Pitch Characteristics Before Ulnar Collateral Ligament Reconstruction in Major League Pitchers Compared With Age-Matched Controls

John Prodromo,*† MD, Nimit Patel,† MD, Neil Kumar,† MD, Kevin Denehy,† MD, Loni Philip Tabb,‡ PhD, and James Tom,† MD

Investigation performed at the Drexel University College of Medicine/Hahnemann University Hospital, Philadelphia, Pennsylvania, USA

Background: Ulnar collateral ligament reconstruction (UCLR) is commonly performed in Major League Baseball (MLB) pitchers, but little is known about the preoperative pitch type and velocity characteristics of pitchers who go on to undergo UCLR.

Hypothesis: Pitchers who required UCLR have thrown a greater percentage of fastballs and have greater pitch velocities compared with age-matched controls in the season before injury.

Study Design: Case-control study; Level of evidence, 3.

Methods: MLB pitchers active during the 2002 to 2015 seasons were included. The UCLR group consisted of MLB pitchers who received UCLR between 2003 and 2015, utilizing the season before surgery (2002-2014) for analysis. The control group comprised age-matched controls of the same season. Players who pitched less than 20 innings in the season before surgery were excluded. Pitch types were recorded as percentage of total pitches thrown. Pitch velocities were recorded for each pitch type. Pitch type and pitch velocities during preoperative seasons for UCLR pitchers were compared with age-matched controls using univariate and multivariate models.

Results: A total of 114 cases that went on to UCLR and 3780 controls were included in the study. Pitchers who went on to UCLR appear to have greater fastball, slider, curveball, changeup, and split-fingered fastball velocities; there were no significant differences in pitch selection between the 2 groups.

Conclusion: In the season before surgery, MLB pitchers who underwent UCLR demonstrated greater fastball, slider, curveball, changeup, and split-fingered fastball velocities, with no significant difference in pitch type.

Keywords: Major League Baseball; pitching; ulnar collateral ligament; elbow

Ulnar collateral ligament (UCL) damage was historically a career-ending injury for Major League Baseball (MLB) pitchers until Frank Jobe performed a reconstruction procedure on Tommy John in 1974, for whom the procedure is often referred.[18] The procedure has recently become more prevalent among professional and amateur pitchers, including patients of younger age.[10,20] The cause of this change is likely multifactorial, resulting from increased awareness, diagnostic ability, improved outcomes, and possible overuse of young throwing arms.[4,10,20,24,28] An increasing number of players are turning to ulnar collateral ligament reconstruction (UCLR) after diagnosis of UCL injury. Previous studies have demonstrated that approximately 80% of pitchers return to play after UCLR, with similar pre- and postoperative performance statistics compared with controls.[4,8,15,19,22] Gibson et al[15] analyzed the pitching and statistical performance of 68 pitchers who underwent UCLR. Of these pitchers, 82% returned to major league play at a mean 18.5 months. Pitchers demonstrated no significant change in earned run average (ERA) or walks

*Address correspondence to John Prodromo, MD, Department of Orthopedic Surgery, Drexel University College of Medicine/Hahnemann University Hospital, 245 North 15th Street, Philadelphia, PA 19102, USA (email: prodromo.john@gmail.com).

†Department of Orthopedic Surgery, Drexel University College of Medicine/Hahnemann University Hospital, Philadelphia, Pennsylvania, USA.

‡Department of Epidemiology and Biostatistics, Dornsife School of Public Health, Drexel University, Philadelphia, Pennsylvania, USA.

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plus hits per innings pitched (WHIP) and no significant change in innings pitched at the second and third postindex seasons. Through multivariate analysis, starting pitchers were demonstrated to be at increased risk of undergoing UCLR. The current literature has also shown similar pre- and postoperative pitch velocity after UCLR.[15,17]

The anatomy and biomechanics of the UCL have been well studied. The UCL consists of an anterior oblique ligament (AOL), posterior oblique ligament (POL), and transverse ligament.[2,14] In MLB pitchers, the anterior band of the UCL in the dominant throwing arm is often hypertrophied, contains more calcifications, and demonstrates greater hypoechoic foci within the ligament when compared with the contralateral nonthrowing arm.[4,5] Ligamentous injury can also lead to increased ulnohumeral joint space when the throwing elbow is placed in valgus stress.[5,7] Force on the medial elbow varies with pitch type: Fastballs and curveballs produce the highest medial force, while sliders and changeups produce a relatively lower force.[9,11,12,23] Strain of the medial elbow is also dependent on pitch velocity.[27] Pitchers with maximum pitch velocity greater than 89 miles per hour (mph) may be at greater risk of developing elbow injuries, perhaps due to poor pitching mechanics.[1,3,27] The current data regarding preoperative pitch type and velocity in MLB pitchers requiring UCLR compared with noninjured pitchers are limited. We hypothesized that pitchers undergoing UCLR have thrown a greater percentage of fastballs and have greater pitch velocities in the season before injury compared with noninjured pitchers.

METHODS

A list of MLB pitchers and their date of surgery was compiled from a publicly available site (http://mlbreports.com/tj-surgery), and those pitchers who were active during the 2002 to 2015 seasons were considered in this study. The UCLR group comprised pitchers who underwent UCLR between 2003 and 2015 and had pitched more than 20 innings in the season before UCLR. This number of innings was selected to provide an adequate sample for pitch-type percentages as well as to exclude primarily position players who may pitch a small number of innings in a season. Pitchers were then excluded if there were not 10 age-matched controls available for their preoperative season. For this group, data from their respective preoperative season were included and compared with a control group. The control group consisted of all age-matched controls in the same preoperative season who pitched more than 20 innings.

Pitch types were recorded as percentage of total pitches thrown for each fastball, slider, cut fastball, curveball, changeup, split-fingered fastball (split-finger), knuckleball, and other. Mean pitch velocities were recorded for each pitch type. Pitch type and velocity data were compiled using a publicly available website (www.fangraphs.com). Descriptive statistics were carried out for performance variables, including mean velocity and pitch percentage for each pitch type.

TABLE 1
Percentage of Each Pitch Type[a]

Pitch Type	Pitch Percentage		
	Total (N = 3894)	Cases (n = 114)	Controls (n = 3780)
Fastball	0.61 ± 0.11	0.62 ± 0.10	0.62 ± 0.11
Slider	0.15 ± 0.13	0.15 ± 0.12	0.15 ± 0.13
Cut fastball	0.04 ± 0.09	0.04 ± 0.09	0.04 ± 0.09
Curveball	0.09 ± 0.09	0.08 ± 0.10	0.09 ± 0.09
Changeup	0.10 ± 0.08	0.09 ± 0.08	0.10 ± 0.08
Split-fingered fastball	0.01 ± 0.05	0.01 ± 0.04	0.01 ± 0.05
Other pitch	0.02 ± 0.04	0.03 ± 0.05	0.02 ± 0.04

[a]Data are presented as mean ± SD.

Several performance variables were considered for the analysis to compare cases with their matched controls. The variables included fastball percentage and velocity, slider percentage and velocity, cut fastball percentage and velocity, curveball percentage and velocity, changeup percentage and velocity, split-finger percentage and velocity, knuckleball percentage and velocity, and other pitch percentage. Due to a limited number of pitchers with available knuckleball percentage and velocity measures, these performance measures were eliminated from further analyses.

Statistical Analysis

Statistical analyses were conducted using R (The R Project for Statistical Computing).[25] Descriptive statistics were calculated for all performance variables for the entire study sample and by case and control status. Conditional logistic regression models were used to assess whether there are differences between pitchers in the season before UCL surgery and age-matched controls.[16] Both univariate and multivariate models were considered. A multivariate conditional logistic regression model was built using the statistically significant performance variables from the univariate models. Statistical significance was measured at a level of 0.20 for model selection for all models. Multicollinearity was assessed via the correlation between all significant performance variables.

RESULTS

A total of 114 pitchers, who went on to receive UCLR, and 3780 controls were included in the study. Although the original dataset had 117 cases, 2 cases were excluded because they had no matched controls and another was excluded because of a limited number of matched-control pitchers. Table 1 presents descriptive statistics for the entire study sample (N = 3894), as well by case (n = 114) and control (n = 3780) status with respect to various performance variables. Cases appear to have greater fastball, slider, curveball, changeup, and split-finger velocity. The percentage of each pitch type was not significantly different between the 2 groups.

TABLE 2
Mean Velocity by Pitch Type[a]

Pitch Type	Pitch Velocity, mph		
	Total (N = 3894)	Cases (n = 114)	Controls (n = 3780)
Fastball	91.35 ± 2.56	92.08 ± 2.61	91.33 ± 2.56
Slider	83.03 ± 2.72	83.62 ± 2.92	83.01 ± 2.72
Cut fastball	87.36 ± 3.82	87.12 ± 3.71	87.36 ± 3.83
Curveball	76.88 ± 3.12	77.75 ± 3.59	76.86 ± 3.11
Changeup	82.97 ± 2.89	83.57 ± 2.75	82.96 ± 2.89
Split-fingered fastball	84.21 ± 4.63	85.41 ± 2.63	84.16 ± 4.69

[a]Data are presented as mean ± SD.

The mean pitch velocities in the season before surgery (cases vs age-matched controls, respectively) were as follows: fastball, 92.08 versus 91.33 mph; slider, 83.62 versus 83.01 mph; curveball, 77.75 versus 76.86 mph; changeup, 83.57 versus 82.96 mph; and split-finger, 85.41 versus 84.16 mph. Pitch types in the preoperative season for both cases and their age-matched controls averaged 62% fastballs, 15% sliders, 4% cut fastballs, and 1% split-fingers. Curveballs were thrown 8% in cases compared with 9% in controls, changeups were thrown 9% in cases compared with 10% in controls, and other pitches were thrown 3% in cases compared with 2% in controls. These between-group differences did not reach statistical significance.

Table 2 presents the univariate conditional logistic regression results in examining the impact of each performance variable. The velocity measures for fastball, slider, curveball, changeup, and split-finger were all statistically significant. For each 1-mph increase in fastball velocity, the odds of undergoing UCLR increased 15%. For a 5-mph increase in fastball velocity, the odds of injury increased by 98%. Pitchers with greater changeup velocity also had an increased risk, but their increased risk was 9% per 1-mph increase.

In the multivariate model, using both a stepwise and backward selection method, the only significant performance variable that remained in the final model was fastball velocity. The correlation between fastball velocity and the remaining significant performance variables from the univariate conditional logistic regression models is displayed in the correlation matrix in Table 3. All 5 performance variables were significantly correlated, where the correlations ranged from 0.29 up to as large as 0.75 ($P < .001$). Because of the large amount of correlation between these performance variables, our final analyses focused on the univariate model results in Table 4.

TABLE 3
Correlation Matrix of Significant Performance Variables[a]

Performance Variable	FBV	SLV	CBV	CHV	SFV
FBV	1.00	0.61	0.56	0.75	0.37
SLV		1.00	0.47	0.59	0.33
CBV			1.00	0.52	0.29
CHV				1.00	0.44
SFV					1.00

[a]CBV, curveball velocity; CHV, changeup velocity; CTV, cut fastball velocity; FBV, fastball velocity; SFV, split-fingered fastball velocity; SLV, slider velocity.

TABLE 4
Results of Univariate Conditional Logistic Regression Models[a]

Performance Variable	Odds Ratio (95% CI)	*P* value
FBV	1.15 (1.06-1.24)	.001[b]
SLV	1.10 (1.02-1.20)	.020[b]
CTV	1.01 (0.94-1.08)	.850
CBV	1.11 (1.03-1.20)	.009[b]
CHV	1.09 (1.02-1.18)	.016[b]
SFV	1.13 (0.94-1.34)	.191[b]

[a]CBV, curveball velocity; CHV, changeup velocity; CTV, cut fastball velocity; FBV, fastball velocity; SFV, split-fingered fastball velocity; SLV, slider velocity.
[b]Statistically significant ($P < .20$).

DISCUSSION

In the overhead athlete, the UCL provides a significant role in restricting valgus stress at the elbow. Research focus has often cited biomechanical differences across pitch types. Escamilla et al[9] examined medial elbow forces before ball release for fastballs, curveballs, sliders, and changeups. The authors determined the greatest amount of valgus force for fastballs (292 N), which was almost 9% greater than curveballs (268 N). On the other hand, changeups had the least amount of medial elbow force (235 N), 3% less than sliders (244 N). Interestingly, similar differences in elbow torque are found in the young pitcher. Adolescent pitchers typically place approximately 10% more torque on the elbow throwing fastballs compared with curveballs.[6,23] Despite these biomechanical differences for pitch type, our study showed no difference in pitch-type percentages between pitchers who went on to injury in the following season and those who did not.

Despite evidence that the fastball poses the greatest stress to the medial elbow, breaking pitches, such as the curveball and slider, were historically thought to increase the risk of elbow injury. In a prospective study of pitchers aged 9 to 14 years, Lyman et al[21] found regular usage of curveballs and sliders to significantly increase the risk of developing shoulder and elbow pain. More recently, regular usage of curveballs as a secondary pitch has been associated with a 1.66 greater odds of developing symptomatic elbow pain and arm fatigue in athletes ages 9 to 18 years.[28] However, biomechanical studies may indicate that breaking pitches with proper pitching mechanics are safe for young athletes.[13,23] At this point, utilization of the curveball as a secondary pitch by young athletes is controversial. Study of pitch type in the elite athlete is limited. In this investigation, the UCLR group threw the same percentages

of curveballs, but with a higher mean velocity than age-matched controls.

In a study of 147 MLB pitchers undergoing UCLR, Makhni et al[22] found fastball percentage of 64.90% with mean velocity of 91.2 mph, both of which are similar to results of our UCLR group. The harmful effect of pitch velocity was investigated by Bushnell et al,[3] who found a 4-mph difference in mean maximum pitch velocity between pitchers who developed elbow injuries compared with non-injured players. This investigation found greater velocity across pitch types, except cut fastballs, in the UCLR group. Cut fastballs made up a mean of just 4% of pitches for both groups. Fastball, slider, curveball, changeup, and split-finger velocity were all greater in the UCLR group than the control group. By percentage, the majority of pitches thrown were fastballs: 62% in both groups. Fastball velocity in the UCLR group (92.08 mph) was greater than the control group (91.33 mph). Pitching with increasing speed may in fact be incongruous with proper pitching mechanics,[27] perhaps the central reason why velocity has been so often correlated with UCL pathology. An alternative possibility is that increased velocity correlates to higher stress being placed across the UCL, leading to an increased risk of injury.

Historically, pitch type has been targeted by biomechanical studies as a precursor for injury. Our study suggests that in major league pitchers, the pitch-type distribution is similar in the season before injury in comparison with age-matched controls, and it is pitch velocity that is related to injury risk.

There was significant correlation of velocity across pitch types. The correlation of fastball, slider, curveball, changeup, and split-finger velocity were significantly correlated, where the correlations ranged from 0.29 up to as large as 0.75 ($P < .001$). Mean major league fastball pitch velocity has risen from 89.9 mph in the 2002 season to 91.8 mph in the 2014 season. The slider, curveball, changeup, and split-finger have also demonstrated an increase in velocity over this time period. This rising velocity may contribute to the increasing injury incidence; as velocity increases, the possibility of injury appears to increase. In the past 3 years, the number of MLB pitchers who have undergone Tommy John surgery per year has been 25 to 30, compared with a historical average of 15 to 20 per year.[26] As major league velocity rises, injuries may continue to rise.

There are limitations to this study. The cohort, pitch type, and pitch velocity data were derived from publicly available information. Because of the private nature of medical records, it is possible that some pitchers underwent UCLR and were not recognized. This data set includes only those who underwent UCLR. Other pitchers may have sustained a UCL injury and opted for nonoperative treatment or retirement. However, based on the number of players included in both the preoperative and control groups, it is unlikely to significantly alter the results of the study. The impact of other characteristics that relate to pitching was not included in this study, including workload of innings and games pitched, pitching role as a starter or reliever, and other concomitant injuries. The impact of these specific variables has not been studied extensively. In a comparison of pitchers who underwent UCL reconstruction versus controls matched by age, body mass index, position, handedness, experience, and performance, Erickson et al[8] demonstrated that pitchers who went on to injury had decreased innings pitched, games played, wins, and win percentages. Thus, even with control for these variables, pitchers demonstrate differences in the season before injury. In addition, the current study evaluated only the preoperative season of the cases and controls. It is reasonable to suggest that repetitive stress on the elbow related to pitch volume and velocity may both contribute to differences; further research into pitch volume may elucidate the relationship between volume and injury.

CONCLUSION

In the season before surgery, MLB pitchers who underwent UCLR demonstrated greater mean pitch velocity for fastball, slider, curveball, changeup, and split-finger than did age-matched controls. Pitch-type percentage was not significantly different between the 2 groups.

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