

Performance After Rotator Cuff Tear and Operative Treatment: A Case-Control Study of Major League Baseball Pitchers

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Context: Little is known about pitching performance or lack of it among Major League Baseball (MLB) pitchers who undergo operative treatment of rotator cuff tears.

Objective: To assess pitching performance outcomes in MLB players who needed operative treatment of rotator cuff tears and to compare performance in these athletes with that in a control group of MLB players.

Design: Case-control study.

Setting: Publicly available player profiles, press releases, and team injury reports.

Patients or Other Participants: Thirty-three MLB pitchers with documented surgery to treat rotator cuff tears and 117 control pitchers who did not have documented rotator cuff tears were identified.

Main Outcome Measure(s): Major League Baseball pitching attrition and performance variables.

Results: Players who underwent rotator cuff surgery were no more likely not to play than control players. Performance variables of players who underwent surgery improved after surgery but never returned to baseline preoperative status. Players who needed rotator cuff surgery typically were more experienced and had better earned run averages than control players.

Conclusions: Pitchers who had symptomatic rotator cuff tears that necessitated operative treatment tended to decline gradually in performance leading up to their operations and to improve gradually over the next 3 seasons. In contrast to what we expected, they did not have a greater attrition rate than their control counterparts; however, their performances did not return to preoperative levels over the course of the study.

Key Words: pitching, clinical outcome, shoulder

Key Points

- Pitchers who had operative treatment of symptomatic rotator cuff tears tended to have a gradual decline in performance before surgery and to improve gradually over the 3 seasons after surgery.
- The attrition rate was not greater in pitchers who had operative treatment than in the control pitchers.
- Pitchers who had surgery for rotator cuffs tears did not return to their preoperative performance levels during the study period.

Rotator cuff tears (RCTs) can cause great pain and dysfunction in both work-related and non-work-related activities of daily living, as well as loss of shoulder motion and strength. Without treatment, full-thickness RCTs can be career-ending injuries for professional athletes. Although tears often occur in patients aged 40 years and older,^{1,2} overhead athletes, particularly professional baseball pitchers, present a unique cohort of athletes at great risk for this type of overuse injury.

Professional baseball pitchers subject the rotator cuff to supraphysiologic loads that lead to rotator cuff tendinitis, partial-thickness RCTs, and, in advanced stages, full-thickness RCTs.^{3–5} At one time, RCT was considered a career-ending injury for a Major League Baseball (MLB) pitcher. As the approach to the operative and nonoperative management of RCTs in athletes has evolved over the past 3 decades, the goal of operative treatment

of partial-thickness and full-thickness tears in these elite-level athletes also has changed. Whereas pain relief and restoration of function are considered good outcomes in a general population, the goal for MLB pitchers is to return to athletic competition with the same preinjury performance ability.

Subjective patient-derived outcomes and physician-derived physical examination variables often are improved after rotator cuff surgery in elite pitchers; however, return of players to athletic performance at high levels has been variable.^{4,6,7} Mazoué and Andrews⁴ reviewed the results of 12 professional pitchers who underwent repair of full-thickness RCTs of the dominant shoulder and noted that only 1 player (8%) was able to return to a high competitive level of baseball without great shoulder dysfunction. Similarly, Reynolds et al⁶ examined preoperative and intraoperative findings of 82 professional pitchers who had undergone debridement of partial-thickness RCTs and found

that most athletes returned to competitive pitching; however, returning to their previous levels of competition remained a challenge for many players. Little is known about postoperative pitching performance among pitchers who return to MLB play. Performance outcomes have been described in MLB pitchers who have undergone repair of the ulnar collateral ligament⁸ and repair of isolated glenoid labral injuries.⁹ Therefore, the purpose of our study was to describe pitching performance outcomes in MLB players who needed surgery to treat RCTs and to compare performance variables and return to play between these athletes and a randomly selected cohort of MLB players. We hypothesized that players who had operative treatment of RCTs would be less likely to return to play in any given year than a randomly selected group of players. In addition, we hypothesized that rotator cuff surgery (RCS) would have a deleterious effect on athletic performance variables.

METHODS

Our main outcomes of interest were performance-based factors that were continuous measures; therefore, a power analysis was conducted based on the *t* test for independent samples. For an α level of .05 and a power of 0.8, a harmonic mean number of 50 players was necessary to detect a medium standardized difference (Cohen $d=0.5$) for the outcomes of interest. Our study exceeded this number, with 33 affected players and 117 control players (harmonic mean = 51 players).¹⁰

Data were reviewed for 33 MLB pitchers who pitched in at least 1 MLB game before undergoing surgery to treat RCTs. All pitchers appeared in more than 1 game before surgery, and most pitchers appeared in several games during multiple seasons. Pitchers were identified from team injury reports, press releases, and player profiles indicating that they underwent surgery to treat RCTs in their pitching shoulders. We did not determine whether a patient had a partial-thickness or a full-thickness tear. Furthermore, we could not determine the surgical approach or technique. Data obtained were available via Article XIII, Section C of the Major League Baseball Players Association's collective bargaining agreement, which provides

standards for injury reporting in MLB. It states, "Application by a Club to the Commissioner to place a Player on the Disabled List shall be accompanied by a Standard Form of Diagnosis" that "shall be completed by the Club physician."¹¹

Surgery was performed between 1976 and 2003. Age and MLB pitching experience were determined at the time of surgery. Body mass index (BMI), throwing handedness, all-star status, and pitching role (starting or relief pitcher) were recorded for each pitcher (Table 1). Body mass index was calculated from height and mass data. The date of return to MLB play was recorded, and the duration from surgery to return was calculated. Mean innings pitched (IP) per season, earned run average (ERA), walks and hits per inning pitched (WHIP), and strikeouts per 9 innings (K/9) were compared for each MLB pitcher for 3 seasons before (preindex seasons 1, 2, and 3) and after (postindex seasons 1, 2, and 3) surgery. Preindex season 1 was defined as the season immediately before the operative year, and postindex season 1 was defined as the season immediately after the operative year. This resulted in a study duration of 7 consecutive seasons for each player. The ERA is the average number of earned runs allowed per 9 innings pitched. An earned run is any run scored by the opposing team for which the pitcher is held accountable. Walks and hits per inning are determined by dividing the sum of walks and hits by the total number of innings pitched. The K/9 is defined as the sum of strikeouts divided by 9 innings. These are standard measures of pitching performance in MLB.

A control group was selected to allow comparison of the treated players with a sample of players representing all MLB pitchers who did not undergo rotator cuff surgery. Every fifth name was selected from a complete alphabetical roster of MLB pitchers from the 2000 season for a total of 117 pitchers in the control group. For this cohort, the 2000 MLB season was defined as the index (equivalent to the operative year for the operatively treated pitchers) year for this cohort. Similarly, data were obtained for 3 seasons before (preindex seasons 1, 2, and 3) and after the index year (postindex seasons 1, 2, and 3). Players with a known history of rotator cuff surgery were excluded from this list before selection. Pitchers were not excluded from

Table 1. Demographics of Pitchers in the Rotator Cuff Surgery and Control Groups

Variable	Group		<i>t</i> ^a	χ^2	<i>P</i>
	Rotator Cuff Surgery (n=33)	Control (n=117)			
Baseline earned run average ^{b,c}	3.93±1.01	5.95±2.41	4.71	NA	<.001 ^d
Age, y ^c	30.87±3.88	28.57±4.17	2.82	NA	.005 ^d
Preindex Major League Baseball seasons ^c	7.82±3.32	5.43±4.04	3.16	NA	.001 ^d
Body mass index ^c	25.41±2.10	26.92±1.99	3.77	NA	.001 ^d
Preindex all-star status ^e					
All-star	17 (51.5%)	17 (14.5%)	NA	18.0	<.001 ^d
Not all-star	16 (48.5%)	100 (85.5%)			
Throwing handedness ^e					
Right	26 (78.8%)	88 (75.2%)	NA	0.03	.84
Left	7 (21.2%)	29 (24.8%)			
Pitching role ^e					
Starting pitcher	24 (72.7%)	48 (41%)	NA	9.13	.003 ^d
Reliever	9 (27.3%)	69 (59%)			

Abbreviation: NA, not applicable.

^aIndicates t_{148} except for baseline earned run average (t_{103}).

^bEarned run average in first season in database.

^cCompared with independent-samples *t* tests. Equal variances were not assumed.

^dIndicates significant difference.

^eCompared with χ^2 test with Yates correction for continuity.

the control group on the basis of any other reported injuries or operative procedures. Age and MLB pitching experience were determined using the 2000 season. The same demographic and performance variables noted earlier were obtained for the control group as for the RCS group.

Because our data were obtained from publicly available sources, they were exempt from institutional board review.

Statistical Analysis

Comparisons of demographic factors between these groups and differences between those who returned to play after the index season and those who did not were conducted with 2-sided *t* tests for independent samples (equal variances not assumed) when the data were continuous and with the χ^2 test with Yates correction when the data were categorical or binary. When the numbers in the categories were 5 or less, a Fisher exact test was used. Paired-samples *t* tests were used to compare IP, ERA, WHIP, and K/9 between the 3 seasons before surgery and the 3 seasons after surgery. A similar calculation was done for the control group. Independent-samples *t* tests were used to compare the change in performance between groups.

Binary logistic regression was performed in both a univariate and multivariate fashion to determine risk factors for attrition and to compare groups while adjusting for potentially confounding factors. Multivariate binary logistic regression was performed with the backward likelihood ratio method using greater than 0.10 as the criterion for removal of a variable at each iteration. Finally, postindex season games played was determined for each player, and a Kaplan-Meier survival analysis was performed to determine whether a difference was found in time to attrition between players who had RCS and those who had not. The log-rank test was used to compare the differences between survival curves for the RCS and control groups. The α level was set a priori at .05. All statistics were calculated using SPSS (version 15.0; SPSS Inc, Chicago, IL).

RESULTS

Pitchers who underwent RCS were more often older, were more experienced, were more often starters, had a lower BMI, and were more likely to be all-stars than control pitchers. Seventy-three percent (24/33) of pitchers returned to MLB play at a mean of 17 months after surgery. No pitchers in the RCS group returned to MLB play during the index year. Twenty (61%) pitchers in the RCS group returned to MLB play during postindex season 1. Three (9%) pitchers in this group returned to MLB play by postindex season 2. One (3%) pitcher in the RCS group returned to MLB play by postindex season 3.

When the RCS group performance was compared between preindex and postindex seasons, the greatest changes were observed between preindex season 2 and the postindex seasons (Table 2). When the differences between preindex season 3 and postindex seasons were examined, fewer postindex innings were played in postindex seasons 1 (67.9 fewer; $t_{20}=3.6$, $P=.002$) and 2 (65.1 fewer; $t_{16}=3.4$, $P=.004$). Because of attrition, fewer pitchers played in postindex season 3; therefore, although players played 57.8 fewer innings, this finding was not different ($t_{12}=2.1$, $P<.05$). We also noted a decline in WHIP ($t_{16}=-2.5$, $P=.03$) and K/9 ($t_{16}=2.3$, $P=.04$) between preindex season 3 and postindex season 2. We observed no other differences between preindex season 3 and any other postindex season. We found no changes between preindex season 1 and any postindex season.

Table 2. Important Performance Factors From Preindex Season 2 to Postindex Seasons 1, 2, and 3 in Players who Underwent Rotator Cuff Surgery^a

Seasons	Innings Pitched		Games Played		Walks and Hits per Inning Pitched		Strikeouts per 9 Innings		Earned Run Average			
	t^b	<i>P</i>	t^b	<i>P</i>	t^b	<i>P</i>	t^b	<i>P</i>	t^b	<i>P</i>		
Preindex 2 – postindex 1 (n=21)	68.80	4.22	<.001 ^c	14.57	3.32	-0.14	-1.92	0.86	2.19	-1.03	-2.90	.009 ^c
Preindex 2 – postindex 2 (n=17)	70.62	3.83	.001 ^c	8.59	2.01	-0.17	-2.53	1.15	3.60	-1.32	-3.25	.005 ^c
Preindex 2 – postindex 3 (n=13)	67.89	2.85	.02 ^c	7.69	1.25	-0.20	-1.92	0.81	1.91	-1.40	-2.02	.07

^aComparisons were made using paired-samples *t* tests.

^bIndicates t_{20} for preindex season 2 to postindex season 2, and t_{12} for preindex season 2 to postindex season 3.

^cIndicates significant difference.

When the change in innings played from preindex to postindex seasons was compared between the RCS and control groups ([control group preindex–postindex]–[RCS group preindex–postindex]), we noted a greater change for the RCS group than the control group between preindex season 3 and postindex season 1 (63.7 fewer innings; $t_{36.6} = -2.9, P = .007$), between preindex season 3 and postindex season 2 (52.1 fewer innings; $t_{25.5} = -2.4, P = .03$), and between preindex season 2 and postindex seasons 1, 2, and 3 (57.9 [$t_{37.9} = -3.1, P = .004$], 60.1 [$t_{25.1} = -2.9, P = .008$], and 54.1 [$t_{33.9} = -3.4, P = .001$] fewer innings, respectively). We also observed a greater decline in ERA between preindex season 2 and postindex season 1 (1.45 lower ERA; $t_{81.7} = 2.1, P = .04$). We found no other differences in the change in performance preindex to postindex between the RCS and control groups.

Figure 1 illustrates the dramatic decline in IP in preindex season 1 and a steady increase in IP over the 3 postindex seasons. Compared with the RCS group, the control group averaged fewer IP at baseline and demonstrated a more consistent performance pattern over the course of the study period. The RCS group pitchers had better baseline ERAs but demonstrated an upward trend in ERA throughout the postindex period (Figure 2). The control group demonstrated more dramatic fluctuations in ERA; however, these did not follow a distinct trend. Changes in WHIP and K/9 from preindex to postindex seasons were not different between groups during any seasons compared. Figures 3 and 4 show that the RCS group began with better performance in terms of WHIP and K/9, respectively, and demonstrated a slight trend toward poorer postindex WHIP and K/9 performance that was not significantly different.

Before other variables were accounted for, preindex experience, all-star status, and pitching role were each associated with lower odds of attrition ($P = .04, .03, \text{ and } .004$, respectively; Table 3). We found no variables that, by themselves, conferred a higher risk of attrition. Specifically, RCS did not confer an increased risk of attrition in the period we studied ($P = .58$).

A multivariate binary logistic regression model for the prob-

ability of a player not returning was constructed, and the primary outcome of interest was a comparison of the RCS and control groups. In this model, age, BMI, preindex seasons, all-star status, starter status, throwing handedness, and baseline ERA were accounted for statistically as potential confounders. The backward likelihood ratio method was used for selection of variables with a probability of association with the outcome greater than 0.10 on the $-2 \log$ likelihood statistic as the criterion for removal at each iteration. Only the number of preindex MLB seasons ($P = .03$) and role as a starting pitcher ($P = .04$) were predictors (negative) for attrition. The BMI ($P = .1$) was a negative predictor of attrition, and age ($P = .09$) was a positive predictor; however, these variables were not significant predictors. Rotator cuff surgery was not a predictor of return to play. Age was a marginally significant positive predictor of attrition (Table 4). Post hoc analysis showed no multicollinearity and showed that the model fit the data well (Hosmer-Lemeshow statistic [$df = 8$] = 5.24, $P = .73$).

The Kaplan-Meier survival analysis showed that although the absolute number of games until attrition averaged 93.7 (median = 65 games) in the control group and 69.9 games (median = 31 games) in the RCS group, these findings were not different (log-rank statistic [Mantel-Cox] $\chi^2_{0.354} = 1, P = .55$).

DISCUSSION

The purpose of our study was to describe pitching performance outcomes in MLB pitchers who had operative treatment of RCTs and to compare performance variables in these athletes with those of a randomly selected cohort of MLB players. We found that MLB pitchers who underwent surgery for RCT often were older, were more experienced, were more likely to be starting pitchers, and performed at higher preindex levels than the average MLB pitcher. More than one-fourth of pitchers who underwent RCS did not return to pitch at the MLB level. The pitchers in the RCS group who did return often missed at least 1 full season in recovery and did not return to their pre-

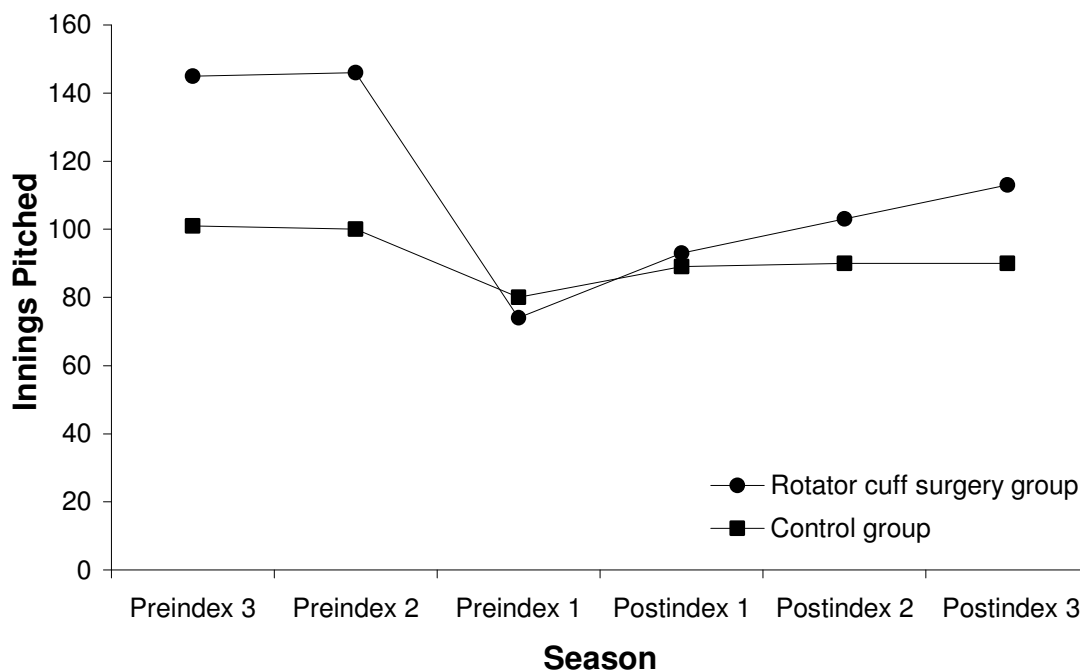


Figure 1. Innings pitched per season in the rotator cuff surgery and control groups over the study period.

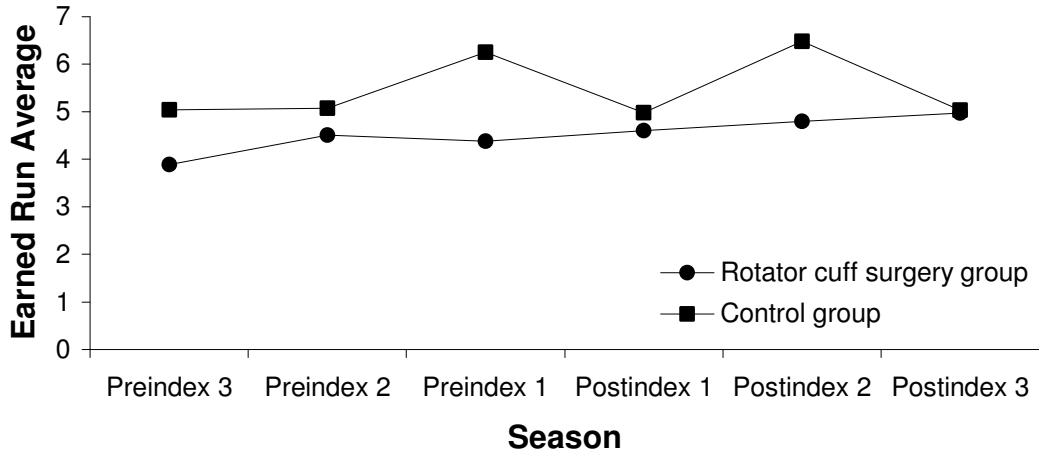


Figure 2. Earned run averages in the rotator cuff surgery and control groups over the study period.

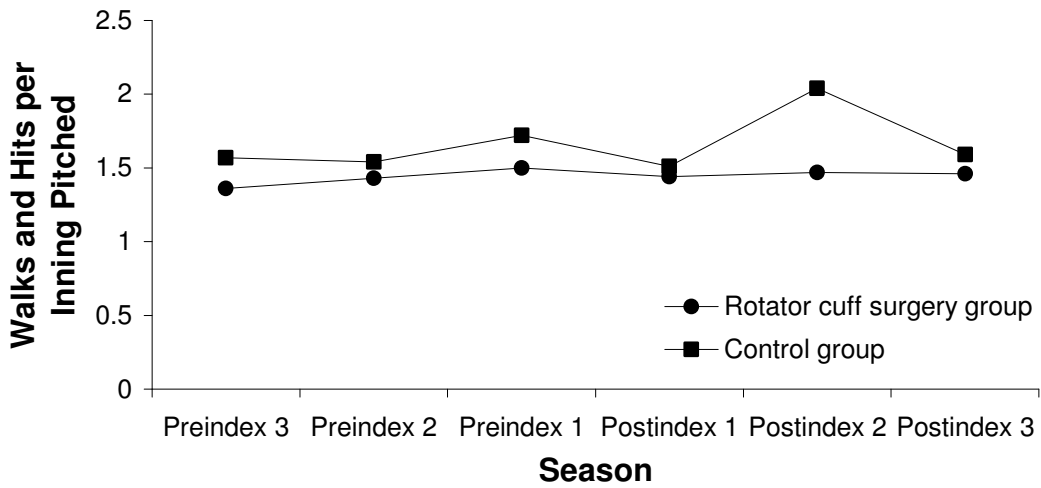


Figure 3. Walks and hits per inning pitched in the rotator cuff surgery and control groups over the study period.

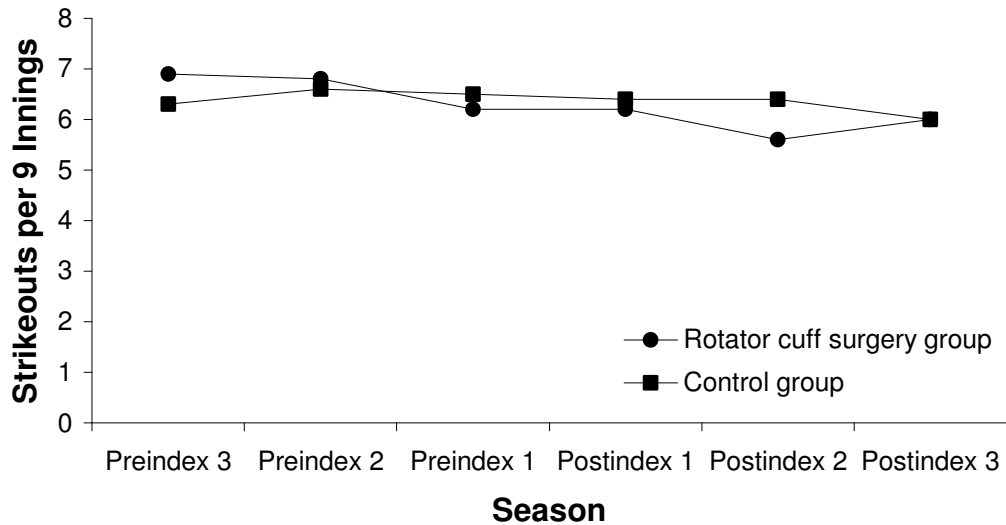


Figure 4. Strikeouts per 9 innings in the rotator cuff surgery and control groups over the study period.

Table 3. Univariate Binary Logistic Regression for Whether a Pitcher Leaves Major League Baseball in a 3-Year Period

Variable	Odds Ratio ^a	95% Confidence Interval	P
Rotator cuff surgery	0.80	0.36, 1.77	.58
Age	0.98	0.91, 1.06	.61
Body mass index	0.87	0.74, 1.02	.09
Experience (preindex seasons)	0.92	0.84, 0.99	.04 ^b
Preindex all-star	0.42	0.19, 0.92	.03 ^b
Starting pitcher	0.36	0.18, 0.72	.004 ^b
Right-handed thrower	0.53	0.23, 1.23	.14
Baseline earned run average	1.10	0.97, 1.26	.14

^aHigher odds ratios indicate higher probability of leaving Major League Baseball.

^bIndicates significant difference.

Table 4. Multiple Binary Logistic Regression of Attrition From Play in Major League Baseball Pitchers

Variable	Odds Ratio ^a	95% Confidence Interval	P
Rotator cuff surgery	0.902	0.354, 2.299	.83
Age	1.149	0.977, 1.352	.09
Body mass index	0.857	0.713, 1.030	.10
Experience (preindex seasons)	0.824	0.691, 0.982	.03 ^b
Starting pitcher	0.456	0.214, 0.971	.04 ^b

^aAll variables were significant factors by -2 log likelihood in logistic regression, with the exception of rotator cuff repair, which was our primary outcome of interest.

^bIndicates significant difference.

index levels of performance in the first 3 postindex seasons. Despite this decline, these pitchers demonstrated attrition rates that were similar to those of pitchers in the control group and continued to perform at levels that were higher than those of their peers. The most salient finding of our study was that players who developed RCTs and subsequently had surgery declined in performance, had surgery, and gradually improved, but they never reached their baseline levels of performance after surgery.

Rotator cuff tears are a common cause of pain, shoulder dysfunction, and loss of work in the general population.¹²⁻¹⁴ In the elite athlete, symptomatic RCTs often prohibit competitive sport participation. The MLB pitchers place great demands on their shoulders, more specifically their rotator cuffs, and are at higher risk for overuse injury. However, few MLB pitchers actually undergo RCS, with only 33 players over 27 years identified in our study. Although pain relief continues to be an important treatment goal, MLB pitchers often seek treatment with the hope of rapid recovery, quick return to play, and high likelihood of regaining preoperative performance.

When comparing the demographics of MLB pitchers who underwent RCS with those who did not, we found that the pitchers in the former group were older, had pitched more preindex seasons, and were more likely to be starting pitchers. All these variables point to shoulder overuse as a factor that predisposes pitchers to RCTs and subsequent surgery. In fact, we found that players in the RCS group pitched an average of 45 more innings per season in the 3 preindex seasons than players in the control

group. In addition to greater numbers of preindex IP, pitchers in the RCS group demonstrated higher preindex performance in other categories (lower ERA, lower WHIP, higher K/9) than pitchers in the control group. Wright et al¹⁵ investigated plain radiographic findings in the shoulders of 57 MLB pitchers and noted that a greater number of IP was associated with increased degenerative changes of the dominant shoulder and elbow, such as osteophytes, cystic changes, joint space narrowing, and loose bodies. However, these radiographic findings were not predictive variables for a pitcher being placed on the disabled list.

In addition, although our survival analysis did not demonstrate a difference in the rate of attrition between groups, the control group included, on average, lower-functioning MLB pitchers and as a result might have been likely to demonstrate attrition irrespective of injury or retirement. On the other hand, the attrition demonstrated by the high-functioning RCS group was probably a direct result of injury or surgery. Logistic regression suggested that age, number of preindex seasons, and being a starting pitcher might play a greater role in attrition than rotator cuff surgery. This implies that the surgery itself might not be responsible but that this increased attrition might be an artifact of eventual burnout of these high-level athletes. The RCT and subsequent surgery might be part of this natural history. Pitchers who had RCS were older at the study's inception and therefore had already pitched more years in MLB than pitchers in the control group.

In terms of performance, the RCS group pitched fewer innings and exhibited higher ERAs, more WHIP, and a lower K/9 value in the postindex than the preindex seasons. Although changes in WHIP and K/9 were less substantial, pitchers did not return to their preindex levels of performance. In their review of 12 professional pitchers who underwent RCS of the dominant shoulder, Mazoué and Andrews⁴ observed that many pitchers were able to return to pitching with good velocity and control but fatigued early, allowing them to pitch effectively for only a short period. In addition, several pitchers reported prolonged recovery times, meaning that they needed several days to weeks between outings to recover sufficient strength to pitch again.⁴ We believe that these findings are consistent with the performance outcomes we observed. Yet we demonstrated that in the postindex period, the RCS group continued to function at a level that was generally higher than that of the average MLB pitcher. Over the postindex period, the pitchers in the RCS group showed a trend toward greater numbers of IP each year; however, their performance did not appear to improve in like form, and mean ERA increased in each postindex season. We cannot state definitively that performance decline is caused by rotator cuff tear or surgery and can assume only that injury and surgery played a large role in pitching performance. Payne et al¹⁶ divided collegiate and professional overhead athletes into 2 groups (A and B) by history and mechanism of injury. Group A included 14 patients who had acute, traumatic injuries; 12 (86%) of these patients had satisfactory postoperative results, and 9 (64%) returned to preinjury sports after arthroscopic subacromial decompression and tear debridement. Group B included 29 overhead athletes who had insidious, atraumatic shoulder pain; 19 (66%) of these patients had satisfactory postoperative results, and 13 (45%) returned to preinjury sports after arthroscopic debridement.¹⁶

Our study had several other weaknesses, including a lack of preoperative imaging or intraoperative data regarding RCT size (eg, partial thickness, full thickness, tendons involved, retractions) and surgical technique (eg, single row, double row, ar-

throscopic, open, mini-open). Other researchers have been able to specifically evaluate these variables in their analyses. In addition, we lacked data on postoperative rehabilitation protocols and do not know how this variable influences performance outcome.^{4,6} Mazoué and Andrews⁴ evaluated full-thickness RCTs by a mini-open approach in 12 professional pitchers and noted that only 1 returned to pitch professionally over a 66.6-month follow-up. Reynolds et al⁶ evaluated 82 professional pitchers who underwent debridement of small, partial-thickness RCTs and found that 76% were able to return to competitive pitching at the professional level and 55% were able to return to the same or higher level of competition. Tibone et al⁷ looked specifically at the results of open repair of full-thickness RCTs in baseball players and included 5 professional baseball pitchers. Three (60%) of these pitchers were unable to play professional baseball after repair, and 2 (40%) players returned to professional pitching but had difficulties with throwing.⁷ We do not know the chronicity, size, or character of the RCTs of the pitchers in our study and cannot comment on methods of surgical treatment, including debridement or repair. Although team injury reports, press releases, and player profiles were reviewed comprehensively, it is possible that some players who underwent surgery for an RCT were not identified or that these data sources were not accurate at times. We cannot comment on physical examination variables in the preoperative or postoperative setting, and our methods did not allow for assessment of satisfaction or patient-derived perceptions of outcomes. In addition, the treatment of RCTs changed much over the time of the study. Extensive changes have occurred in surgical procedures, and there have been some innovations in rehabilitation in the last decade. However, we believe that the findings are applicable in terms of the overall pathogenesis and course of this injury in high-level pitchers.

Despite these weaknesses, our study had notable strengths. We had a clearly defined study sample and outcome variables with adequate prestudy power to detect differences for the outcomes of interest. Each player was his own control during paired analyses, eliminating player-to-player variability; a separate control group was a sample of the entire cohort of MLB pitchers during the study period and represented the average MLB pitcher. Finally, we obtained data on pitchers for 3 pre-index and 3 postindex seasons and were able to present performance trends over a substantial period.

CONCLUSIONS

Pitchers who had symptomatic RCTs that necessitated surgery tended to have a gradual decline in performance leading

up to their surgery and to improve gradually over the next 3 seasons. In contrast to what we expected, they did not have a greater attrition rate than their control counterparts, but their performance did not return to preindex levels over the course of the study.

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