Analysis of Pitching Velocity in Major League Baseball Players Before and After Ulnar Collateral Ligament Reconstruction

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Background: Ulnar collateral ligament (UCL) reconstructions are relatively common among professional pitchers in Major League Baseball (MLB). To the authors' knowledge, there has not been a study specifically analyzing pitching velocity after UCL surgery. These measurements were examined in a cohort of MLB pitchers before and after UCL reconstruction.

Hypothesis: There is no significant loss in pitch velocity after UCL reconstruction in MLB pitchers.

Study Design: Cohort study; Level of evidence, 3.

Methods: Between the years 2008 to 2010, a total of 41 MLB pitchers were identified as players who underwent UCL reconstruction. Inclusion criteria for this study consisted of a minimum of 1 year of preinjury and 2 years of postinjury pitch velocity data. After implementing exclusion criteria, performance data were analyzed from 28 of the 41 pitchers over a minimum of 4 MLB seasons for each player. A pair-matched control group of pitchers who did not have a known UCL injury were analyzed for comparison.

Results: Of the initial 41 players, 3 were excluded for revision UCL reconstruction. Eight of the 38 players who underwent primary UCL reconstruction did not return to pitching at the major league level, and 2 players who met the exclusion criteria were omitted, leaving data on 28 players available for final velocity analysis. The mean percentage change in the velocity of pitches thrown by players who underwent UCL reconstruction was not significantly different compared with that of players in the control group. The mean innings pitched was statistically different only for the year of injury and the first postinjury year. There were also no statistically significant differences between the 2 groups with regard to commonly used statistical performance measurements, including earned run average, batting average against, walks per 9 innings, strikeouts per 9 innings, and walks plus hits per inning pitched.

Conclusion: There were no significant differences in pitch velocity and common performance measurements between players who returned to MLB after UCL reconstruction and pair-matched controls.

Keywords: baseball pitcher; ulnar collateral ligament; elbow injury; Major League Baseball; velocity; performance

Ulnar collateral ligament (UCL) injuries are relatively common among baseball pitchers and other overhead-throwing athletes. A rupture of the UCL of the elbow was historically considered a career-ending injury for baseball pitchers until Dr Frank Jobe first successfully performed an anterior-band UCL reconstruction on Los Angeles Dodgers pitcher Tommy John in 1974.[11] Since then, many publications have reported good clinical outcomes after UCL reconstruction.[5,6,10,12,16-18]

The significance of the UCL in throwing motions has been reported in biomechanical studies. The UCL contributes 55% of the resistive forces against valgus stress with the elbow in 90° of flexion. The anterior band is the primary stabilizer of the elbow to valgus stress. This stress is accentuated during the late cocking phase in the overhead-throwing motion. The mean torque across the UCL during this phase has been reported to be 64 N·m.[13] Thus, this biomechanical finding correlates to the significance of UCL injuries on the performance of overhead-throwing athletes.

Previous studies have reported rates of 73% to 94% for a return to the preinjury level of performance in baseball pitchers after UCL reconstruction.[1,2,5,6,12,15-17] However, until recently, little information has been available on performance after surgery among pitchers who play at the highest professional level. Gibson et al[10] published a study showing similar preinjury and postinjury performance statistics in Major League Baseball (MLB) pitchers after UCL reconstruction with respect to mean innings pitched, earned run average (ERA), and walks plus hits per inning pitched (WHIP). However, to our knowledge, no previously published study has assessed the mean velocity of pitches

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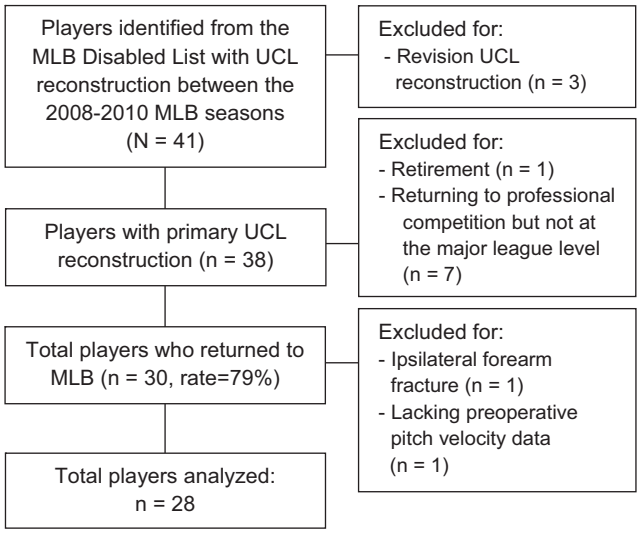

Figure 1. Flow diagram. MLB, Major League Baseball; UCL, ulnar collateral ligament.

thrown by MLB pitchers before and after UCL reconstruction. Thus, this assessment is the primary objective of our study. A secondary objective was to evaluate commonly used baseball performance statistics to see if the preinjury and postinjury performance data from our cohort are consistent with those previously published.

MATERIALS AND METHODS

In 2007, MLB incorporated PITCHf/x (Sportsvision Inc, Chicago, Illinois, USA) as a tool for tracking almost all pitches thrown during each official game. This tool, which records pitch velocity, was used to obtain the raw data necessary for our study. Permission from the institutional review board at our institution was granted. For the 2008-2010 MLB seasons, all pitchers who were placed on the MLB disabled list with a reported elbow injury were screened for inclusion. The MLB Players Association requires injury reports to be completed by a team physician and submitted to the Baseball Commissioner. This process ensures a high degree of reliability in the data provided by MLB injury reports. The details of each player's injury were then further investigated and confirmed by researching for information regarding either UCL reconstruction or "Tommy John surgery" from the press releases of these pitchers' respective teams. Forty-one pitchers were identified as having a UCL injury that required surgery during this time frame. These 3 particular years were selected for this study because they ideally offer a minimum of 1 year of preinjury data (all pitchers) and a minimum of 2 years of postinjury data (2011 and 2012 seasons for the 2010 group of pitchers). We defined the index year in this study as the year of injury.

Demographic data, including age, MLB experience, proportion of left- versus right-handed players, and proportion of starting versus relief pitchers were evaluated for the index year of injury. All available performance data for the pitchers were collected for up to 5 consecutive years from 2007 to 2012. For each pitcher in this study, the mean velocity for 4 commonly thrown pitches (fastball, changeup, curveball, and slider) was calculated for each year if these pitches were part of the players' repertoire. In addition, total innings pitched, ERA, batting average against (BAA) pitcher, walks per 9 innings (BB/9), strikeouts per 9 innings (K/9), and WHIP were also compared among each year of play.[3,7]

TABLE 1
Descriptive Statistics Between the Study Group and Control Group[a]

	Study Group	Control Group	*P* Value
Age at injury, mean ± SD (range), y	28 ± 4 (21-37)	28 ± 4 (22-39)	.92
Height, inches	73.7	75.0	.06
Handedness, n			.74
Right	21	23	
Left	7	5	
Type of pitcher, n			.79
Starting pitcher	15	16	
Relief pitcher	13	12	
Years of MLB experience	4.6	4.2	.68
No. of innings pitched (preindex year)	87.1	87.7	.98
ERA (preindex year)	3.60	3.98	.44

[a]ERA, earned run average; MLB, Major League Baseball.

Control Group

A control group of MLB pitchers was incorporated to assess for changes in pitch velocity, as well as changes in performance outcomes, in pitchers without a known UCL injury over the multiple MLB seasons evaluated in our study. An active MLB pitcher with the most similar career statistics before the index year was selected as a pair-matched control for each pitcher in the study group. The selection was determined from an algorithm used by the website Baseball-Reference.com.[3] This pair-matched group was included to evaluate for reference changes in the velocity of pitches that could be attributed to potential statistical or measurement variations by year. None of the pitchers in the control group had a history of UCL injury. In addition, no pitchers from either the study group or control group were excluded for any other injuries. The mean percentage change in velocity of the study group was compared with the mean percentage change in the control group for each season and pitch type. Commonly measured baseball performance statistics were also compared between the 2 groups of pitchers.

Statistical Analysis

An a priori power analysis showed that 15 players were needed in each group to detect a 1% difference in the mean change in fastball velocity between the 2 groups. This represents a statistical power of 80% with an α value of .05. This

TABLE 2
Mean Pitch Velocity and Mean Change in Velocity Compared With the Index Year for the Study Group

Year	Mean Velocity, mph	Change in Mean Velocity, mph	*P* Value	95% CI
Preinjury year (year –1)				
Fastball	91.5	0.4	.45	–0.10 to 0.88
Changeup	83.0	1.0	.05	0.02 to 1.98
Curveball	79.2	1.0	.07	–0.07 to 2.07
Slider	83.2	0.7	.10	–0.16 to 1.47
Index year (year 0)				
Fastball	91.1	—	—	—
Changeup	82.0	—	—	—
Curveball	78.2	—	—	—
Slider	82.6	—	—	—
Postinjury years				
Year +1				
Fastball	89.7	1.3	<.001	0.78 to 1.88
Changeup	80.7	1.2	.02	0.25 to 2.19
Curveball	77.6	0.5	.42	–0.87 to 1.93
Slider	82.1	0.4	.23	–0.31 to 1.18
Year +2				
Fastball	88.7	1.0	<.001	0.54 to 1.52
Changeup	79.5	1.3	.02	0.21 to 2.28
Curveball	76.7	1.0	.03	0.13 to 1.76
Slider	81.6	0.6	.10	–0.12 to 1.29
Year +3				
Fastball	87.7	1.0	.01	0.26 to 1.78
Changeup	78.5	1.0	.03	0.11 to 1.80
Curveball	75.0	1.7	.004	0.63 to 2.70
Slider	81.2	0.3	.45	–0.55 to 1.22

sample size calculation was based on our study group's 2007 mean fastball velocity of 91.6 mph, 2008 mean fastball velocity of 91.2 mph, and standard deviation of 0.8 mph in the difference in mean velocity. Equal variance between the study group and control group was assumed.

All data from preinjury and postinjury years were compared with those from the index year for each eligible pitcher by using the paired *t* test on SPSS 17 (SPSS Inc, Chicago, Illinois, USA). Similarly, preinjury and postinjury data were also compared in the control group on a yearly basis. Finally, the mean percentage change in velocity of the study group was compared with the mean percentage change in velocity of the control group using a paired *t* test. An independent 2-sample *t* test was used to compare performance statistics including mean innings pitched, ERA, BAA, BB/9, K/9, and WHIP.

RESULTS

Return to Play

Of the 41 MLB pitchers who underwent UCL reconstruction during the 2008-2010 seasons, 3 pitchers were excluded from the study for a prior UCL reconstruction on their dominant arm. One pitcher retired from baseball, and 7 pitchers returned to professional baseball, but not at the major league level, at the time of this study. This represents an overall 79% return (30/38) to the same level of play after primary UCL reconstruction. The mean time of return to major league play after surgery was 17.1 months (median, 15 months; range, 11-27 months). After excluding an additional pitcher with a subsequent ipsilateral forearm fracture and another pitcher with no available preinjury velocity data, the mean pitch velocities of the 28 remaining pitchers in this study were analyzed (Figure 1). Minor league baseball pitchers who underwent UCL reconstruction during this time period and who later reached the major league level were not included in the study.

Demographic Data

There were no significant differences in the demographic data of our study group and control group (Table 1). The mean age was 28 years for both groups ($P = .92$). The mean height of the pitchers was 73.7 inches in the study group and 75.0 inches in the control group ($P = .06$). There was a 25% proportion of left-handed pitchers in the study group and 18% proportion of left-handed pitchers in the control group ($P = .74$). The percentage of starting pitchers was 54% for the study group and 57% for the control group ($P = .79$). The mean MLB experience before injury was 4.6 years for the study group versus 4.2 years for the control group ($P = .68$). The number of innings pitched ($P = .98$) and ERA ($P = .44$) in the preinjury year were also similar between the 2 groups.

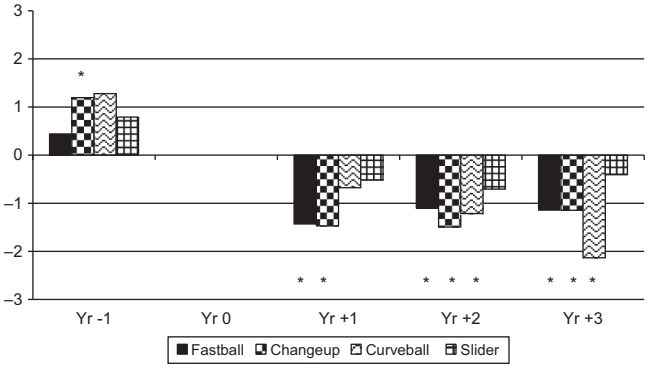

Figure 2. Percentage change in velocity by year (compared with index year) for the study group. *Statistically significant difference compared with the index year ($P < .05$).

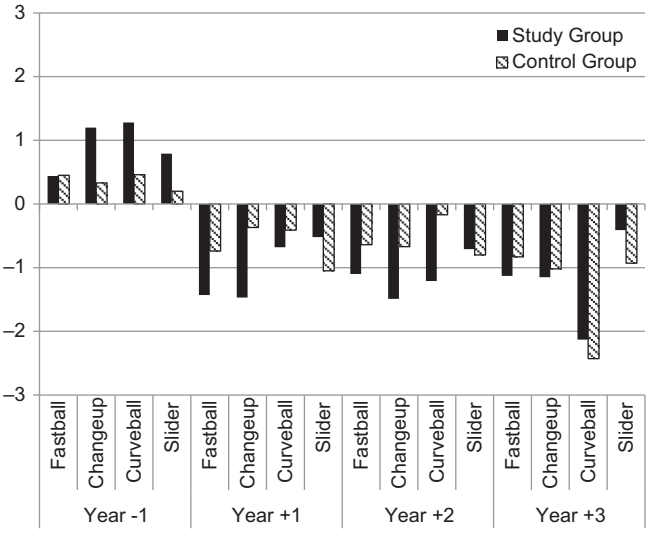

Figure 3. Comparison of percentage change in velocity by year (compared with index year) for each pitch type between the study group and control group. There were no significant differences through all years ($P > .05$).

Pitch Velocity

For the study group, the mean velocities of the preinjury and postinjury years for each of the 4 commonly thrown pitches were compared with those of the index year of injury (Table 2). The mean percentage changes in velocity of the preinjury and postinjury years, as compared with those of the index year, for these 4 pitches are shown in Figure 2. There was a small but statistically significant decrease in fastball and changeup velocities for each postinjury year in the study group. Curveball velocity decreased in postinjury years 2 and 3. There was a statistically significant difference in the changeup velocity for the preinjury year and a trend toward significance for curveballs. There was no difference for change in velocity for sliders thrown in any year.

When the differences in the mean change in velocity of the study group were compared with that of a pair-matched control group, there were no statistically significant differences in any season for any of the pitch types (Figure 3).

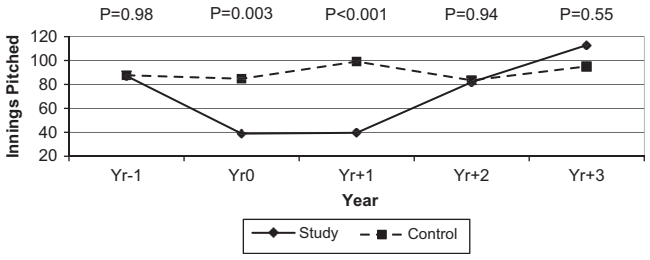

Figure 4. Comparison of innings pitched between the study group and control group by year. There was a significant difference for the index year and the first postinjury year. There were no significant differences in all other years ($P > .05$).

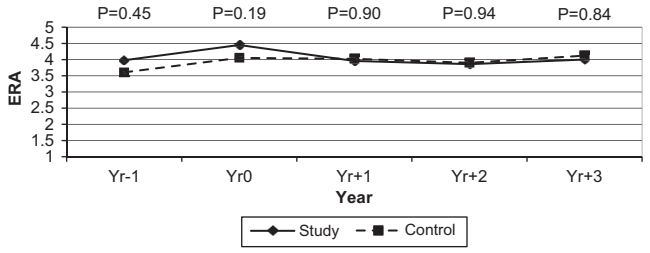

Figure 5. Comparison of earned run average (ERA) between the study group and control group by year.

Performance Measurement Data

When comparing the study group with the control group, there was a statistically significant difference in the number of innings pitched for the index year ($P = .003$) and first postinjury year ($P < .001$). There were no significant differences in all other years compared (Figure 4).

The mean ERA (Figure 5) between the study group and control group showed no statistical difference ($P > .05$) for each year. Similarly, the mean BAA (Figure 6), BB/9 (Figure 7), and K/9 (Figure 8) were not different ($P > .05$) between the 2 groups for each year that was compared. There was a trend approaching significance ($P = .09$) for the difference in WHIP for the index year only (Figure 9).

DISCUSSION

Historically, UCL ruptures in the overhead-throwing athlete have led to significant morbidity because of the associated pain and valgus instability. Studies have shown that the UCL plays a significant role in resisting valgus forces about the elbow.[8,9,13] When these forces generated by throwers exceed the tensile strength of the UCL, microscopic tears can be produced that ultimately lead to ligament attenuation or tears from repetitive usage. Morrey and An[13] suggested that the UCL provided 55% of the stabilizing contribution to valgus stress (64 N·m) with the

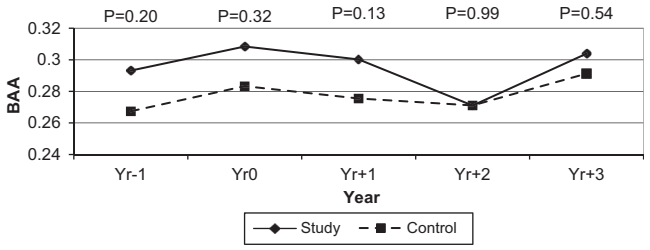

Figure 6. Comparison of opponents' batting average against (BAA) pitchers between the study group and control group by year.

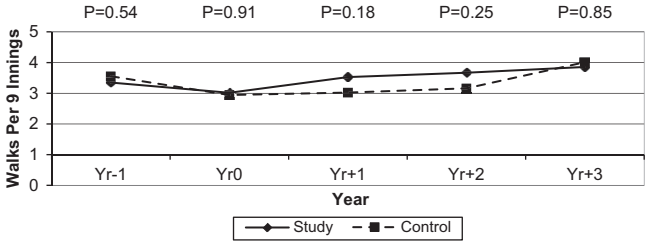

Figure 7. Comparison of walks per 9 innings (BB/9) between the study group and control group by year.

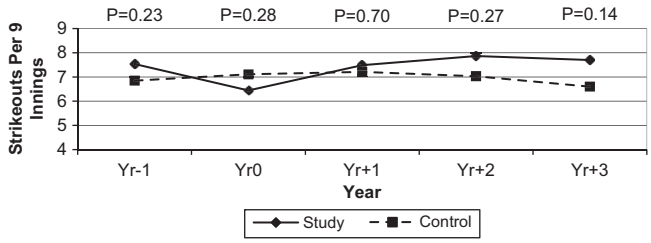

Figure 8. Comparison of strikeouts per 9 innings (K/9) between the study group and control group by year.

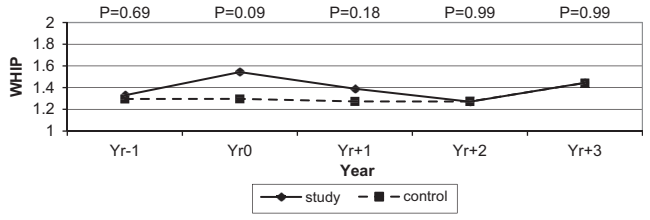

Figure 9. Comparison of walks plus hits per inning pitched (WHIP) between the study group and control group by year.

elbow at 90° in their cadaveric study. Fleisig et al[8] found that the mean varus torque generated during pitching by their group of healthy pitchers was 67 N·m. A follow-up study by the same group classified these data by pitch type and found the mean varus torque to be 82, 71, 79, and 81 N·m for the fastball, changeup, curveball, and slider, respectively.[9] This more recent study showed higher kinetic values partly because of the inclusion of wrist kinematics and improved modeling in their study participants. These studies highlight the biomechanical significance of the UCL in the overhead thrower.

Jobe et al[11] initially published their results of pitchers with UCL reconstruction surgery in 1986 and followed up with another study in 1992.[4] They reported good or excellent outcomes in 80% of their patients with a 68% return to the previous level of athletic participation. Subsequently, multiple studies involving UCL reconstruction have reported a 73% to 94% rate of return to play at a level that is at least comparable with the preinjury level of performance.[1,2,5,6,12,15-17] These studies include a mixture of athletes of multiple sports who play across a range of multiple levels. We wished to analyze a group of baseball pitchers who all played at the highest single level of competition for the sport. In our study, we identified small, but statistically significant, decreases in the velocity of fastballs, changeups, and curveballs thrown by the pitchers after surgery. However, these mean changes in velocity of the pitches were not different when compared with those of a pair-matched control group without a known UCL injury. We also found that the rate of return to the preinjury level of competition was 79%, with a median time of return to MLB play of 15 months (mean, 17.1 months; range, 11-27 months) after surgery.

Gibson et al[10] analyzed the pitching performance of MLB pitchers before and after UCL reconstruction from 1998 to 2003. The results from our study are consistent with their results as no statistical differences were identified with respect to common baseball outcome measurements between our study group and pair-matched control group. The similar BAA and ERA in the 2 groups represent no difference in the pitchers' effectiveness of limiting opposing teams from obtaining hits and runs. The similar BB/9 represents no difference with overall control of pitches thrown, and the similar K/9 represents the comparable likelihood of opposing batters in missing contact with the pitches thrown. The combined measurement of pitch control and effectiveness in limiting hits, as measured by WHIP, did show a statistical trend toward poorer performance in only the index year of the study group. As expected, the mean innings pitched in this study was significantly decreased in the study group compared with that in the control group in the index year of injury and first postinjury year. The reduced participation in the index season can be attributed to the season-ending nature of the injury, and the reduced participation in the first postinjury year can be attributed to the long rehabilitation after UCL reconstruction that often affects the following season of play. The mean innings pitched were similar at 2 and 3 years after surgery.

The limitations of this study include the retrospective nature of the study. Our reliance on an accurate and complete compilation of the surgical patients required reporting of injuries by all major league teams. In addition, the identification of a pair-matched control group required a statistical algorithm offered by Baseball-Reference.com, which is not published.[3] Also, we relied on the accurate identification of the pitch type and its velocity by technology incorporated by MLB. However, even the possible

infrequent inaccuracies associated with technical measurements are minimized by the vast number of pitches thrown by each pitcher over the course of each baseball season. Another limitation is that ideally we would have liked to review a pitcher's velocity up to 3 years before the time of his UCL rupture. However, because pitch velocity data were not publicly available from MLB until the 2007 season, we could only review 1 year of data before the year of injury to obtain a sufficient sample size and follow-up length. We also did not explore the component of fatigue and its potential effect on differences in velocity among our pitchers. A previous study has shown a significant decrease in a pitcher's velocity toward the later parts of a game.[14] Also, our study was powered to only identify differences in the mean velocity of fastballs thrown. It was not specifically powered to identify for differences in commonly used statistical outcome measurements. Thus, while our data appear to show no difference in ERA, BAA, BB/9, K/9, and WHIP, it is possible that a larger sample size is needed to achieve a more definitive conclusion. In addition, because of the heterogeneity of our study population, we are not able to identify and account for differences in surgeon techniques and rehabilitation protocols of each athlete. For example, a meta-analysis by Vitale and Ahmad[18] showed improved clinical results after UCL reconstruction with the docking and modified docking techniques as compared with the figure-of-8 technique. They also showed better clinical results with the muscle-splitting approach compared with detachment of the flexor-pronator mass. Our study is not able to account for the potential effects that these differences in surgical technique may have on velocity and performance measurements. Finally, it is possible that small distinctions in performance measurements, which are not statistically significant, can still represent a noticeable difference in the on-the-field effect of play.

In conclusion, we found that the velocity of fastball and changeup pitches thrown by pitchers who return to MLB after UCL reconstruction decreased by small, but statistically significant, values from preinjury to postinjury years. However, there was no significant difference in the mean velocity of any of the pitches thrown when compared with a pair-matched control group of pitchers who did not have a known UCL injury. In addition, there appears to be no significant differences in commonly used baseball performance measurement statistics such as innings pitched, ERA, BAA, BB/9, K/9, and WHIP between the study group and control group of MLB pitchers.

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