J Shoulder Elbow Surg (2021) 30, 2406–2411

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

# Pitch break and performance metrics remain unchanged in pitchers who returned to the same level of play after ulnar collateral ligament reconstruction in Major League Baseball pitchers

**Brooks N. Platt, MD[a], Anthony J. Zacharias, MD[a], Timothy Uhl, PhD[b], Michael T. Freehill, MD[c], Caitlin E. Conley, PhD[a], Austin V. Stone, MD, PhD[a,*]**

[a]*Division of Sports Medicine, Department of Orthopaedic Surgery, University of Kentucky, Lexington, KY, USA*
[b]*Department of Physical Therapy, University of Kentucky, Lexington, KY, USA*
[c]*Department of Orthopaedic Surgery, Stanford University, Redwood City, CA, USA*

**Background:** The ulnar collateral ligament is commonly injured in overhead-throwing athletes, particularly baseball pitchers. Pitch movement (break) is a critical aspect to pitching performance. The primary purpose of this study was to determine the changes in pitch velocity, pitch break, angle of break, and pitch performance metrics before and after ulnar collateral ligament reconstruction (UCLR) in Major League Baseball (MLB) pitchers. The secondary purpose was to determine changes in pitch performance metrics before and after UCLR. We hypothesized that pitch break and pitch performance metrics would be unchanged following UCLR.

**Materials and methods:** This was a retrospective case-series study of pitchers who had undergone primary UCLR between 2008 and 2014. Velocity, horizontal movement (Hmov), and vertical movement (Vmov) of each pitch were collected from the PITCHf/x system for each pitcher 12-24 months before surgery, 12-24 months after surgery, and 24-36 months after surgery. Overall break was calculated by taking the Pythagorean sum of Hmov and Vmov. Angle of break was determined by taking the inverse tangent of Vmov divided by Hmov. Repeated-measures analysis of covariance was performed to determine differences in pitch velocity, movement, angle of movement, and performance metrics between preoperative and postoperative time frames. Performance metrics included balls, strikes, swings, fouls, swings and misses, ground balls, line drives, pop-ups, fly balls, and home runs. Covariates included age at surgery, time from MLB debut to surgery, innings pitched as a starter, innings pitched as a reliever, and total pitches thrown.

**Results:** In a cohort of 46 pitchers who underwent UCLR between 2008 and 2014, pitch velocity, movement, and angle were not significantly changed with respect to preoperative or postoperative time frames. In addition, postoperative time frames had clinically insignificant differences in pitch performance metrics.

**Conclusion:** Pitch break and performance metrics are not significantly affected in pitchers who return after UCLR.

**Level of evidence:** Level IV; Case Series; Treatment Study



**Keywords:** Ulnar collateral ligament reconstruction; Tommy John surgery; performance; elbow injury; prognosis; overhead throwing

Ulnar collateral ligament reconstruction (UCLR) is a common procedure in pitchers from youth to professional. The number of Major League Baseball (MLB) pitchers undergoing UCLR has increased.[7,17] Between 83% and 86% of players who undergo UCLR have been able to

Owing to the public nature of all data used, institutional review board approval was not required for this case series.

*Reprint requests: Austin V. Stone, MD, PhD, University of Kentucky, 740 S Limestone St, K401, Lexington, KY 40503, USA.

E-mail address: austinvstonemd@gmail.com (A.V. Stone).

1058-2746/$ - see front matter © 2021 Journal of Shoulder and Elbow Surgery Board of Trustees. All rights reserved.
https://doi.org/10.1016/j.jse.2021.04.036

return to sport,[4,10] but the rate of return to the major-league level is lower, at 67%-83%.[8,18,19] MLB pitcher performance after UCLR remains a hotly contested issue, with some studies showing no performance change and others showing declining performance postoperatively.[12-15,18,27] Some rumors even persist in the community regarding improved performance and velocity postoperatively that have not been substantiated by scientific research.[6]

Multiple advanced tracking technologies have emerged with the intent to aid in performance metrics. The PITCHf/x system (SportsVision, Chicago, IL, USA)[3,23] was introduced into MLB stadiums in 2007 to track pitch characteristics, such as pitch type, velocity, release point, and movement. Horizontal movement (Hmov) is measured by the PITCHf/x system as the number of inches the ball travels left or right at home-plate crossing compared with its release point. Vertical movement (Vmov) measures the calculated movement of a pitch without the effect of gravity.[3]

Several studies have investigated the effects of UCLR on pitchers using the PITCHf/x database.[13-15,18,24] One such study found no difference in 4-seam fastball velocity after UCLR,[13] whereas 2 studies found a decrease in postoperative velocity.[15,18] One study investigated pitch movement after UCLR, measuring Hmov and Vmov separately.[24] It showed decreases in Hmov for the 4-seam fastball and slider and a decrease in curveball Vmov postoperatively. In the baseball analytics community, pitch trajectory measured by the PITCHf/x system has been used to estimate spin rate.[16]

A main question facing pitchers after ulnar collateral ligament injury is, Does the damage to the flexor-pronator mass, whether occurring from injury[22] or iatrogenically during reconstruction,[1] have the potential to affect pitch movement or break? Calculating pitch break and trajectory is an important way pitchers and coaches estimate the value of individual pitches.[21] To determine any deleterious effects of a previous UCLR on pitch break, we used measured Hmov and Vmov to calculate overall preoperative and postoperative break vectors. We then analyzed pitch performance metrics, including swing-and-miss rate, to analyze the clinical significance of any potential changes. We hypothesized that pitch break and pitch performance metrics would be unchanged following UCLR.

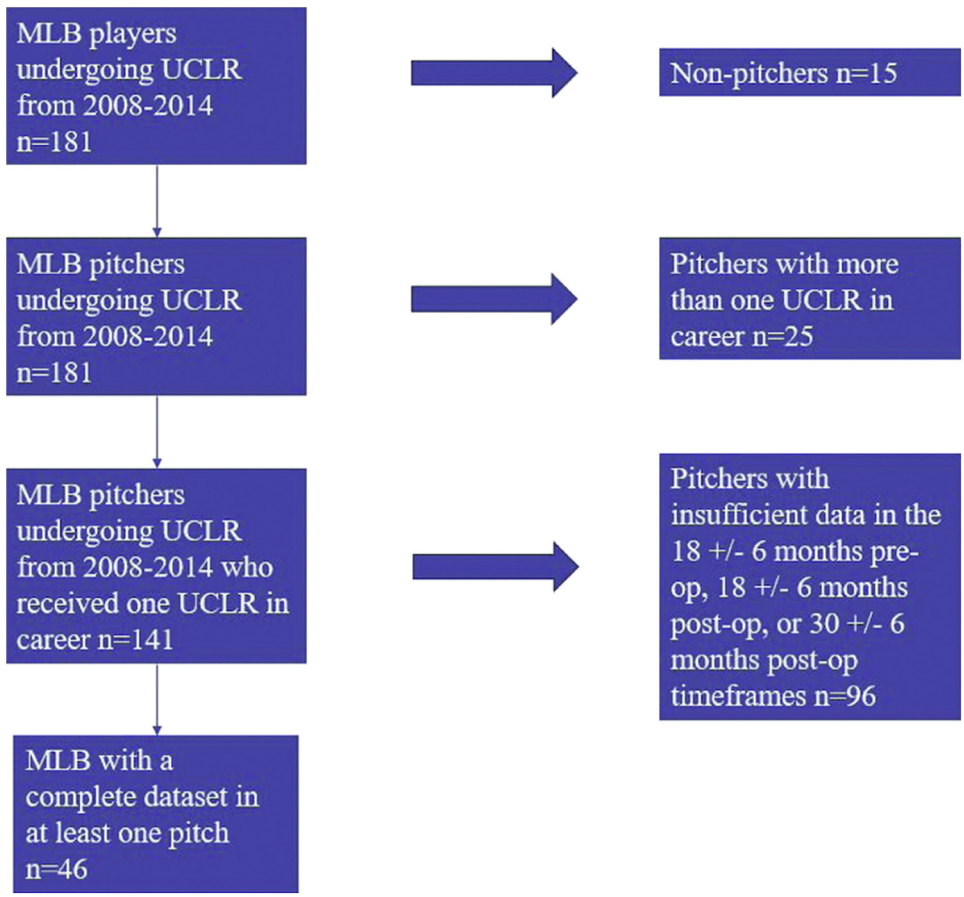


**Figure 1** Inclusion flowchart for pitch movement analysis before and after ulnar collateral ligament reconstruction *(UCLR)*. *MLB*, Major League Baseball; *pre-op*, preoperatively; *post-op*, postoperatively.

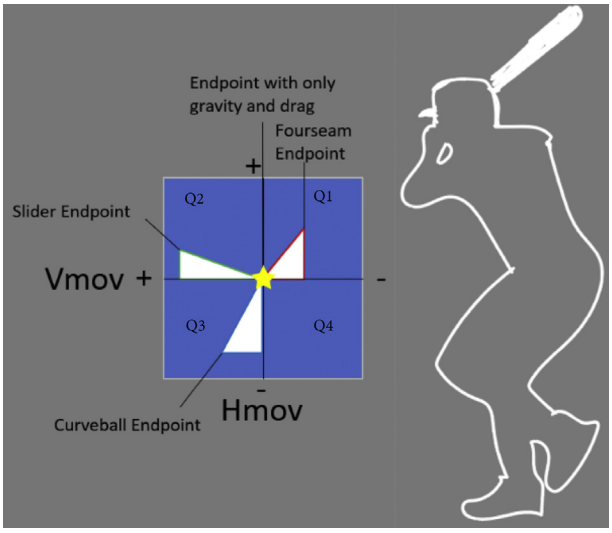


**Figure 2** Demonstration of data reduction method determining angle and break of each pitch compared with path expected due to gravity alone. The average 4-seam fastball was measured to be in quadrant 1 *(Q1)*; the average slider, in quadrant 2 *(Q2)*; and the average curveball, in quadrant 3 *(Q3)*. One should note that these paths do not reflect the ball rising but falling less than expected. *Vmov*, vertical movement; *Q4*, quadrant 4; *Hmov*, horizontal movement.

## Materials and methods

### Subject selection

This was a retrospective case-series study of pitchers who had undergone primary UCLR between 2008 and 2014. To analyze pitch break differences before and after UCLR, pitchers who underwent primary UCLR from 2008 to 2014 were identified from a data set of pitchers that is established and maintained on a publicly accessible source at MLB Reports (www.mlbreports.com), which has been used in previous studies.[20,25,30] Pitchers were excluded if they had undergone >1 UCLR in their careers and if they did not have ≥20 pitches of the same type in the 12- to 24-month preoperative, 12- to 24-month postoperative, and 24- to 36-month postoperative time frames. The cutoff of 20 pitches approximates the qualifying cutoff used by the Baseball Savant database (≥10 pitches per team game and use of the pitch being analyzed ≥5% of the time) (Fig. 1).

### Data collection

In the UCLR cohort, demographic data including debut date, total pitches thrown in each time frame, innings pitched as a starter, innings pitched as a reliever, and age at surgery were recorded from baseball-reference.com.[26] This database was used because it is the most complete database in terms of demographic data. Pitch data were collected from the PITCHf/x database (pitchinfo.com) by pitch type (4-seam fastball, curve, or slider). PITCHf/x is a system that uses multiple high-speed cameras to capture pitch movement and velocity data that are then made publicly available.[9] Information related to 4-seam fastball, curve, and slider pitches was collected for each pitcher in 3 distinct time frames: 18 ± 6 months before surgery, 18 ± 6 months after surgery, and 30 ± 6 months after surgery. Measures collected for each pitch type included the number thrown, average velocity, average Hmov, and average Vmov. In addition, the rates of balls, strikes, swings, fouls, swings and misses, balls in play, fly balls, line drives, pop-ups, and home runs were collected as performance metrics for each pitch.

### Data reduction

Because PITCHf/x records pitch movement in horizontal and vertical vectors, further manipulation was necessary to record overall pitch break and angle of break. First, for all left-handed pitchers, the horizontal axis was adjusted to match that of a right-handed pitcher by multiplying the Hmov value by –1. The angle of each pitch was then calculated with the following equation:

$$Angle = \arctan\left(\frac{Vmov}{Hmov}\right)$$

The pitch angles were placed on a 360°, 4-quadrant scale based on the values of their Hmov and Vmov vectors. A negative Hmov and a positive Vmov gave a value between 0° and 90°, a positive Hmov and a positive Vmov gave a value between 90° and 180°, a positive Hmov and a negative Vmov gave a value between 180° and 270°, and a negative Hmov and a negative Vmov gave a value between 270° and 360° (Fig. 2).[29] Pitch break was calculated using the Pythagorean theorem:

$$Hmov^2 + Vmov^2 = (Pitch\,Break)^2$$

$$Pitch\,Break = \sqrt{Hmov^2 + Vmov^2}$$

Outlier analysis was performed by calculating the first and third quartiles and the interquartile range (IQR). Angle and pitch break values 1.5 × the interquartile range above the third quartile or below the first quartile were removed for analysis.[28]

### Statistical analysis

Separate repeated-measures analyses of covariance (ANCOVAs) were performed to determine differences in pitch velocity, pitch break, and angle of break between the preoperative and 2 postoperative time frames. In addition, to determine whether any pitch differences may have resulted in a clinically significant difference, a repeated-measures ANCOVA model was created separately for each pitch performance metric recorded to determine differences before and after surgery. Covariates included age at surgery, time from debut to surgery, innings pitched as a starter, innings pitched as a reliever, and total pitches thrown. These variables were selected as each could reasonably have an impact on a pitcher's fatigue level or performance and could have served as confounders if not accounted for properly.

## Results

Forty-six pitchers met the inclusion criteria for the second analysis, including 87.0% (40 of 46) in the 4-seam fastball group, 63.0% (29 of 46) in the curveball group, and 56.5% (26 of 46) in the slider group (Fig. 1). We identified 2 outliers in the 4-seam fastball data, 2 outliers in the curveball data, and 1 outlier in the slider data. This left 38,

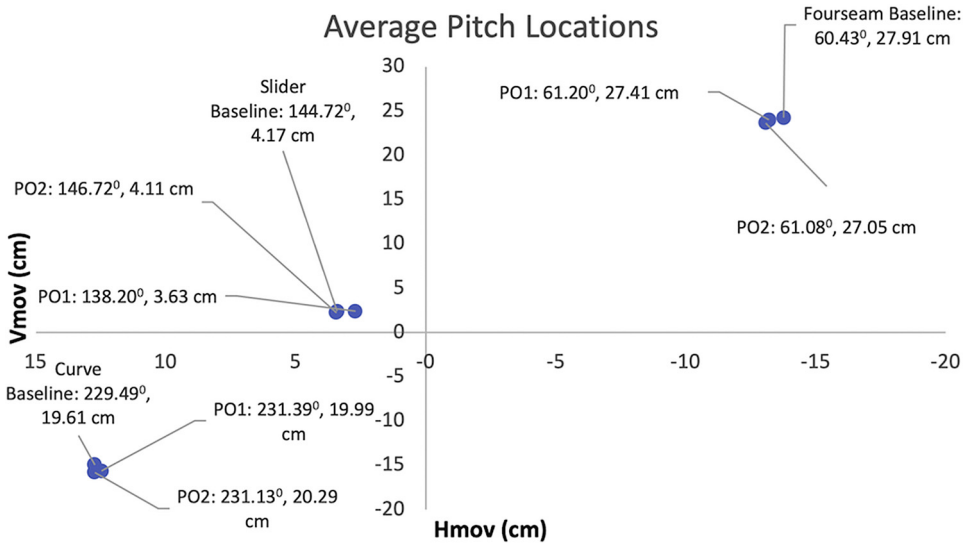


**Figure 3** Average pitch break at baseline (preoperatively), postoperative time frame 1 *(PO1)*, and postoperative time frame 2 *(PO2)*. The 4-seam fastball, curveball, and slider all maintained very similar movement patterns in each time frame, with maximal movement differences from baseline being 0.86 cm, 0.48 cm, and 0.69 cm, respectively. *VMov*, vertical movement; *in*, inches; *Hmov*, horizontal movement.

27, and 25 subjects for the 4-seam fastball group, curveball group, and slider group, respectively. Sensitivity analysis determined that the sample sizes were sufficient to determine effect sizes of 0.514, 0.592, and 0.627, respectively, at a power of 0.8. The average age at the time of surgery was 28.0 years (range, 21-37 years).

The repeated-measures ANCOVA models for each performance metric variable in each pitch type showed no significant differences with movement, velocity, or angle changes for any with respect to time frame (Fig. 3; Supplementary Tables S1–S4). In terms of performance metrics, there was a statistically significant increase in the line-drive rate for the 4-seam fastball with respect to time frame.

## Discussion

The principal finding of this study was that pitch break was not significantly different before and after UCLR in MLB pitchers who returned to pitching at the major-league level. Four-seam fastball trajectory, slider trajectory, and curveball trajectory were all not significantly changed after UCLR. Calculation of pitch break and trajectory has become a critical component of analyzing a pitcher's potential and has been increasingly identified as a major factor in a pitcher's ability to create swings and misses and weak contact.[2] Our analysis helps fill a gap in pitching performance because the majority of the MLB UCLR literature focuses on velocity and not pitch movement.[13-15]

With respect to velocity, our analysis supports the conclusion of Jiang and Leland,[13] which suggested there was no change in fastball velocity after UCLR when compared with controls, and is inconsistent with results from Makhni et al[18] and Lansdown and Feeley,[15] which suggested a small yet significant decrease in 4-seam fastball velocity postoperatively. In terms of pitch movement, our results differ from those published in a study by Portney et al,[24] who also used PITCHf/x data. They reported a small decrease in Hmov of the 4-seam fastball. In addition, Portney et al reported significant decreases in slider Hmov and curveball Vmov, which were not reproduced in our study.

The differing results are likely because of our differing methods of control and our addition of covariates. Portney et al[24] and Makhni et al[18] used matched controls to determine the effects of UCLR. Lansdown and Feeley[15] applied a similar method of control by using 2 seasons preoperatively and 2 seasons postoperatively to determine the effects of UCLR and used a paired *t* test to determine significant differences. By using each pitcher as his own control, with the preoperative time frame selected in the 1- to 2-year period before surgery to measure an appropriate healthy baseline, and adding covariates to a repeated-measures ANCOVA model, a potentially more accurate representation of cause and effect was obtained.

Although the significance of a change in 4-seam fastball movement is variable depending on statistical methodology, it is possible that a true difference exists postoperatively, but the sensitivity allowed with the current data does not confirm its meaningful existence. The potential loss of 4-seam fastball break may be explained by a loss in wrist flexion power. Flexor-pronator muscle injuries frequently occur alongside ulnar collateral ligament injuries and have been associated with poor outcomes.[22] This may also result from the violation of the flexor-pronator mass

during UCLR, as is often required during the surgical approach.[1,5] However, the lack of significance in the repeated-measures ANCOVA with additional covariates suggests that UCLR may not be the only factor leading to loss of break. Our results additionally suggest that any pitch movement difference is sufficiently small to be of dubious clinical significance. This conclusion is supported by the lack of performance metric differences in line with what would be expected with a decrease in 4-seam fastball movement, particularly the lack of change in the swing-and-miss rate. The only noticeable difference was a statistically significant increase in the line-drive rate. However, this is likely a result of error of multiple comparisons, as the Bonferroni-corrected *P* value for the line-drive rate is .244. The lack of statistical significance in the other measured outcomes without Bonferroni correction underscores the impressive consistency in outcomes before and after UCLR in each pitch (Supplementary Tables S1–S3).

Although trends were observed, limited statistical significance was achieved. The rigorous exclusion process, which included pitcher injury history, data set size, and position, decreased the available sensitivity of the repeated-measures ANCOVA. Because of this, a significant portion of pitchers in the PITCHf/x database were excluded, many owing to a lack of return to play, delayed return to play, or transient return to play. Although the exclusion criteria improved the quality of the data overall, the inability to include pitchers who did not return to play owing to lack of data may underestimate the effects of UCLR on pitch break, as their lack of return to play may have resulted from a loss in pitch movement and thus effectiveness as a pitcher at an elite level. Therefore, some of those excluded from our analysis may have been those with the most loss of movement or velocity in their pitches. However, the number of subjects included was sufficient to determine a medium effect size of 0.514 in the 4-seam fastball population. Even in the curveball and slider groups, in which only large effect sizes were likely to be determined, the lack of consistently significant differences among the performance metric variables suggests lack of clinical significance.

As with all studies, this investigation has limitations. The specialized population of MLB pitchers renders these results not generalizable to all professional or amateur pitchers. Using publicly accessible data also limits the ability to make comparisons based on the extent of injury, surgical technique, or graft use. Moreover, we were unable to control for rehabilitation protocols and use data from pitching at the minor-league level. Differences in biomechanics were also not assessed or evaluated in this study. However, a cohort study from Griffith et al[11] found no significant difference in outcomes dependent on graft types or surgical technique, so it is likely that the inability to control for these variables resulted in minimal confounding effect.

Improved technology by companies such as Trackman (Vedbæk, Denmark) and Hawk-Eye (London, UK) have enhanced pitch tracking of MLB pitchers to directly measure spin rate and spin axis. Future studies should explore these tools to better understand how pitch characteristics are affected by UCLR as well as treatment of other orthopedic injuries when enough data have been accrued to accommodate meaningful sample sizes.

## Conclusion

Following UCLR, MLB pitchers who returned to the major-league level experienced no changes in the 4-seam fastball, curveball, and slider break when adjusted for age and other potential confounders. Similarly, the pitchers experienced insignificant changes in important performance metrics, such as the strike rate, swing-and-miss rate, and home run rate, following surgery.

## Disclaimer

Anthony J. Zacharias reports support from DePuy Synthes, outside the submitted work.

Michael T. Freehill reports personal fees from Smith & Nephew; nonfinancial support from Smith & Nephew and Integra LifeSciences; support from Smith & Nephew, Integra LifeSciences, Wright Medical Technology, and Ascension Orthopedics; and grants from Encore Medical, outside the submitted work.

Austin V. Stone reports nonfinancial support from Smith & Nephew and Stryker and support from Smith & Nephew, Stryker, Arthrex, Medwest Associates, DJO, Wright Medical, Vericel, and CDC Medical, outside the submitted work, and is a member of the American Orthopaedic Society for Sports Medicine and Arthroscopy Association of North America.

The other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

## Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jse.2021.04.036.

## References

1. Andrews JR, Jost PW, Cain EL. The ulnar collateral ligament procedure revisited: the procedure we use. Sports Health 2012;4:438-41. https://doi.org/10.1177/1941738112455318
2. Aucoin D, O'Connell M, Jagers E. A deeper dive into fastball spin rate. Kent, WA: Driveline Baseball; 2019.

3. Brooks Baseball. PITCHf/x database. Available at: www.brooksbaseball.net. Accessed March 15, 2019
4. Cain EL Jr, Andrews JR, Dugas JR, Wilk KE, McMichael CS, Walter JC II, et al. Outcome of ulnar collateral ligament reconstruction of the elbow in 1281 athletes: results in 743 athletes with minimum 2-year follow-up. Am J Sports Med 2010;38:2426-34. https://doi.org/10.1177/0363546510378100
5. Cain EL Jr, McGonigle O. Return to play following ulnar collateral ligament reconstruction. Clin Sports Med 2016;35:577-95. https://doi.org/10.1016/j.csm.2016.05.004
6. Cleveland Clinic. Can Tommy John surgery improve your throwing? 2019. Available at: https://health.clevelandclinic.org/can-tommy-john-surgery-improve-your-throwing/#:~:text=No.,after%20having%20Tommy%20John%20surgery. Accessed August 26, 2020
7. Conte SA, Fleisig GS, Dines JS, Wilk KE, Aune KT, Patterson-Flynn N, et al. Prevalence of ulnar collateral ligament surgery in professional baseball players. Am J Sports Med 2015;43:1764-9. https://doi.org/10.1177/0363546515580792
8. Erickson BJ, Gupta AK, Harris JD, Bush-Joseph C, Bach BR, Abrams GD, et al. Rate of return to pitching and performance after Tommy John surgery in Major League Baseball pitchers. Am J Sports Med 2014;42:536-43. https://doi.org/10.1177/0363546513510890
9. Fast M. What the heck is PITCHf/x. Hardball Times Baseball Annual 2010. Available at: http://baseball.physics.illinois.edu/FastPFXGuide.pdf. Accessed April 10, 2019
10. Ford GM, Genuario J, Kinkartz J, Githens T, Noonan T. Return-to-play outcomes in professional baseball players after medial ulnar collateral ligament injuries: comparison of operative versus nonoperative treatment based on magnetic resonance imaging findings. Am J Sports Med 2016;44:723-8. https://doi.org/10.1177/0363546515621756
11. Griffith TB, Ahmad CS, Gorroochurn P, D'Angelo J, Ciccotti MG, Dines JS, et al. Comparison of outcomes based on graft type and tunnel configuration for primary ulnar collateral ligament reconstruction in professional baseball pitchers. Am J Sports Med 2019;47:1103-10. https://doi.org/10.1177/0363546519831705
12. Griffith TB, Duralde XA. Successful performance after ulnar collateral ligament reconstruction: an analysis of 88 drafted professional baseball pitchers with a matched comparison cohort. Orthop J Sports Med 2019;7:2325967119880820. https://doi.org/10.1177/2325967119880820
13. Jiang JJ, Leland JM. Analysis of pitching velocity in Major League Baseball players before and after ulnar collateral ligament reconstruction. Am J Sports Med 2014;42:880-5. https://doi.org/10.1177/0363546513519072
14. Keller RA, Marshall NE, Guest JM, Okoroha KR, Jung EK, Moutzouros V. Major League Baseball pitch velocity and pitch type associated with risk of ulnar collateral ligament injury. J Shoulder Elbow Surg 2016;25:671-5. https://doi.org/10.1016/j.jse.2015.12.027
15. Lansdown DA, Feeley BT. The effect of ulnar collateral ligament reconstruction on pitch velocity in Major League Baseball pitchers. Orthop J Sports Med 2014;2:2325967114522592. https://doi.org/10.1177/2325967114522592
16. Long J. Pitching backward: what we know about spin rate. Baseball Prospectus. 2016. Available at: https://www.baseballprospectus.com/news/article/30465/pitching-backward-what-we-know-about-spin-rate/. Accessed July 9, 2020
17. Mahure SA, Mollon B, Shamah SD, Kwon YW, Rokito AS. Disproportionate trends in ulnar collateral ligament reconstruction: projections through 2025 and a literature review. J Shoulder Elbow Surg 2016;25:1005-12. https://doi.org/10.1016/j.jse.2016.02.036
18. Makhni EC, Lee RW, Morrow ZS, Gualtieri AP, Gorroochurn P, Ahmad CS. Performance, return to competition, and reinjury after Tommy John surgery in Major League Baseball pitchers: a review of 147 cases. Am J Sports Med 2014;42:1323-32. https://doi.org/10.1177/0363546514528864
19. Marshall NE, Keller RA, Limpisvasti O, ElAttrache NS. Pitching performance after ulnar collateral ligament reconstruction at a single institution in Major League Baseball pitchers. Am J Sports Med 2018;46:3245-53. https://doi.org/10.1177/0363546518795670
20. MLBReports. TJ surgery: all time MLB list. Available at: www.mlbreports.com. Accessed March 15, 2019
21. O'Connell M. Bauer units, pitch movement, and evaluating pitches. Kent, WA: Driveline Baseball; 2019.
22. Osbahr DC, Swaminathan SS, Allen AA, Dines JS, Coleman SH, Altchek DW. Combined flexor-pronator mass and ulnar collateral ligament injuries in the elbows of older baseball players. Am J Sports Med 2010;38:733-9. https://doi.org/10.1177/0363546509351558
23. Pavlidis H, Rozenson D, Morrison K, Apostoleris L, Brooks D. Pitch info. 2014. Available at: Pitchinfo.com. Accessed March 15, 2019
24. Portney DA, Lazaroff JM, Buchler LT, Gryzlo SM, Saltzman MD. Changes in pitching mechanics after ulnar collateral ligament reconstruction in Major League Baseball pitchers. J Shoulder Elbow Surg 2017;26:1307-15. https://doi.org/10.1016/j.jse.2017.05.006
25. Smith R, Lombardo DJ, Petersen-Fitts GR, Frank C, Tenbrunsel T, Curtis G, et al. Return to play and prior performance in Major League Baseball pitchers after repair of superior labral anterior-posterior tears. Orthop J Sports Med 2016;4:2325967116675822. https://doi.org/10.1177/2325967116675822
26. Sports Reference. Player Standard Pitching. Available at: https://www.baseball-reference.com/leagues/MLB/2014-standard-pitching.shtml. Accessed March 15, 2019
27. Swindell HW, Trofa DP, Confino J, Sonnenfeld JJ, Alexander FJ, Ahmad CS. Performance in collegiate-level baseball players after elbow ulnar collateral ligament reconstruction. Orthop J Sports Med 2020;8:2325967120913013. https://doi.org/10.1177/2325967120913013
28. Upton G, Cook I. Understanding statistics. Oxford, UK: Oxford University Press; 1996.
29. Willman D. Baseball savant. Major League Baseball. 2015. Available at: Baseballsavant.mlb.com. Accessed July 9, 2020
30. Wilson AT, Pidgeon TS, Morrell NT, DaSilva MF. Trends in revision elbow ulnar collateral ligament reconstruction in professional baseball pitchers. J Hand Surg Am 2015;40:2249-54. https://doi.org/10.1016/j.jhsa.2015.07.024