Performance, Return to Competition, and Reinjury After Tommy John Surgery in Major League Baseball Pitchers

A Review of 147 Cases

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Background: Pitching performance metrics, durability, and reinjury after Tommy John surgery in professional baseball players have not been well described.

Purpose: The purpose of this study was to determine the likelihood of return to professional competition, reinjury rate, and change in performance after Tommy John surgery in Major League Baseball pitchers. The hypothesis was that performance metrics and durability will decline after surgery.

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

Methods: Publicly available records were accessed to generate a list of all Major League Baseball pitchers from 1999 to 2011 who had undergone ulnar collateral ligament reconstruction at any point in their careers; those with multiple reconstructive procedures were excluded. Return to active ($\geq$1 game) or established ($\geq$10 games) competition and/or placement on the disabled list was documented for each player. Among established players, pitching performance was compared pre- and postoperatively, as well as with age-matched control pitchers.

Results: Of 147 pitchers included, 80% returned to pitch in at least 1 Major League Baseball game. Only 67% of established pitchers returned to the same level of competition postoperatively, and 57% of established players returned to the disabled list because of injuries to the throwing arm. Finally, performance declined across several metrics after surgery compared with preinjury levels, such as earned run average, batting average against, walks plus hits per inning pitched, percentage of pitches thrown in the strike zone, innings pitched, percentage fastballs thrown, and average fastball velocity ($P < .05$ for all). However, these declines were not statistically different from similar declines found in age-matched controls who did not undergo Tommy John surgery.

Conclusion: Return to the disabled list after Tommy John surgery is common among professional pitchers (>50%), and performance declines across several major metrics after surgery. Patients undergoing Tommy John surgery should be counseled appropriately regarding the likelihood of return to preinjury levels of competition and performance.

Keywords: outcomes; ulnar collateral ligament reconstruction; professional baseball

Major League Baseball (MLB) pitchers in the United States are especially susceptible to injuries of the upper extremity,[11] and rupture of the ulnar collateral ligament (UCL) in these overhead athletes is one of the most notorious injuries in modern sports. Reconstruction of this ligament, known as "Tommy John surgery," is now considered a career-preserving procedure, allowing players at all levels, from Little League to MLB, to continue their careers. The surgery is named after Tommy John, the first player to undergo this procedure, performed in 1974 by Dr Frank Jobe. Since then, hundreds of professional baseball players, from all positions, have undergone this procedure, and many have returned to resume productive

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careers. According to a recently published study regarding public perception of Tommy John surgery,[1] many athletes and coaches perceive surgery as a means to enhance performance, even in healthy athletes. Therefore, reliable reporting of outcomes is paramount in providing accurate counseling (and setting realistic expectations) to patients and families considering UCL reconstruction.

Several studies have attempted to determine outcomes after Tommy John surgery among professional baseball pitchers. Many of these have been case series of select cohorts of patients,[5,8] while others have been reviews of public performance records of larger groups of players who have undergone this procedure.[6,7] Typically, however, only major metrics have been documented, such as return to competition or basic performance statistics after this return to competition. One recent study by Erickson et al[6] detailed return to both MLB and minor league competition, but rates of reinjuries, especially those warranting redesignation to the disabled list (DL), are still largely unknown. Therefore, despite the prevalence of this injury and subsequent reconstruction, there is still much that is unknown regarding healthy return to preinjury level of performance at the highest levels of competition.

This retrospective cohort study had 3 goals: (1) to determine the likelihood of return to MLB competition after Tommy John surgery in MLB pitchers, (2) to determine the likelihood of return to the DL after Tommy John surgery in MLB pitchers, and (3) to determine the change in pitching performance after return from Tommy John surgery in MLB pitchers compared with presurgery performance.

We hypothesized that return to major league competition would be lower than previously reported in smaller case series, while return to the DL would be a common occurrence in these elite athletes. Finally, we predicted that performance after surgery would decline compared with both preoperative levels and with a similar control cohort of age-matched pitchers.

MATERIALS AND METHODS

For this retrospective cohort study, we used information that was publicly accessible from a variety of references, including online databases, popular sports media, Web sites, and online press releases.

Player Inclusion and Participation in Major League Competition

A comprehensive list of all MLB pitchers who had undergone UCL reconstruction was obtained from multiple publicly available databases. These players included all pitchers who, at any point in their careers, (1) underwent UCL reconstruction and (2) appeared in $\geq$1 MLB game before surgery. We further defined "established players" as those pitchers who appeared in $\geq$10 MLB games during the course of a single season (either before or after surgery).

Two different online databases were used to identify pitchers who had undergone UCL reconstruction: Baseball Prospectus (http://www.baseballprospectus.com) and Baseball Heat Maps (http://www.baseballheatmaps.com). Information from these databases was verified against each other and through independent Web-based searches (http://www.google.com) of team press releases that confirmed the date of surgery for each player. This method of player inclusion has been used in prior studies.[5,7]

With regard to the timing of surgery, players from 1974 (marking the first occurrence of the procedure) through October 2012 were included for consideration in this study. However, players who underwent surgery after the midpoint of the 2011 season (defined as the date of the MLB All-Star Game, July 12, 2011) or later were excluded from outcome-related metrics (including return to the DL and performance metrics). This was done to exclude players who would not have had sufficient time (at least half a season) to fully rehabilitate and return to major league competition at the time of the study (which included pitcher outcomes through the 2012 season). Additionally, all players who underwent surgery before 1999 were also excluded, because this cohort consisted of players who underwent the surgery during its initial years. The surgical technique has since been modified with various techniques, and 1999 has been used as a base year in other studies as well.[7]

In this study, an age-matched control cohort of pitchers was identified to make comparisons regarding injury statistics (ie, return to the DL) as well as performance metrics. We determined that the median surgery year of the 147 surgeries studied was 2008. As a result, all pitchers who appeared in $\geq$1 game in 2008 were accessed from online databases (http://www.baseballinfosolutions.com and http://www.retrosheet.org). Then, we selected a subset of those pitchers who had pitched in $\geq$10 games in 2008 and also in 2009 to provide a comparison group for the study cohort of established players. Finally, pitchers were randomly selected to be included in the final control group on an age-matched basis. These potential control pitchers were divided into age groups as $<$25, 25-30, and $>$30 years and were randomly selected using Microsoft Excel (Microsoft Corp, Redmond, Washington, USA) in an approximate 2:1 ratio, with a goal of approximately 200 pitchers. Those control pitchers who had undergone prior UCL reconstruction were excluded. After inclusion and exclusion criteria were met, the final cohort of age-matched control pitchers numbered 192.

Return to Major League Competition

Each player was assessed on his ability to return to MLB competition after Tommy John surgery. Those who returned to $\geq$1 game postoperatively were considered to be "active" postoperatively. Players who appeared in $\geq$10 games in a single season were considered "established" players.

Each player who met the inclusion criteria (as defined earlier) was assessed for ability to return to MLB competition, either as an active player or as an established player, after surgery. Those who did not return to competition were also noted. Comparisons were made according to player age and status as a relief or starting pitcher.

Return to the DL

Only designations to the DL regarding injuries to the dominant, throwing arm were considered in this study. Those players who were established before and after surgery were considered in this analysis. Each pitcher was assessed for the frequency and number of designations on the DL. These designations were also documented for age-matched control players. For each unique designation to the DL, the precise cause of the visit was noted (elbow related or not). Comparisons were made between the number and frequency of visits preoperatively and postoperatively for pitchers who underwent Tommy John surgery, as well as those between all players with Tommy John surgery and age-matched control players.

Pitching Performance After Tommy John Surgery

Several independent statistical sources were used to verify player performance data both before and after surgery. Data for each pitcher were verified across 3 different statistical sources to maximize the accuracy of the information. These included Baseball Info Solutions/Retrosheet (http://www.fangraphs.com), the Elias Sports Bureau (http://www.espn.com), and STATS LLC (http://www.stats.com). A battery of statistics were collected for each pitcher and are listed in Appendix A (available online at http://ajsm.sagepub.com/supplemental).

Certain data categories were routinely reported only after 2002, such as total pitches, average pitches per inning, pitches per plate appearance, percentage of fastballs thrown, fastball velocity, and percentage of pitches thrown in the strike zone. Therefore, these data were not available for all players, which is reflected in the reporting of results.

Pitcher performance was collected only for games during which the pitcher was playing in an MLB game. Therefore, all minor league competition was excluded. Moreover, only established players before and after surgery were included in these calculations, to minimize the effect of outlier data. Additionally, data were collected in a span of 3 seasons of MLB competition before and after surgery. This window was chosen to reduce any natural effect of aging or fatigue that could affect performance metrics.

Performance outcomes were assessed in 3 different cases. In the first, the average performance for each category was compared both before and after surgery, across all players. In the second case, performance only for the year preceding surgery and the year after surgery was compared. Finally, in the third scenario, performance data from the year preceding surgery were compared with those from the second year after return from surgery.

In addition to the average performance across all players, individual performance improvement or decline in a given category was noted for each player. The percentage of players who declined within a given category was then calculated according to the 3 time scenarios used in the average performance reporting. Therefore, individual performance was noted (1) before and after surgery, (2) 1 year before and 1 year after surgery, and (3) 1 year before and 2 years after surgery.

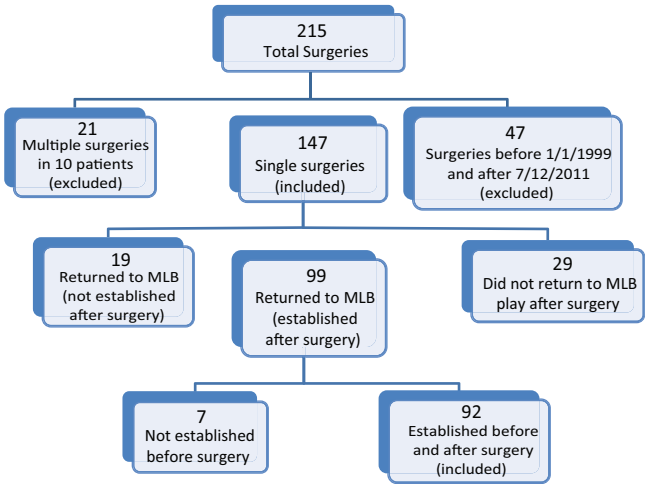

Figure 1. Return to active major league competition. Of the 147 pitchers included in this assessment, 118 (80%) were able to return to major league competition after surgery, while 20% did not return to major league play. MLB, Major League Baseball.

Statistical Methods

Paired *t* tests were performed on average performance data comparisons before and after surgery. A 5% level of significance was used for these continuous data. All statistical analyses were performed using SPSS version 19 (IBM Corporation, Armonk, New York, USA). Analyses comparing multiple groups of whole-number data, such as the proportion of pitchers who were designated to the DL before surgery compared with those designated after surgery, were completed using Fisher exact test or χ^2 analysis as appropriate. P values $< .05$ were considered to indicate statistical significance.

RESULTS

Return to Major League Competition

A total of 215 incidents of Tommy John surgery in MLB players were identified in this study, from the index surgery in 1974 through October 2012. All players appeared in $\geq$1 MLB game before surgery. This included 10 players who underwent multiple surgeries (accounting for 21 total procedures) (Figure 1). Additionally, 34 surgeries were performed in players after July 12, 2011, along with 13 performed before 1999, and these were also excluded from consideration. Therefore, 147 players were included in this review, and the average age of these players was 28.2 years (range, 21-48 years).

All 147 players were considered active before undergoing Tommy John surgery (ie, they each appeared in $\geq$1 MLB game before surgery). Among these players, 29 (20%) failed to return to MLB competition, 19 (13%) returned only to active status (failing to appear in $\geq$10 games in a single season), and the remaining 99 (67%)

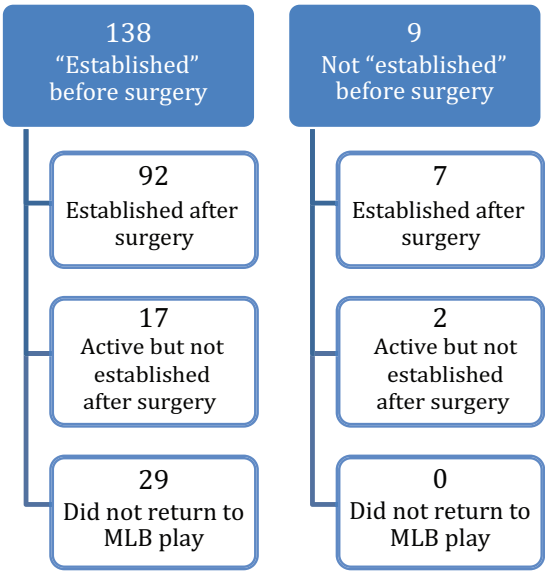

Figure 2. Return to ''established'' play, defined as appearing in ≥10 games during the course of a single season. For those pitchers who were established before surgery (n = 138), there was a 67% chance of returning to established play after surgery. MLB, Major League Baseball.

returned to established play after surgery. Players who returned to MLB competition returned at an average of 16.8 months after surgery, and the average age of these players was 28.3 years. Starters and relief pitchers returned to play in similar proportions, as did pitchers who were ≥28 years of age compared with those <28 years of age (P = .55 and P = .49, respectively).

Among this cohort of 147 pitchers, 138 were considered to have been established before surgery, appearing in ≥10 games in any single season (Figure 2). Of these 138 established players preoperatively, 92 (67%) returned to the established level of competition after surgery. An additional 17 players (12%) returned to MLB competition but not at the established level. Finally, 29 players (21%) failed to return to MLB competition after surgery, despite being established players before surgery.

Return to the DL

Return to the DL was documented for all players who were established (≥10 games in any given season) before and after surgery (n = 92). The reason for return to the DL was documented as either a condition specific to the dominant, throwing elbow or a condition related to the dominant, throwing arm (but not including elbow-related conditions, denoted as "non-elbow" injuries).

Among the cohort of 92 players who underwent surgery, rate of return to the DL was noted both before and after surgery. Before surgery, a total of 68 players (74%) went to the DL because of injury to the dominant arm (Figure 3). Fifty-three players (58%) went to the DL for elbow-related injuries, while 15 players (16%) went for non–elbow related injuries to the throwing arm. Postoperatively, 52 of 92 players (57%) went to the DL because of injuries to the throwing arm (P = .02). This included 24 players (26%) with elbow injuries and 28 players (30%) with non-elbow injuries. The difference in elbow and non-elbow injuries between the preoperative group and the postoperative group was statistically significant (P = .0005; Figure 4). In total, considering both pre- and postoperatively, 80 players (87%) went to the DL for injuries to the throwing arm; 63 different players went to the DL at least once for elbow injuries (68.5%), whereas 17 (18.5%) went only for non-elbow injuries (except for the designation related to the Tommy John surgery itself).

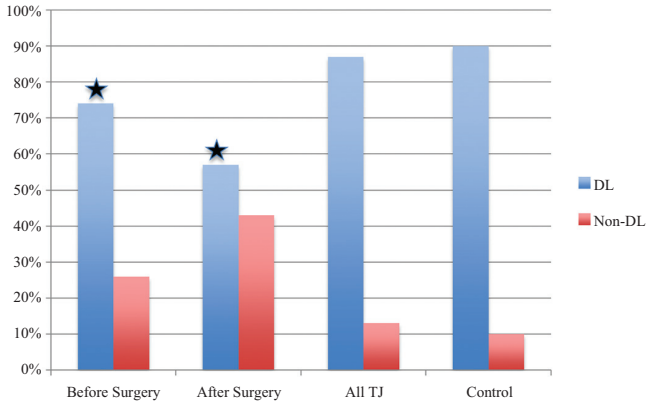

Figure 3. Designation to the disabled list (DL). Among the 92 pitchers who underwent Tommy John (TJ) surgery, a total of 80 (87%) were designated to the DL at any time for injury to the dominant arm (not including designation for TJ surgery). Preoperatively, this included 68 players (74%), and postoperatively, this included 52 players (57%). In the 192 control players, a total of 172 (90%) went to the DL for injuries to the throwing arm. *denotes statistical significance (P < .05).

DL visits were recorded for the cohort of 192 control pitchers as well. Among these players, a total of 172 (90%) visited the DL for any reason related to the throwing arm. Moreover, 97 (51%) went to the DL at least once with elbow injuries, while the remaining 75 (39%) went for non-elbow reasons related to the throwing arm. When considering the total number of trips to the DL for throwing arm–related reasons (both elbow and non-elbow), no statistically significant difference was found between players from the Tommy John cohort and the control cohort (P = .55). However, a higher proportion of players in the Tommy John cohort went to the DL for injuries to the elbow (63 of 92 players vs 97 of 192 players, P = .005).

In addition to calculating the number of unique players who went to the DL from both cohorts, the frequency of trips per player was also noted. In the Tommy John cohort, there were a total of 168 visits preoperatively (Figure 5), with 95 trips for elbow injuries and 73 non-elbow trips. This corresponded to frequencies of 1.83, 1.03, and 0.79 trips per player for total visits, elbow visits, and non-elbow

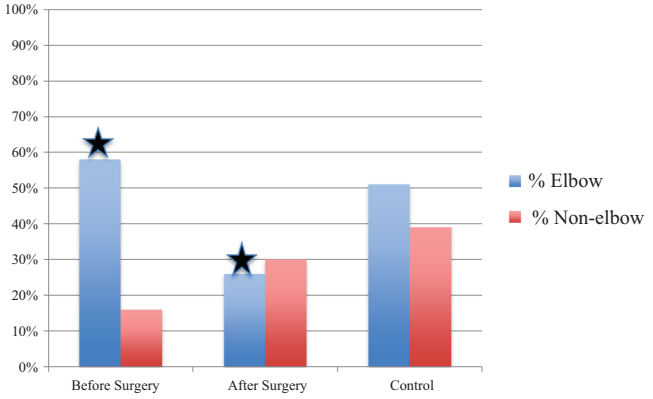

Figure 4. Elbow versus non-elbow injury in players designated to the disabled list (DL). Preoperatively, 53 players (58%) in the Tommy John cohort went to the DL for elbow-related injuries, compared with only 24 players (26%) postoperatively ($P = .0005$). * denotes statistical significance ($P < .05$).

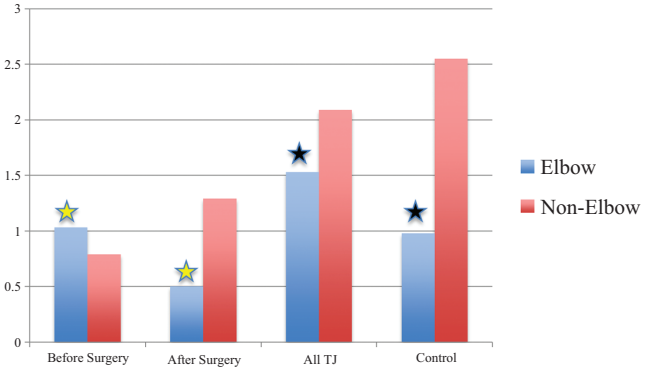

Figure 5. The frequency of visits to the disabled list (DL) for elbow injury was significantly higher preoperatively for players with Tommy John (TJ) surgery compared with after return (1.03 vs 0.5 trips per player, $P = .002$). In total, the frequency of elbow injury was higher in the players with TJ surgery compared with controls (1.53 vs 0.98 trips per player, $P = .004$). *denotes statistical significance ($P < .05$).

visits, respectively. Postoperatively, there was a total of 165 trips (46 elbow and 119 non–elbow), with frequencies of 1.79, 0.50, and 1.29 trips per player, respectively. The frequency of elbow-related trips to the DL was significantly lower after surgery compared with before surgery (1.03 vs 0.50 trips per player, $P = .006$). Among the 92 players in the Tommy John cohort, the total number of DL trips both pre- and postoperatively was 333, with 141 elbow-related trips and 192 non–elbow related trips, corresponding to frequencies of 3.62, 1.53, and 2.09 trips per player, respectively.

Among the 192 control players, there were a total of 678 trips to the DL, with 189 elbow-related trips and 489 non–elbow related trips. The corresponding frequencies were 3.53, 0.98, and 2.55 trips per player, respectively. Statistically, there was a lower frequency of elbow-related trips in control players (0.98 vs 1.53 trips per player, $P = .004$).

Performance Outcomes After Surgery

Performance data were collected in several different performance categories (see Appendix A, available online), and these statistics were compared across all pitchers who were established before and after surgery (n = 92) and inclusive of 3 years of statistics both before and after surgery. These comparisons were made in 3 different scenarios: (1) before and after surgery, (2) 1 year before and 1 year after surgery, and (3) 1 year before and 2 years after return from surgery.

Performance Before and After Surgery

When considering performance before surgery compared with performance after return (maximum 3 years before and after), performance declined in virtually every category (Table 1). Notably, there were statistically significant declines in earned run average (ERA) (from 4.23 before surgery to 4.63 after surgery, $P = .027$), batting average against (from .249 to .257, $P = .046$), walks plus hits per inning pitched (WHIP) (from 1.368 to 1.432, $P = .029$), and percentage of pitches thrown in the strike zone (from 51.9% to 49.6%, $P < .001$). Additional declines included innings pitched (from 94.3 to 77.3, $P = .001$), percentage fastballs thrown (from 63.9% to 59.0%, $P < .001$), and average fastball velocity (from 91.2 to 90.8 mph, $P = .023$). Additional comparisons were made among the Tommy John cohort according to age and status as a starter or relief pitcher (see Appendix B, available online).

Performance 1 Year Before and 1 Year After Surgery. When comparing only the year before surgery and the year after surgery (Table 2), all statistical categories again showed declines after surgery. However, only 3 metrics demonstrated statistically significant declines in the year after surgery compared with the year preceding surgery. These metrics included percentage of pitches thrown in the strike zone (from 51.4% to 48.5%, $P < .001$), innings pitched (from 85.5 to 72.7, $P = .035$), and percentage fastballs thrown (from 62.8% to 60.4%, $P = .027$).

Performance 1 Year Before and 2 Years After Surgery. There were 70 pitchers with performance data available 1 year before surgery and in the second season after surgery (Table 3). In these players, the number of pitches actually increased when comparing the second year after surgery with the year immediately before surgery (from 1280 to 1539, $P = .031$). This was associated with an increase in innings pitched (from 84.1 to 89.3), but this difference was not statistically significant ($P = .448$). There were select categories with performance declines, however, including percentage of pitches thrown in the strike zone (from 52.5% to 49.1%, $P < .001$) and percentage fastballs thrown (from 64.9% to 60.9%, $P = .001$). Among metrics that showed a modest decline (yet not statistically significant) in the second year after surgery were ERA (from 4.16 to 4.46, $P = .22$) and WHIP (from 1.343 to 1.398, $P = .213$).

Comparison With Age-Matched Controls. Comparisons were made between the change in performance after surgery and the change in performance with time in the

TABLE 1
Average Performance Before and After Surgery[a]

Statistic	Before Surgery	After Surgery	*P*
ERA[b]	4.23	4.63	.027
Batting average against pitcher[b]	.249	.257	.046
Strikeout-to-walk ratio[b]	2.34	2.29	.642
Strikeouts per 9 innings[b]	7.49	7.27	.191
WHIP[b]	1.368	1.432	.029
Average pitches per inning[c]	16.6	16.9	.081
Average pitches per plate appearance[c]	3.89	3.88	.797
Percentage of pitches thrown in the strike zone[c]	51.9	49.6	<.001
Innings pitched (season)[b]	94.3	77.3	.001
Total pitches (season)[c]	1449	1274	.082
Percentage fastballs thrown[c]	63.9	59.0	<.001
Average fastball velocity, mph[c]	91.2	90.8	.023

[a]After return from surgery, average performance significantly declined in several metrics, such as earned run average (ERA), batting average against, walks plus hits per inning pitched (WHIP), and percentage of pitches thrown in the strike zone. There were also declines in the number of innings pitched per season, the percentage of fastballs thrown, and average fastball velocity.
[b]n = 92 pitchers.
[c]n = 66 pitchers.

TABLE 2
Performance 1 Year Before Surgery Compared With 1 Year After Return[a]

Statistic	Before Surgery	After Surgery	*P*
ERA[b]	4.33	4.60	.257
Batting average against pitcher[b]	.248	.258	.072
Strikeout-to-walk ratio[b]	2.33	2.27	.563
Strikeouts per 9 innings[b]	7.51	7.27	.256
WHIP[b]	1.373	1.432	.12
Average pitches per inning[c]	16.5	16.9	.068
Average pitches per plate appearance[c]	3.85	3.88	.462
Percentage of pitches thrown in the strike zone[c]	51.40	48.50	<.001
Innings pitched (season)[b]	85.5	72.7	.035
Total pitches (season)[c]	1336	1202	.241
Percentage fastballs thrown[c]	62.80	60.40	.027
Average fastball velocity, mph[c]	91.0	90.8	.124

[a]Performance significantly declined as measured by percentage of pitches thrown in the strike zone, innings pitched, and percentage fastballs thrown. ERA, earned run average; WHIP, walks plus hits per inning pitched.
[b]n = 92 pitchers.
[c]n = 66 pitchers.

cohort of 192 age-matched control players (Table 4). When considering the 3-year pre- and postoperative period in the Tommy John cohort along with a similar period among control pitchers, virtually all statistical categories showed similar changes in performance. The decrease in innings pitched among players with Tommy John surgery was greater than that experienced by control pitchers (a 17- vs 6-inning decline), and this difference approached statistical significance ($P = .06$). When considering the years before and after surgery, there were no statistical differences in performance change among the Tommy John and control cohorts. When considering the year before surgery and the second year after return, some improvements were seen in the Tommy John cohort that were not noted in control pitchers. These included total pitches (+259 vs −144, $P = .004$) and innings pitched (+5.2 vs −9.1, $P = .07$), along with percentage of pitches thrown in the strike zone (−3.36% vs −4.53%, $P = .055$). Control players did demonstrate improvement in strikeouts per 9 innings compared with the Tommy John cohort (+0.14 vs −0.43, $P = .05$).

Individual Performance Before and After Surgery

Using the same comparative time points for the group performance analysis (ie, before and after surgery, 1 year before and 1 year after surgery, and 1 year before and 2 years after surgery), individual improvements and declines in performance were measured across all pitchers.

When considering performance up to 3 years pre- and postoperatively (Appendix C, available online), the proportion of players in the Tommy John cohort who experienced declines in performance was calculated across all metrics.

TABLE 3
Performance 1 Year Before Surgery Compared With 2 Years After Return[a]

Statistic	Before Surgery	After Surgery	P
ERA[b]	4.16	4.46	.22
Batting average against pitcher[b]	.244	.25	.318
Strikeout-to-walk ratio[b]	2.4	2.22	.215
Strikeouts per 9 innings[b]	7.68	7.25	.093
WHIP[c]	1.343	1.398	.213
Average pitches per inning[c]	16.4	16.7	.222
Average pitches per plate appearance[c]	3.84	3.87	.392
Percentage of pitches thrown in the strike zone[c]	52.50	49.10	<.001
Innings pitched per season[b]	84.1	89.3	.448
Total pitches per season[c]	1280	1539	.031
Percentage fastballs thrown[c]	64.90	60.90	.001
Average fastball velocity, mph[c]	91.2	91.1	.722

[a]Whereas several metrics demonstrated declines in the second year after return from surgery, some metrics showed improvements. These included number of pitches (statistically significant) and innings pitched (not statistically significant). ERA, earned run average; WHIP, walks plus hits per inning pitched.
[b]n = 70 pitchers.
[c]n = 47 pitchers.

The highest likelihood of decline in performance was noted in average pitches per innings, percentage of pitches thrown in the strike zone, innings pitched, and percentage fastballs thrown. In these respective categories, 62%, 83%, 69%, and 77% of players experienced declines postoperatively. When assessing performance in the year immediately after return from surgery, compared with the year before surgery (Appendix D, available online), there were similar declines in pitches per inning (declines in 62% of players), percentage of pitches thrown in the strike zone (71%), and innings pitched (63%).

When considering performance 1 year before surgery and in the second year after return from surgery, certain statistical categories actually demonstrated higher likelihoods for improvement after return to play (Appendix E, available online). This was most notable in innings pitched, in which only 39% of players experienced declines in performance during their second year after surgery, as well as total pitches, in which only 28% of players experienced declines in the second season after return (compared with the year before surgery). A majority of players also experienced improved fastball velocity in this second year after return from surgery.

DISCUSSION

This review of 147 MLB pitchers is among the first such studies to report on detailed return to competition and the DL after Tommy John surgery in these elite athletes, in addition to reporting on detailed performance metrics pre- and postoperatively. We found that although a majority of players were able to return to MLB competition after surgery (approximately 80%), a large number of players (>30%) who were established performers before surgery (appearing in ≥10 games during a single season) were unable to return to a similar level of competition postoperatively. Moreover, a majority of players returned to the DL after surgery for conditions related to the throwing arm. Finally, there were declines in several major statistical performance and durability categories after surgery across all players, with a majority of players declining compared with their preoperative performance levels. This contradicts prior studies of performance after Tommy John surgery in this patient population.

Return to competition is one of the most documented metrics of success after UCL reconstruction. These rates have typically been reported as the ability to return to preinjury level of competition and have been reported to be approximately 70% to 80%,[2,3,7,8,12] but some studies have reported rates as high as 90% to 95%.[4,9,10] However, these studies have examined only return to competition and have not reported degree of competitiveness or performance metrics. Our study similarly reports on this return to competition (with 80% of players appearing in ≥1 game at the major league level postoperatively) but additionally stratifies to report return to established competition (ie, appearance in ≥10 games during a single season after surgery). We report that only 67% of players who were established competitors before surgery returned to similar levels of competition postoperatively, and this represents a rate at the lower end of the spectrum of reported results. Such reporting of rates of return to established competition, as was done in our study, may be more relevant in defining "successful" return to competition postoperatively rather than simply documenting rates of return to competition in general.

This study reports for the first time, to our knowledge, detailed rates of return to the DL after return from Tommy John surgery in professional baseball pitchers. We noted that >50% of players returned to the DL because of injuries to the throwing arm after their return from surgery, with 26% returning to the DL for injuries specific to the elbow. However, we did note a decrease in the likelihood

TABLE 4
Pitching Performance in Tommy John and Control Cohorts[a]

Variable	Pitchers With Tommy John Surgery		Control Pitchers		
	n	Difference in Performance	n	Difference in Performance	*P*
3 y before surgery and 3 y after return					
ERA	92	0.39	192	0.25	.515
Batting average against pitcher	92	0.008	192	0.007	.809
Strikeout-to-walk ratio	92	–0.05	192	–0.07	.89
Strikeouts per 9 innings	92	–0.22	192	–0.25	.889
WHIP	92	0.063	192	0.062	.97
Average pitches per inning	66	0.3	192	0.3	.887
Average pitches per plate appearance	66	–0.01	192	0.01	.517
Percentage of pitches thrown in the strike zone	66	–2.33	192	–3.51	.205
Innings pitched per season	92	–17.0	192	–5.9	.059
Total pitches per season	66	–176	192	–96	.453
Percentage fastballs thrown	66	–4.94	192	–3.72	.327
Average fastball velocity	66	–0.4	192	–0.2	.308
1 y before surgery and 1 y after return					
ERA	92	0.26	192	0.29	.935
Batting average against pitcher	92	0.010	192	0.007	.623
Strikeout-to-walk ratio	92	–0.07	192	–0.08	.941
Strikeouts per 9 innings	92	–0.24	192	–0.12	.631
WHIP	92	0.059	192	0.062	.952
Average pitches per inning	66	0.4	192	0.3	.494
Average pitches per plate appearance	66	0.03	192	0.01	.453
Percentage of pitches thrown in the strike zone	66	–2.81	192	–1.93	.087
Innings pitched per season	92	–12.8	192	–3.4	.118
Total pitches per season	66	–135	192	–54	.435
Percentage fastballs thrown	66	–2.38	192	–1.84	.665
Average fastball velocity	66	–0.3	192	0.2	.149
1 y before surgery and 2 y after return					
ERA	70	0.30	145	0.10	.477
Batting average against pitcher	70	0.006	145	0.001	.434
Strikeout-to-walk ratio	70	–0.18	145	0.04	.338
Strikeouts per 9 innings	70	–0.43	145	0.14	.047
WHIP	70	0.055	145	0.031	.637
Average pitches per inning	47	0.3	145	0.2	.794
Average pitches per plate appearance	47	0.04	145	0.02	.55
Percentage of pitches thrown in the strike zone	47	–3.36	145	–4.53	.055
Innings pitched per season	70	5.2	145	–9.1	.066
Total pitches per season	47	259	145	–144	.004
Percentage fastballs thrown	47	–4.09	145	–2.98	.452
Average fastball velocity	47	–0.1	145	–0.1	.916

[a]Compared with control pitchers, pitchers who underwent Tommy John surgery experienced similar declines with time in most statistical categories. However, when considering the year before surgery and the second year after return, pitchers with surgery demonstrated improvements in total pitches and innings pitched. ERA, earned run average; WHIP, walks plus hits per inning pitched.

of DL designation for injuries in the throwing arm postoperatively, from 74% to 57% ($P = .02$). Moreover, there was a significant decrease in the DL return rate postoperatively for elbow injury, from 58% to 26%. Surprisingly, the likelihood of designation to the DL for throwing arm injury in the players who ultimately underwent Tommy John surgery (87%) was similar to that in control players (90%). However, there was a significantly higher likelihood of having an elbow injury in the Tommy John cohort (69% vs 51%, $P < .001$). These rates of return to the DL may be relayed to players and teams when counseling pitchers regarding future injury risk after Tommy John surgery.

When considering return to competition, we identified an average length of recovery to be approximately 16.8 months, which is similar to the study by Gibson et al[7] (who reported return at 18.5 months). These times to return are longer than those found in other prior reports, such as 11.6 months by Cain et al,[3] 11.5 months by Paletta and Wright,[10] and 13.1 months by Koh et al.[9] This is likely due to our definition of return to competition as the date of return to competition in MLB (as opposed to semiprofessional or minor league play). Therefore, players from our study likely returned to "rehabilitation" play in the minor leagues, but this return was not considered a successful

return in our study (or the Gibson et al[7] study). Because our study focused only on MLB players, we believe that the return to MLB play should be documented to accurately reflect the average time needed to return to the preinjury level of competition.

In this review, several established performance metrics were compared before and after surgery, encompassing a period of up to 3 years before surgery and 3 years after surgery. During this assessment, we found statistically significant declines in performance across several different metrics. For example, we found significant declines in performance statistics of ERA, batting average against, WHIP, and percentage of pitches thrown in the strike zone; other notable findings included declines in innings pitched, percentage fastballs thrown, and average fastball velocity. Although these declines were statistically significant, the players were still able to maintain a comparable change in level of performance compared with "control" pitchers who did not undergo UCL reconstruction.[7] Therefore, although pitchers experienced declines in many performance metrics after surgery, these declines were similar to control pitchers' declines with similar time frames. Of note, when comparing the second year after return from Tommy John surgery in the year immediately preceding surgery, certain performance metrics (namely, total pitches) showed improvements compared with data from the year immediately preceding surgery. This finding may indicate a relative drop in performance leading up to Tommy John surgery that recovers, in some metrics, only at the second season after return.

The findings from this study appear to contradict those of Gibson et al[7] and Erickson et al,[6] who reported no statistically significant declines in ERA or WHIP in the postoperative period. With regard to innings pitched, Gibson et al[7] reported a significant postoperative decline, from 97.10 innings preoperatively to 70.2 innings postoperatively. In our study, we reported a similar finding, with innings pitched declining to 77.3 from 94.3 before surgery. However, when comparing the season before Tommy John surgery with the second season after return from surgery, there was actually an increase in innings pitched in these players, signifying a possible decrease in durability immediately preceding surgery that then recovered in the second season after return from surgery. Moreover, the study by Gibson et al[7] was limited in its reporting of outcomes postoperatively, including only innings pitched, ERA, and WHIP. Our study included a number of performance and durability-related metrics, as well as reporting of the frequency of return to the DL after surgery. Erickson et al[6] actually showed improvements postoperatively in various key metrics among pitchers undergoing Tommy John surgery. Although their study similarly drew from publicly available information, they included a larger cohort of pitchers (pitchers who appeared in $\geq$1 MLB game) and included data spanning the course of these pitchers' careers. These methodologic differences may help explain the difference in outcomes when comparing our findings. Additionally, our study reported on the likelihood of improvement or decline in performance within these categories according to individual players. For example, we reported that compared with metrics from the year before surgery, a majority of players declined in virtually all 12 performance metrics in the year after surgery. This finding has not been reported in the literature to date. Moreover, such data can help provide realistic expectations to players and teams when measuring the success of Tommy John surgery with regard to performance postoperatively. Additional strengths of our study included the reporting of performance outcomes only in players who had pitched in $\geq$10 games in a season both before and after surgery. This served to minimize outlier data from players who only appeared in a single game (or very few games) pre- or postoperatively.

This study does have limitations. Because this was a review reliant on public information, the data were governed by the content of these public databases. It is possible that there were players who were not included in these databases and therefore may have been excluded from our study. There may have been additional players that were listed on a team's roster but did not appear in any games before or after surgery; these players would have been excluded as well. However, by verifying our player inclusion list across 3 different databases, the likelihood of erroneous exclusion was minimized.

Additionally, all data relating to DL visits and performance metrics were retrieved from similarly public databases. There is a possibility of inaccuracy in these databases; however, standardized data collection in this study across all players helped limit any effect on outcomes from this theoretical possibility.

Another limitation involves reporting of the nature of injuries resulting in DL designations. Attempts were made to identify precise reasons for visits (ie, medial elbow injury, lateral epicondylitis); however, these designations were often solely listed according to anatomic part (eg, forearm, shoulder, elbow). Therefore, we were unable to identify repeat injuries to the medial elbow and/or UCL in both surgical and control pitchers.

Finally, we primarily investigated outcomes of established MLB pitchers, who represent the highest echelon of competitive participation. As such, these results may not be generalizable to pitchers at other levels of competition.

CONCLUSION

Although professional pitchers return to MLB competition after Tommy John surgery, return to established and durable levels of competition is less guaranteed. Moreover, the majority of players return to the DL at least once after surgery for recurrent injuries to the throwing arm. Finally, we found that several key performance metrics actually declined after return from surgery, which contradicts many prior studies that used significantly smaller cohorts. These declines were similar to age-matched controls, however. Given the potential inaccuracies in public perceptions of outcomes after Tommy John surgery,[1] it is important to provide accurate outcomes data in these athletes to provide

effective and practical counseling to patients considering the procedure.

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