

Correlation of Rehabilitation and Throwing Program Milestones With Outcomes After Ulnar Collateral Ligament Reconstruction

An Analysis of 717 Professional Baseball Pitchers

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Background: There remains room for improvement in surgical outcomes after medial ulnar collateral ligament reconstruction (MUCLR) in professional pitchers. The role and influence of postoperative rehabilitation on the outcomes of MUCLR are unknown. There is a paucity of clinical data in the current literature comparing the success of various postsurgical rehabilitation protocols after MUCLR.

Purpose: To summarize the current rehabilitation process for professional pitchers recovering from MUCLR, evaluate what player and surgical factors correlate with outcomes, and determine whether rehabilitation timing and milestones correlate with successful outcomes.

Study Design: Case series; Level of evidence, 4.

Methods: 717 professional baseball pitchers who underwent MUCLR between 2010 and 2016 were identified and included in the analysis. Player characteristics evaluated included age at the time of surgery, throwing side dominance, primary pitching role (starter vs reliever), and level of play (MLB, AAA, AA, A). Surgical factors studied included date of surgery, graft type (palmaris longus autograft vs gracilis autograft), and surgical technique (figure of 8 vs docking vs other). The rehabilitation and throwing progression details were as follows: initiation date; first throw date; dates to start throwing from various distances; longest distance thrown; first flat ground throw date; first mound throw date; and first live batting practice (BP) date. The primary outcomes of interest were the ability to return to play at any level (RTP), the ability to return to the same level (RSL), and the time to RTP/RSL.

Results: On average, pitchers threw a baseball for the first time 4.9 months after surgery, with a broad range (2.8-14.9 months). For the 675 (94%) pitchers who were able to progress to mound throwing, the first throws off a mound occurred at a mean of 9.4 months after surgery. Before progressing to the mound, the mean longest long-toss distance reached was 137.5 feet, with a broad range (105-300 feet). A high variation in the time to RTP (7.6-53.9 months) and RSL (8.6-60.7 months) was noted. A total of 599 (84%) pitchers were able to RTP at a mean time of 14.9 ± 4.9 months after surgery (range, 7.6-53.9 months). Also, 528 (74%) pitchers were able to RSL after MUCLR at a mean of 17.4 ± 7 months (range, 8.6-60.7 months) postoperatively. Age was the most significant predictor of RTP (hazard ratio [HR], 1.03 [95% CI, 1.01-1.05]; $P = .01$) and RSL (HR, 0.96 [95% CI, 0.93-0.99]; $P < .01$). For every 1-year increase in age, there was a 3% increase in the chance of RTP. Conversely, for every 1-year decrease in age, there was a 4% increase in the chance of RSL. MLB players were more likely to RTP (HR, 1.39 [95% CI, 1.18-1.63]; $P < .01$) but not necessarily to RSL (HR, 0.90 [95% CI, 0.75-1.08]; $P = .24$). The time from surgery to any of the rehabilitation milestones of interest (first throw, first flat ground pitching, first mound throwing, and first live BP) did not correlate with RTP or RSL (all, $P > .05$). The same was true for the greatest long-toss distance thrown before transitioning to the mound.

Conclusion: Significant variability in the postoperative rehabilitation protocols after MUCLR was observed in 717 professional baseball pitchers. The timing of achievement of throwing progression and rehabilitation milestones postoperatively varied widely but did not correlate with outcomes. Player characteristics—except for player age and professional pitching level—did not correlate with RTP and RSL outcomes. Older pitchers and MLB pitchers were more likely to RTP, but younger players were more likely to RSL. Surgical factors did not correlate with rehabilitation outcomes.

Keywords: professional baseball; rehabilitation; return to play; Tommy John surgery; ulnar collateral ligament reconstruction

Excessive valgus torque placed on the medial elbow during the late cocking and early acceleration phases of throwing leads to repetitive microtrauma and medial ulnar collateral ligament (MUCL) insufficiency.¹⁶ The rates of MUCL reconstruction (MUCLR) surgery are increasing in professional pitchers in the United States.^{2,6-8} Return to play (RTP) and return to the same preinjury level of competition (RSL) rates of 79% to 91% and 71% to 90%, respectively, have been reported after MUCLR.^{1,3,10,11,14,15,17} Surgical factors—such as the role of graft type, surgical technique, and associated ulnar nerve surgery at the time of MUCLR—have not been found to significantly influence outcomes in current or drafted professional pitchers.^{4,15,21} However, there remains room for improvement in surgical outcomes, as a postoperative throwing elbow injury rate of 46% and a mean time to RTP ranging from 14.5 to 20.5 months have been documented.^{5,13,14}

The role of postoperative rehabilitation and its influence on the outcomes of MUCLR are unknown. Largely, postoperative protocols vary by surgeon and have not been fully validated. A recent study by Lightsey et al¹⁸ highlighted the significant rehabilitation variability after MUCLR. The authors evaluated 30 protocols from both published studies and various orthopaedic training programs and found significant diversity among protocols in the timing of throwing and the timing of return to competition. Factors such as the timing of return to throwing and the achievement of progressive throwing milestones during the rehabilitation process—including time to first flat ground throw, mound throw, live batting practice (BP), and the longest distance achieved before progressing to the mound—may have a significant influence on a professional pitcher's ability and time to RTP and RSL.

The creation of the Major League Baseball (MLB) Health and Injury Tracking System (HITS) has provided a robust, reliable resource that includes detailed information regarding all professional baseball players, both in MLB and Minor League Baseball (MiLB).⁹ All professional pitchers requiring MUCLR are included, with treatment by a multitude of surgeons, surgical techniques, and graft choices available for comparison. This resource now allows for larger-scale comparisons that were not previously

possible. Accordingly, the primary purposes of this investigation were to utilize the HITS medical record system to (1) summarize the current rehabilitation and return to throw process for professional baseball pitchers recovering from MUCLR, (2) understand what player and surgical factors correlate with outcomes, and (3) determine whether rehabilitation timing and milestones correlate with successful outcomes for professional pitchers returning after MUCLR.

METHODS

After approval from the Mayo Clinic institutional review board and the MLB Research Committee, the MLB HITS medical record system was utilized to identify professional baseball pitchers who underwent MUCLR between 2010 and 2016. To be included in the study, pitchers had to be on an active MLB or MiLB roster at the time of surgery, have a primary MUCLR, have postoperative rehabilitation and throwing milestone information available, and have a minimum follow-up of 2 years. Players were excluded if they were not pitchers, were not on an active roster at the time of surgery, underwent primary repair or revision reconstruction of the MUCL, or had an insufficient follow-up.

Player characteristics extracted included age at the time of surgery, throwing side dominance, primary pitching role (starter vs reliever), and level of play (MLB, AAA, AA, A). Surgical factors studied included date of surgery, graft type (palmaris longus autograft vs gracilis autograft), and surgical technique (figure of 8 vs docking vs other). The rehabilitation and throwing progression details were as follows: initiation of rehabilitation date, first throw date, dates to start throwing from various distances (ie, 45', 60', 75', 90', 105', 120', 150', 180'), longest distance thrown, first flat ground throw date, first mound throw date, and first live BP date. The primary outcomes of interest were the ability to RTP, the ability to RSL, and the time to RTP/RSL. Pitchers were considered to have achieved RTP at any level if and when they made a postoperative

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Submitted August 9, 2021; accepted March 10, 2021.

One or more of the authors has declared the following potential conflict of interest or source of funding: T.B.G. has received support for education from Smith & Nephew, Arthrex, United Orthopedics, Stryker, and Zimmer Biomet; and research support from Major League Baseball. C.L.C. has received support for education from Arthrex and Zimmer Biomet; and research support from Major League Baseball. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

TABLE 1
Summary of Throwing Program Milestones^a

Time to Reach Milestone	N	Mean (SD)	Median	Q1, Q3	Range
Months from surgery to first...					
Throw of any type	717	4.9 (1.1)	4.6	4.1, 5.4	2.8-14.9
Flat ground pitching	453	8.6 (1.9)	8.4	7.3, 9.4	5.2-26.4
Mound pitching	675	9.4 (2)	9.2	8.3, 10.3	4.9-27.6
Live BP	661	11.8 (2.6)	11.3	10.3, 12.4	4.2-29.1
Live game activity at any level (RTP)	599	14.9 (4.9)	13.2	11.9, 16.1	7.6-53.9
Live game activity same level (RSL)	528	17.4 (7)	14.7	12.6, 20.7	8.6-60.7
Longest long-toss distance before transitioning to mound, ft	666	137.5 (23.6)	127.5	120, 150	105-300

^aBP, batting practice; N, number; Q, quartile; RSL, return to play at the same level; RTP, return to play at any level.

appearance in a professional game. RSL was defined as pitching in at least 1 game that was at or above the level of play (ie, MLB, AAA, AA, or A) before the time of surgery.

Statistical Analysis

Descriptive statistics (mean, median, minimums, maximums, etc) were used to describe standard variables and summarize the current rehabilitation and return to throw processes for included pitchers. Univariate cox models were created for all variables and outcomes of interest to correlate player characteristics, surgical factors, and rehabilitation factors with outcomes. These results are reported in hazard ratios (HRs) with 95% CIs and their corresponding *P* values. For this analysis, the HR represents the relative risk that the outcome (RTP, RSL, etc) was achieved. Accordingly, a higher HR represents an increased likelihood that the pitchers in that group were able to RTP or RSL. Kaplan-Meier curves were used to describe the time required to RTP or RSL after particular rehabilitation/throwing milestones. For all statistical measures, statistical significance was set at *P* < .05.

RESULTS

A total of 916 professional baseball pitchers were initially identified as undergoing MUCLR during the study period. Of these, 717 (78%) had rehabilitation and throwing program milestones available for review, and this group made up the study cohort. The mean age at the time of surgery was 23.7 years (range, 17-48 years). Right-handed pitchers comprised 77% of the cohort, and 23% were left-handed. Also, 70% of pitchers were primarily starters and 30% were primarily relievers.

The times to reach various milestones in the rehabilitation process are outlined in Table 1. On average, pitchers threw a baseball for the first time 4.9 months after surgery, but the range was broad at 2.8 to 14.9 months. Only 453 (63%) pitchers were noted to have performed flat ground pitching before progressing to the mound. For the 675 (94%) pitchers who were able to progress to mound throwing, the first throws off a mound occurred at a mean of 9.4 months after surgery. Before progressing to the

mound, the mean longest long-toss distance reached was 137.5 feet with a range of 105 to 300 feet. There was also notable variability in the range in the time to RTP (7.6-53.9 months) and RSL (8.6-60.7 months) (Table 1).

Ultimately, 599 (84%) pitchers were able to RTP at a mean time of 14.9 ± 4.9 months after surgery (range, 7.6-53.9 months). The time needed to RTP after reaching each of the milestones of interest (surgery, first throw, first mound throw, and first live BP) is depicted in Figure 1. A total of 528 (74%) professional pitchers were able to RSL after MUCLR at a mean of 17.4 ± 7 months (range, 8.6-60.7 months) postoperatively. The temporal progression from milestones of interest to RSL is demonstrated in Figure 2. As expected, as players successfully progressed through the various milestones, they were more frequently able to RTP. The percentage of players able to RTP/RSL within a given time frame after each of these milestones is outlined in Table 2.

When correlating the studied player, surgical, and rehabilitation factors with outcomes, age was the most significant predictor of RTP (HR, 1.03 [95% CI, 1.01-1.05]; *P* = .01) and RSL (HR, 0.96 [95% CI, 0.93-0.99]; *P* < .01) (Table 3). For every 1-year increase in age, there was a 3% increase in the chance of RTP. Conversely, for every 1-year decrease in age, there was a 4% increase in the chance of RSL. Similarly, MLB players were more likely to RTP (HR, 1.39 [95% CI, 1.18-1.63]; *P* < .01) but not necessarily to RSL (HR, 0.90 [95% CI, 0.75-1.08]; *P* = .24) than MiLB players. Surgical factors, such as graft type (HR, 1.16 [95% CI, 0.95-1.41]; *P* = .14) and MUCLR technique (HR, 1.16 [95% CI, 0.96-1.40]; *P* = .12), did not correlate with pitchers' ability to RSL. Ultimately, the time from surgery to any of the rehabilitation milestones of interest (first throw, first flat ground pitching, first mound throwing, and first live BP) did not correlate with RTP or RSL (all, *P* > .05). The same was true for the greatest long-toss distance thrown before transitioning to the mound (Table 3). Despite the variance in rehabilitation and throwing protocols encountered in this study, the following describes a composite general protocol inclusive of the basic rehabilitation guidelines encountered for the pitchers included in the results: The postoperative splint is removed 7 to 10 days postoperatively, and the patient's arm is placed into a hinged elbow brace. While wearing the brace, the patient is allowed elbow range of motion (ROM) from 30° to 90°

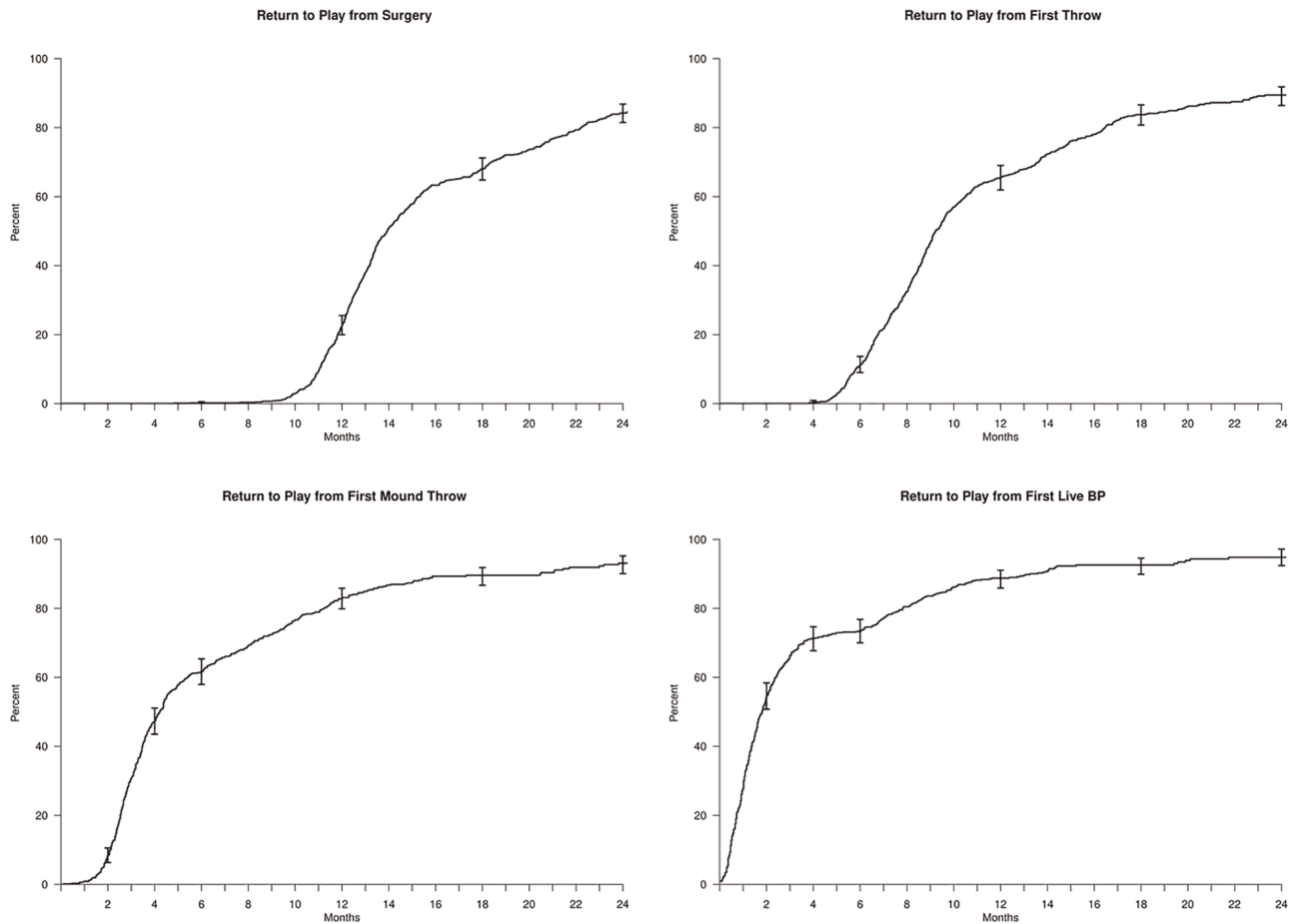


Figure 1. Kaplan-Meier survival analysis of pitchers’ ability to return to play at any level after reaching various milestones in the rehabilitation process. BP, batting practice.

initially, and this is advanced to 15° to 105° between weeks 3 and 5. The brace is discontinued at 6 weeks and formal physical therapy is initiated. From weeks 6 to 16, the focus of physical therapy is on elbow ROM and shoulder and wrist strength and ROM. This is advanced as tolerated. Beginning at 16 to 24 weeks, a formal throwing program is initiated. Throwing begins at a distance of 45 feet on flat ground and is slowly advanced as tolerated. Once the patient is able to throw at least 135 feet on flat ground without pain, typically 9 to 11 months after surgery, throwing from the mound is permitted. This is slowly advanced over the next 3 to 5 months with the goal of returning to competitive pitching at 12 to 16 months.

DISCUSSION

The role of postoperative rehabilitation and the achievement of progressive throwing milestones during the rehabilitation process after MUCLR—such as the timing of return to throwing, the time to first flat ground throw, mound throw, live BP, and the longest distance achieved before progressing to the mound—may have a significant influence on

a professional pitcher’s ability and time to RTP and RSL. However, before this study, the effects of postoperative rehabilitation and the timing of achievement of these milestones on the outcomes of MUCLR were unknown. In this study, there was significant variability in the postoperative rehabilitation protocols after MUCLR in professional baseball pitchers. The timing of achievement of rehabilitation milestones did not correlate with successful outcomes. Player and surgical factors—except for age and level—did not correlate with RTP and RSL outcomes. Older pitchers and MLB pitchers were more likely to RTP, but younger players were more likely to RSL.

Considerable variability in postoperative rehabilitation after MUCLR has been previously described. There have been no clinically validated, comprehensive rehabilitation programs for this surgical procedure.²⁰ Lightsey et al¹⁸ noted significant rehabilitation variability after MUCLR in a cross-sectional analysis evaluating 30 protocols from both published studies and various orthopaedic training programs. The authors described significant diversity among protocols with regard to the timing of throwing and the timing of return to competition. A more detailed description of progressive throwing milestones during the

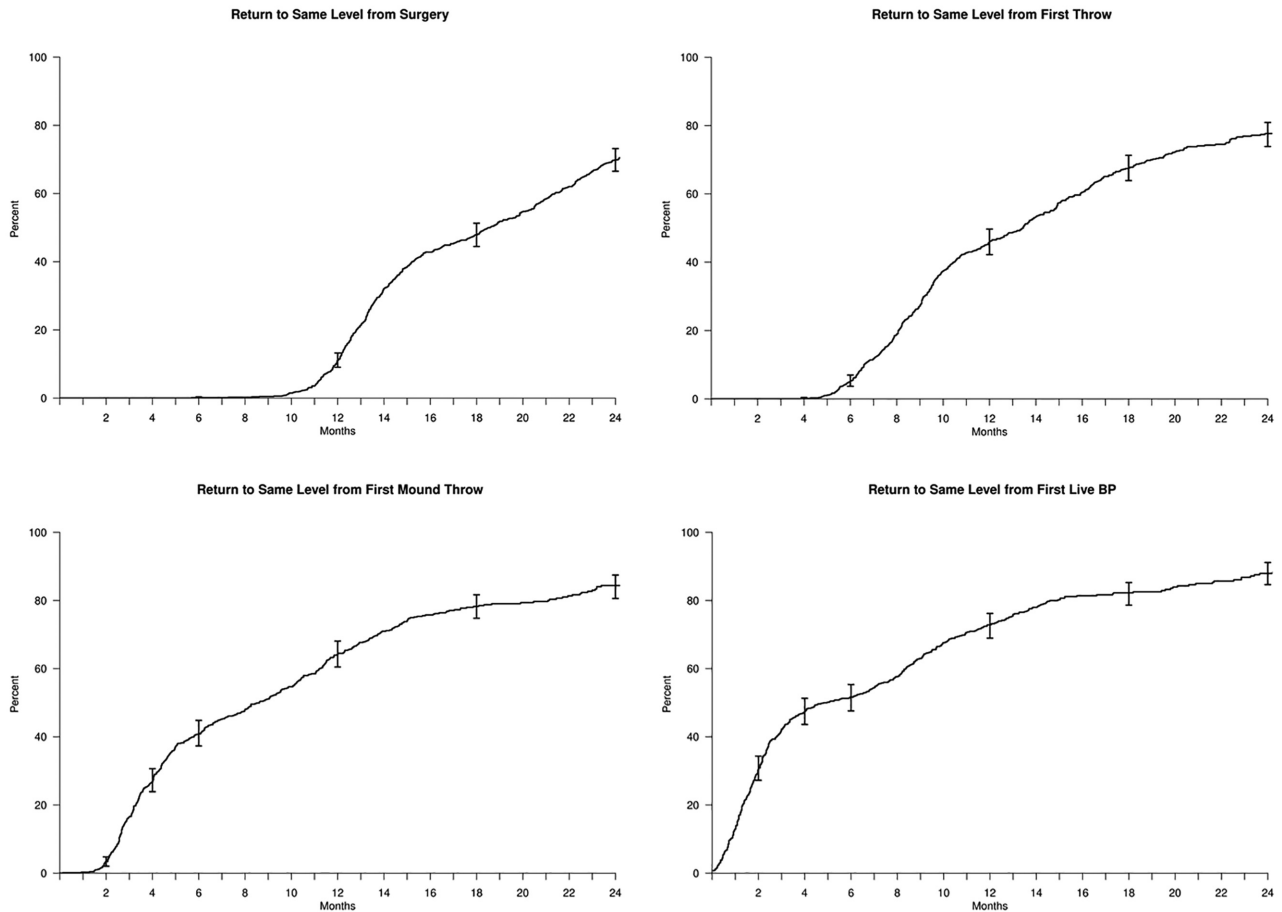


Figure 2. Kaplan-Meier survival analysis of pitchers' ability to return to the same level of play after reaching various milestones in the rehabilitation process. BP, batting practice.

TABLE 2
Percentages of Players Able to RTP/RSL by Various Time Points After the Rehabilitation Milestones of Interest^a

Time From Milestone to Return	1 Month	3 Months	6 Months	9 Months	12 Months	15 Months	18 Months	21 Months	24 Months
RTP rates after first..., % (95% CI)									
Throw of any type	0 (0-0)	0 (0-0)	11 (9-13)	47 (43-50)	66 (62-69)	76 (73-79)	84 (81-86)	87 (84-90)	89 (86-92)
Flat ground pitching	0 (0-1)	15 (12-18)	53 (48-58)	68 (63-72)	78 (73-81)	86 (82-89)	89 (85-91)	89 (85-92)	92 (88-95)
Mound pitching	1 (0-2)	31 (27-34)	62 (58-65)	72 (69-76)	83 (80-86)	88 (85-90)	90 (87-92)	90 (87-93)	93 (90-95)
Live BP	28 (24-31)	66 (63-70)	74 (70-77)	84 (81-87)	89 (86-91)	92 (90-94)	93 (90-95)	94 (92-96)	95 (92-97)
RSL rates after first..., % (95% CI)									
Throw of any type	0 (0-0)	0 (0-0)	5 (4-7)	27 (24-30)	46 (42-50)	57 (53-61)	68 (64-71)	74 (70-77)	78 (74-81)
Flat ground pitching	0 (0-1)	6 (4-9)	35 (30-39)	47 (42-52)	60 (55-64)	70 (65-74)	76 (71-80)	78 (74-82)	84 (79-88)
Mound pitching	0 (0-1)	17 (14-19)	41 (37-44)	51 (47-55)	65 (61-68)	74 (70-78)	78 (75-81)	80 (76-83)	84 (81-88)
Live BP	13 (10-16)	42 (38-46)	52 (48-55)	63 (59-67)	73 (69-76)	80 (77-84)	83 (79-85)	85 (82-88)	88 (84-91)

^aBP, batting practice; RSL, return to play at the same level; RTP, return to play at any level.

rehabilitation process—such as the time to first flat ground throw, mound throw, live BP, and the longest distance achieved before progressing to the mound—was unavailable. In our study of 717 professional pitchers, considerable variability existed in the rehabilitation protocols. The range of time after surgery for the initiation of a throwing program was quite broad at 2.8 to 14.9 months. The majority

of pitchers were noted to have performed flat ground pitching before progressing to the mound, but 37% of pitchers never attempted flat ground pitching. Before progressing to the mound, the range of the mean long-toss distance reached was considerably broad, at 105 to 300 feet. There was also notable variability in the range in the time to RTP (7.6-53.9 months) and RSL (8.6-60.7 months).

TABLE 3
Correlation of Player, Surgical, and Rehabilitation
Factors to RTP/RSL Outcomes^a

Variable	HR	95% CI	P
RTP			
Age, y	1.03	(1.01-1.05)	.01
Role (starter vs reliever)	1	(0.84-1.20)	.99
Level (MLB vs MiLB)	1.39	(1.18-1.63)	>.01
Surgical technique (modified Jobe vs docking)	1.13	(0.95-1.36)	.17
Graft type (palmaris vs hamstring)	1.13	(0.94-1.36)	.19
Time from surgery to first throw	0.97	(0.90-1.05)	.45
Time from surgery to flat ground pitching	0.98	(0.93-1.03)	.37
Time from surgery to mound throwing	0.98	(0.94-1.02)	.39
Time from surgery to live BP	0.97	(0.94-1.00)	.07
Longest distance before mound throwing	1.01	(0.99-1.02)	.53
RSL			
Age, y	0.96	(0.93-0.99)	<.01
Role (starter vs reliever)	1.10	(0.91-1.32)	.34
Level (MLB vs MiLB)	0.90	(0.75-1.08)	.24
Surgical technique (modified Jobe vs docking)	1.16	(0.96-1.40)	.12
Graft type (palmaris vs hamstring)	1.16	(0.95-1.41)	.14
Time from surgery to first throw	1.01	(0.93-1.10)	.80
Time from surgery to flat ground pitching	0.96	(0.91-1.02)	.16
Time from surgery to mound throwing	0.98	(0.93-1.02)	.30
Time from surgery to live BP	0.98	(0.95-1.01)	.18
Longest distance before mound throwing	1	(0.99-1.02)	.75

^aBold P values are those <.05 and considered to represent statistical significance. BP, batting practice; HR, hazard ratio; MiLB, Minor League Baseball; MLB, Major League Baseball; RSL, return to play at the same level; RTP, return to play at any level.

Player characteristics evaluated in our study included age at the time of surgery, throwing side dominance, primary pitching role (starter vs reliever), and level of play (MLB, AAA, AA, A). Surgical factors studied included date of surgery, graft type (palmaris longus autograft vs hamstring autograft), and surgical technique (figure of 8 vs docking vs other). Of all factors analyzed, only pitcher age and professional level correlated with the outcomes of interest: the ability to RTP, the ability to RSL, and the time to RTP/RSL. No surgical factors affected outcomes. Older pitchers and MLB pitchers were more likely to RTP, but younger players were more likely to RSL. We believe this is because older players were more likely to have been at the MLB level at the time of surgery. Therefore, it was more likely that older MLB players would return to any level, while younger players, who are more likely to be MiLB players, had an easier time to RSL, as it was a lower level at the outset. Therefore, there is an inherent bias for the older players to RTP and the younger players to RSL. Our findings are consistent with those of our previous study of 566 professional baseball pitchers, where we found no statistical difference in RTP or RSL by surgical factors such as technique (docking vs modified Jobe) and graft type (palmaris vs gracilis autograft), and where we also found a statistically higher RTP in MLB pitchers than MiLB pitchers.¹⁵

The rehabilitation and throwing progression details analyzed were as follows: initiation of rehabilitation date, first throw date, start throwing from various distances dates (ie, 45', 60', 75', 90', 105', 120', 150', 180'), the longest distance thrown, first flat ground throw date, first

mound throw date, and first live BP date. These milestones did not predict the primary outcomes of the pitcher's ability to RTP, the ability to RSL, and the time to RTP/RSL. To our knowledge, there have been no previous studies investigating whether rehabilitation timing and milestones correlate with successful outcomes for professional pitchers returning after MUCLR. Erickson et al,¹² in 2020, evaluated the timing of return to batting milestones and the subsequent effect on batting performance after MUCLR in 137 professional baseball position players. The authors noted a 77% return to hitting and a 75% return to fielding in a real game, with a statistically significant decrease in at bats, hits, and runs after surgery. A total of 599 (84%) of the 717 professional pitchers in our study were able to RTP at a mean time of 14.9 ± 4.9 months after UCLR (range, 7.6-53.9 months), and a total of 528 (74%) professional pitchers were able to RSL after surgery at a mean of 17.4 ± 7 months (range, 8.6-60.7 months). Makhni et al,¹⁹ in 2014, when studying 147 MLB pitchers, demonstrated similar numbers with an RTP of 80% and an RSL of 67.7% after UCLR. In a previous investigation, we reported very similar RTP (79.9%) and RSL (71.2%) rates after UCLR and postoperative rehabilitation.¹⁵

There were several limitations to this study. This was a retrospective review of the prospectively collected data in the MLB HITS medical record system. Thus, this study relied on the accuracy of information provided to the HITS database by the medical professionals of each professional baseball team in the MLB—including athletic trainers, physical therapists, and physicians—and thus there is a potential for errors or omissions in data entry. However, the medical personnel of each team are well trained, meticulous, and leaders in their respective medical fields. To minimize the potential for data entry errors, all diagnoses and procedures were confirmed by reviewing the operative reports of all pitchers. All details of the previously stated rehabilitation milestones were carefully reviewed and compared. Of the 916 professional baseball pitchers who were identified as undergoing MUCLR during the study period, only 717 (78%) had thorough rehabilitation records available for review as the study cohort. An additional limitation of this study is the inability to document the durability of surgical outcomes, as a substantial number of players studied in the MLB HITS database are still playing. Further, using the definition of RTP and RSL as the ability to make 1 postoperative appearance in a professional game and pitching in at least 1 game that was at or above the level of play before the time of surgery, respectively, qualified as a "return" in this study; however, in isolation, this may not be considered a successful result by the pitchers or surgeons.

There are also many strengths of this study. To our knowledge, this is the only study that evaluates and summarizes the current rehabilitation and return to throw process for professional baseball pitchers recovering from MUCLR, the player and surgical factors correlating with outcomes during rehabilitation, the assessment of rehabilitation timing and milestones, and how they correlate with successful outcomes for professional pitchers returning after MUCLR. The MLB HITS database used for this study is a comprehensive, reliable, and accurate resource that

includes detailed information regarding all professional baseball players both in MLB and MiLB who require surgical treatment and provides the opportunity to thoroughly evaluate the rehabilitation outcomes of a multitude of pitchers. Compared with small, single-center databases, the MLB HITS database allows for a more detailed evaluation of the variables studied as well as greater statistical power.⁹

CONCLUSION

Significant variability in the postoperative rehabilitation protocols after MUCLR was observed in 717 professional baseball pitchers. The timing of achievement of throwing progression and rehabilitation milestones postoperatively varied widely but did not correlate with outcomes. Player characteristics—except for player age and professional pitching level—did not correlate with RTP and RSL outcomes. Older pitchers and MLB pitchers were more likely to RTP, but younger players were more likely to RSL. Surgical factors did not correlate with rehabilitation outcomes. As there was no significant correlation of surgical outcomes with the timing and the progression of throwing milestones, we believe that our results support the notion that the rehabilitation process for UCLR must be tailored to each athlete.

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