Reasons for Retirement Following Ulnar Collateral Ligament Reconstruction Among Major League Baseball Pitchers

Brandon J. Erickson,*†‡ MD, Junyoung Ahn,‡ MD, Peter N. Chalmers,§ MD, Christopher S. Ahmad,‖ MD, Bernard R. Bach Jr,‡ MD, Nikhil N. Verma,‡ MD, and Anthony A. Romeo,‡ MD

Investigation performed at Rush University Medical Center, Chicago, Illinois, USA

Background: Ulnar collateral ligament reconstruction (UCLR) has become an increasingly common procedure among Major League Baseball (MLB) pitchers. The long-term effects of this procedure on the career of an MLB pitcher are largely unknown.

Purpose/Hypothesis: The purpose of this study was to determine why and when MLB pitchers who underwent UCLR during their careers retired from baseball as compared with controls. We hypothesized that pitchers who underwent UCLR are no more likely than control pitchers to retire from elbow or shoulder problems.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: All MLB pitchers who underwent UCLR were identified through publicly available data. A cohort of pitchers who did not undergo UCLR were matched to pitchers with a history of UCLR, based on sex, age, draft year, and draft round. Of those who were no longer pitching in the MLB, the reason for retirement was determined. Reason for retirement and length of career following UCLR (surgical group) and index year (control group) were determined and compared through prior studies via the MLB HITS database, MLB team websites, and publicly available internet-based injury reports.

Results: Overall, 153 MLB pitchers who underwent UCLR between 1974 and 2015 are currently retired. Mean ± SD time to retirement was 4.4 ± 4.7 years (range, 0-26 years) after the index year in the control group and 4.4 ± 3.5 years (range, 0-15 years) after surgery in the UCLR group ($P = .388$). Patients who were status post-UCLR were significantly more likely to be released during the season (34 of 144, 23.6%) than were players who were not status post-UCLR (14 of 144, 9.7%) ($P = .002$). Shoulder injury as a reason for retirement was more common in the control group than the UCLR group ($P = .011$). Elbow injury as a reason for retirement was not more common in either group ($P = .379$). Leg injury as a reason for retirement was more common in the control group ($P = .013$). Performance as a reason for retirement was more common in the UCLR group than the control group ($P < .001$).

Conclusion: MLB pitchers who have undergone UCLR are no more likely to retire from shoulder or elbow injuries than are those who have not undergone UCLR. MLB career length was similar between pitchers with and without a history of UCLR.

Keywords: ulnar collateral ligament reconstruction; UCLR; Major League Baseball; MLB; Tommy John; pitcher; retire; elbow

The ulnar collateral ligament (UCL), which functions as the primary valgus restraint to the elbow, experiences a tremendous amount of stress during the overhand baseball pitch.[18,28,29] Numerous studies have documented the rising number of UCL reconstructions (UCLRs) among adolescent as well as professional baseball pitchers, as this is the current standard for players with UCL injuries who have failed conservative treatment and wish to return to competition at a high level.[3,15,17,23] Fortunately, results following UCLR among Major League Baseball (MLB) pitchers and adolescents have been encouraging, with many studies reporting a >80% return-to-sport rate at the same or higher level of competition.[3,7,10,24,31,32] While many authors have worked toward identifying risk factors for sustaining a UCL injury and implementing strategies to reduce the risk of injuring the UCL, further work on this subject must be done.[2,4,5,14,16,19,20,34,35]

Witnauer et al[37] performed a comprehensive review of all MLB position players to determine the mean length of a position player's career once reaching the majors. The authors found the mean MLB career length of a position player to be 5.6 years. While this study shed some light on the expected longevity of MLB players, the authors excluded pitchers, given their high injury rates, and did not report on the reasons for retirement. Recent studies found that MLB pitchers who successfully returned to sport

The Orthopaedic Journal of Sports Medicine, 5(12), 2325967117745021
DOI: 10.1177/2325967117745021

following UCLR play for an additional 3.9 ± 2.84 seasons (mean ± SD) before they retire.[15] However, their reasons for retirement are currently unknown. If these pitchers are retiring because of a common modifiable reason, it may be possible to increase the length of a pitcher's career by preventing the issue that causes one to retire.

Therefore, the purpose of this study was to determine the reasons for retirement among MLB pitchers who underwent UCLR and to compare these reasons with those of a matched cohort of MLB pitchers with no history of UCLR. We hypothesized that pitchers who underwent UCLR would be no more likely than control pitchers to retire from elbow or shoulder injuries.

METHODS

All MLB pitchers who underwent UCLR between 1974 and 2015 were evaluated. Pitchers were identified from prior studies, MLB team websites, and publicly available internet-based injury reports.[14,15,27,36] These pitchers were then cross-referenced with team injury reports, and a prior database verified the MLB HITS database to ensure accuracy.[13-15] Numerous prior publications have utilized this method of data collection.[15,27,30] As these data were publically available, Institutional Review Board approval was not necessary. Inclusion criteria were MLB pitchers (defined as having pitched in at least 1 MLB game prior to undergoing UCLR) who pitched for at least 1 season following UCLR and who are currently retired. Exclusion criteria were collegiate pitchers (NCAA [National Collegiate Athletic Association]), position players (nonpitchers), pitchers who never pitched in MLB, and pitchers who never returned to the MLB following UCLR, as it would not be possible to accurately determine the cause of failure. The presumed cause would be from an elbow injury, and prior data exist on this; as such, these players were excluded to focus on why players who were able to successfully return to pitching following UCLR retired. Pitchers who were <20 months out from their index UCLR were excluded.

A control group was selected to compare career length with that of the cases (UCLR). Controls were matched with cases based on sex, age, draft year, and draft round. An "index year" was designated for controls, analogous to UCLR year among cases. In other words, the controls pitched the same number of years before the index year as the cases pitched before surgery. For example, if a pitcher underwent UCLR 3 years into his career, the index year for the matched control was set at 3 years. This year was used to determine the length of a player's career and to allow comparison between the control group and the UCLR group. In essence, the index year functioned as the surgical year for the controls. The reason for the retirement of all pitchers, cases and controls, was then determined through MLB team websites, publicly available internet-based injury reports, and press releases (Table 1). Players who had no specific injury issue at the time of retirement were classified as having retired because of a decline in performance. Pitchers who underwent UCLR were then compared with controls in regard to WHIP ([walks + hits] / innings pitched), a sabermetric measure that calculates the number of base runners that a pitcher allows per inning, as a snapshot of pitching effectiveness.

Statistical Analysis

Pathologies were combined by body part. Chi-square tests were performed to compare UCLR and control groups per body part as well as the path that the player took to the MLB (high school vs college vs foreign). Similar test were used to compare groups for whether a player's release took place during or after the season. Time to retirement was compared between the UCLR and control groups using the Mann-Whitney U test, as the data were not normally distributed, as measured using the Kolmogorov-Smirnov test. Similar tests were used to compare the best WHIP, the WHIP during their last year of pitching, and their salary. P values <.05 were considered statistically significant. All analyses were conducted in Excel and SPSS 23 (IBM).

RESULTS

A total of 153 MLB pitchers with a history of UCLR were able to return to sport and are now retired. Time to retirement was 4.4 ± 4.7 years (range, 0-26 years) for the control group and 4.4 ± 3.5 years (0-15 years) for the UCLR group ($P = .388$). Patients who were status post-UCLR were significantly more likely to be released during the season (34 of 144, 23.6%) than players who were not (14 of 144, 9.7%) ($P = .002$). The most common reasons for retirement for pitchers with a history of UCLR and controls were decline in performance, shoulder problems, and elbow problems

*Address correspondence to Brandon J. Erickson, MD, Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021, USA (email: brandon.j.erickson@gmail.com).
†Division of Sports and Shoulder, Hospital for Special Surgery, New York, New York, USA.
‡Midwest Orthopaedics at Rush, Rush University Medical Center, Chicago, Illinois, USA.
§Department of Orthopaedic Surgery, University of Utah, Salt Lake City, Utah, USA.
‖Department of Orthopaedic Surgery, Columbia University, New York, New York, USA.

One or more of the authors has declared the following potential conflict of interest or source of funding: C.S.A. receives royalties from Arthrex and Lead Player; is a paid consultant for Arthrex; receives research support from Arthrex, Major League Baseball, and Stryker; and has stock/stock options in At Peak. B.R.B. receives research support from Arthrex, ConMed Linvatec, DJ Orthopaedics, Ossur, Smith & Nephew, and Tornier and receives publishing royalties from SLACK Inc. N.N.V. receives research support from Arthrex, Arthrosurface, DJ Orthopaedics, Ossur, Athletico, ConMed Linvatec, Miomed, and Mitek; receives publishing royalties from *Arthroscopy* and Vindico Medical–Orthopedics Hyperguide; has stock/stock options in Cymedica and Omeros; is a paid consultant for Minivasive, Orthospace, and Smith & Nephew; and receives royalties from Smith & Nephew. A.A.R. receives royalties from Arthrex; is a paid consultant for Arthrex; is a paid speaker for Arthrex; receives research support from DJO Surgical, Ossur, and Smith & Nephew; and receives publishing royalties from Saunders/Mosby-Elsevier and SLACK Inc.

Ethical approval was not sought for the present study, as publically available data were utilized.

TABLE 1
Reasons for Retirement for Major League Baseball Players

Shoulder inflammation
Shoulder labral injury
Shoulder rotator cuff tear
Shoulder rotator cuff tendinitis
Shoulder latissimus injury
Shoulder infection
Shoulder pain
Shoulder injury not otherwise specified
Combined rotator cuff and labral injury
Elbow revision ulnar collateral ligament reconstruction
Elbow bone chips
Elbow distal humerus fracture
Elbow numbness/nerve injury
Elbow pain/not otherwise specified
Anterior cruciate ligament injury
Achilles tendon injury
Other foot and ankle injury/fractures
Injuries of the hamstring/knee
Lumbar disc herniation
Cervical disc herniation
Low back pain
Thoracic outlet syndrome
Abdominal/oblique injury
Medical problem contributing to retirement
Injuries of the hip/thigh/groin and death

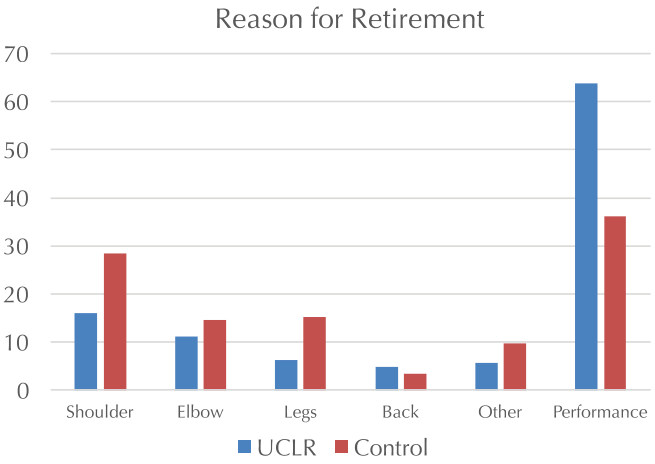

Figure 1. Percentage of players in the UCLR and non-UCLR groups retiring for issues related to each body area. UCLR, ulnar collateral ligament reconstruction.

(Figure 1). Table 2 presents data for the specific body regions that were the cause for retirement for both groups. Control pitchers (ie, without a history of UCLR) were more likely to retire from shoulder and leg injuries than were pitchers with a history of UCLR (28.5% vs 16%, $P = .011$; 15% vs 6%, $P = .013$, respectively) (Table 3). Pitchers with a history of UCLR were no more likely than control pitchers to retire secondary to elbow problems (11.1% vs 14.6%, $P = .379$). Pitchers with a history of UCLR were more likely than control pitchers to retire owing to a decline in performance (63.8% vs 36.2%, $P < .001$). When education levels among UCLR and non-UCLR players were compared,

TABLE 2
Players Retiring per Pathology[a]

	Players, % (No.)	
Area: Pathology	UCLR	Control
Shoulder		
Inflammation	1.4 (2)	14.6 (21)
Labral tear	4.2 (6)	4.9 (7)
Rotator cuff tear	4.9 (7)	5.6 (8)
Rotator cuff tendonitis	2.1 (3)	0 (0)
Latissimus strain	0.7 (1)	1.4 (2)
Other	2.8 (4)	4.2 (6)
Elbow		
Revision UCLR	2.8 (4)	0 (0)
Bone chips	1.4 (2)	2.8 (4)
Humeral fracture	0.7 (1)	0.7 (1)
Hand numbness	0.7 (1)	0 (0)
Other	5.6 (8)	11.1 (16)
Other		
Anterior cruciate ligament injury	1.4 (2)	0 (0)
Achilles tear	0.7 (1)	0.7 (1)
Foot/ankle injury	1.4 (2)	0 (0)
Hamstring/knee injury	2.8 (4)	3.5 (5)
Lumbar disc herniation	1.4 (2)	0.7 (1)
Cervical disc herniation	2.1 (3)	0 (0)
Low back pain	1.4 (2)	2.8 (4)
Thoracic outlet	1.4 (2)	2.1 (3)
Hand injury	0.7 (1)	2.1 (3)
Abdominal/oblique injury	1.4 (2)	4.9 (7)
Other	1.4 (2)	0.7 (1)
Thigh/hip/groin injury	0.7 (1)	11.1 (16)

[a]UCLR, ulnar collateral ligament reconstruction.

TABLE 3
Players Retiring for Pathologies per Body Part[a]

	Players, % (No.)		
Area	UCLR	Control	*P* Value
Shoulder	16 (23)	28.5 (41)	**.011**
Elbow	11.1 (16)	14.6 (21)	.379
Legs	6.3 (9)	15.3 (22)	**.013**
Back	4.9 (7)	3.5 (5)	.555
Other	5.6 (8)	9.7 (14)	.183
Performance	63.8 (90)	36.2 (50)	**<.001**

[a]*P* values are based on the results of chi-square tests. Significant differences are in bold ($P < .05$). UCLR, ulnar collateral ligament reconstruction.

significantly more players were drafted out of high school in the UCLR group than the control group (Table 4). Similarly, significantly more players in the control group were drafted out of college and hence had a college education. Significantly more foreign-born players underwent UCLR than not. When performance was compared between players who underwent UCLR and their matched controls, players with a history of UCLR had a statistically significantly better (ie, lower) WHIP during the peak performance

TABLE 4
Level of Play Prior to Major League Baseball[a]

	Players, % (No.)	
Source	UCLR	Control
High school	34 (49)	29 (42)
College	51 (74)	70 (101)
Foreign	14 (20)	1 (1)

[a]$P < .001$. UCLR, ulnar collateral ligament reconstruction.

TABLE 5
Performance Statistics Between Player Groups[a]

	Players, Mean ± SD	
Variable	UCLR[b]	Control
Best WHIP	1.13 ± 0.2	1.27 ± 0.34
WHIP at retirement	1.55 ± 0.33	1.93 ± 0.76
Salary, $	2,756,103 ± 3,987,015	1,972,485 ± 3,994,329

[a]UCLR, ulnar collateral ligament reconstruction; WHIP, walks plus hits per inning pitched.
[b]Performance statistics were better in the UCLR group ($P < .001$ per row).

year of their careers and in their last year before retirement (Table 5). Annual salary was significantly higher among players who underwent UCLR than not.

DISCUSSION

While more than 80% of MLB pitchers who undergo UCLR are able to successfully return to sport, it is currently unknown what causes these players to retire and whether the reasons are different from those of MLB pitchers with no history of UCLR. Our hypothesis was confirmed: MLB pitchers with a history of UCLR were no more likely than control pitchers to retire because of shoulder or elbow injuries. Furthermore, as compared with control pitchers, MLB pitchers with a history of UCLR played a similar number of seasons following surgery. As compared with those of the controls, the peak performance and the performance for the last year of the career were better among pitchers who underwent UCLR; salary was also higher among pitchers who underwent UCLR.

The UCL has received a tremendous amount of attention in recent literature given the epidemic increase in the number of UCLRs performed among adolescent and elite-level athletes.[6,8,11,25,38] A concern over revision rates and failures following UCLR has arisen, as the number of revision UCLRs has increased over the last 10 years.[27,36] This concern has called into question the longevity of the UCLR procedure. Several studies have reported on the revision rates among adolescent and elite-level pitchers following UCLR.[10,27,36] These rates ranged between 0% and 15%, with the majority of studies citing a rate of <10%.[3,7,15,26,31,36] This study found that pitchers with a history of UCLR were no more likely to retire from an elbow problem than pitchers with no history of UCLR (11.1% vs 14.6%, $P = .379$). Hence, despite having had prior surgery on the elbow, continuing problems with the elbow are not a common reason for retirement among pitchers who have undergone UCLR.

Pitchers who are successfully able to return to sport in MLB following UCLR must complete a demanding rehabilitation process. While very little is understood about the ideal rehabilitation protocol following UCLR, much of this process focuses on proper pitching mechanics to limit excessive stress on the shoulder and elbow, as some believe that improper pitching mechanics is one of the risk factors for injury of the UCL.[1,9,21,33] Hence, when pitchers return to sport following UCLR, their pitching mechanics may often be better than they were before surgery. Hannon et al[22] studied 33 collegiate and high school baseball pitchers to determine their single-leg balance before and after UCLR. Each participant underwent a standard UCL protocol that focused on lower extremity balance and neuromuscular control exercises. The authors found that pitchers who sustained a UCL tear had significant balance deficits in stance ($P < .001$) and lead ($P = .009$) limbs before UCLR versus after surgery, indicating that the rehabilitation protocol was successful at optimizing their core strength and balance. The present study found that, compared with pitchers who underwent UCLR, control pitchers without a history of UCLR were more likely to retire because of leg injuries. This finding corroborates the prior study, as pitchers have improved balance following UCLR, thereby decreasing their risk of lower extremity injury.

Previous studies found a link between lack of total glenohumeral motion and risk for elbow injury among MLB pitchers.[35] However, the converse has not been proven. No study to date has definitively shown prior elbow injury or elbow surgery, including UCLR, to be a risk factor for sustaining a shoulder injury, although many surgeons believe it to be the case. The current study found that pitchers with a history of UCLR were less likely to retire from shoulder injuries than were pitchers with no history of UCLR. This finding again speaks to the rehabilitation process and the improvement in pitching mechanics seen following UCLR, which may be protective against future shoulder injuries, although further work must be done to definitively prove this.

The main reason for retirement among pitchers with a history of UCLR was a decline in performance and not a distinct, reported injury. Many pitchers do not sustain a distinct injury but rather suffer a decline in overall performance toward the end of their careers and are not re-signed with their teams, or they are directed to the minor leagues and never return to the major leagues. When performance was measured by WHIP, players' peak performance and performance in the final season were better in the UCLR group than the control group. Furthermore, pitchers who underwent UCLR had a higher season salary than controls. This shows that, according to performance and salary, better pitchers were more likely to undergo UCLR than pitchers who were not as highly valued or as effective (controls). However, at the end of their careers, players who underwent UCLR were more likely than controls to be released

during the season. This finding could indicate a rapid in-season decline in performance among these pitchers, as they were not retained through the end of their final seasons, although the etiology of this decline is unknown. This correlates with the fact that pitchers with a history of UCLR were more likely than control pitchers to retire for performance reasons. One other possibility is that players with a history of UCLR had significantly higher salaries than control pitchers, indicating that they made more total money during their careers. Hence, they may have been more likely to retire in season and forego the rest of their contracts because they had generated a higher income during their careers than had control pitchers, or it is possible that a higher-paid player was released midseason to free up space and money on the roster to pick up other players. Further studies evaluating possible reasons for the decline in performance among these players should be conducted.

This study found no significant difference in the number of seasons played in the majors following UCLR when compared with the index years assigned to control pitchers. This essentially means that although the performance level of pitchers following UCLR declined over time, it did not decline at any faster rate than that of pitchers without a history of UCLR. It is possible that pitchers have a limited number of innings and/or pitches before they are no longer effective, although this has not been proven. Furthermore, pitchers with a history of UCLR were less likely to retire from a distinct injury, possibly indicating that the surgery—and, more likely, the rehabilitation process—may have a protective effect against future shoulder and leg injuries, although this cannot be proven. Finally, there were significantly more foreign pitchers who underwent UCLR than not. Foreign pitchers are not subject to the stringent pitch counts during their adolescence that are in effect in the United States. This may indicate that pitch counts that have been implemented in the United States are becoming effective in preventing UCLR down the road among these pitchers.[12] Further longitudinal studies are necessary to confirm this finding.

Limitations

Although this study is the first to evaluate reasons for retirement among MLB pitchers following UCLR, it has several limitations. There is the possibility that some pitchers who underwent UCLR were missed during the search and were therefore not included. Although meticulous attention to detail was used to discern reasons for retirement, these reasons were based on team injury reports, press releases, and so on; therefore, it is possible that some of this information was inaccurate. There is the possibility that some pitchers in the control group may have undergone UCLR in high school or college and so were incorrectly placed in the control group. Pitchers were included in this study only if they returned to sport following UCLR. This could have introduced a selection bias that may have affected the performance outcome data during comparison between the UCLR and control groups. Surgical details, including approach, graft type, management of the ulnar nerve, and surgical technique, were not available, so this study cannot comment on the superiority of one technique over another. Similarly, rehabilitation protocols for individual pitchers following UCLR were unknown; accordingly, a recommendation on the ideal protocol cannot be made. Finally, a decline in performance was the reason for retirement for many of the cases and controls. However, it is possible that some of these players had issues and injuries that they were not willing to disclose to agents, media, and others and were therefore erroneously assigned to the "decline in performance" group.

CONCLUSION

MLB pitchers who have undergone UCLR are no more likely to retire from shoulder or elbow injuries than those who have not undergone UCLR. MLB career length was similar between pitchers with and without a history of UCLR.

REFERENCES

1. Bernas GA, Ruberte Thiele RA, Kinnaman KA, Hughes RE, Miller BS, Carpenter JE. Defining safe rehabilitation for ulnar collateral ligament reconstruction of the elbow: a biomechanical study. *Am J Sports Med*. 2009;37(12):2392-2400.
2. Bushnell BD, Anz AW, Noonan TJ, Torry MR, Hawkins RJ. Association of maximum pitch velocity and elbow injury in professional baseball pitchers. *Am J Sports Med*. 2010;38(4):728-732.
3. Cain EL Jr, Andrews JR, Dugas JR, 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(12):2426-2434.
4. Chalmers PN, Erickson BJ, Ball B, Romeo AA, Verma NN. Fastball pitch velocity helps predict ulnar collateral ligament reconstruction in Major League Baseball pitchers. *Am J Sports Med*. 2016;44(8): 2130-2135.
5. DeFroda SF, Kriz PK, Hall AM, Zurakowski D, Fadale PD. Risk stratification for ulnar collateral ligament injury in Major League Baseball players: a retrospective study from 2007 to 2014. *Orthop J Sports Med*. 2016;4(2):2325967115627126.
6. Degen RM, Camp CL, Bernard JA, Dines DM, Altchek DW, Dines JS. Current trends in ulnar collateral ligament reconstruction surgery among newly trained orthopaedic surgeons. *J Am Acad Orthop Surg*. 2017;25(2):140-149.
7. Dines JS, ElAttrache NS, Conway JE, Smith W, Ahmad CS. Clinical outcomes of the DANE TJ technique to treat ulnar collateral ligament insufficiency of the elbow. *Am J Sports Med*. 2007;35(12): 2039-2044.
8. Dugas JR. Ulnar collateral ligament repair: an old idea with a new wrinkle. *Am J Orthop (Belle Mead NJ)*. 2016;45(3):124-127.
9. Ellenbecker TS, Wilk KE, Altchek DW, Andrews JR. Current concepts in rehabilitation following ulnar collateral ligament reconstruction. *Sports Health*. 2009;1(4):301-313.
10. Erickson BJ, Bach BR Jr, Cohen MS, et al. Ulnar collateral ligament reconstruction: the Rush experience. *Orthop J Sports Med*. 2016;4(1): 2325967115626876.
11. Erickson BJ, Bach BR Jr, Verma NN, Bush-Joseph CA, Romeo AA. Treatment of ulnar collateral ligament tears of the elbow: is repair a viable option? *Orthop J Sports Med*. 2017;5(1):2325967116682211.
12. Erickson BJ, Chalmers PN, Axe MJ, Romeo AA. Exceeding pitch count recommendations in little league baseball increases the chance of requiring Tommy John surgery as a professional baseball pitcher. *Orthop J Sports Med*. 2017;5(3):2325967117695085.
13. Erickson BJ, Chalmers PN, Bach BR Jr, et al. Length of time between surgery and return to sport after ulnar collateral ligament

reconstruction in Major League Baseball pitchers does not predict need for revision surgery. *J Shoulder Elbow Surg*. 2017;26(4): 699-703.
14. Erickson BJ, Cvetanovich GL, Bach BR Jr, Bush-Joseph CA, Verma NN, Romeo AA. Should we limit innings pitched after ulnar collateral ligament reconstruction in Major League Baseball pitchers? *Am J Sports Med*. 2016;44(9):2210-2213.
15. Erickson BJ, Gupta AK, Harris JD, et al. Rate of return to pitching and performance after Tommy John surgery in Major League Baseball pitchers. *Am J Sports Med*. 2013;42(3):536-543.
16. Erickson BJ, Harris JD, Tetreault M, Bush-Joseph C, Cohen MS, Romeo AA. Is Tommy John surgery performed more frequently in Major League Baseball pitchers from warm weather areas? *Orthop J Sports Med*. 2014;2(10):2325967114553916.
17. Erickson BJ, Nwachukwu BU, Rosas S, et al. Trends in medial ulnar collateral ligament reconstruction in the United States: a retrospective review of a large private-payer database from 2007 to 2011. *Am J Sports Med*. 2015;43(7):1770-1774.
18. Erickson BJ, Romeo AA. The ulnar collateral ligament injury: evaluation and treatment. *J Bone Joint Surg Am*. 2017;99(1):76-86.
19. Fleisig GS, Andrews JR. Prevention of elbow injuries in youth baseball pitchers. *Sports Health*. 2012;4(5):419-424.
20. Fleisig GS, Andrews JR, Cutter GR, et al. Risk of serious injury for young baseball pitchers: a 10-year prospective study. *Am J Sports Med*. 2011;39(2):253-257.
21. Garrison JC, Arnold A, Macko MJ, Conway JE. Baseball players diagnosed with ulnar collateral ligament tears demonstrate decreased balance compared to healthy controls. *J Orthop Sports Phys Ther*. 2013;43(10):752-758.
22. Hannon J, Garrison JC, Conway J. Lower extremity balance is improved at time of return to throwing in baseball players after an ulnar collateral ligament reconstruction when compared to preoperative measurements. *Int J Sports Phys Ther*. 2014;9(3):356-364.
23. Hodgins JL, Vitale M, Arons RR, Ahmad CS. Epidemiology of medial ulnar collateral ligament reconstruction: a 10-year study of New York State. *Am J Sports Med*. 2016;44(3):729-734.
24. Jones KJ, Dines JS, Rebolledo BJ, et al. Operative management of ulnar collateral ligament insufficiency in adolescent athletes. *Am J Sports Med*. 2014;42(1):117-121.
25. Keller RA, Mehran N, Khalil LS, Ahmad CS, ElAttrache N. Relative individual workload changes may be a risk factor for rerupture of ulnar collateral ligament reconstruction. *J Shoulder Elbow Surg*. 2017; 26(3):369-375.
26. Liu JN, Garcia GH, Conte S, ElAttrache N, Altchek DW, Dines JS. Outcomes in revision Tommy John surgery in Major League Baseball pitchers. *J Shoulder Elbow Surg*. 2016;25(1):90-97.
27. Marshall NE, Keller RA, Lynch JR, Bey MJ, Moutzouros V. Pitching performance and longevity after revision ulnar collateral ligament reconstruction in Major League Baseball pitchers. *Am J Sports Med*. 2015;43(5):1051-1056.
28. Morrey BF. Applied anatomy and biomechanics of the elbow joint. *Instr Course Lect*. 1986;35:59-68.
29. Morrey BF, An KN. Articular and ligamentous contributions to the stability of the elbow joint. *Am J Sports Med*. 1983;11(5):315-319.
30. Namdari S, Baldwin K, Anakwenze O, Park MJ, Huffman GR, Sennett BJ. Results and performance after microfracture in National Basketball Association athletes. *Am J Sports Med*. 2009;37(5):943-948.
31. O'Brien DF, O'Hagan T, Stewart R, et al. Outcomes for ulnar collateral ligament reconstruction: a retrospective review using the KJOC assessment score with two-year follow-up in an overhead throwing population. *J Shoulder Elbow Surg*. 2015;24(6):934-940.
32. Savoie FH 3rd, Morgan C, Yaste J, Hurt J, Field L. Medial ulnar collateral ligament reconstruction using hamstring allograft in overhead throwing athletes. *J Bone Joint Surg Am*. 2013;95(12): 1062-1066.
33. Seto JL, Brewster CE, Randall CC, Jobe FW. Rehabilitation following ulnar collateral ligament reconstruction of athletes. *J Orthop Sports Phys Ther*. 1991;14(3):100-105.
34. Whiteside D, Martini DN, Lepley AS, Zernicke RF, Goulet GC. Predictors of ulnar collateral ligament reconstruction in Major League Baseball pitchers. *Am J Sports Med*. 2016;44(9):2202-2209.
35. Wilk KE, Macrina LC, Fleisig GS, et al. Deficits in glenohumeral passive range of motion increase risk of elbow injury in professional baseball pitchers: a prospective study. *Am J Sports Med*. 2014; 42(9):2075-2081.
36. 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(11):2249-2254.
37. Witnauer WD, Rogers RG, Saint Onge JM. Major League Baseball career length in the twentieth century. *Popul Res Policy Rev*. 2007; 26(4):371-386.
38. Wymore L, Chin P, Geary C, et al. Performance and injury characteristics of pitchers entering the Major League Baseball draft after ulnar collateral ligament reconstruction. *Am J Sports Med*. 2016;44(12): 3165-3170.