

Pitching Performance After Ulnar Collateral Ligament Reconstruction at a Single Institution in Major League Baseball Pitchers

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Background: Ulnar collateral ligament (UCL) reconstruction (UCLR) has shown reliable rates of return to play, with conflicting results on pitching performance after players' return.

Purpose: To evaluate Major League Baseball (MLB) pitching performance before and after UCLR performed at a single institution.

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

Methods: MLB pitchers (minor league players were excluded) who underwent UCLR at our institution between 2002 and 2016 were identified. Player information and return to play were determined including pitching level (MLB vs minor league) and total number of years played after surgery. Pitching performance statistics were evaluated for 3 years before surgery and for 3 years after returning to play including earned run average (ERA), walks plus hits per inning pitched (WHIP), innings pitched, wins above replacement, runs above replacement, and pitch velocity.

Results: A total of 54 MLB pitchers were identified, with 46 primary and 8 revision reconstructions. The mean time to return to play was 13.8 months (primary reconstruction: 13.7 months). The majority returned to play with a 94% return rate (primary reconstruction: 96%), and 80% returned to MLB play (primary reconstruction: 82%). Three primary reconstructions required revision surgery. Pitchers played a mean of 3.2 years in MLB and 4.6 years total after surgery (39% still playing). Pitching workload and performance were maintained or improved after surgery. The preoperative ERA was 4.63 versus 4.13 after returning to play ($P = .268$). Fastball velocity ($P = .032$), ERA ($P = .003$), and WHIP ($P = .001$) worsened the first year after surgery and then improved the second year (ERA: 4.63 to 4.06 [$P = .380$]; WHIP: 1.35 to 1.32 [$P = .221$]; fastball velocity: 91.3 to 91.9 mph [$P = .097$]). Compared with a matched control group, pitchers who had UCLR showed improvements or maintained performance after reconstruction including improved ERA ($P = .007$), WHIP ($P = .025$), and fastball velocity ($P = .006$).

Conclusion: MLB players experienced a high rate of return to play and previous level of play after UCLR. Pitching workload was maintained after returning to play. Pitching performance initially decreased the first year after returning and then improved or reverted to previous levels after the first year from UCLR.

Keywords: Tommy John surgery; UCL reconstruction; MLB; pitchers

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Ulnar collateral ligament (UCL) reconstruction (UCLR) is a common procedure performed on Major League Baseball (MLB) pitchers that has been increasing in incidence.^{2,6} Previous studies have shown overall high rates of return to play after surgery, with reports from 75% to 97%.^{2,8,9,18,26} However, there have been conflicting results regarding pitching performance after reconstruction, as some studies have shown improved performance while others have shown decreased earned run average (ERA) and walks plus hits per inning pitched (WHIP) after returning to play.^{8,10,18}

Since Dr Frank Jobe first performed the surgical procedure in 1974, a UCL injury was no longer considered a career-ending injury.¹⁴ A study by Cain et al² evaluated 1281 pitchers who underwent primary UCLR and found an overall rate of return to previous levels of play of 83%. Other studies have shown an overall return-to-play rate

of 75% to 97%, with an MLB return-to-play rate of about 80%.^{2,5,8,18,22,25,28} Many players and coaches also believe that players will return beyond their preinjury level after UCLR.¹ To evaluate more in-depth outcomes than simply return to play, recent studies have evaluated pitching statistics and in-game performance metrics after players' return, which sought to offer more information into playing level once pitchers return.^{8,10,16,18} However, studies evaluating statistical performance have conflicting results. For example, Erickson et al⁸ evaluated MLB pitchers and found improved in-game statistical performance after UCLR including ERA, walks, hits, and runs, whereas Makhni et al¹⁸ found worse ERA, batting average against, innings pitched, and fastball velocity after returning to play in MLB pitchers.

Previous studies that have focused on MLB pitching performance have been largely based on online databases for injury and surgical data, which can be inconsistent and unreliable.^{8,16,18} The purpose of our study was to evaluate MLB pitching performance before and after UCLR performed at our institution. We hypothesized that there would be an overall high rate of return to play and level of play with sustained pitching performance after reconstruction.

METHODS

Institutional review board approval was obtained from our institution. Pitchers were identified who underwent UCLR at the Kerlan-Jobe Orthopaedic Clinic between 2002 and 2016. Inclusion criteria were MLB pitchers, available surgical and clinical data for follow-up, and known UCLR at our institute. Only MLB pitchers were included because of the more consistent pitching statistical information as compared with minor league data, which can be variable and add confounding data. Exclusion criteria were minor league-only pitchers, UCL repair, or concomitant surgery to other areas than the elbow. A total of 177 professional pitchers were identified who underwent UCLR. Of these, 26 played professional baseball internationally, and 97 played predominately minor league baseball only; 54 pitchers were identified who played at the MLB level. Demographic and history information was collected on all patients, which included age at the time of surgery, handedness, years in MLB before and after surgery, and years in the minor league before and after surgery. The technique used for reconstruction was either the modified Jobe technique (56%) or docking technique (44%). The docking technique was used more frequently after 2013, with a preference for using a palmaris graft if available and a gracilis graft if not available. The choice of technique was based on surgeon preference.

Pitching performance statistics were then collected for 3 years before surgery and 3 years after returning to play in which only MLB statistics were used. Performance statistics included games, complete games, wins, losses, winning percentage, innings pitched, ERA, WHIP, walks per 9 innings, strikeouts per 9 innings, strikeout-to-walk ratio, home runs per 9 innings, hits per 9 innings, wins above

replacement, and runs above replacement. Fastball velocity and fastball percentage were also collected. Statistics were not used in a year if a starting pitcher pitched fewer than 20 innings or a relief pitcher pitched less than 10 innings, as this small, limited amount of play would proportionately elevate or decrease performance statistics and be inappropriately reflective of a pitcher's true performance. A control group was also formed to evaluate if any pitching performance changes noted were because of normal career length changes; this was selected similarly to previous studies.^{8,16,18,21} Controls were matched by age, which represented age at the time of surgery for the respective reconstructed pitcher, and by level of position of starting or relief (all were MLB level). Age, rather than MLB experience, was selected to match controls, as there is a variety of ages at which a pitcher begins his MLB career, and we thought that age would provide a much more reliable representation of normal changes over time. Controls were excluded if they had undergone previous UCLR or had a previous UCL injury. Performance data were collected for control pitchers including wins, losses, winning percentage, innings pitched, ERA, WHIP, and fastball velocity. The year of surgery for the respective matched pitcher was noted as the index year in the control group. Data were collected for 3 years before and 3 years after the index year in the control group.

Pitchers who underwent UCLR were compared before surgery and after returning from surgery. They were also compared with pitchers in the control group for data before surgery and after returning to play. Continuous variables were reported as means \pm SDs and percentages. Years before surgery and years after surgery were reported as means, and a comparison to means was performed using a *t* test with significance set at $P < .05$.

RESULTS

A total of 54 pitchers played at the MLB level and were included in the study. The mean age at the time of surgery was 26.6 ± 4.2 years (range, 18-37 years). Thirty-five pitchers (65%) were right handed. Starting pitchers represented 56% (30/54), and relief pitchers represented 44% (24/54). Primary reconstruction was performed in 85% (46/54), and revision reconstruction was performed in 15% (8/54).

Pitchers were able to return to play 94% (50/53) of the time, with 1 pitcher still on the disabled list for reconstruction. Of those who returned, 80% (40/50) returned to the MLB level. Pitchers who underwent primary reconstruction returned to play 96% (43/45) of the time, with 82% (36/44) returning to MLB play. Pitchers who underwent revision surgery returned to play 88% (7/8) of the time, with 80% (4/5) returning to the MLB level (2 recently returned to the minor league and are still playing) (Table 1). The mean time to return to play was 13.8 months (range, 8-23 months), with pitchers who underwent primary reconstruction returning at a mean of 13.7 months (range, 10-23 months).

TABLE 1
Patient Information^a

	Value (n = 54)
Primary reconstruction, n (%)	46 (85)
Age, y	26.6 ± 4.2
Right-hand dominance, n (%)	35 (65)
Starting pitcher, n (%)	30 (56)
Relief pitcher, n (%)	24 (44)
Total years of playing before surgery	7.2 ± 3.9
MLB	4.8 ± 3.3
Minor league	3.4 ± 1.8
Total years of playing after surgery	4.6 ± 3.1
MLB	3.2 ± 2.5
Minor league	3.1 ± 2.2
Primary reconstruction (n = 46)	4.8 ± 3.1
MLB	3.2 ± 2.5
Primary reconstruction	3.2 ± 2.6
Minor league	3.1 ± 2.2
Primary reconstruction	3.3 ± 2.3
Total years of playing after surgery (not current player; n = 33)	4.0 ± 2.3
MLB	2.7 ± 2.1
Minor league	2.6 ± 1.3
Total years of playing after surgery (current players; n = 21)	5.4 ± 3.8
MLB	3.9 ± 3.0
Minor league	3.8 ± 3.0
Time to return, mean (range), mo	13.8 (8-23)
Primary reconstruction, mean (range), mo	13.7 (10-23)
Return to play ^b (n = 53), n (%)	50 (94)
Primary reconstruction (n = 45), n (%)	43 (96)
Return to MLB ^c (n = 50), n (%)	40 (80)
Primary reconstruction (n = 44), n (%)	36 (82)
Return to pitching role ^c (n = 50), n (%)	40 (80)
Primary reconstruction (n = 44), n (%)	37 (84)

^aData are presented as mean ± SD unless otherwise indicated. MLB, Major League Baseball.

^bOne pitcher was on the disabled list for ulnar collateral ligament reconstruction.

^cFour pitchers either were on the disabled list or just returned to the minor league; 2 underwent revision surgery.

The mean years of MLB play before surgery was 4.8 ± 3.3 years, with total years before surgery of 7.2 ± 3.9 years in which total years included MLB and minor league play. The mean years played after surgery was 3.2 ± 2.5 years (range, 0-10 years) in MLB and 4.6 ± 3.1 total years. Twenty-one players (39%) were still currently playing, with one pitcher still playing 11 years after surgery. Seven pitchers had been listed as all-stars before surgery and 7 listed as all-stars after surgery, with 1 listed before and after surgery. A total of 3 primary reconstructions required revision surgery (Table 1).

Pitching performance improved slightly after returning from surgery compared with before surgery in most categories. Pitching workload overall remained the same after surgery, with a decrease in innings pitched for relief pitchers (52.2 innings preoperatively vs 40.1 innings postoperatively; *P* = .032), which was not significant for relief

pitchers who underwent primary surgery (*P* = .061). Complete games showed a decrease after surgery for starting pitchers (0.37 games preoperatively vs 0.25 games postoperatively; *P* = .034). There was a small increase in WHIP for all pitchers (1.35 preoperatively vs 1.37 postoperatively; *P* = .037), which was not significant for those who underwent primary reconstruction (1.39 preoperatively vs 1.37 postoperatively; *P* = .094). ERA showed a nonsignificant improvement after surgery for all pitchers (4.63 preoperatively vs 4.13 postoperatively; *P* = .268). All other performance statistics were similar from before to after surgery (Table 2).

In evaluating pitchers in their first year back after UCLR compared with before, there were several areas of decreased performance. Overall, pitchers pitched fewer innings the first year after returning to play compared with the year before surgery (74.0 innings preoperatively vs 55.4 innings postoperatively; *P* = .050), which held true for those who underwent primary reconstruction as well (74.6 innings preoperatively vs 56.5 innings postoperatively; *P* = .050). Starting pitchers had significantly worse ERA in the first year back (4.36 preoperatively vs 4.49 postoperatively; *P* = .003), which was similar in those who underwent primary reconstruction (4.36 preoperatively vs 4.61 postoperatively; *P* = .003). WHIP also was significantly worse the first year after returning to play (1.39 preoperatively vs 1.41 postoperatively; *P* = .020). Starting pitchers also gave up more hits per 9 innings (*P* = .006) and more walks per 9 innings (*P* = .039), and relief pitchers had an increase in strikeouts per 9 innings (*P* = .040) (Table 3). However, comparing the second year after surgery to before surgery, most pitching performance returned to pre-UCLR levels or even improved above pre-UCLR levels. ERA in the second year after surgery was 4.06 compared with 4.63 before surgery (*P* = .380), and WHIP was 1.32 the second year after surgery and 1.35 before surgery (*P* = .221) (Table 4).

Fastball velocity after surgery was maintained compared with before surgery (91.2 mph preoperatively vs 91.6 mph postoperatively; *P* = .396), with pitchers who underwent primary reconstruction at 91.0 mph before surgery and 91.6 mph after returning to play (*P* = .445). Fastball percentage, however, was decreased after surgery from 62.1% before surgery to 59.0% after returning to play (*P* = .037). Fastball velocity demonstrated a small decrease in the first year back from surgery at 91.0 mph compared with 91.2 mph before UCLR (*P* = .032). However, fastball velocity increased to 91.9 mph the second year after UCLR compared with 91.3 mph before UCLR (*P* = .097) (Table 5).

Compared with age- and position-matched controls, there were no significant performance differences before surgery in pitchers who underwent UCLR, except for WHIP, which was lower after returning from surgery in the UCLR group (*P* = .029). In comparing pitchers with controls, the UCLR group had significant improvements in several pitching performance measures. Pitchers who underwent UCLR showed improvements in winning percentage (0.51 UCLR vs 0.44 control; *P* = .027), ERA (4.13 UCLR vs 5.02 control; *P* = .007), WHIP (1.37 UCLR vs

TABLE 2
Pitching Performance Comparing Preoperatively With Postoperatively^a

	All Pitchers (n = 54 [30 Starting, 24 Relief])			Primary Reconstruction (n = 46 [27 Starting, 19 Relief])		
	Preoperative	Postoperative	P Value	Preoperative	Postoperative	P Value
Games	31.0	29.4	.080	27.2	27.4	.083
Starting	19.4	21.7	.218	19.2	23.4	.218
Relief	49.6	42.3	.140	44.8	38.7	.155
Innings pitched	80.5	79.4	.054	82.3	82.0	.065
Starting	98.3	97.9	.130	97.4	97.9	.130
Relief	52.2	40.1	.032	48.9	37.0	.061
Complete games	0.23	0.17	.034	0.26	0.33	.034
Starting	0.37	0.25	.034	0.38	0.25	.034
Wins	4.8	4.9	.100	4.9	5.0	.122
Starting	5.6	6.2	.321	5.5	6.2	.321
Relief	3.5	2.2	.028	3.4	1.8	.051
Losses	4.9	4.5	.073	5.2	4.6	.077
Starting	5.8	5.6	.138	6.0	5.6	.138
Relief	3.4	2.3	.015	3.5	1.9	.014
Winning percentage	0.38	0.51	.296	0.44	0.51	.314
Starting	0.46	0.50	.261	0.45	0.50	.261
Relief	0.46	0.52	.172	0.43	0.52	.198
ERA	4.63	4.13	.268	4.45	4.11	.419
Starting	4.63	4.11	.484	4.70	4.11	.484
Relief	3.68	4.18	.238	3.91	4.13	.411
WHIP	1.35	1.37	.037	1.39	1.37	.094
Starting	1.38	1.33	.103	1.39	1.33	.103
Relief	1.30	1.45	.118	1.37	1.49	.312
Hits per 9 innings	8.9	9.0	.168	9.2	9.0	.257
Starting	9.3	9.0	.199	9.5	9.1	.199
Relief	8.1	8.8	.336	8.6	8.9	.417
Home runs per 9 innings	1.1	1.1	.483	1.1	1.0	.458
Starting	1.2	1.1	.407	1.2	1.1	.407
Relief	1.0	1.0	.404	1.0	1.0	.441
Walks per 9 innings	3.4	3.4	.026	3.4	3.4	.078
Starting	3.2	3.0	.217	3.2	3.0	.217
Relief	3.7	4.3	.022	3.8	4.4	.124
Strikeouts per 9 innings	7.9	7.7	.253	7.5	7.6	.301
Starting	7.2	7.8	.205	7.3	7.8	.205
Relief	8.9	7.5	.466	8.1	6.8	.037
Strikeout-to-walk ratio	2.7	2.5	.013	2.6	2.5	.035
Starting	2.5	2.8	.077	2.6	2.8	.077
Relief	2.9	1.9	.055	2.5	1.7	.148
Wins above replacement	0.67	0.86	.336	0.58	0.91	.497
Starting	0.65	1.16	.323	0.60	1.20	.323
Relief	0.69	0.22	.090	0.53	0.21	.196
Runs above replacement	7.1	8.9	.279	6.3	9.4	.401
Starting	6.8	11.8	.380	6.3	11.8	.380
Relief	7.6	2.8	.061	6.6	2.4	.128

^aBold values are statistically significant, $P < .05$. ERA, earned run average; WHIP, walks plus hits per inning pitched.

1.49 control; $P = .025$), and fastball velocity (91.6 mph UCLR vs 90.2 mph control; $P = .006$) (Table 6).

DISCUSSION

UCLR has previously shown high rates of return to play in MLB pitchers. Pitching performance after reconstruction, however, has shown conflicting results.^{8,10,18} In MLB pitchers who underwent UCLR at our institution, we found

a high rate of return to play and a high rate of return to MLB play. Pitching performance after UCLR returned to previous levels or improved in most categories. However, we did find that pitchers experienced a small decrease in performance metrics and velocity their first year in returning to sport, which subsequently improved to their pre-UCLR levels or higher by their second year back.

Return to play after UCLR has previously shown relatively high rates depending on playing level.^{2,8,24-26,28} A study by Cain et al² previously reported return-to-play

TABLE 3
Pitching Performance Comparing First Year Before Surgery With First Year After Return^a

	All Pitchers (n = 54 [30 Starting, 24 Relief])			Primary Reconstruction (n = 46 [27 Starting, 19 Relief])		
	First Year Preoperatively	First Year Postoperatively	P Value	First Year Preoperatively	First Year Postoperatively	P Value
Games	28.5	25.2	.075	26.9	21.3	.058
Starting	17.2	15.5	.080	17.2	15.6	.078
Relief	57.4	44.6	.328	62.0	50.7	.328
Innings pitched	74.0	55.4	.050	74.6	56.5	.050
Starting	79.7	59.5	.078	79.7	59.8	.078
Relief	59.3	47.2	.140	70.4	40.6	.139
Complete games	0.12	0.00	N/A	0.13	0.00	N/A
Starting	0.17	0.00	.104	0.17	0.00	N/A
Wins	4.7	3.7	.185	4.7	3.8	.185
Starting	5.1	4.3	.197	5.1	4.0	.197
Relief	3.7	2.6	.437	4.8	2.7	.437
Losses	4.5	2.7	.011	4.5	2.6	.011
Starting	4.3	2.5	.050	4.3	2.8	.050
Relief	4.9	3.0	.035	6.8	2.3	.035
Winning percentage	0.49	0.56	.172	0.49	0.57	.172
Starting	0.53	0.60	.367	0.53	0.56	.367
Relief	0.40	0.49	.263	0.35	0.54	.263
ERA	4.27	4.20	.110	4.32	4.30	.110
Starting	4.36	4.49	.003	4.36	4.61	.003
Relief	4.05	3.61	.301	4.40	2.83	.301
WHIP	1.39	1.41	.020	1.38	1.42	.020
Starting	1.35	1.43	.001	1.35	1.44	.001
Relief	1.48	1.36	.282	1.48	1.28	.282
Hits per 9 innings	9.1	9.2	.033	9.1	9.3	.033
Starting	9.1	9.4	.006	9.1	9.5	.006
Relief	9.2	8.8	.193	9.3	8.3	.193
Home runs per 9 innings	1.0	1.0	.081	1.0	1.1	.081
Starting	1.0	1.1	.054	1.0	1.2	.054
Relief	1.0	0.9	.398	1.0	0.7	.397
Walks per 9 innings	3.4	3.4	.108	3.3	3.5	.108
Starting	3.1	3.5	.039	3.1	3.5	.039
Relief	4.2	3.4	.383	4.0	3.2	.383
Strikeouts per 9 innings	7.5	8.2	.125	7.3	8.0	.125
Starting	7.4	8.2	.075	7.4	8.0	.075
Relief	7.5	8.1	.040	7.1	8.4	.040
Strikeout-to-walk ratio	2.5	2.6	.010	2.5	2.5	.010
Starting	2.7	2.6	.003	2.7	2.6	.003
Relief	1.9	2.4	.419	1.9	2.6	.419
Wins above replacement	0.56	0.53	.055	0.57	0.48	.055
Starting	0.67	0.47	.066	0.67	0.45	.066
Relief	0.30	0.66	.371	0.28	0.53	.371
Runs above replacement	6.5	5.5	.053	6.5	5.1	.053
Starting	7.3	4.9	.061	7.3	4.7	.061
Relief	4.4	6.8	.379	4.8	6.0	.379

^aBold values are statistically significant, $P < .05$. ERA, earned run average; N/A, not applicable; WHIP, walks plus hits per inning pitched.

rates of 83% at all levels of play. Other studies of MLB pitchers have shown return-to-play rates of 75% to 95%, with return-to-MLB rates of about 80%.^{8,17,18} Our rates of return to play were similar to and even higher than those of some recent studies, with almost all pitchers returning to play at a rate of 94%, with those who underwent primary reconstruction returning at 96%. A large majority of these pitchers also returned to MLB play, with 80% returning to the MLB level.

Revision reconstruction has shown less promising rates of return to play.^{7,21} Previous studies have reported rates of players returning to the MLB level after revision reconstruction of about 65%.²¹ When evaluating only revision reconstruction, the pitchers in our study who underwent revision returned 88% of the time. About 80% were able to return to MLB play, with 2 players recently returning to minor league play, which if they do not return to MLB would represent 62.5% returning to MLB play, which is

TABLE 4
Pitching Performance Comparing Preoperatively With Second Year After Return^a

	All Pitchers (n = 54 [30 Starting, 24 Relief])			Primary Reconstruction (n = 46 [27 Starting, 19 Relief])		
	Preoperative	Second Year Postoperatively	P Value	Preoperative	Second Year Postoperatively	P Value
Games	31.0	33.3	.448	27.2	31.3	.389
Starting	19.4	24.9	.260	19.2	25.2	.297
Relief	49.6	48.0	.391	44.8	48.8	.469
Innings pitched	80.5	92.9	.441	82.3	97.2	.484
Starting	98.3	112.7	.460	97.4	113.6	.471
Relief	52.2	58.1	.131	48.9	45.0	.285
Complete games	0.23	0.23	.211	0.26	0.25	.212
Starting	0.37	0.29	.163	0.38	0.31	.214
Wins	4.8	5.4	.354	4.9	5.6	.384
Starting	5.6	6.5	.492	5.5	6.8	.371
Relief	3.5	3.5	.238	3.4	1.6	.061
Losses	4.9	5.5	.397	5.2	5.8	.361
Starting	5.8	6.9	.320	6.0	7.1	.345
Relief	3.4	3.0	.188	3.5	2.4	.434
Winning percentage	0.38	0.51	.343	0.44	0.50	.282
Starting	0.46	0.47	.120	0.45	0.47	.337
Relief	0.46	0.60	.318	0.43	0.58	.380
ERA	4.63	4.06	.380	4.45	3.98	.397
Starting	4.63	4.02	.491	4.70	4.03	.423
Relief	3.68	4.13	.362	3.91	3.80	.447
WHIP	1.35	1.32	.221	1.39	1.31	.479
Starting	1.38	1.28	.341	1.39	1.29	.368
Relief	1.30	1.38	.278	1.37	1.38	.390
Hits per 9 innings	8.9	8.5	.486	9.2	8.5	.303
Starting	9.3	8.6	.412	9.5	8.6	.425
Relief	8.1	8.3	.456	8.6	8.2	.313
Home runs per 9 innings	1.1	1.1	.385	1.1	1.0	.110
Starting	1.2	1.1	.427	1.2	1.1	.216
Relief	1.0	1.0	.415	1.0	0.7	.203
Walks per 9 innings	3.4	3.4	.067	3.4	3.3	.233
Starting	3.2	2.9	.287	3.2	3.0	.218
Relief	3.7	4.1	.080	3.8	4.2	.467
Strikeouts per 9 innings	7.9	8.0	.320	7.5	7.8	.356
Starting	7.2	8.2	.295	7.3	8.0	.297
Relief	8.9	7.7	.442	8.1	7.1	.325
Strikeout-to-walk ratio	2.7	2.6	.043	2.6	2.6	.132
Starting	2.5	3.0	.186	2.6	2.8	.165
Relief	2.9	2.0	.080	2.5	1.9	.333
Wins above replacement	0.67	1.02	.411	0.58	1.15	.194
Starting	0.65	1.31	.212	0.60	1.38	.128
Relief	0.69	0.50	.331	0.53	0.32	.396
Runs above replacement	7.1	10.6	.407	6.3	11.7	.228
Starting	6.8	13.4	.232	6.3	13.9	.144
Relief	7.6	5.8	.329	6.6	3.4	.332

^aBold values are statistically significant, $P < .05$. ERA, earned run average; WHIP, walks plus hits per inning pitched.

a similar rate as in previous studies. Overall, this shows that UCLR is a successful procedure that allows professional baseball players to return to play at a very high rate and also return at a high level. It also continues to support the need of continued vigilance of those who return, as players who later require revision reconstruction are at an increased risk of not returning to MLB.

Although one of the most important considerations for undergoing UCLR is whether a pitcher will return to play, often the next most important consideration is how

well he can expect to perform after reconstruction. It appears important to evaluate performance rather than simply return to play, as previous studies have described high rates of return to play (80% to MLB level,¹⁸ 87% to MLB level¹⁶) but showed declines in performance with regard to ERA and innings pitched. Our study found that pitchers who returned after UCLR were able to attain previous levels of performance after returning to play and, in some categories, even improve performance. Previous studies that have evaluated pitching performance have found

TABLE 5
Fastball Velocity and Fastball Percentage
Before and After Surgery^a

	Fastball Velocity, mph	Fastball Percentage, %
All pitchers		
Preoperative	91.2	62.1
Postoperative	91.6	59.0
<i>P</i> value	.396	.037
Primary reconstruction		
Preoperative	91.0	61.0
Postoperative	91.6	58.7
<i>P</i> value	.445	.024
Revision surgery		
Preoperative	92.3	65.6
Postoperative	91.4	55.6
<i>P</i> value	.417	.31
All pitchers		
First year preoperatively	91.2	62.0
First year postoperatively	91.0	58.0
<i>P</i> value	.032	.080
All pitchers		
Preoperative	91.3	62.1
Second year postoperatively	91.9	58.3
<i>P</i> value	.097	.213

^aBold values are statistically significant, *P* < .05.

conflicting results, with some studies showing improved ERA, walks, and hits and other studies showing worse ERA and innings pitched.^{8,16,18} Our study found that overall ERA, wins above replacement, runs above replacement, and winning percentage showed improvements after UCLR; however, these were not statistically significant. Starting pitchers showed the greatest improvement in ERA and WHIP, with relief pitchers showing more decreases in performance statistics. The importance of reporting advanced baseball statistics such as wins above replacement and runs above replacement, as collected in this study, has been increasing in recent articles.^{3,12,19,20} These metrics help to provide more valuable data to control for changes in ERA and other performance measures that are difficult to control for, like the league a pitchers plays in and opponents a pitcher faces.

A very important finding in our study is that the improvement in performance is not immediate upon returning to play, as in the first year after returning from reconstruction, pitchers showed a decline in most performance measures including innings pitched, ERA, and WHIP. Some of these first-year performance changes may partially be attributed to managers trying to protect these pitchers or making the decision to pull them earlier in games; however, this is difficult to gauge. These initial declines in performance, however, returned to normal levels or increased levels during the second year after returning, with starting pitchers showing the greatest improvement in innings pitched, ERA, and WHIP. This is an encouraging finding for MLB pitchers who undergo reconstruction, as they should not only expect a high

return-to-play rate but also maintain and, by some metrics, improve performance after returning.

Another important metric for pitchers is their pitch velocity. For MLB pitchers, velocity is a measurable outcome metric that lends insight to overall elbow and throwing arm physiological function.^{4,15} Studies have previously evaluated pitch velocity as a risk factor for shoulder injuries as well as UCL injuries; however, very little has been reported on maintaining velocity after UCLR.^{9,11,13,17,23,24,27} Our study found fastball velocity to be maintained after reconstruction compared with before UCLR, with a decrease in fastball percentage after surgery. There was a small, significant drop in velocity the first year after surgery; however, the second year after UCLR saw an increase to pre-UCLR levels or higher. The initial drop in velocity may be attributed to the fact that although pitching mechanics should be optimized at this point, by having over a year off from competitive play, the player may take time to redevelop this level of velocity. Fastball percentage also showed a small decrease compared with before surgery, which may be a reflection of pitchers changing their variety of pitches. This decreased percentage may be advantageous, as previous studies have shown increased fastball percentage to be a risk for UCL injuries.¹⁵

There are several limitations to this study. Although we used only MLB data to provide a more uniform set of data for the highest level of pitchers, the use of minor league data as well may have given a greater amount of data to draw conclusions. Many of the pitchers that we evaluated also are currently still playing, and further data from these pitchers may have offered important information as they continue to play. We did obtain data for 3 years before surgery and then 3 years after returning to play to provide a more representative sample of a pitcher's performance. Some of these data, however, can be dependent on the teams and leagues in which pitchers play, which may influence a pitcher's performance and cannot be completely controlled for. Data also do not account for situational pitcher use, as relief pitchers do not have an equal role between teams; similarly, a starting pitcher in the National League (NL) versus American League (AL) has an effect on the number of innings pitched because of the presence of a designated hitter in the AL. Some data after returning to play, specifically pitching workload, may also be influenced by teams looking to protect pitchers after their return; Pitchers may be limited in innings pitched and games played in the first year after surgery and beyond. Individual teams may have different return-to-play protocols, and although we are in contact with teams about rehabilitation protocols and return to play, this can still play a role in returning to play. Previous research that has evaluated pre- and post-UCLR performance outcomes has consisted of studies predominantly constructed using online information and databases. These methods can add the potential for error in reporting and accuracy of procedures performed. This current study evaluated outcomes after UCLR performed at a single institution, which controls more for confounding variables and provides more reliable information compared with previous studies. However, a single-institution study

TABLE 6
Performance of All Pitchers Compared With Controls Before and After Reconstruction^a

	Preoperative			Postoperative		
	All Pitchers	Controls	P Value	All Pitchers	Controls	P Value
Wins	4.8	4.6	.459	4.9	4.49	.395
Primary reconstruction	4.9	4.2	.119	5.0	4.37	.407
Losses	4.9	4.3	.482	4.5	5.24	.140
Primary reconstruction	5.2	3.5	.051	4.3	5.09	.139
Winning percentage	0.46	0.55	.085	0.51	0.44	.027
Primary reconstruction	0.44	0.58	.085	0.51	0.45	.072
Innings pitched	80.5	81.9	.281	79.4	84.69	.269
Primary reconstruction	82.3	72.9	.162	82.0	81.27	.295
ERA	4.27	4.57	.241	4.13	5.02	.007
Primary reconstruction	4.45	4.63	.387	4.11	5.17	.001
WHIP	1.35	1.44	.029	1.37	1.49	.025
Primary reconstruction	1.39	1.46	.070	1.37	1.51	.020
Fastball velocity	91.2	90.6	.066	91.6	90.2	.006
Primary reconstruction	91.0	90.8	.084	91.6	90.5	.019
Age	26.6	26.4	.347			
Primary reconstruction	26.5	26.3	.404			

^aBold values are statistically significant, $P < .05$. ERA, earned run average; WHIP, walks plus hits per inning pitched.

has limitations, specifically, the concern of reproducible results to a generalized population.

CONCLUSION

MLB pitchers experienced a high rate of return to play as well as a high rate of return to previous levels of play after UCLR. Pitching workload was maintained after returning to play. Pitching performance, including velocity, initially decreased the first year after returning and then was restored or improved in most categories after the first year back from UCLR.

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