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# Outcomes in revision Tommy John surgery in Major League Baseball pitchers



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**Background:** With the recent rise in the number of Tommy John surgeries, a proportionate rise in revisions is expected. However, much is unknown regarding the current revision rate of Tommy John surgery, return to play, and change in performance in Major League Baseball (MLB) pitchers.

**Methods:** Publicly available databases were used to obtain a list of all MLB pitchers who underwent primary and revision Tommy John surgery. Pitching performance preoperatively and postoperatively for pitchers who returned to 1 or more MLB games after revision surgery was compared with controls matched for age and position.

**Results:** Since 1999, 235 MLB pitchers have undergone Tommy John surgeries; 31 pitchers (13.2%) underwent revision surgery, and 37% underwent revision within 3 years of the index procedure. Twenty-six revisions had more than 2 years of follow-up; 17 pitchers (65.4%) returned to pitch at least 1 major league game, whereas only 11 (42.3%) returned to pitch 10 or more games. Of those who returned to MLB competition, the average length of recovery was 20.76 months. Compared with controls matched for age and position, MLB pitchers undergoing revision surgery had a statistically shorter career after revision surgery (4.9 vs 2.6 seasons,  $P = .002$ ), pitched fewer innings, and had fewer total pitches per season.

**Conclusions:** The rate of revision Tommy John surgery is substantially higher than previously reported. For MLB pitchers, return to play after revision surgery is much lower than after primary reconstruction. The overall durability of MLB pitchers after revision ulnar collateral ligament reconstruction decreases significantly compared with controls matched for age and matched controls.

**Level of evidence:** Level III, Retrospective Cohort Design, Treatment Study.

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**Keywords:** Ulnar collateral ligament; Tommy John surgery; Major League Baseball; pitching; revision; return to sport

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The perception of elbow ulnar collateral ligament (UCL) reconstruction, colloquially known as Tommy John surgery, has dramatically changed since its conception in 1974 when Dr Frank Jobe first performed the operation.<sup>13</sup> Once considered a career-ending injury, the advent of newer surgical techniques<sup>2,5</sup> and refinement through the

years has cultivated improved outcomes in high performing overhead throwing athletes such as Major League Baseball (MLB) pitchers, with up to 90% of athletes successfully returning to competitive play.<sup>7,14,20-22</sup> The modern success of Tommy John surgery has even skewed a significant portion of the public into believing that UCL reconstruction should be performed as a prophylactic procedure to enhance performance in an uninjured athlete.<sup>1</sup> Predictably, these perceived outcomes have also been associated with a rapid increase in the frequency of reconstructions performed at the professional level as well as in high school-aged and younger athletes,<sup>10,19</sup> suggestive of an epidemic.<sup>9</sup>

With the recent rise in total number of Tommy John surgeries, a proportionate rise in revision procedures is to be expected. Prior studies have suggested that the revision rate is small, reporting rates between 1% and 3.9%,<sup>4,10,15,18</sup> and have largely excluded these cases from their analyses. Limited data are available on revision outcomes in MLB pitchers. To date, only 3 small case series have investigated their performance metrics after return from revision surgery.<sup>6,12,16</sup> Thus, although recent studies have more clearly elucidated the functional outcomes of primary Tommy John surgery in MLB pitchers, much is still unknown regarding the outcomes surrounding revision surgery.

We sought to determine (1) the current revision rate of Tommy John surgery in MLB pitchers, (2) the likelihood of return to MLB pitching after revision Tommy John surgery, and (3) the change in performance after Tommy John revision surgery. We hypothesized that revision rates in MLB pitchers are higher than previously reported and that performance metrics and durability would decrease after surgery.

## Materials and methods

### Player inclusion

We performed a retrospective review of all MLB pitchers with UCL injuries requiring reconstruction. The comprehensive list was obtained from multiple publicly available databases and included all pitchers who underwent UCL reconstruction surgery after appearing in 1 or more MLB games. Player information, including profiles, surgery dates, return dates, and performance metrics, were cross-referenced through MLB team Web sites and publicly available Internet-based reports ([fangraphs.com](http://fangraphs.com), [baseball-prospectus.com](http://baseball-prospectus.com)). This method of data collection has been used in previously published literature.<sup>8,10-12,15,16</sup>

MLB pitchers undergoing Tommy John surgery from the 1974 to 2014 were included for initial consideration in this study. For the purposes of calculating modern trends and revision rate, players with Tommy John surgeries occurring before 1999 (base year in previous studies) were excluded from the revision rate calculation to account for modern modifications to the surgical technique.<sup>11,15</sup> Thus, the time frame for analyzing revision rate was 1999 to 2014.

### Control group selection

Control pitchers were selected in a blinded process from a group of age-matched and position-matched MLB pitchers. Starting with the complete database of MLB pitchers, players were first excluded from the group of possible controls if they had a known history of revision UCL reconstruction. After a blinding process, players were then selected based on the year of revision UCL reconstruction for the respective pitcher in the original cohort, designated as the index year. After matching for index year, the control pitchers were also selected based on age during the index year, within 1 year of the age of the respective player in the revision cohort, and also by position (starting vs relief pitcher). The final matched control was selected via a randomized selection of the remaining players matched for age and position to create a 1:1 ratio of control vs revision UCL pitchers.

### Return to MLB

All revision UCL reconstructions performed on MLB pitchers were considered for the performance analysis. Time between revision and return to play was defined as the length of time between the date of revision surgery and the first MLB game after surgery. Pitchers who underwent revision surgery after 2012, however, were excluded because these players would not have had enough time to rehabilitate and return to MLB competition at the time of analysis.<sup>10</sup> This also allowed all analyzed players to have at least 2 years of follow-up from their revision surgery date. A return to active play was defined as participating in 1 or more MLB games after revision surgery. A successful established return was further defined as at least 10 games pitched after revision in 1 season, regardless of position at return (starter or reliever).<sup>15</sup> The first revision Tommy John surgery was performed in 1996; thus, the final cohort for performance analysis was 1996 to 2012.

### Pitching performance after revision Tommy John Surgery

Several independent online statistical sources were used to verify player performance before and after revision surgery. This method of data collection has been used in prior literature.<sup>8,10-12,15,16</sup> Collected statistics and their definitions are listed in [Appendix A](#). These statistics were also collected for control pitchers during the same time periods.

Certain statistics were only routinely collected after 2002. These categories included total pitches thrown, average pitches per inning, average pitches per plate appearance, percentage of fastballs thrown, fastball velocity, and percentage of pitches thrown in the strike zone. These data were not available for all players, and this absence is reflected in the Results section. In addition, the standardization of certain metrics (percentage pitches thrown in the strike zone, percentage fastballs thrown, and fastball velocity) changed after 2007 with the introduction of PITCHf/x (Sportvision, Chicago, IL, USA). Before 2007, those metrics were collected by Baseball Info Solutions (Coplay, PA, USA) and not standardized across all stadiums.

Pitching performance was only collected for performance in an MLB game. Minor league performance was excluded. To

avoid selection bias, results were obtained for all pitchers who returned to MLB play after revision surgery, irrespective of whether the player returned to established play. Data were collected in a span of 3 seasons of MLB competition before and after revision surgery to limit the effects of aging or fatigue on performance metrics.

Comparative performance outcomes were evaluated for 3 scenarios akin to the analysis performed by Makhni et al.<sup>15</sup> First, the average performance across the 3 years before and after revision surgery were compared, across all players. In the second scenario, the performance for the year preceding and after revision surgery was compared. Finally, in the last scenario, performance data from the year preceding revision surgery and the second year after return from revision surgery were compared. The same time frames were used to note individual improvement or decline for each category, and the percentage of players who improved or declined was reported.

## Statistics

Paired *t* test with 2-sided hypothesis testing was used to compare continuous variables. Statistical significance was set at  $P < .05$ . The Fisher 2-tailed exact test was used to compare categorical variables, and again, significance was set to  $P < .05$ .

## Results

### Trends in Tommy John surgery

An overall increase occurred in the number of UCL reconstructions performed on MLB pitchers from 1999 to 2014. Concomitantly, the number of UCL revision reconstructions per year performed on MLB pitchers from 1999 to 2014 significantly increased to one-third of all Tommy John surgeries in 2014. Comparatively, the proportionate rise of primary UCL reconstructions was less than the rise of revision surgeries (Fig. 1). Thirty-seven percent of revision Tommy John Surgeries occurred within 3 years of the index procedure (Table I).

### Revision rate

Between 1974 and 2014, 286 MLB players underwent 308 Tommy John surgeries, of which 50 were performed before 1999 and were excluded. Since 1999, 241 MLB pitchers have undergone 258 Tommy John surgeries, of which 38 procedures were revision surgeries. Of these revision surgeries, 6 players underwent the index procedures before 1999 and were excluded from the modern revision rate calculation because the index procedure was performed with earlier reconstruction techniques. In addition, 1 player underwent 3 Tommy John surgeries after 1999. The player's third surgery, which occurred in 2014, is outside of the scope of this report and was excluded from our revision rate analysis. This yields a revision rate of  $(38 - 6 - 1) / (241 - 6) = 13.2\%$  since 1999.

### Return to play after revision surgery

Of the 38 MLB pitchers who underwent revision UCL reconstructions, the operations in 12 pitchers were in 2013 to 2014; thus, only 26 MLB pitchers remained for return to play analysis. Seventeen pitchers (65.4%) returned to pitch at least 1 MLB game (Table I). Only 11 pitchers (42.3%) returned to established play. The average time between the revision surgery and return to play was 20.76 months. The average number of games pitched after revision surgery was 74.7 games over 2.64 seasons (range 3-288 games, 1-7 seasons). Thirteen (76%) pitched more than 1 season, but only 5 (29%) pitched more than 2 seasons after their return.

Comparing MLB pitchers who did and did not returned to professional play, there was a trend toward a greater time between the index and revision surgery (6.06 vs 3.59 years,  $P = .134$ ). There was no significant difference in the average number of seasons pitched at the MLB level before revision surgery in those who did and did not return (6.8 vs 5.4,  $P = .35$ ). The average age of those who returned was 30.9 years compared with 29.3 years for those who did not ( $P = .379$ ).

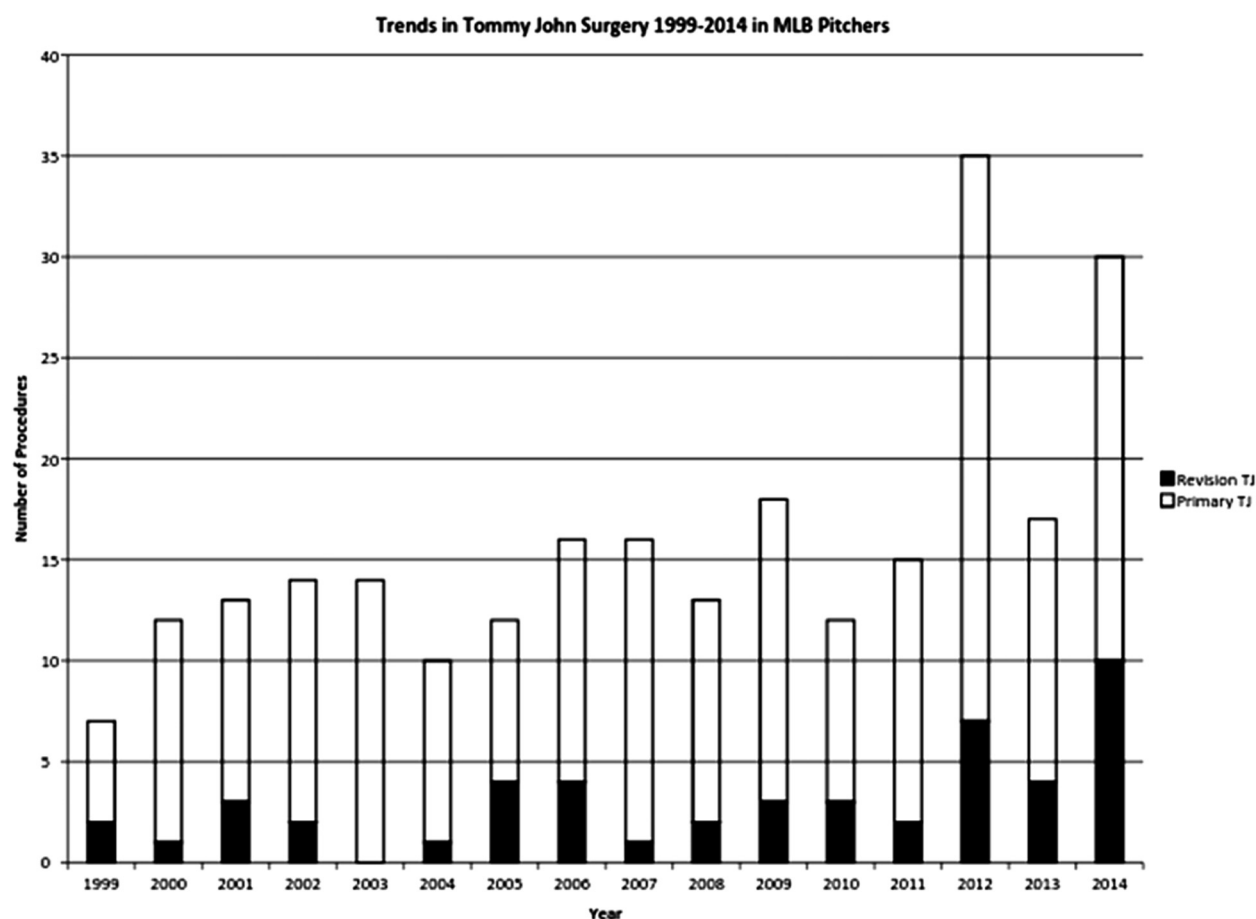
No significant difference was found between the average fastball velocity for those who returned vs those who did not (91.1 vs 91.5,  $P = .72$ ). However, those who did not return threw a higher percentage of fastballs in their repertoire than those who did return (67.3% vs 56.2%,  $P = .027$ ). When MLB pitchers who returned to established play were compared with those who only returned to active play, there was no statistical difference in the time between revision surgery and return to first MLB game (1.49 vs 2.18 years,  $P = .22$ ). Of the 9 players who did not return to MLB play, 5 players did not return to any competitive play, including minor league competition.

### Relief vs starting pitcher return to play

Starters and relievers both had similar probabilities of returning to active play (67% vs 64%,  $P = 1.0$ ). Only 25% of starters returned to established play compared with 57% of relievers ( $P = .1302$ ). Of the 8 starters who returned to any MLB pitching (active or established play), 5 (62.5%) returned to some form of starting duties, but only 1 (12.5%) continued starting duties after the second season (Table II).

### Performance outcomes before and after revision surgery

When performance outcomes averaged 3 years before and 3 years after return from surgery were compared, most of the performance categories regressed (Table III). There were statistically significant declines in innings pitched per season ( $P = .012$ ) and in total pitches per season ( $P = .016$ ). When the year before revision surgery was compared with the year after, again, most metrics experienced regression



**Figure 1** An exponential rise in the total number of Tommy John (TJ) surgeries in Major League Baseball (MLB) pitchers can be seen from 1999 to 2014. A greater proportion of revision surgeries can also be seen in recent years.

(Appendix B), with statistically significant decreases in the same categories of innings pitched and total pitches (both  $P = .006$ ). When the performance 1 year before revision surgery was compared with 2 years after revision surgery, those same trends did not reach statistical significance, likely reflecting that only 12 players had performance data available in the second season after surgery (Appendix C).

### Comparison with controls matched for age and position

There was no difference in the preindex year demographics or presurgery performance metrics between cases and controls (Appendix D), including age and number of years in MLB before the index (revision surgery) year. Compared with controls, revision UCL pitchers played in fewer seasons (2.64 v. 4.92,  $P = .002$ ) after revision surgery. When the 3-year preoperative and postoperative period in the Tommy John cohort was compared with the similar period among the control pitchers, there was a statistically significant difference in the decrease in the number of total pitches thrown per season ( $-720$  vs  $-82$ ,  $P = .04$ ); similarly, there was a difference in innings pitched that

approached statistical significance ( $-47$  vs  $-10$ ,  $P = .059$ ; Appendix E). When the years immediately before and after surgery were considered, these differences were in total innings pitched and total number of pitches and were more dramatic (total pitches:  $-860$  vs  $+73$ ,  $P < .01$ ; total innings:  $-54$  vs  $+4.83$ ,  $P < .01$ ). In addition, the difference in average fastball decline also neared statistical significance ( $-1.1$  vs  $-0.28$ ,  $P = .058$ ). When the year before surgery and the second year after return were considered, these differences did not reach statistical significance.

### Individual performance before and after revision surgery

Individual performance analyses were measured using the same time frames as the group performance analysis. When performance metrics averaged 3 years before and after revision surgery were compared (Appendix F), most players experienced regression across nearly all metrics. Notably, pitchers were most likely to experience regression in average pitches per inning (70.6%), percentage of pitches thrown in the strike zone (81.25%), innings pitched per season (94.1%), and total pitches thrown (88.2%).

**Table I** Return to play for Major League Baseball pitchers after revision Tommy John surgery\*

Position at time of revision	Age at revision (y)	Time between index and revision (y)	Time between revision and return to MLB (y)	Games/seasons after revision	Comments
SP	35.3	6.90	4.30	3/1 season	
SP	28.19	4.81	1.19	5/2 seasons	Still pitching
SP	24.55	4.91	1.22	5/2 seasons	Still pitching
SP	36.21	7.34	1.54	6/1 season	May pitch in 2015
RP	30.28	1.00	2.73	9/3 seasons	
SP	32.46	1.00	2.08	9/1 season	
SP	30.79	9.88	0.89	13/1 season	
RP	28.69	3.55	1.42	58/2 seasons	
SP	29.2	6.33	1.74	70/2 seasons	
RP	27.89	9.00	1.26	74/2 seasons	Still pitching
RP	30.12	8.98	1.34	79/2 seasons	Still pitching
RP	34.53	10.22	1.46	87/2 seasons	
RP	36.8	11.43	1.82	103/2 seasons	
RP	28.92	3.03	1.72	134/7 seasons	
SP	29.76	6.00	2.05	154/5 seasons	Still pitching
RP	26.37	7.25	1.00	173/4 seasons	Still pitching
RP	35.32	1.35	1.66	288/6 seasons	
SP	27.69	1.03	DN RTP	DN RTP	Able to return to minor league
SP	35.83	0.98	DN RTP	DN RTP	
SP	24.49	2.33	DN RTP	DN RTP	
RP	25.8	1.90	DN RTP	DN RTP	Able to return to minor league
SP	34.24	0.98	DN RTP	DN RTP	
RP	31.96	7.07	DN RTP	DN RTP	
RP	23.92	2.09	DN RTP	DN RTP	Able to return to minor league
RP	28.58	2.97	DN RTP	DN RTP	
RP	31.88	12.97	DN RTP	DN RTP	Able to return to minor league
RP	28.18	7.71 <sup>†</sup>	HN RTP	HN RTP	Revision surgery in 2013 or 2014, not included in performance analysis
SP	26.30	0.94	HN RTP	HN RTP	
SP	28.98	1.74	HN RTP	HN RTP	
SP	28.46	3.58	HN RTP	HN RTP	
SP	27.56	1.75	HN RTP	HN RTP	
SP	25.35	4.41	HN RTP	HN RTP	
RP	35.35	5.90	HN RTP	HN RTP	
SP	30.25	6.73	HN RTP	HN RTP	
RP	28.45	3.89	HN RTP	HN RTP	
RP	31.74	9.71	HN RTP	HN RTP	
SP	24.62	8.07	HN RTP	HN RTP	
SP	28.60	1.12	HN RTP	HN RTP	
<b>AVG</b>	29.83	5.02	1.73		

DN RTP, did not return to play; HN RTP, has not returned to play; MLB, Major League Baseball; RP, relief pitcher; SP, starting pitcher.

\* Thirty-seven percent of revision Tommy John surgeries occurred within 3 years of the index procedure. Seventeen pitchers (65%) returned to pitch at least 1 major league game, but only 11 pitchers (42%) pitched more than 10 games in 1 season. When MLB pitchers who returned to play were compared with those who did not, there was a trend toward a greater time between index and revision surgery (6.06 vs 3.59 years,  $P = .134$ ).

<sup>†</sup> Pitcher had his third Tommy John surgery 1.34 years after the second surgery.

When individual performances in the years immediately before revision surgery were compared with the first year after return (Appendix G), similar declines were seen in the average pitches per inning (80%), percentage of pitches thrown in the strike zone (80%), innings pitched (73.3%), and total pitches (73.3%). When individual performance 1 year before surgery was compared with the second year after return (Appendix H), a similar pattern of decline was seen, with the highest likelihood of decline in performance

noted in the percentage of pitches thrown in the strike zone (72.7%) and average fastball velocity (81.8%).

## Discussion

Although recent articles have reported the detailed return to competition after primary Tommy John surgeries in MLB pitchers,<sup>10,15</sup> this review is among the first to report the



**Table II** Position at return to play for starting pitchers undergoing revision surgery\*

Year 1 after Return	Year 2 after return	Year 3 after return	Comments
RP > SP <sup>‡</sup>	Did not play	Did not play	
SP	RP	Did not play	
RP	Did not play	Did not play	
RP	Did not play	Did not play	
RP > SP <sup>‡</sup>	SP > RP <sup>†</sup>	SP > RP <sup>†</sup>	Returned as SP and RP in year 4 and 5 after return, still pitching
SP	Did not play	RP	
RP	RP	2015 <sup>§</sup>	Still pitching
SP > RP <sup>†</sup>	2015 <sup>§</sup>	2016 <sup>§</sup>	May still pitch in 2015

RP, relief pitcher; SP, starting pitcher.

\* Only 5 of 8 SPs (62.5%) returned to some form of starting duties, and only 1 of 8 SPs (12.5%) continued starting duties after his second season after revision surgery.

<sup>†</sup> SP > RP represents more games pitched as a SP than as an RP.

<sup>‡</sup> RP > SP represents more games pitched as RP than as an SP.

<sup>§</sup> No data are available for 2015 or 2016.

**Table III** Average performance before and after revision surgery\*

Variable	Before surgery (n = 17)	After surgery (n = 17)	P value <sup>†</sup>
Earned run average (ERA)	4.14	4.89	.336
Batting average against pitcher	0.250	0.255	.789
Strikeout-to-walk ratio (K/BB)	2.35	2.09	.490
Strikeouts per 9 innings (K/9)	7.26	7.71	.586
Walks plus hits per inning pitched (WHIP)	1.45	3.10	.291
Average pitches per inning	16.50	18.11	.053
Average pitches per plate appearance	3.82	3.98	.056
Percentage pitches thrown in strike zone	51.43	48.54	.103
Percentage pitches thrown for strike	60.09	60.23	.938
Innings pitched (season)	83.97	36.95	<b>.012</b>
Total pitches (season)	1355.98	635.72	<b>.016</b>
Percentage fastballs thrown	56.26	46.39	.059
Average fastball velocity, mph	91.11	90.53	.483
Field independent pitching (FIP)	4.48	4.75	.627

\* After return from revision surgery, average performance regressed significantly in innings pitched and total pitches. There were also declines in average pitches per inning, average pitches per plate appearance, percentage fastballs thrown, and percentage pitches thrown in strike zone.

<sup>†</sup> Values in bold indicate statistical significance ( $P < .05$ ).

trends, metrics, and outcomes for revision Tommy John surgery in elite pitchers in the modern era. As reported by these recent studies,<sup>10,15</sup> the number of Tommy John surgeries in MLB pitchers increased dramatically in the last decade. We found a 13.2% revision rate from 1999 to 2014. Although 65.4% of pitchers did return from revision surgery, less than half of those players (42.3%) returned to any established pitching in the MLB. In addition, for those who

returned, there was a statistically significant decline in their durability compared with presurgery performance metrics.

The revision rate of 13.2% reported in our study is substantially higher than in previous reports. In the largest published cohort to date, Cain et al<sup>4</sup> reported a 1% revision rate at 2 years of follow-up, and Osbahr et al<sup>18</sup> reported 6 revisions in 313 players (1.9%) at 10 years of follow-up. These studies, however, only included 45 and 24 major league players, respectively, and included other overhead-throwing athletes. In these studies of mainly nonprofessional players, most patients are more likely to opt to discontinue play rather than undergo revision surgery, which would explain the low revision rates in these studies.

With regards to MLB pitchers specifically, Erickson et al<sup>10</sup> reported 7 revision surgeries and a revision rate of 3.9% from a cohort of 179 MLB pitchers from 1986 to 2012. Makhni et al<sup>15</sup> reported 21 multiple surgeries in 10 patients from a cohort of 157 MLB pitchers undergoing surgery between 1999 and 2011 but did not formally report a revision rate. Using a similar type of type of calculation, the revision rate in their cohort would be 7%.

The dramatic difference in our revision rate from those reported in prior studies is likely the inclusion of the data set between 2012 and 2014. An exponential growth in the number of revision surgeries occurred during this 3-year period. Our data are consistent with the trend observed by Jones et al<sup>12</sup> showing a 3-fold increase in the number of revision procedures in the latter half of their study group (14 revisions between 2003 and 2009) compared with the first half (4 revisions between 1996 and 2002).

An important statistic to highlight is that 37% of all revisions occurred within 3 years of the index procedure. The details surrounding the rehabilitation and the type of reconstruction for all players were unknown because this is not publicly accessible information. Therefore, we cannot make any conclusions regarding outcomes based on surgical technique or whether other elbow pathology outside of

UCL tears affected the need for revision, return to play, or performance metrics after surgery. However, in the context of an increasing rate of revision surgery in the modern era, there may be a push toward a lower threshold for early revision surgery if the results of the index procedure are not as expected.

Professional baseball is an incredibly popular sport, with an annual revenue of \$9 billion<sup>3</sup> and pitching salaries ranging from \$500,000 to \$30 million<sup>17</sup> in 2014; thus, the ability of pitchers to perform at the professional level may have significant financial considerations. From the player's perspective, the same financial benefit exists to undergo surgery or revision surgery to remain employed, albeit at a lower pay scale, rather than give up his profession. This may also explain the emergence of a second revision surgery in an MLB pitcher in 2014. These economic factors, even in the face of somewhat poor return to play results after revision, could account for the increase in revision rate as well as the high proportion of "early" revisions being performed.

After revision surgery, 65.4% of MLB pitchers returned to active MLB pitching; however, only 42.3% returned to established play, pitching in 10 or more games upon their return. Our results corroborate those of Marshall et al,<sup>16</sup> who also reported a 65.5% return to MLB but did not comment on return to established pitching. Jones et al<sup>12</sup> reported a 78% (14 of 18) return to MLB pitching within 2 full seasons and 44% (8 of 18) return to established pitching. The results of these revisions are not as optimistic as those reported in primary Tommy John surgery (80% return to play, 67% to established play)<sup>15</sup> but are certainly higher than previously expected. In addition, 3 MLB pitchers are currently still pitching who could potentially pitch more than 10 games in 1 season if they return to pitch in MLB in 2015. If this occurs, more than 50% of pitchers will have returned to established pitching.

In our assessment of performance metrics, we found a statistically significant decrease in durability, defined as total pitches and innings pitched per season. Both in the group and individual analyses, innings pitched and total pitches thrown demonstrated a statistically significant decrease at almost all time comparison points. This finding is consistent with the results reported by Jones et al<sup>12</sup> that showed most pitchers did not achieve 50% of their pre-injury workload. This may be partially explained by the conversion of starting pitchers into relievers after revision surgery, because most of the starting pitchers became relievers by their second season after surgery. In addition, teams may opt to manage a pitcher's workload differently after revision surgery, which may also account for the decrease in pitching volume. However, only 29% of pitchers sustained their career longer than 2 seasons in the MLB after revision surgery, which suggests that the life-span of a revision surgery is substantially shorter than a primary operation. In contrast, Erickson et al<sup>10</sup> reported

that the average career length for an MLB pitcher after primary Tommy John surgery was 3.9 years. In addition, the durability of primary Tommy John surgeries improved. Makhni et al<sup>15</sup> demonstrated that only the minority of players experience a decline in the number of innings pitched, particularly in the second year after surgery. The comparison between 1 year before and 2 years after revision surgery in our cohort trended towards less durability but did not reach statistical significance ( $P = .058$  and  $P = .064$ , respectively). This was likely due to the decrease in the number of players who had 2-year outcomes after surgery.

As with any retrospective study, this study is not without limitations. Our reliance on publicly available information puts it at risk of excluding players who may not be included in these public databases or of retrieving inaccurate player statistics (information bias). However, by cross-referencing our data collection among a number of different sources, these exclusions or errors would likely be limited.

Another major limitation is the relative lack of follow-up. Most revisions occurred in the last 3 years. Given the length of time needed for rehabilitation (average of 20.76 months in this study), performance outcomes could not be obtained for a significant portion of the revisions (revision surgeries in 2013 and after). The 2-year and 3-year outcomes were also limited for those revisions performed in the latter years of our cohort (namely, 2011 and 2012). Thus, the relatively small size of our cohort decreased our statistical power in many of our analyses.

Finally, the generalizability of this study is limited. The analysis is limited to MLB pitchers and may not be applicable to players at other positions or playing levels.

## Conclusion

While outcomes and return to play after primary Tommy John surgery in MLB pitchers may be more predictable, return to play and performance is far less guaranteed after revision surgery, particularly with respect to durability. Although not necessarily an epidemic, the rate of revision surgery is significantly higher than previously reported. Players considering reconstruction must be adequately counseled regarding their expected outcomes, length of rehabilitation, and risk of future surgery.

## Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not

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## Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/J.jse.2015.08.040>

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