

# Preventing Tommy John Surgery

## The Identification of Trends in Pitch Selection, Velocity, and Spin Rate Before Ulnar Collateral Ligament Reconstruction in Major League Baseball Pitchers

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**Background:** Ulnar collateral ligament (UCL) reconstruction is a common surgery among Major League Baseball (MLB) pitchers that results in a significant number of missed games. Little has been reported regarding game-by-game trends that can identify those on the verge of becoming injured.

**Purpose:** To determine if there is a patterned change in MLB pitchers' pitch selection, velocity, or spin rate in games leading up to Tommy John surgery that may predict subsequent UCL surgery.

**Study Design:** Case series; Level of evidence, 4.

**Methods:** A retrospective review of MLB pitchers who underwent primary UCL reconstruction between 2009 and 2019 was performed. Pitch characteristics were evaluated on a game-by-game basis for the 15 games leading up to surgery. A Mann-Kendall trend test was used to identify trends in pitch selection, velocity, and spin rate for multiple pitch types. A Kendall  $\tau_b$  correlation coefficient was identified, with values closer to 1 or -1 signifying a stronger monotonic trend.

**Results:** A total of 223 MLB pitchers underwent UCL reconstruction in the time period. In the 15 games leading up to surgery, decreases in pitch velocity for 4-seam fastballs ( $\tau_b = -0.657$ ;  $P < .001$ ), 2-seam fastballs ( $\tau_b = -0.429$ ;  $P = .029$ ), and sliders ( $\tau_b = -0.524$ ;  $P = .008$ ) were significantly associated with game number closer to injury. There was a significant positive association in the spin rate for cutters ( $\tau_b = 0.410$ ;  $P = .038$ ) and a significant negative association in spin rate for 4-seam fastballs over the course of these 15 games ( $\tau_b = -0.581$ ;  $P = .003$ ). In addition, there was a significant positive association in the percentage of curveballs thrown ( $\tau_b = 0.486$ ;  $P = .013$ ).

**Conclusion:** The study results suggest that there is a patterned change in certain pitch statistics in MLB pitchers in the games leading up to Tommy John surgery. Although the absolute change from game to game may be small, it may be possible for these trends to be monitored before a player becomes injured, thus reducing the significant burden Tommy John surgery places on these athletes.

**Keywords:** ulnar collateral ligament; Major League Baseball; pitch velocity; risk factors

Ulnar collateral ligament (UCL) reconstruction is a major surgery that roughly 26% of surveyed Major League Baseball (MLB) pitchers undergo in their pitching career.<sup>14</sup> While modern techniques have improved return-to-sport (RTS) rates and have reduced complication rates, roughly 20% of MLB pitchers are unable to return to their same level of play after undergoing UCL reconstruction.<sup>4</sup> In addition to being a potentially devastating injury for the career

of a player, UCL reconstruction represents a significant economic effect on MLB teams, with costs of recovery averaging roughly \$1.9 million per player overall and \$3.9 million for each starting pitcher.<sup>18</sup>

There are some data to suggest that UCL reconstruction has an effect on pitching mechanics and performance, with medialization of fastball, sinker, curveball, and changeup release points; reduced elbow extension after ball release; increased walks plus hits per inning pitched (WHIP); and increased earned run average (ERA) seen in some studies.<sup>6,10,24</sup> Risk factors such as deficits in throwing-shoulder total rotation and flexion, increased range of

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nondominant arm internal rotation, increased mean pitch velocities, and numerous others have been documented in predisposing pitchers to UCL injuries.<sup>26,29</sup> However, little has been reported on identifying game-by-game changes in pitch characteristics that may be used to identify those who may be nearing a devastating injury.

Identification of this vulnerable pitching population may be possible via biomechanics and pitch-specific deviations from control levels of performance; much in the same way, studies have been conducted to assess parameters before and after UCL reconstruction.<sup>6,17,22,25</sup> Evaluation and application of conservative treatment strategies could then theoretically be applied to prevent or delay more severe UCL tearing. Platelet-rich plasma injection has been evaluated as a conservative treatment for UCL tears with mixed results. Some studies have demonstrated platelet-rich plasma injection to be a successful nonoperative approach to the management of partial UCL tears,<sup>12,23</sup> while another larger study found no improvement in return-to-play outcomes or ligament survivorship.<sup>5</sup>

The purpose of this study was to determine if there is a patterned change in MLB pitchers' pitch selection, velocity, or spin rate in games leading up to Tommy John surgery that may predict subsequent UCL surgery.

## METHODS

A retrospective review of MLB pitchers who underwent primary UCL reconstruction between 2009 and 2019 was performed. Pitch characteristics were evaluated on a game-by-game basis for the 15 games leading up to surgery using publicly available PITCHf/x technology (SportsVision Inc) data (<https://baseballsavant.mlb.com>). Specifically, the type of pitch thrown and the velocity and spin rate of those pitches were analyzed for the 15 games immediately before surgery. The total number of 15 games was chosen as the time cutoff to maximize the number of players who completed this stretch of games in less than a 365-day span while providing a long enough length of time to establish a baseline value for all data points. In addition, increasing the length of time would exacerbate the disparity in the number of players included for each game because of varying lengths of careers.

### PITCHf/x Tracking Data

Since the 2006 season, the MLB has made pitch tracking through PITCHf/x publicly available. The PITCHf/x technology, which is used at all MLB ballparks, uses high-speed cameras to track the path of the baseball from the pitcher's

release point to home plate along its entire trajectory within centimeters of precision. Algorithms are then used to calculate the velocity, spin, and ball movement of each pitch. Subsequently, ball movement algorithms are applied to classify a pitch as 1 of 11 different pitch types. The specific variables of interest in this study for each pitcher were pitch type, velocity, and spin rate. Of note, spin rate was not collected until the 2015 season.

## Statistical Analysis

Data extraction from the publicly available domain was performed using Python (Version 3.7.0; Python Software Foundation). All data analysis was performed using Stata/MP 13.1 for Mac (StataCorp LP). A Mann-Kendall trend test was used to identify trends in each statistic over the 15 games leading up to surgery. The Mann-Kendall test is a nonparametric test that assesses for monotonic trends in data over time and reports a Kendall  $\tau_b$  correlation coefficient between the 2 variables. A Kendall  $\tau_b$  correlation coefficient was identified, with values closer to 1 or -1 signifying a stronger monotonic trend. The level of significance was set at  $P < .05$ . A locally weighted scatterplot smoothing line was used to graphically depict the trend of means. This line allows for graphical identification of visual trends that occur in nonparametric data using localized weighted polynomial regression.

## RESULTS

A total of 223 MLB pitchers underwent UCL reconstruction between 2009 and 2019 and were included in the analysis. Not every pitcher consistently utilized all types of pitches analyzed, and therefore the number of players in each pitch analysis by game is reported in Table 1. In this data set, the majority of pitches thrown were 4-seam fastballs, followed by sliders and changeups. The least common pitches were cutters and sinkers.

In the 15 games leading up to surgery, decreases in pitch velocity for 4-seam fastballs ( $\tau_b = -0.657$ ;  $P < .001$ ), 2-seam fastballs ( $\tau_b = -0.429$ ;  $P = .029$ ), and sliders ( $\tau_b = -0.524$ ;  $P = .008$ ) were significantly associated with game number closer to injury (Table 2 and Figure 1, B-D). There was a significant positive association in the spin rate for cutters ( $\tau_b = 0.410$ ;  $P = .038$ ) and a significant negative association in the spin rate for 4-seam fastballs over the course of these 15 games ( $\tau_b = -0.581$ ;  $P = .003$ ) (Table 2 and Figure 1, E and F). In addition, there was a significant positive

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Ethical approval was not sought for the present study.

TABLE 1  
Minimum and Maximum Number of Players in Each Analysis by Pitch Type

Variable	Changeup	Curveball	Cutter	4-Seam	2-Seam	Sinker	Slider
Percentage thrown							
Minimum	68	50	22	114	49	28	89
Maximum	83	67	31	130	63	32	100
Velocity							
Minimum	68	50	22	114	49	28	89
Maximum	87	67	31	130	63	32	100
Spin							
Minimum	14	12	5	28	10	3	19
Maximum	24	16	12	39	18	5	28

TABLE 2  
Summary of Kendall Rank Correlation Coefficient and P Values for Each Pitch Type<sup>a</sup>

	Changeup	Curveball	Cutter	4-Seam	2-Seam	Sinker	Slider
Percentage thrown							
$\tau_b$	0.371	<b>0.486</b>	-0.333	0.276	-0.010	-0.200	-0.200
P	.060	<b>.013</b>	.093	.166	>.999	.322	.322
Velocity							
$\tau_b$	0.010	0.029	-0.352	<b>-0.657</b>	<b>-0.429</b>	-0.352	<b>-0.524</b>
P	>.999	.921	.075	<b>&lt;.001</b>	<b>.029</b>	.075	<b>.008</b>
Spin							
$\tau_b$	-0.124	0.067	<b>0.410</b>	<b>-0.581</b>	0.029	-0.067	0.162
P	.553	.767	<b>.038</b>	<b>.003</b>	.921	.767	.429

<sup>a</sup>P values were calculated using the Mann-Kendall trend test for monotonic trends. Bolded values indicate statistical significance ( $P < .05$ ).

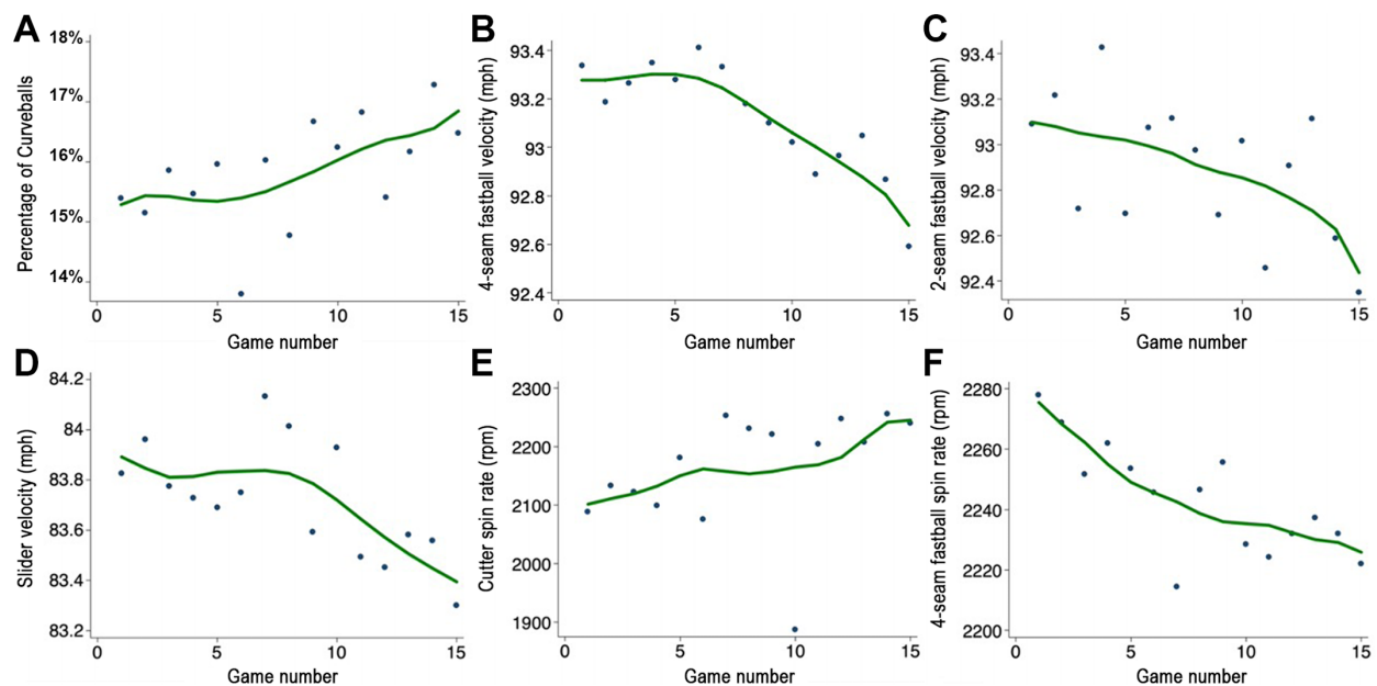


Figure 1. Graphs depicting changes in pitching characteristics by game, with game 15 being the last before injury: (A) percentage of curveballs thrown, (B) mean velocity of 4-seam fastballs, (C) mean velocity of 2-seam fastballs, (D) mean velocity of sliders, (E), mean spin rate of cutters, and (F) mean spin rate of 4-seam fastballs.

association in the percentage of curveballs thrown ( $\tau_b = 0.486$ ;  $P = .013$ ) (Table 2 and Figure 1A).

## DISCUSSION

The results of this study demonstrate that there are identifiable associations between pitch characteristics and the game number leading up to UCL reconstruction surgery. In the games immediately before UCL surgery, MLB pitchers had a decrease in the velocity of their 4-seam fastballs, 2-seam fastballs, and sliders. Players also had an increase in the spin rate of their cutters, a decrease in the spin rate of their 4-seam fastballs, and an increase in the percentage of curveballs thrown. These results suggest that there is an identifiable patterned alteration in pitch biomechanics in games leading up to surgery that may be due to sub-clinical injury at the UCL.

As pitchers approached UCL surgery, they had a decrease in the velocity of both their 2-seam and 4-seam fastballs, as well as their sliders. For 4-seam fastballs, this was noted to begin around 9 games before injury, with a total decrease of 0.7 mph. This equates to a roughly 0.1 mph decrease per game leading up to injury. Slider velocity also demonstrated a relative drop-off at around 8 games before injury, with a decrease of 0.5 mph. Two-seam fastballs featured a more gradual decline. Although the absolute decreases in velocity were small, slight changes in velocity may represent significant changes in the cumulative stress placed at the medial elbow.<sup>7</sup>

Previous studies have evaluated whether pitch velocity is an independent risk factor for UCL injury. MLB pitchers who sustained medial elbow injuries have been found to have a higher maximal pitch velocity compared with uninjured controls, and adolescent pitchers who threw >85 mph have been shown to have an increased risk for UCL injury.<sup>3,21</sup> However, the work by Keller et al<sup>13</sup> contradicts these findings, suggesting that UCL injury is associated with the percentage of pitches thrown at a high velocity (eg, fastballs) rather than velocity itself being a risk factor.<sup>13</sup> This suggests that overuse and fatigue place a pitcher at risk for UCL injury. It is reasonable to assume that pitch velocity would decrease as players get closer to the date of injury, as studies have found decreased pitch velocity to be a marker of muscle fatigue,<sup>1</sup> and muscle fatigue to be a risk factor for UCL injury in baseball pitchers.<sup>2,9</sup> Similarly, sliders place more valgus torque at the medial elbow than does any other pitch, with the exception of fastballs, and are associated with increased medial-side elbow pain in pitchers who use them.<sup>11,16</sup> These findings suggest that sliders may also contribute to UCL injury and could account for the decreased velocity we saw in this study.

Spin rate was found to decrease in 4-seam fastballs and increase in cutters as injury approached. The cutter spin rate showed a gradual increase over the entire 15-game span, increasing around 10 rpm per game. Similarly, the 4-seam fastball showed a continuous decrease in spin rate over the study period at a rate of around 5 rpm per game. The spin rate is known to vary among different types of

pitches, with higher spin rates associated with higher pitch velocity and better on-field results in MLB pitchers.<sup>19,20,28</sup> We would have expected a decrease in 2-seam fastball spin rate with the velocity decrease. A potential explanation for this is the greater coefficient of variance for spin rate than for pitch velocity.<sup>20</sup> In addition, it has been reported that the compensatory pronation to resist excessive forearm supination during the pitching motion is associated with increased stress placed on medial elbow structures such as the UCL.<sup>27</sup> A weakening of the UCL as injury approaches could therefore be associated with increased variance in spin rate in the games leading up to surgery.

Unfortunately, the results of this retrospective analysis are unable to provide solid insight as to why different pitch types experience different changes in spin rate. However, a possible explanation may be the difference in pitch mechanics as well as muscle fatigue. Fastball pitches tend to have a greater amount of horizontal spin than do cutters, which have a predominant end-over-end spin. As structures on the medial side of the elbow such as the pronator fatigue, it may be more difficult to impart horizontal spin on the ball, which is needed in a fastball. In contrast to cutters, which do not rely as much on pronation and supination, fatigue in those muscles may result in an overcompensation of spin in the vertical plane.

There was an increase in the percentage of curveballs thrown in the games leading up to UCL injury. Curveballs place significantly lower torque on the medial elbow than do fastballs,<sup>15</sup> and an increased percentage of curveballs thrown was not found to be associated with an increased risk for UCL injuries.<sup>13</sup> This may explain the positive association we noted, as pitchers could be throwing more curveballs, either intentionally or subconsciously, in order to compensate for weakness or pain at the medial elbow that they were experiencing when throwing fastballs and sliders. Peterson et al<sup>22</sup> found that there is an increased use of curveballs and sliders, with a compensatory decrease in fastballs thrown, after UCL reconstruction as well as in the year before surgery. We did not find a significantly significant decline in other pitches. It is possible that the larger increase in curveballs took a small number from each of the other pitch types, which was not enough to be statistically significant. The present study may have been underpowered to detect these smaller changes but may have had enough power to detect the larger change in curveballs.

There are several limitations to this study. The data used for our analysis are publicly available and their accuracy and completeness are not vetted by any independent source. However, there are multiple other studies that have used the same open-source data.<sup>3,7,8,13</sup> In addition, as these data are drawn from MLB pitchers only, they may not be generalizable to a general population of baseball pitchers. Other potential confounders, such as player age, body mass index, weather, and altitude, were not accounted for in this analysis. The statistical analysis also did not account for pitchers who did not throw each pitch type every game. While this may have been a confounding variable, a majority of the pitchers who do utilize certain pitch types regularly use them in a majority of their games. The MLB did not begin collecting and publishing spin rate data until the

2015 season. This limits the strength of the conclusions we can draw, specifically as it relates to the statistically significant finding of increased cutter spin rate. Although the change in each variable from one game to the next may be small, when there is a sustained change over several games, it may suggest an injury is nearing. In addition, as several different pitch characteristics showed significant changes closer to injury, changes in  $>1$  of these variables may more strongly indicate that an injury to the UCL requiring reconstruction is looming.

Another limitation is that the statistics were only analyzed for the 15 games before injury. While this may not have captured changes relative to their entire career, we believed a shorter time span would be more relevant to identify subtle changes that may occur as an injury approached. Fifteen games was believed to be an optimal length, as it minimized the time span between the first and last games while providing enough data points to identify a change. Limiting the length of time decreases possible confounding factors that occur over a player's career, such as intentional changes in mechanics or grip, conditioning, and age, and better identifies subtle, short-term changes immediately leading up to injury. In addition, even if a player sustains a different injury during this time frame that could alter their throwing, they still are at risk of UCL injury and thus should be monitored for changes that could identify a looming injury. Similarly, this study did not include a control group to assess whether these changes may occur across all pitchers, including those who do not become injured. However, the endpoint of UCL surgery was not at a consistent point in the season across pitchers. Thus, consistently seeing these changes as injury approaches despite being at different points in the season makes this less likely. Although the results of this study suggest it may be possible to identify pitchers who are nearing UCL surgery, it is unclear whether this identification will allow them to avoid surgery. While there are some nonoperative treatments that are used for medial-side elbow injuries, the point at which they are identified may be a point at which players already have irreversible damage that will not recover without surgery. Future prospective studies are needed to identify if the need for surgery could be decreased by pitch trend monitoring.

## CONCLUSION

This study found that, in the 15 games leading up to UCL surgery, MLB players had a decrease in the velocity of their 4-seam and 2-seam fastballs as well as their sliders. They also had an increase in the spin rate of their cutters and a decrease in the spin rate of 4-seam fastballs. In addition, they had an increase in the percentage of curveballs thrown, with no statistically significant compensatory decrease in any 1 other pitch type. It may be possible for MLB teams to monitor these trends and intervene non-operatively before catastrophic UCL injury, thereby evading the need for UCL reconstruction surgery.

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