, as over 400 pitchers would have been needed to detect a difference if one existed, and this number far exceeds the number of pitchers in a single organization. Hence, a larger scale study across multiple organizations is needed to better answer this question.

Limitations

This study evaluated professional baseball pitchers for a single organization over the course of a single season. The included players were all professional athletes, and as such, these results may not be generalizable to other populations. There may be an inherent selection bias, as these athletes were all professionals and may have learned to compensate for abnormalities in their elbow valgus carrying angle. Injury history was not evaluated, as the purpose of this study was to prospectively follow pitchers over the course of a season. It is also possible that the valgus carrying angle effect may have been overwhelmed by other risk factors, and a multivariate analysis would be needed (with a large number of participants) to sort out whether the valgus carrying angle was significant. Further studies evaluating multiple baseball clubs over a longer period may be necessary to study this clinical question even further.

CONCLUSION

The elbow carrying angle was not associated with an injury risk during a single season in professional baseball pitchers.

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