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Rate of Return to Pitching and Performance After Tommy John Surgery in Major League Baseball Pitchers

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Background: Medial ulnar collateral ligament (UCL) reconstruction is a common procedure performed on Major League Baseball (MLB) pitchers in the United States.

Purpose: To determine (1) the rate of return to pitching (RTP) in the MLB after UCL reconstruction, (2) the RTP rate in either the MLB and minor league combined, (3) performance after RTP, and (4) the difference in the RTP rate and performance between pitchers who underwent UCL reconstruction and matched controls without UCL injuries.

Study Design: Cohort study; Level of evidence, 3.

Methods: Major League Baseball pitchers with symptomatic medial UCL deficiency who underwent UCL reconstruction were evaluated. All player, elbow, and surgical demographic data were analyzed. Controls matched by age, body mass index, position, handedness, and MLB experience and performance were selected from the MLB during the same years as those undergoing UCL reconstruction. An ''index year'' was designated for controls, analogous to the UCL reconstruction year in cases. Return to pitching and performance measures in the MLB were compared between cases and controls. Student *t* tests were performed for analysis of within-group and between-group variables, respectively.

Results: A total of 179 pitchers with UCL tears who underwent reconstruction met the inclusion criteria and were analyzed. Of these, 148 pitchers (83%) were able to RTP in the MLB, and 174 pitchers were able to RTP in the MLB and minor league combined (97.2%), while only 5 pitchers (2.8%) were never able to RTP in either the MLB or minor league. Pitchers returned to the MLB at a mean 20.5 $\pm$ 9.72 months after UCL reconstruction. The length of career in the MLB after UCL reconstruction was 3.9 $\pm$ 2.84 years, although 56 of these patients were still currently actively pitching in the MLB at the start of the 2013 season. The revision rate was 3.9%. In the year before UCL reconstruction, pitching performance declined significantly in the cases versus controls in the number of innings pitched, games played, and wins and the winning percentage ($P < .05$). After surgery, pitchers showed significantly improved performance versus before surgery (fewer losses, a lower losing percentage, lower earned run average [ERA], threw fewer walks, and allowed fewer hits, runs, and home runs) ($P < .05$). Comparisons between cases and controls for the time frame after UCL reconstruction (cases) or the index year (controls) demonstrated that cases had significantly ($P < .05$) fewer losses per season and a lower losing percentage. In addition, cases had a significantly lower ERA and allowed fewer walks and hits per inning pitched.

Conclusion: There is a high rate of RTP in professional baseball after UCL reconstruction. Performance declined before surgery and improved after surgery. When compared with demographic-matched controls, patients who underwent UCL reconstruction had better results in multiple performance measures. Reconstruction of the UCL allows for a predictable and successful return to the MLB.

Keywords: ulnar collateral ligament; Tommy John surgery; Major League Baseball; return to sport; elbow injury; pitching

The medial ulnar collateral ligament (UCL) of the elbow provides stability to valgus stress during throwing sports such as baseball.[9] Since its initial performance on a Major League Baseball (MLB) pitcher (Tommy John) in 1974, perceptions have been mixed among athletes, coaches, parents, and media with respect to the indications and outcomes for UCL reconstruction. Outcomes of the procedure have evolved from "career-ending" to significantly improving performance in pitchers. These improved outcomes could explain the recent increase in the number of UCL reconstructions performed in both MLB pitchers, cited at almost 10% of all MLB pitchers, as well as in amateurs.[3,13] Technical aspects of UCL reconstruction (eg, ulnar nerve management, fixation methods, flexor-pronator management, and postoperative rehabilitation) have changed with time, and several

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modifications of the procedure are currently used. To date, there has not been a comparative study evaluating the outcomes of MLB pitchers who undergo UCL reconstruction against MLB pitchers who do not have UCL injuries.

The purposes of this study were to determine (1) the rate of return to pitching (RTP) in the MLB after UCL reconstruction, (2) the rate of RTP in either the MLB and minor league combined after UCL reconstruction, (3) performance after RTP, and (4) the difference in the RTP rate and performance between pitchers who underwent UCL reconstruction and matched controls without UCL injuries. The authors hypothesized that there would be a high rate of RTP in professional pitchers undergoing UCL reconstruction. In addition, the authors hypothesized that there would be no significant difference in the rate of RTP or performance between cases (UCL reconstruction) and controls (no UCL injury).

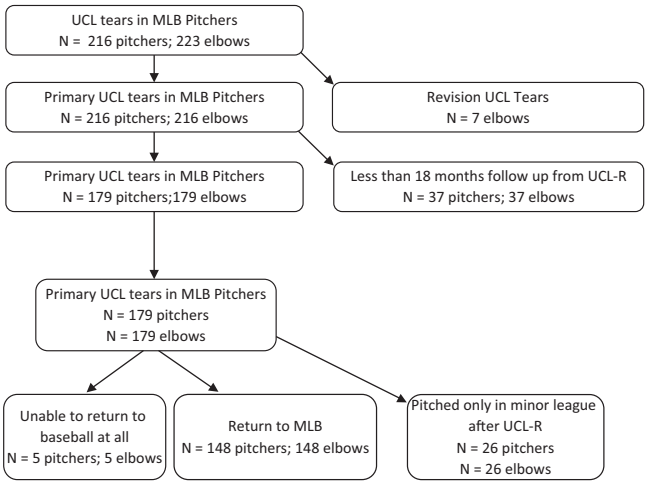

Figure 1. Flowchart of selection process for inclusive Major League Baseball pitchers. UCL, ulnar collateral ligament.

MATERIALS AND METHODS

Major League Baseball pitchers with a symptomatic UCL injury who underwent reconstruction were evaluated. These players were identified through MLB team websites and publicly available Internet-based injury reports. Player profiles, biographies, and press releases were cross-referenced with the MLB injury database. This method of data collection has been used in multiple prior publications.[2,4,8,10,16,17] The MLB database (HITS) contains information from 2010 to 2013, and this information was cross-referenced with the publicly available information to ensure accuracy over the available time period. The search was manually conducted by an orthopaedic surgery resident and a board-eligible orthopaedic surgeon with sports medicine fellowship training. Searches were performed for all MLB teams and players. All players identified were included in this study as it related to the RTP rate. A player was deemed to have returned to pitching if he pitched in any MLB game after surgery. Pitchers who underwent UCL reconstruction with a minimum 18 months' follow-up were included in the study. Inclusion criteria were any male MLB pitcher (after being drafted in the MLB or playing at least 1 game in the MLB before the UCL tear) who pitched at least 1 game in the MLB and not just the minor league. Exclusion criteria were collegiate (National Collegiate Athletic Association [NCAA]) pitchers, pitchers who never pitched in the MLB, and nonpitcher position players. Pitchers who underwent revision UCL reconstruction were included only once in the data analysis. Hence, the number of pitchers and elbows was the same. There were no players in whom performance data could not be found (Figure 1).

Players who returned to the MLB and had played in at least 1 game were included in the statistical analysis of preinjury and postreconstruction in-game performance. Data on player demographic and performance measures were collected (Table 1). In-game performance variables were analyzed as mean values over the preinjury and postreconstruction course of players' careers. In addition, in-game performance variables were analyzed separately in each of the first 3 subsequent seasons that the player returned to the MLB after the injury as well as the 3 preceding seasons leading up to the injury.

A control group was selected to compare the data to the case (UCL reconstruction) group. Controls were matched to cases based on sex, age, body mass index (BMI), years of experience in the MLB, pitching performance in the MLB, year of injury, pitching position, and handedness. An "index year" was designated for controls, analogous to the UCL reconstruction year in cases. In other words, the controls pitched the same number of years before the index year as the cases pitched before surgery. The same demographic data (BMI, age, and years in the MLB) and in-game performance data were collected and analyzed over

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TABLE 1
Demographic and Performance Variables Measured in Cases and Controls[a]

Demographic Data	Performance Data
Age at time of injury	Innings pitched per game
Body mass index	Games pitched per season
Age and year when first pitched in MLB	Wins per season
Year when last pitched in MLB	Losses per season
Total years pitched in MLB	Earned run average per season
Year of surgery	Complete games per season
Age at time of surgery	Shutouts per season
Years of MLB experience when underwent surgery	Saves per season
Years played in MLB after surgery	Hits allowed per season
Pitching style (overhead, sidearm)	Runs allowed per season
Pitching position (starter, middle reliever, closer)	Home runs allowed per season
Months from surgery to throwing	Walks allowed per season
Months from surgery to return to pitching	Hit batters per season
Side of injury (right vs left)	Strikeouts per season
Surgical technique used	Walks plus hits per inning pitched
Surgeon who performed surgery	
Games played before and after surgery	

[a]MLB, Major League Baseball.

the course of the controls' careers as a total before and after the index year. Also, in-game performance data were collected and analyzed for 3 individual seasons before and after their index year.

Single-variable analyses for all continuous variables (performance measures) within groups were performed using paired-sample Student *t* tests for normally distributed data. One-sample Kolmogorov-Smirnov goodness-for-fit tests for Gaussian data distribution were performed and confirmed the normality of all data. Because the number of wins, losses, complete games, shutouts, and saves are dependent on the number of games played, these variables were normalized to the number of games played per season; because the number of strikeouts, walks, hits given up, runs given up, and home runs given up are dependent on the number of innings pitched, these variables were normalized to the number of innings pitched per season. Linear regression was used to determine if there was a significant increase in the incidence of UCL tears per year. Comparisons were made between cases and controls for survival in the MLB and each individual parameter's overall mean (all years before and all years after UCL reconstruction [or index year]) and each individual year (up to 3 years) before and after UCL reconstruction (or index year). Significance was set using an α value of .05. Bonferroni correction was used to determine significance in the setting of multiple comparisons. All statistical analyses were performed using PASW Statistics Student Version 18.0.0 (IBM, Armonk, New York, USA).

RESULTS

A total of 179 pitchers with UCL tears who underwent reconstruction met the inclusion criteria and were analyzed. Of these, 148 were able to RTP in the MLB (83% rate of RTP). One hundred seventy-four pitchers were able to RTP in the MLB or minor league combined (97.2%), while only 5 pitchers (2.8%) were never able to RTP in either the MLB or minor league. Pitchers returned to the MLB at a mean of 20.5 $\pm$ 9.72 months after UCL reconstruction. The length of career in the MLB after UCL reconstruction was 3.9 $\pm$ 2.84 years after rehabilitation and RTP in the MLB. However, 56 pitchers (32%) were still active in the MLB at the start of the 2013-2014 season. There was no significant difference between cases and controls before surgery or the index year in any performance variable (Table 2). There was an overall significant increase in the number of UCL reconstructions performed on MLB pitchers from 1986 to 2012 ($P < .001$), including a significant increase from 2000 to 2012 ($P = .014$). However, there was no statistically significant increase in the number of UCL reconstructions performed in the 1980s or 1990s (Figure 2).

After UCL reconstruction (Table 3), pitchers had significantly fewer innings pitched per season and had both fewer wins and losses per season versus before surgery. Additionally, pitchers who had undergone UCL reconstruction had a significantly lower earned run average (ERA) and walks plus hits per inning pitched (WHIP) (calculated by adding together a pitcher's total walks and hits for that season and dividing the sum by the number of innings pitched that season). After the index year in controls (Table 4), pitchers had a significantly lower winning percentage (normalized to the number of games played). After UCL reconstruction (or index year in controls), pitchers who underwent UCL reconstruction had a significantly lower ERA and WHIP, had a lower losing percentage, and gave up fewer hits per inning versus controls (Table 5).

Two years before UCL reconstruction (or index year in controls), there were no significant performance differences between cases and controls (Appendix A, available online at http://ajsm.sagepub.com/supplemental). However, in the year before UCL reconstruction, pitchers played in significantly fewer innings, pitched fewer games,

TABLE 2
Comparison of Data Before UCL Reconstruction (Cases) Versus Before Index Year (Controls)[a]

	Cases	Controls	*P* Value (Paired-Sample Student *t* Test)	95% CI
Age, y	28.4 ± 4.30	28.3 ± 4.23	.947	–1.2 to 1.2
Right-handed pitchers, %	74.3	75.7	.821	–0.14 to 0.11
Starting pitchers, %	39.9	39.2	.920	–0.13 to 0.14
Closing pitchers, %	10.8	10.8	.999	–0.09 to 0.09
Middle relief pitchers, %	49.3	50.0	.922	–0.15 to 0.13
Seasons of MLB experience, n	9.14 ± 4.75	8.74 ± 3.84	.502	–0.77 to 1.6
Seasons of MLB experience before surgery (or index year), n	5.27 ± 4.34	5.24 ± 4.38	.965	–1.2 to 1.2
Innings pitched per game, n	3.27 ± 2.13	3.80 ± 1.96	.073	–1.1 to 0.05
Innings pitched per season, n	77.4 ± 51.7	85.3 ± 56.1	.294	–23 to 7.0
Games played per season before surgery (or index year), n	27.3 ± 15.2	25.9 ± 13.7	.513	–2.8 to 5.5
Wins per season before surgery (or index year), n	4.46 ± 3.38	5.14 ± 3.60	.167	–1.7 to 0.29
Wins before surgery (or index year), %	18.9 ± 14.5	23.0 ± 15.3	.060	–8.2 to 0.07
Losses per season before surgery (or index year), n	4.40 ± 3.05	4.57 ± 3.09	.686	–1.0 to 0.68
Losses before surgery (or index year), %	19.3 ± 13.8	20.0 ± 13.9	.717	–4.6 to 3.2
ERA per season before surgery (or index year)	5.67 ± 4.01	5.66 ± 2.73	.994	–1.0 to 1.0
Complete games per season before surgery (or index year), n	0.525 ± 0.985	0.625 ± 1.70	.579	–0.46 to 0.26
Complete games before surgery (or index year), %	2.1 ± 3.7	2.3 ± 5.6	.788	–1.4 to 1.1
Shutouts per season before surgery (or index year), n	0.198 ± 0.426	0.202 ± 0.459	.945	–0.13 to 0.12
Shutouts before surgery (or index year), %	0.73 ± 1.4	0.79 ± 1.7	.766	–0.47 to 0.35
Saves per season before surgery (or index year), n	2.07 ± 5.05	1.31 ± 4.33	.268	–0.59 to 2.1
Saves before surgery (or index year), %	4.6 ± 9.9	3.0 ± 8.7	.241	–1.1 to 4.3
Hits given up per season before surgery (or index year), n	77.1 ± 51.5	86.2 ± 53.2	.220	–24 to 5.5
Hits given up before surgery (or index year) (normalized to IP)	1.03 ± 0.385	1.03 ± 0.218	.959	–0.09 to 0.10
Runs given up per season before surgery (or index year), n	39.4 ± 26.0	39.5 ± 25.1	.966	–7.4 to 7.1
Runs given up before surgery (or index year) (normalized to IP)	0.552 ± 0.247	0.536 ± 0.198	.614	–0.05 to 0.08
Home runs given up per season before surgery (or index year), n	8.73 ± 6.07	10.1 ± 6.75	.116	–3.2 to 0.35
Home runs given up before surgery (or index year) (normalized to IP)	0.119 ± 0.068	0.121 ± 0.044	.808	–0.02 to 0.02
Walks given up per season before surgery (or index year), n	30.3 ± 19.8	33.1 ± 20.7	.337	–8.4 to 2.9
Walks given up before surgery (or index year) (normalized to IP)	0.438 ± 0.167	0.409 ± 0.117	.173	–0.01 to 0.07
Strikeouts per season before surgery (or index year), n	58.2 ± 36.9	62.3 ± 44.7	.471	–15 to 7.0
Strikeouts before surgery (or index year) (normalized to IP)	0.802 ± 0.240	0.724 ± 0.195	.131	–0.02 to 0.14
WHIP per season before surgery (or index year)	1.60 ± 0.567	1.60 ± 0.415	.966	–0.14 to 0.15

[a]Values are expressed as mean ± standard deviation. Bonferroni correction (18 items: .05/18 = <.0028). ERA, earned run average; IP, innings pitched; MLB, Major League Baseball; UCL, ulnar collateral ligament; WHIP, walks plus hits per inning pitched.

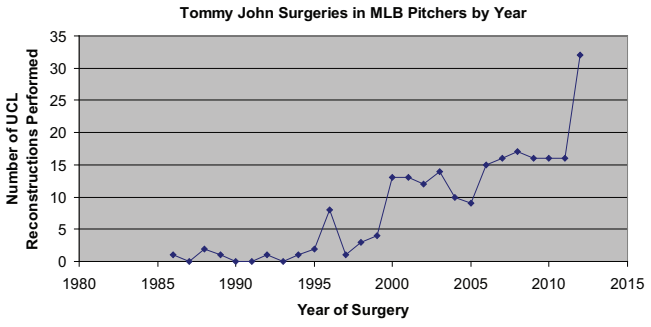

Figure 2. Number of ulnar collateral ligament reconstructions performed each year in Major League Baseball pitchers.

and had fewer wins (Appendix B, available online). In the first season that pitchers pitched in the MLB after their UCL reconstruction, they had a lower ERA and WHIP as well as fewer losses versus controls (Appendix C, available online). In the second season that pitchers pitched in the MLB after their UCL reconstruction, they had a lower ERA, WHIP, and losing percentage versus controls (Appendix D, available online). Data could not be compared for 3 years before or after the UCL reconstruction or index year because there were a large number of pitchers for whom these data did not exist.

DISCUSSION

The purposes of this study were to determine (1) the rate of RTP in the MLB after UCL reconstruction, (2) the rate of RTP in the MLB and minor league combined after UCL reconstruction, (3) performance after RTP, and (4) the difference in the RTP rate and performance between pitchers who underwent UCL reconstruction and matched controls without UCL injuries. We hypothesized that there would be a high rate of RTP in the MLB, as well as the MLB and minor league combined, in pitchers undergoing UCL reconstruction and

TABLE 3
Performance Comparison Before and After UCL Reconstruction (Cases)[a]

	Before UCL Reconstruction	After UCL Reconstruction	*P* Value (Paired-Sample Student *t* Test)	95% CI
Innings pitched per game, n	3.27 ± 2.13	2.67 ± 1.91	.011	0.14 to 1.1
Innings pitched per season, n	77.4 ± 51.7	58.7 ± 47.2	**.001**	7.3 to 30
Games played per season, n	27.3 ± 15.2	27.1 ± 16.7	.898	–3.4 to 3.9
Wins per season, n	4.46 ± 3.38	3.33 ± 3.10	**.003**	0.39 to 1.9
Wins (normalized to games played), %	18.9 ± 14.5	14.9 ± 15.0	.021	0.62 to 7.3
Losses per season, n	4.40 ± 3.05	3.08 ± 2.72	*<.001*	0.65 to 2.0
Losses (normalized to games played), %	19.3 ± 13.8	14.1 ± 13.8	*.001*	2.1 to 8.4
ERA per season	5.67 ± 4.01	4.18 ± 1.36	*<.001*	0.80 to 2.2
Complete games per season, n	0.525 ± 0.985	0.224 ± 0.529	**.001**	0.12 to 0.48
Complete games (normalized to games played), %	2.1 ± 3.7	0.85 ± 1.9	**<.001**	0.60 to 1.9
Shutouts per season, n	0.198 ± 0.426	0.091 ± 0.247	.009	0.03 to 0.19
Shutouts (normalized to games played), %	0.73 ± 1.4	0.35 ± 0.89	.004	0.12 to 0.65
Saves per season, n	2.07 ± 5.05	2.13 ± 5.09	.930	–1.2 to 1.1
Saves (normalized to games played), %	4.59 ± 9.88	5.57 ± 12.9	.466	–3.6 to 1.7
Hits given up per season, n	77.1 ± 51.5	57.8 ± 47.4	*.001*	8.0 to 31
Hits given up (normalized to IP)	1.03 ± 0.385	1.01 ± 0.244	.516	–0.05 to 0.10
Runs given up per season, n	39.4 ± 26.0	30.2 ± 23.5	*.002*	3.5 to 15
Runs given up (normalized to IP)	0.552 ± 0.247	0.641 ± 0.831	.215	–0.23 to 0.05
Home runs given up per season, n	8.73 ± 6.07	6.70 ± 5.21	*.002*	0.73 to 3.3
Home runs given up (normalized to IP)	0.119 ± 0.068	0.140 ± 0.137	.096	–0.05 to 0.004
Walks given up per season, n	30.3 ± 19.8	21.6 ± 15.7	*<.001*	4.6 to 13
Walks given up (normalized to IP)	0.438 ± 0.167	0.487 ± 0.813	.471	–0.18 to 0.09
Strikeouts per season, n	58.2 ± 36.9	45.6 ± 38.0	.004	4.0 to 21
Strikeouts (normalized to IP)	0.802 ± 0.240	0.792 ± 0.254	.706	–0.05 to 0.07
WHIP per season	1.60 ± 0.567	1.39 ± 2.52	***<.001***	0.11 to 0.31

[a]Values are expressed as mean ± standard deviation. Bonferroni correction (15 items: .05/15 = <.0033). Bold indicates significantly better before reconstruction, and italic indicates significantly better after ($P < .05$). ERA, earned run average; IP, innings pitched; UCL, ulnar collateral ligament; WHIP, walks plus hits per inning pitched.

that there would be no significant difference in the rate of RTP or performance between cases (UCL reconstruction) and controls (no UCL injury). The study hypotheses were partially confirmed: The RTP rate for MLB pitchers undergoing UCL reconstruction was 83% in the MLB and 97% in all professional leagues, with only 2.8% of MLB pitchers undergoing UCL reconstruction who were unable to return to the MLB, minor league, or overseas leagues. After UCL reconstruction, pitchers played in fewer innings per season and had both fewer wins and losses per season versus before surgery. However, these pitchers also had a lower ERA and WHIP per season. In comparison with controls, pitchers who underwent UCL reconstruction had a lower ERA and WHIP, had a lower losing percentage, and gave up fewer hits per inning. The fewer wins and losses after UCL reconstruction could be explained by the fewer innings pitched because it is an MLB requirement to pitch a minimum of 5 complete innings before a pitcher earns a decision. This is very clinically relevant information when discussing postoperative expectations with players and coaches because both the longevity and quality of pitching are paramount to the success of a team.

Professional baseball is one of the most popular spectator sports in the United States with an annual revenue of $7.7 billion in 2012.[19] There were 389 pitchers on MLB rosters in 2012, with salaries ranging from $480,000 to $23,145,011. Thirty-five pitchers made $10 million or more in 2012, 82 pitchers made $5 million or more, and 216 pitchers made at least $1 million.[21] Hence, aside from a team morale and overall team performance perspective, the health and ability of pitchers in the MLB to perform at their expected level have a large monetary component and financial incentive.

Since its initial description, the Jobe "Tommy John" technique has undergone many modifications,[15,18] of which 4 have emerged as the most popular: DANE-TJ, docking, modified Jobe, and hybrid techniques. These technique modifications, increasing clinical experience, and biomechanical studies have demonstrated that UCL reconstruction can appropriately restore elbow stability and provide superior outcomes versus primary repair.[6,12] Reconstruction of the UCL is becoming a more popular procedure among professional athletes as the results of this procedure have demonstrated improved performance and outcomes over the past decade.[3,7] The findings in this study corroborated this trend, as there was a significantly increased incidence of UCL reconstructions in MLB pitchers since 2000 compared with the years prior. It is possible that such a trend may continue given the potential performance improvements associated with UCL reconstruction.

Despite the findings demonstrating a high rate of RTP at the highest level and superior outcomes on multiple performance measures, the authors caution surgeons on the

TABLE 4
Performance Comparison Before and After Index Year (Controls)[a]

	Before Index Year	After Index Year	*P* Value (Paired-Sample Student *t* Test)	95% CI
Innings pitched per game, n	3.80 ± 1.96	3.12 ± 1.88	.036	0.04 to 1.3
Innings pitched per season, n	85.3 ± 56.1	65.3 ± 51.7	.029	2.1 to 38
Games played per season, n	25.9 ± 13.7	24.2 ± 16.7	.499	–3.3 to 6.8
Wins per season, n	5.14 ± 3.60	2.98 ± 2.75	**<.001**	1.1 to 3.2
Wins (normalized to games played), %	23.0 ± 15.3	12.4 ± 11.5	**<.001**	6.1 to 15
Losses per season, n	4.57 ± 3.09	4.30 ± 2.94	.585	–0.73 to 1.3
Losses (normalized to games played), %	20.0 ± 13.9	22.8 ± 18.7	.318	–8.2 to 2.7
ERA per season	5.66 ± 2.73	6.36 ± 3.31	.173	–1.7 to 0.31
Complete games per season, n	0.625 ± 1.70	0.175 ± 0.355	.029	0.05 to 0.85
Complete games (normalized to games played), %	2.29 ± 5.59	0.73 ± 1.44	.023	0.22 to 2.9
Shutouts per season, n	0.202 ± 0.459	0.069 ± 0.164	.022	0.02 to 0.25
Shutouts (normalized to games played), %	0.79 ± 1.65	0.31 ± 0.752	.027	0.06 to 0.90
Saves per season, n	1.31 ± 4.33	1.32 ± 5.07	.987	–1.6 to 1.5
Saves (normalized to games played), %	3.0 ± 8.7	2.5 ± 8.4	.741	–2.4 to 3.3
Hits given up per season, n	86.2 ± 53.2	69.8 ± 49.4	.059	–0.65 to 34
Hits given up (normalized to IP)	1.03 ± 0.218	1.17 ± 0.343	.004	–0.23 to –0.04
Runs given up per season, n	39.5 ± 25.1	37.8 ± 26.0	.685	–6.7 to 10
Runs given up (normalized to IP)	0.536 ± 0.198	0.712 ± 0.412	**.002**	–0.29 to –0.07
Home runs given up per season, n	10.1 ± 6.75	8.71 ± 6.54	.202	–0.78 to 3.6
Home runs given up (normalized to IP)	0.121 ± 0.044	0.160 ± 0.112	.008	–0.07 to –0.01
Walks given up per season, n	33.1 ± 20.7	25.7 ± 16.4	.021	1.1 to 14
Walks given up (normalized to IP)	0.409 ± 0.117	0.461 ± 0.253	.118	–0.12 to 0.01
Strikeouts per season, n	62.3 ± 44.7	47.4 ± 38.9	.038	0.87 to 29
Strikeouts (normalized to IP)	0.724 ± 0.195	0.692 ± 0.213	.355	–0.04 to 0.10
WHIP per season	1.60 ± 0.415	1.70 ± 0.456	.162	–0.25 to 0.04

[a]Values are expressed as mean ± standard deviation. Bonferroni correction (15 items: .05/15 = <.0033). Bold indicates significantly better before than after index year ($P < .05$). ERA, earned run average; IP, innings pitched; WHIP, walks plus hits per inning pitched.

indications for UCL reconstruction in all levels of athletes. Currently, there are limited data on the outcomes of UCL reconstruction in high school and collegiate athletes. Common misperceptions that UCL reconstruction will improve an asymptomatic pitcher's skill are becoming more pervasive among media, athletes, parents, coaches, trainers, and agents.[1] Ahmad et al[1] found that 51% of high school and 26% of collegiate athletes believed that UCL reconstruction should be performed on players without injuries to enhance performance. To date, there are no data to support or even consider prophylactic UCL reconstruction to improve throwing velocity or prevent injuries in the future. For this reason, thorough discussions with athletes, parents, coaches, and trainers are paramount in gauging the expectations of the parties involved.

Relative rest periods and changes in pitching mechanics are often adequate to return the athlete to an asymptomatic state. In a retrospective review of 31 athletes with UCL injuries treated nonoperatively, Rettig et al[20] found that 42% were able to return to sport at the same preinjury level at a mean 24.5 weeks after diagnosis. For this reason, many advocate exhausting nonoperative treatment before pursuing surgical intervention. Despite this duration being much shorter than that of UCL reconstruction, the level of performance after returning to that level, using sport-specific outcome measures, was not determined.

Several clinical studies to date have demonstrated improved outcomes with UCL reconstruction. In a systematic review evaluating 8 outcome studies after UCL reconstruction, Vitale and Ahmad[22] found that 83% of athletes had an excellent outcome with an overall 10% complication rate. The most common complication was ulnar neuropathy. The muscle-splitting approach yielded better results than approaches using flexor-pronator takedown. In addition, abandoning obligatory ulnar nerve transposition yielded superior results. In the largest consecutive series to date, involving 942 athletes, Cain et al[3] found an 83% rate of return to the same or higher level of sport, similar to the findings in the present study. The mean time to return to full competition, however, was 11.2 months, which was a shorter duration than the findings in this study. There may have been pitchers who returned as a different type of pitcher (starter returned as a reliever, closer returned as a middle reliever, etc). For example, if a starter returned as a reliever, then not only would he likely pitch in fewer innings, but he could also have fewer wins and/or losses. In addition, the pitching style may have changed (ie, a fastball pitcher may have returned as a breaking ball pitcher). There were 2 players who were starting pitchers when they underwent surgery and then returned as closers and 1 player who returned as a middle reliever. All 3 of the pitchers pitched in fewer innings and had fewer wins and losses after surgery. It is possible that this occurred in more pitchers or that as their careers persisted, they changed pitching roles and/or styles. However, only 2 were identified from our search. This study only analyzed statistics for individual years for a limited

TABLE 5
Comparison of Data After UCL Reconstruction (Cases) Versus After Index Year (Controls)[a]

	Cases	Controls	*P* Value (Paired-Sample Student *t* Test)	95% CI
Seasons in MLB after surgery (or index year), n	3.89 ± 2.84	3.50 ± 2.68	.333	–0.40 to 1.2
Total innings pitched (or index year), n	282 ± 341	308 ± 330	.601	–123 to 72
Innings pitched per game, n	2.67 ± 1.91	3.12 ± 1.88	.104	–1.0 to 0.093
Innings pitched per season, n	58.7 ± 47.2	65.3 ± 51.7	.358	–21 to 7.5
Total games played (or index year), n	124 ± 136	104 ± 107	.278	–17 to 57
Games played per season (or index year), n	27.1 ± 16.7	24.2 ± 16.7	.244	–2.0 to 7.7
Total wins (or index year), n	16.2 ± 21.6	14.9 ± 18.4	.665	–4.7 to 7.3
Wins per season (or index year), n	3.33 ± 3.10	2.98 ± 2.75	.424	–0.51 to 1.2
Wins after surgery (or index year), %	14.9 ± 15.0	12.4 ± 11.5	.220	–0.02 to 0.07
Total losses (or index year), n	15.2 ± 18.7	18.9 ± 19.9	.184	–9.2 to 1.8
Losses per season (or index year), n	3.08 ± 2.72	4.30 ± 2.94	**.003**	–2.0 to –0.41
Losses after surgery (or index year), %	14.1 ± 13.8	22.8 ± 18.7	**<.001**	–13 to –4.3
ERA per season (or index year)	4.18 ± 1.36	6.36 ± 3.31	**<.001**	–3.0 to –1.34
Complete games per season (or index year), n	0.224 ± 0.529	0.175 ± 0.355	.492	–0.091 to 0.19
Complete games after surgery (or index year), %	0.85 ± 1.9	0.73 ± 1.4	.640	–0.39 to 0.63
Shutouts per season (or index year), n	0.091 ± 0.247	0.069 ± 0.164	.515	–0.043 to 0.086
Shutouts after surgery (or index year), %	0.35 ± 0.89	0.31 ± 0.75	.800	–0.21 to 0.28
Saves per season (or index year), n	2.13 ± 5.09	1.32 ± 5.07	.283	–0.67 to 2.3
Saves after surgery (or index year), %	5.6 ± 13	2.5 ± 8.4	.040	0.14 to 5.9
Hits given up per season (or index year), n	57.8 ± 47.4	69.8 ± 49.4	.089	–26 to 1.8
Hits given up after surgery (or index year) (normalized to IP)	1.01 ± 0.244	1.17 ± 0.343	**<.001**	–0.24 to –0.08
Runs given up per season (or index year), n	30.2 ± 23.5	37.8 ± 26.0	.033	–15 to –0.61
Runs given up after surgery (or index year) (normalized to IP)	0.641 ± 0.831	0.712 ± 0.412	.507	–0.28 to 0.14
Home runs given up per season (or index year), n	6.70 ± 5.21	8.71 ± 6.54	.016	–3.6 to –0.38
Home runs given up after surgery (or index year) (normalized to IP)	0.140 ± 0.137	0.160 ± 0.112	.284	–0.06 to 0.02
Walks given up per season (or index year), n	21.6 ± 15.7	25.7 ± 16.4	.081	–8.7 to 0.51
Walks given up after surgery (or index year) (normalized to IP)	0.487 ± 0.813	0.461 ± 0.253	.797	–0.17 to 0.22
Strikeouts per season (or index year), n	45.6 ± 38.0	47.4 ± 38.9	.756	–13 to 9.4
Strikeouts after surgery (or index year) (normalized to IP)	0.792 ± 0.254	0.692 ± 0.213	.005	0.03 to 0.17
WHIP per season (or index year)	1.39 ± 0.252	1.70 ± 0.456	**<.001**	–0.43 to –0.19

[a]Values are expressed as mean ± standard deviation. Bonferroni correction (15 items: .05/15 = <.0033). Bold indicates significantly better in cases than controls ($P < .05$). ERA, earned run average; IP, innings pitched; MLB, Major League Baseball; UCL, ulnar collateral ligament; WHIP, walks plus hits per inning pitched.

number of years before and after UCL surgery, so it is difficult to determine if this occurred in more pitchers, as this information was not readily available. Further studies evaluating the alterations in pitching role and style after UCL reconstruction would be beneficial. We must also address the possibility of selection bias. Although a comprehensive search of all MLB pitchers who underwent UCL reconstruction was performed, we did not search for minor league pitchers who underwent UCL reconstruction or for MLB pitchers who may have had a low grade or partial UCL tear not requiring surgery. Therefore, it is possible that these results may not apply directly to minor league pitchers and not apply to MLB pitchers managed nonoperatively.

In addition to clinical studies, multiple recent biomechanical studies evaluating the available techniques of UCL reconstruction have demonstrated varied results, with some techniques outperforming others.[5,11,14,15] A correlation between superior biomechanical performance and clinical/level of play performance, however, has yet to be fully elucidated.

Strengths of this study include its case-control comparative design and use of sport-specific performance parameters. In addition, demographic- and performance-matched controls were used as a comparison group. Limitations include the use of publicly available data, which can be subject to observer bias because of anticipated media and/or public scrutiny. However, the authors did cross-reference the publicly available data with the MLB player injury database. Further, this method of patient selection has been used in multiple high–evidence level studies published in sports medicine journals.[2,4,8,10,16,17] The exact extent of the UCL tear and concomitant injury (eg, ulnar neuritis, loose body, posteromedial osteophytes) and exact chronicity of the injury were not available for every athlete reviewed in this study. We did attempt to determine when pitchers underwent concomitant ulnar nerve transposition, what type of grafts were used (palmaris vs hamstring, autograft vs allograft), specific surgical technique used, and the rehabilitation protocol followed, but these data could not be found for each player. Inferences can be made based on the preferred surgical technique of the treating surgeon,

but without proof, the potential for inaccuracies would be too great. Further, no patient-reported or clinician-measured outcomes were available. This includes general health (eg, Short Form–36), joint-specific (eg, Simple Shoulder Test, American Shoulder and Elbow Surgeons score), and patient demographic-specific (eg, Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow Score) scores. Moreover, patient satisfaction and personal perception of elbow pain, function, and stability were unable to be assessed versus before injury. These factors may influence RTP performance. Information on surgical technique and geographic location of the treatment (hospital, city, state) was unobtainable for all pitchers from publicly available sources, although it can be inferred by the treating surgeon based on preferences expressed in publications and/or presentations. However, the accuracy and validity of this information are questionable and therefore lead to confirmation bias. Because of the high-profile nature of these athletes, they are unable to be easily contacted to assess these outcome measures. The current investigation has shown that the incidence of UCL reconstructions increased by year. Three reasons may account for this: (1) the infrequent utilization of electronic reporting of injuries during the early years of the study, (2) the less common divulgence of player injury information and status during the early years of the study, and (3) the more common recent use of social media in sports medicine by athletes themselves in reporting their injuries (Twitter and Facebook). Postoperative physical examination (eg, tenderness, valgus stress, laxity, special testing) and imaging (radiographic assessment of degenerative changes, magnetic resonance imaging assessment of graft and/or concomitant intra- or extra-articular damage) outcomes were unavailable. Additionally, the rehabilitation program utilized postoperatively was unavailable. Even though some players were unable to RTP in the MLB after UCL reconstruction, the inability to return cannot solely be attributed to the UCL injury and surgery, as other confounders inevitably coexist. Further, although all performance-based measures were used to compare preoperative and postoperative outcomes and between cases and controls, other intangible factors (team leadership, teammate motivation, etc) cannot be assessed for relationships.

CONCLUSION

There is a high rate of RTP in professional baseball after UCL reconstruction. Performance declined before surgery and improved after surgery. When compared with demographic-matched controls, patients who underwent UCL reconstruction had better results in multiple performance measures. Reconstruction of the UCL allows for a predictable and successful return to professional baseball.

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