

Effects of Ulnar Collateral Ligament Reconstruction on Pitch Selection in Major League Baseball Pitchers

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Background: Ulnar collateral ligament (UCL) injuries represent one of the most common impairments to the throwing arm of professional pitchers. Return to play and postoperative performance metrics have been studied extensively, but pitch selection before and after surgery has not been evaluated.

Purpose/Hypothesis: This study aimed to characterize the effects of UCL reconstruction on pitch selection in Major League Baseball (MLB) pitchers. We hypothesized that pitchers will throw fewer fastballs and a greater percentage of off-speed pitches after undergoing UCL reconstruction.

Study Design: Retrospective cohort study; Level of evidence, 3.

Methods: Using publicly available data, we evaluated MLB pitchers who underwent UCL reconstruction between 2003 and 2014. Pitching data were collected for the 2 seasons before UCL reconstruction as well as the first 2 seasons after reconstruction; the data consisted of the total number of pitches thrown and the percentage of fastballs, curveballs, changeups, and sliders. Repeated-measures analysis of variance was used with post hoc least significant difference pairwise *t* tests to evaluate for statistical significance at $P < .05$.

Results: Overall, 87 pitchers (mean age, 28.2 ± 3.5 years) met all inclusion and exclusion criteria. There was a statistically significant difference in the total number of pitches thrown before and after surgery ($P < .01$) as well as in the percentage of fastballs thrown before and after surgery ($P = .02$). There was also a statistically significant increase in the use of curveballs between 1 and 2 years postoperatively (7.5% and 8.8%, respectively; $P = .01$). No other findings were statistically significant.

Conclusion: Pitchers who underwent UCL reconstruction were shown to have a statistically significant decline in the percentage of fastballs thrown postoperatively as compared with before injury, with a compensatory trend toward an increased use of curveballs and sliders.

Keywords: Tommy John; Major League Baseball; pitcher; ulnar collateral ligament reconstruction

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Ulnar collateral ligament (UCL) injuries represent one of the most prevalent impairments to the throwing arm among Major League Baseball (MLB) pitchers, with up to 25% of pitchers having a history of undergoing UCL reconstruction.³ Biomechanical analysis has shown that overhead-throwing motion places a considerable amount of valgus stress on the medial stabilizing structures of the elbow, which is thought to place the UCL at risk of injuries.⁶ UCL reconstruction was popularized based on its success in pitcher Tommy John in 1974, and it has since garnered a reputation for improving the performance of pitchers who undergo the procedure. Studies have indeed shown that of all pitchers who undergo UCL reconstruction, about 90% are able to return to competition.¹⁰ However, postoperative performance metrics have shown varying trends. A study of 41 pitchers returning to play between 2008 and 2010 showed no significant difference in pitch velocity after UCL reconstruction.⁹ Gibson et al⁸

analyzed postoperative performance in 2007 and found no significant difference in innings pitched, earned run average (ERA), or walks plus hits per inning pitched (WHIP) 2 years after surgery. A cohort study by Erickson et al⁴ showed that players who return to play after UCL reconstruction pitch fewer innings per season and complete fewer games per season. More recent studies on return to play and postoperative performance metrics have shown less optimistic return-to-play rates and statistically significant declines in postoperative batting average against, average fastball velocity, ERA, and WHIP.^{11,12}

Several studies have examined whether pitch type and pitch velocity play a role in the development of UCL injuries. Biomechanical studies have found pitch velocity to be the single most significant determinant of torque across the medial elbow during the throwing motion. This correlates clinically as well, as it has been shown that among pitchers who required UCL reconstruction, pitch velocities across all pitch types were found to be higher than in appropriate age-matched controls, with fastball velocity being the greatest indicator for the risk of future UCL injuries.^{1,2} Prodromo et al¹⁴ estimated that with every 1-mph increase in peak pitch velocity in MLB pitchers, the chance of requiring UCL surgery increased by 15%. Pitch type has also been implicated as a risk factor in UCL injuries. In a study looking at MLB pitchers, Keller et al¹⁰ concluded that an increased percentage of fastballs thrown was correlated with an increased risk for UCL injuries, while curveballs, sliders, and changeups were not.

While the risk factors and outcomes of UCL reconstruction have been widely studied, to our knowledge, the changes in pitching habits after UCL surgery have not. The purpose of this study was to examine the pitch choices of MLB pitchers before and after undergoing UCL reconstruction. Our hypothesis was that the percentage of fastballs thrown will decrease after UCL reconstruction compared with before and that there will be a compensatory increase in the percentage of off-speed pitches (curveball, slider, changeup) thrown. Interestingly, narratives of Tommy John's postoperative career note that he began throwing more off-speed pitches after surgery, providing an intriguing historical basis for this study. The results of this study can improve our understanding of the effects of UCL injuries in professional baseball players and allow us to provide future patient-athletes with more accurate expectations when returning to play after UCL reconstruction.

METHODS

This study utilized publicly available data to identify MLB pitchers who had undergone UCL reconstruction. Inclusion criteria included pitchers at the major league level of competition who underwent UCL reconstruction between the years of 2003 and 2014. Included athletes were required to have 2 consecutive years of competitive MLB pitching experience before surgery as well as 2 consecutive years of competitive pitching after surgery, regardless of the duration of the rehabilitation period. The 2 seasons immediately before surgery and the first 2 seasons after reconstruction and rehabilitation were included in our analysis. Pitchers who

underwent revision surgery were excluded to avoid this confounding factor. Other exclusion criteria included throwing fewer than 500 pitches at the Major League level in any single year within the study window of the past 2 years before surgery and the first 2 years of pitching after surgery. We chose 500 pitches as a cutoff that was felt to represent a large enough sample while also maximizing the size of our cohort in this relatively new and growing data set. Two years before and after surgery was selected as a time period that was felt to be adequate to assess any trends in pitch selection specifically related to UCL injuries and reconstruction, without lengthening the study period to the extent that aging may introduce a confounding factor to changes in pitch selection. Pitch data were collected utilizing the online database of FanGraphs.com.⁵

Data collected included the total number of appearances and pitches thrown before and after UCL reconstruction as well as the percentage of each pitch type thrown, including fastballs, curveballs, changeups, and sliders. All pitchers were grouped together for the purposes of this study, as a large number of pitchers were used in both starting and relief roles during the duration of the study. Subgroup analysis was also performed on a cohort of starting pitchers who returned to a starting role after surgery. Repeated-measures analysis of variance was conducted to evaluate for changes in pitch selection within each pitch subcategory over time both before and after UCL reconstruction. Post hoc analysis was performed using least significant difference pairwise *t* tests, and *P* values were adjusted using the Greenhouse-Geisser adjustment. The Greenhouse-Geisser adjustment was used because the data failed to adhere to the assumption of sphericity determined via the Mauchly test. Results are reported as *P* values for each pitch category, with an acceptable level of significance at *P* = .05.

RESULTS

A total of 893 pitchers were identified in MLB at the major or minor league levels who had undergone UCL reconstruction between 2003 and 2014. Inclusion and exclusion criteria were applied, and a final study population of 87 MLB pitchers was identified. The mean age at the time of surgery was 28.2 ± 3.5 years, and the percentage of right-handed pitchers was 78.1%.

The mean number of pitching appearances and mean number of pitches thrown are displayed in Table 1. The number of combined appearances per pitcher in the 2 seasons before surgery was 76.1 ± 36.8 versus 62.3 ± 31.5 in the 2 seasons after surgery. The total number of pitches thrown varied between a few hundred to several thousand pitches each in the preoperative and postoperative time periods. The mean number of pitches thrown before surgery was 3026 ± 1606.8 , with a mean of 53.0 ± 38.1 pitches per appearance. The mean number of pitches thrown after surgery was 2219.9 ± 1484.2 , with a mean of 45.7 ± 34.3 pitches per appearance. The number of pitches thrown and number of appearances were each found to be a statistically significantly different between the preoperative and postoperative time periods (*P* < .01 and *P* = .01, respectively).

TABLE 1
Pitching Appearances and Pitches Thrown^a

	Before UCLR	After UCLR	P Value
Appearances			
All pitchers	76.1 ± 36.8	62.3 ± 31.5	.01
Starting pitchers (n = 28)	47.7 ± 12.6	43.0 ± 13.9	.19
Pitches thrown, mean ± SD (range)	3026.2 ± 1606.8 (647-6970)	2219.9 ± 1484.2 (508-6624)	<.01
Pitches per appearance			
All pitchers	53.0 ± 38.1	45.7 ± 34.3	.19
Starting pitchers (n = 28)	92.6 ± 8.8	89.4 ± 8.3	.16

^aData are expressed as mean ± SD unless otherwise stated. Analysis was conducted on data from 87 pitchers with pitch data available 2 years before and after UCLR. P values were obtained from a 2-tailed Student t test, with equal variance proven on an F test. Statistically significant differences are noted in bold. UCLR, ulnar collateral ligament reconstruction.

TABLE 2
Pitch Selection Summary^a

	Time Point Relative to UCLR				P Value
	2 y preoperatively	1 y preoperatively	1 y postoperatively	2 y postoperatively	
Fastball, %					.02
Mean (SE)	64.3 (1.19)	62.2 (1.14)	61.6 (1.28)	61.3 (1.22)	
P value		<.01	.03	<.01	
Curveball, %					.15
Mean (SE)	8.3 (0.98)	8.2 (1.03)	7.5 (0.96)	8.8 (1.07)	
P value		.68	.17	.44	
Changeup, %					.34
Mean (SE)	8.5 (0.78)	9.0 (0.90)	9.4 (0.99)	8.7 (0.87)	
P value		.26	.18	.73	
Slider, %					.37
Mean (SE)	14.6 (1.15)	15.1 (1.30)	15.5 (1.53)	15.9 (1.36)	
P value		.41	.32	.13	

^aP values were obtained from repeated-measures analysis of variance with the Greenhouse-Geisser adjustment because of failure of sphericity via the Mauchly test. Main effects for time were assessed for mean equivalence via least significant difference-adjusted pairwise tests. Statistically significant difference between preoperative and postoperative values are noted in bold. Significant mean differences on pairwise testing are indicated via italics, with individual P values listed below each time point compared with 2 years before surgery. UCLR, ulnar collateral ligament reconstruction.

However, the mean number of pitches per appearance was not found to be significantly different before versus after surgery (*P* = .19).

In the subgroup analysis performed on the cohort of starting pitchers, there were no significant differences seen in appearances before or after surgery (47.7 ± 12.6 and 43.0 ± 13.9, respectively; *P* = .19). The mean number of pitches per appearance was found to be similar, with 92.6 ± 8.8 before surgery and 89.4 ± 8.3 after surgery (*P* = .16).

Of the pitch types studied, we found a statistically significant decline when examining the percentage of fastballs thrown 2 years before surgery as compared with 1 year before surgery (*P* < .01), 1 year after surgery (*P* = .03), and 2 years after surgery (*P* < .01). Pitch selection data are displayed in Table 2, with a graphical representation provided in Figure 1. The percentage of fastballs thrown peaked at a mean of 64.3% (SE, 1.19%) 2 years before surgery and was lowest at 2 years after surgery at a mean of 61.3% (SE, 1.22%). On pairwise analysis, there was also found to be a statistically significant increase in the mean percentage of

curveballs thrown in the second year after surgery (8.8% [SE, 1.07%]) relative to the first year after surgery (7.5% [SE, 0.96%]) (*P* = .01). The changeup trended toward a slightly increased use in the year before and the year after surgery but returned to similar numbers in the second year after reconstruction. The slider trended toward increasing use with each consecutive year after the time point of 2 years before surgery, increasing from 14.6% at 2 years before surgery to 15.9% at 2 years after surgery and yielding a *P* value of .13 on pairwise comparison. Despite the trends in changeup and slider use, statistical significance was not reached.

DISCUSSION

The most important finding of our study was that pitch selection in pitchers who had undergone UCL reconstruction was significantly different than before surgery. The effects of UCL reconstruction on athletes' return to play, performance metrics, and pitch velocity have been well studied. However,

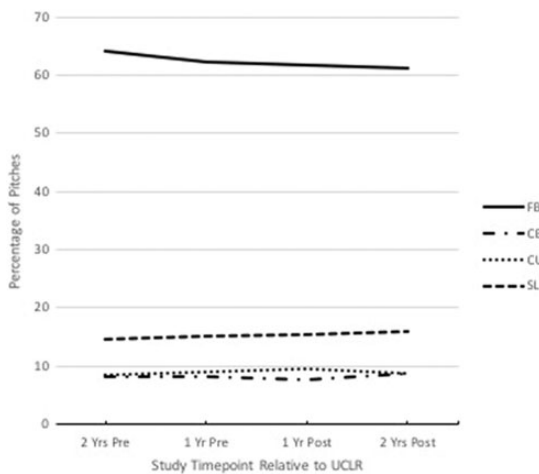


Figure 1. Changes in the percentage of each pitch type thrown over time before and after ulnar collateral ligament reconstruction (UCLR). CB, curveball; CU, changeup; FB, fastball; SL, slider.

pitch selection and the effects of UCL surgery on pitch use after return to play have not. In our study population, there was a statistically significant decrease in the total number of pitches thrown in the 2-year period before surgery compared with after surgery ($P < .01$). The pitchers in our study population also made significantly fewer appearances ($P = .01$) in the time period after surgery compared with before surgery, with a coinciding nonsignificant trend toward fewer pitches per appearance. The subgroup analysis of starting pitchers showed that there was no significant difference in the number of appearances or the number of pitches thrown per appearance in the preoperative compared with the postoperative period. There are a multitude of factors that may confound these findings, including changes in roles after surgery, pitch counts imposed by coaches or training staff postoperatively, and departure or return to play in the mid-season. The percentage of fastballs thrown declined from a mean of 64.3% at 2 years before injury to 61.3% at 2 years after UCL reconstruction ($P < .01$). While a statistically significant difference was found in the percentage of fastballs thrown and the total number of pitches, the clinical significance of these findings is less clear and may vary from pitcher to pitcher.

Interestingly, the decline in the use of fastballs was found to begin in the year before surgery. It is difficult to speculate the cause for the change in the rates of fastballs pitched before or after reconstruction. Fleisig et al⁷ showed that pitching biomechanics are unchanged after UCL reconstruction, refuting this as a reason why an athlete may fail to return to the same level of performance. An evaluation of stresses across the elbow with different pitch types may provide insight. A recent biomechanical study found that fastballs produced the greatest stress across the medial elbow at an average of 45.56 N·m, which was significantly greater than for changeups (43.77 N·m) and curveballs (43.83 N·m).¹³ Conclusions should be drawn carefully, as torque across the medial elbow is being used as a

representation of stress on the UCL, but it provides a valuable comparative measure between pitches. Increased torque across the elbow may cause increased discomfort in the painful throwing elbow, causing pitchers to knowingly or unknowingly refrain from using their fastball at normal rates. Although the magnitude of the effect is small, this finding in our study suggests a possible method to monitor for injuries by tracking the percentage of fastballs thrown.

The rate of off-speed pitches examined in this study did not show any statistically significant changes after surgery; however, a compensatory trend toward an increased use of curveballs and sliders was seen. Although pitch selection before and after UCL reconstruction will vary from player to player based on preinjury ability, pitching style, and other individual factors, this information can be utilized by surgeons to explain trends after reconstruction and can assist in providing realistic expectations to players when deciding on surgery. Despite the small magnitude of the effect, leading to questionable clinical significance, we feel that this remains a valuable point of discussion with the injured athlete while considering individual factors. Using this information, athletes and their coaches will better understand the effects that UCL reconstruction will have on pitching habits. Players will be able to better prepare themselves for such possible changes, depending on their current strengths and weaknesses with various pitch types.

The current study was limited to professional pitchers, which may make it poorly generalizable to a general overhead-throwing population. MLB pitchers were used because of the amount of data that is publicly available regarding their pitch selection. The accuracy of data from a source such as FanGraphs.com is difficult to verify, but it provides a useful platform for studies of this nature. Many athletes were excluded from our study because of failure to return to the major league level after surgery. These exclusions limit the scope of our findings, as the results may not be applicable to athletes who do not return to the same level of play. Another limitation is that these findings are not directly related to any performance results, and performance may differ after surgery, depending on a pitcher's skill and prior use of different pitches. With reference to performance metrics, power pitchers who thrive on throwing predominantly fastballs may be affected more after surgery than pitchers who excel in the use of off-speed pitches. However, the results provide valuable information about how pitch selection may change after surgery, which players and trainers can use on an individualized basis as the players train and progress through their postoperative playing careers.

In the "Moneyball" era of baseball, databases such as FanGraphs.com and MLB's Statcast continue to grow and collect new data. Beyond the scouting and advanced statistics tracking capabilities that these data provide for the industry, they also offer further insight into risk factors for certain injuries, novel ways to monitor for injuries, and improved evaluation methods of postoperative performance for physicians and trainers. Further directions on this topic, as data become more robust, may include studying performance metrics on individual pitch types before and after surgery to better quantitate the difference in pitch

quality and execution after an injury. A study of this kind may be helpful to further elucidate whether the effectiveness of pitches in the postoperative playing career causes changes in pitch selection.

CONCLUSION

The results of our study confirmed our hypothesis that pitchers would throw a decreased percentage of fastballs after undergoing UCL reconstruction. This finding adds to the existing body of literature to further inform athletes, physicians, athletic trainers, and other rehabilitation professionals on postoperative expectations after UCL reconstruction. Further studies on this topic should aim to evaluate performance metrics for individual pitch types to more directly correlate the effects of UCL reconstruction on postoperative pitching performance.

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