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Major League Baseball pitch velocity and pitch type associated with risk of ulnar collateral ligament injury

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Background: The number of Major League Baseball (MLB) pitchers requiring ulnar collateral ligament (UCL) reconstructions is increasing. Recent literature has attempted to correlate specific stresses placed on the throwing arm to risk for UCL injury, with limited results.

Methods: Eighty-three MLB pitchers who underwent primary UCL reconstruction were evaluated. Pitching velocity and percent of pitch type thrown (fastball, curve ball, slider, and change-up) were evaluated 2 years before and after surgery. Data were compared with control pitchers matched for age, position, size, innings pitched, and experience.

Results: The evaluation of pitch velocity compared with matched controls found no differences in pre-UCL reconstruction pitch velocities for fastballs (91.5 vs. 91.2 miles per hour [mph], $P = .69$), curveballs (78.2 vs. 77.9 mph, $P = .92$), sliders (83.3 vs. 83.5 mph, $P = .88$), or change-ups (83.9 vs. 83.8 mph, $P = .96$). When the percentage of pitches thrown was evaluated, UCL reconstructed pitchers pitch significantly more fastballs than controls (46.7% vs. 39.4%, $P = .035$). This correlated to a 2% increase in risk for UCL injury for every 1% increase in fastballs thrown. Pitching more than 48% fastballs was a significant predictor of UCL injury, because pitchers over this threshold required reconstruction ($P = .006$).

Conclusion: MLB pitchers requiring UCL reconstruction do not pitch at higher velocities than matched controls, and pitch velocity does not appear to be a risk factor for UCL reconstruction. However, MLB pitchers who pitch a high percentage of fastballs may be at increased risk for UCL injury because pitching a higher percent of fastballs appears to be a risk factor for UCL reconstruction.

Level of evidence: Level III; Case-Control Design; Epidemiology Study

Keywords: Pitching; Major League Baseball; UCL injury; elbow; velocity; ligament

Injuries to the medial ulnar collateral ligament (UCL) are common in overhead-throwing athletes. Major League Baseball (MLB) pitchers, in particular, are at high risk for injuries about the throwing elbow.[1,4,19] Recent literature supports that the number of MLB pitchers requiring UCL reconstruction (UCL-R) continues to increase, with estimates near 25% of all MLB pitchers undergoing UCL-R.[4]

Recent investigations have attempted to analyze factors that contribute to UCL injuries with the aim to decrease the rate of injury. Studies have suggested that possible risk factors

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include pitching mechanics, pitch type (curve ball, fastball, etc), glenohumeral internal rotation deficit, pitching fatigue, chronic overuse, and pitch velocity, among other factors.[1,5,8,10,20] Specifically, increased pitch velocity has been implicated as a risk factor for UCL injury[3,14,15,18] However, no study has exclusively attempted to assess whether MLB pitchers who required UCL-R pitch at a higher velocity than matched controls.

Pitch type (fastball, curveball, slider, etc) is another significant factor that has been investigated as a contributor to UCL injuries. Various biomechanical studies have attempted to correlate pitch types with torque across the throwing elbow,[1,17] with contrasting results: some suggest fastballs create more torque, whereas others found off-speed pitches produce increased stresses.[6,8,17] Beyond not evaluating MLB pitchers, these previous studies also failed to evaluate the volume or amount of a specific pitch type thrown by these pitchers that may contribute to UCL injuries.

This study evaluated whether MLB pitchers who require UCL-R have higher pitching velocities compared with matched MLB controls and assessed whether pitch velocity is a specific risk factor for subsequent UCL injury. We also aimed to assess whether pitchers requiring UCL-R had different pitching patterns in regards to the percentage of specific pitch types thrown and whether pitching more of a specific pitch increased the risk of injury.

Materials and methods

We conducted a retrospective, case-controlled study.

UCL-R pitchers

A cohort of 83 MLB pitchers who had undergone primary UCL-R between 2008 and 2015 were identified. Players who underwent UCL-R were identified in similar methods to previous studies.[7,9,12,15,16] The UCL pitchers were indentified via team Web sites, press releases indicating players had undergone UCL-R, personal Web sites, and baseball statistical Web sites, including baseballreference.com and fangraphs.com. To verify each pitcher's year of surgery, we cross-referenced each pitcher's reported surgical date with a gap in pitching statistics.

Statistics were obtained using two independent statistical sources (http://www.baseballreference.com and http://www.fangrafts.com) to maximize completeness and accuracy. Pitcher demographics included handedness, date of birth, age at surgery, position (reliever or starter), height, and weight. We also collected each pitcher's MLB experience.

Pitching performance statistics were collected for 2 seasons before the UCL injury to establish appropriate, uninjured performance velocities.[12] Pitching velocities were also evaluated for 2 years after UCL-R to assess any change in velocity attributable to reconstructive surgery. Only MLB statistics were evaluated, minor league data were excluded. Specific metrics collected included innings pitched, average seasonal pitch velocities (including fastballs, curveballs, sliders, and change-ups), and percentage of pitch types thrown (including fastballs, curveballs, sliders, and change-ups).

Control pitchers

A control group was created to match for potential confounders to UCL injury, which included size (height and weight), age, and overuse (pitching role: starter vs. reliever, innings pitched, and major league experience).[19] As such, a group of MLB pitchers matched for year, age, position, size, MLB experience, and innings pitched were identified in a blinded process. We identified 83 control pitchers. The controls were selected by first creating a database of deidentified MLB pitchers. Players with a known history of UCL-R were removed from the group of possible controls. Pitchers were not excluded from the control group if they had sustained other injuries to the elbow, shoulder, or other extremities. Controls were then selected via a regression model that first selected for index year, followed by age, size (height and weight), innings pitched, position (reliever vs. starter), and MLB experience. The index year was based on the last season of play before UCL-R for the respective pitcher in the original cohort.

Statistical pitching data for controls were then collected similar to cases for 2 years before the index year and 2 years after the index year for an adequate trend. Pitcher demographic data included handedness, date of birth, age at index year, and position (starter or relief). MLB years played before the index year were collected. The same pitching performance metrics (speed and pitch type percentages) as used in the UCL-R cohort were collected in the control group.

Statistical analysis

The primary aim of the analysis was to investigate predictors of UCL injury using a case-control design. Cases (pitchers with UCL injury) and controls (no UCL injury) were first described using means, standard deviations, counts, and percentages. Differences and associations were tested with a Welch t test or χ^2 test for the 6 matching criteria. The testing of predictors of UCL-R was done via univariate conditional logistic regression, testing each pitching parameter separately. Odds ratios and 95% confidence intervals were computed via exact partial likelihood estimation.

For the secondary goal of comparing pitching speeds before and after surgery, univariate generalized estimating equations were used with pitching speed as the dependent variable and time (before, after) and the independent variable, clustering on match identification. Statistical significance was set at $P < .05$. Analyses were performed using R 3.2.0 software (The R Foundation for Statistical Computing, http://www.r-project.org/foundation/). Conditional logistic regression was performed using the survival package, and generalized estimating equations were performed using the gee package.

Results

Pitcher demographics

There were no statistical differences among the controlled demographics (Table I). The average age at UCL-R surgery was 28.1 years (range, 21-38 years). The average age of the control pitchers was 28.0 years (range, 22-38 years; $P = .97$). Most pitchers (59 of 83 [71.8%]) in the UCL-R and control groups were right handed. At the time of reconstructive surgery, UCL-R pitcher's roles were almost split, as 43 of 83 (51.8%) were starting pitchers and 40 of 83 (48.2%) were relief pitchers. Control pitchers only slightly differed in pitching role, with 41 of 83 (49.4%) as starters and 42 of 83 (50.6%) pitching in a relief role ($P = .87$). Pitchers did not differ in the amount of innings pitched on average for the 2 years before UCL-R nor in years pitched in MLB before the incident year. UCL-R pitchers also had equal heights and weights compared with controls.

UCL-R pitching speed vs. controls

No significant differences were seen when pitching speeds between the UCL-R pitchers and controls were compared (Table II). Specifically, no significant differences were seen between fastball velocity ($P = .69$), slider velocity ($P = .88$), curveball velocity ($P = .92$), and change-up velocity ($P = .96$).

UCL-R pitch type vs. controls

In comparing specific percentages of pitch types thrown, UCL-R pitchers pitched a significantly higher percentage of fastballs than control pitchers (Table III). UCL-R pitchers pitched 46.8% fastballs compared with 39.7% in control pitchers ($P = .03$). Results of the regression model for the odds of having UCL-R compared with the percentage of fastballs thrown found an odds ratio of 1.02 (95% confidence interval, 1.00-1.03). This suggests a 2% increase in the risk of a UCL injury for every 1% increase in fastballs thrown. Using a classification and regression tree (CART) model, we found a unique predictor of UCL injury was pitching 48% fastballs, which was still significant after pitch velocity was added to the model ($P = .006$). Pitchers who exceeded this threshold of fastballs pitched all required UCL-R.

In evaluating other pitch types, there were no other statistical differences in percentage of curveballs ($P = .88$), sliders ($P = .11$), or change-ups thrown ($P = .13$).

Table I Descriptive statistics for pitchers with ulnar collateral ligament reconstruction and controls

Variable*	UCL (n = 83)	Controls (n = 83)	*P* value
Age, y	28 ± 4.22	28 ± 4.01	.97
Pitching role			
Reliever	40 (48.2)	42 (50.6)	.87
Starter	43 (51.8)	41 (49.4)	
Height, cm	189 ± 6.1	189 ± 6.1	.69
Weight, kg	97.8 ± 10.2	97.7 ± 9.5	.95
Handedness			
Left	25 (30.1)	25 (30.1)	>.99
Right	58 (69.8)	58 (69.8)	
MLB experience,† y	5.4 ± 3.9	6.4 ± 3.7	.12
Innings pitched,‡ No.	105.8 ± 66.0	105.9 ± 62.2	.98

MLB, Major League Baseball; *UCL*, ulnar collateral ligament.
* Continuous data are reported as means ± standard deviation and categoric data as number (%).
† MLB experience represents years played before incident date (year of UCL reconstruction).
‡ Innings pitched was calculated as the average for 2 years before the incident date.

Table II Pitch velocity statistics for pitchers ulnar collateral ligament reconstruction vs. controls

Pitch type	UCL (Mean ± SD)	Controls (Mean ± SD)	*P* value
Fastball, mph	91.5 ± 3.0	91.3 ± 2.7	.69
Slider, mph	83.3 ± 3.5	83.5 ± 2.8	.88
Curveball, mph	78.2 ± 4.7	77.9 ± 4.4	.92
Change-up, mph	83.9 ± 2.7	83.8 ± 3.3	.96

mph, miles per hour; *SD*, standard deviation; *UCL*, ulnar collateral ligament.

Post-UCL pitching speed

When fastball velocity before and after UCL-R was compared, there was no difference after UCL-R (Table IV). The average velocity before UCL-R was 91.5 miles per hour (mph) and the average velocity after UCL-R was 90.9 mph ($P = .35$). Pitch velocity after UCL-R was also not significantly different when compared with controls against controls ($P = .53$).

Discussion

As the incidence of UCL-R continues to rise in MLB pitchers, a greater amount of research is being pursued to identify specific risk factors for UCL injury. Previous studies have focused on shoulder range of motion, torque during pitching for differing pitches, pitching fatigue, and overuse.[1,5,8,10,20] The evaluation of pitch velocity and pitch type as a risk factor for UCL injury has previously been loosely correlated with limited evaluation.[8,14] This current study's findings suggest that pitch velocity in MLB pitchers does not appear to be a direct risk factor for UCL injury compared with uninjured controls, whereas pitch type does appear to be a risk factor.

Previous biomechanical studies on the stresses to the elbow during pitching have shown that increased velocity leads to higher stress about the elbow. The greatest amount of valgus torque has previously been demonstrated as highest when pitching a fastball compared with other pitches.[7] Bushnell et al[2] prospectively evaluated a small cohort of MLB pitchers to elucidate factors that increased the chance of elbow injury.

Table III Pitch type percentages for pitchers with ulnar collateral ligament reconstruction vs. controls

Pitch type	Cases (Mean ± SD)	Controls (Mean ± SD)	Odds ratio (95% CI)*	*P* value†
Fastball, %	46.8 ± 20.7	39.7 ± 19.8	1.02 (1.00-1.03)	**.035**
Slider, %	16.6 ± 10.9	19.8 ± 13.9	0.98 (0.96-1.00)	.11
Curveball, %	8.5 ± 12.0	8.2 ± 9.9	1.00 (0.97-1.03)	.88
Change-up, %	10.3 ± 11.2	7.9 ± 7.2	1.03 (0.99-1.07)	.13

CI, confidence interval; *SD*, standard deviations.
* Odds ratios are results from univariate conditional logistic regression models, modeling the odds of having receiving primary ulnar collateral ligament reconstruction.
† Bold *P* value indicates statistical significance ($P < .05$)

Table IV Comparison of pitching velocity before and after ulnar collateral ligament pitchers surgery

Fastball velocity*		*P* value
Pre-UCL reconstruction	Post- UCL reconstruction	
91.5 ± 3.2 mph	90.9 ± 3.3 mph	.35

mph, miles per hour; *UCL*, ulnar collateral ligament.
* Values are reported as adjusted means ± standard deviations.

Of the 23 pitchers evaluated, 9 pitchers developed elbow injuries (5 with UCL injury). The pitchers who sustained an injury had a higher maximal ball velocity compared with uninjured controls. They concluded that increased velocity correlates with increased risk for elbow injuries.[2] Our findings, from a larger cohort, differ from that study and suggest that there is no correlation with UCL injury and pitch velocity, because we found no difference in pitch velocity compared with matched controls.

The risk of injury from throwing a specific pitch type has also been evaluated in the literature. Previously, it was assumed that pitching a curve ball placed more stress on the elbow, with the suggestion that adolescent pitchers refrain from pitching curveballs. Lyman et al[14] used questionnaires to evaluate youth pitchers and found that curveballs increased the risk of shoulder pain and sliders increased the risk of elbow pain in these pitchers, recommending caution in youths throwing breaking pitches. Biomechanical studies, however, have shown that the moments of force on the shoulder and elbow as well as valgus torque were lower when pitching curveballs compared with fastballs.[8,17]

Our study supports this rationale and suggests that fastballs rather than breaking balls place MLB pitchers at high risk of sustaining UCL injuries. We found that pitchers who required UCL-R pitched on average more than 7% more fastballs than our control group. This correlated to a 2% increase risk for UCL injury with every 1% increase in fastball percentage thrown. We also found a threshold of 48% of fastballs thrown as a significant predictor of UCL injury, because pitchers throwing over this percentage required UCL-R. No such risk increase existed for the percentages of curveballs, sliders, or change-up pitches thrown.

Olsen et al[18] have also previously suggested that throwing faster than 85 mph was a risk factor for UCL injuries in adolescent pitchers, which would place all of our MLB pitchers into this risk category. We believe that although pitch velocity does not directly lead to a risk of UCL injury, pitching at this high velocity at a higher rate, as evidenced by an increased percentage of fastballs, leads to increased risk of injury.

Several investigations, including the study by Olsen et al,[18] have concluded that overuse of the elbow leads to increased risk for injury. In their study of adolescent pitchers, they found that factors associated with overuse and fatigue had the strongest association with injury and also concluded that high pitch velocity was associated with an increased risk for injury.[18] In this current study of MLB pitchers, our results suggest that fatigue and overuse due to the increased amount of fastballs pitched is associated with risk of UCL rupture. Although the average velocity of pitches thrown was not significant, throwing at a high velocity for a greater percentage of time (ie, throwing a higher percentage of fastballs compared with offspeed pitches) appears to place more stress to the elbow, therefore leading to more elbow fatigue and overuse and subsequent UCL injury.

Our evaluation of pitching velocity after surgery found no decrease in velocity after return from UCL-R in our pitchers. Lansdown and Feeley[13] recently evaluated 80 MLB pitchers before and after UCL-R and found a significant decrease in pitching speed, although the drop in speed only averaged 0.7 mph, which brings into question the clinical significance of this decrease in velocity.[13] Jiang and Leland[11] evaluated MLB pitchers before and after UCL reconstruction and found no change in velocity compared with controls after surgery. This is consistent with our findings, because the UCL-R pitchers pitched at an average 91.5 mph before surgery and an average of 90.9 mph after surgery ($P = .35$), also showing no difference from controls.

This study has several limitations. As with any observational study such as this, there is the potential for confounding and bias. Potential areas of bias include the information bias from potential missing data because we used an Internet-based

review method for evaluation of player statistics. There is confounding bias when assessing for associated risk factors. Also, it is likely that some pitchers in the control group could have had other, non-UCL, pitching injuries. This could lead to incorrect and misguided postulation regarding potential risks.

Another limitation is this current cohort comprised only MLB pitchers, and caution should be used when extrapolating these findings for other levels of play (minor league, collegiate, and high school). Randomized, prospective trials would necessary to better assess these risks.

Conclusion

Pitch velocity in MLB pitchers does not appear to be a direct risk factor for UCL injury. The percentage of fastballs thrown, however, is a significant risk factor in pitchers requiring UCL-R. A 2% increase in risk for UCL injury was found with every 1% increase in the number of fastballs thrown, with 48% of fastballs thrown serving as a significant threshold for requiring reconstruction. Stresses due to the amount of high velocity pitches thrown rather than the absolute maximum velocity obtained leads to an increased risk for UCL injury in MLB pitchers.

Disclaimer

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