



# Decreased Upward Vertical Movement for Fastballs After Ulnar Collateral Ligament Reconstruction in Major League Baseball Pitchers

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**Purpose:** To analyze the velocity and movement of the 4-seam fastball, curve, and slider thrown before and after ulnar collateral ligament reconstruction (UCLR) in Major League Baseball pitchers using PITCHf/x data. **Methods:** Velocity and movement data of the 4-seam fastball, curve, and slider were collected for 3 time frames (12-24 months before the date of UCLR as an uninjured baseline, 12-24 months after the date of UCLR, and 24-36 months after the date of UCLR). Pitchers were separated into 3 age groups (<26, 26 to 31, and >31 years). A paired *t*-test for means was used to assess mean differences between 2 time periods and a generalized linear model, with time-dependent covariance structure and age group as a covariate, was used to determine differences across time. All analyses were performed using SAS, version 9.4. **Results:** Vertical movement of the 4-seam fastball decreased in the 24 to 36 months' postoperative time frame, compared with 12 to 24 months' preoperatively (9.46 to 9.14 inches,  $P = .032$ ). Movement decreases in the 4-seam fastball were not age-related. Velocity did not significantly change for any pitch and movement did not change for the slider or curve pitches. **Conclusions:** Following UCLR, Major League Baseball pitchers experienced no changes in horizontal or vertical movement or velocity of the curve or slider in either time frame. Decreased upward vertical movement of the fastball occurred after UCLR at final follow-up, but no change was observed in velocity. Similar trends in pitch movement and velocity effects were observed regardless of age. **Level of Evidence:** IV, case series.

The first ulnar collateral ligament reconstruction (UCLR) was performed in 1974, and the number of Major League (MLB) Baseball pitchers undergoing UCLR has gradually increased.<sup>1,2</sup> Of those who have undergone UCLR, between 5% and 33% are unable to return to their previous high level of pitching performance.<sup>3,4</sup> Previous studies have reported conflicting results about pitching performance after UCLR in MLB pitchers, with some showing no change in performance

and others showing declining performance postoperatively.<sup>5-10</sup>

In 2007, PITCHf/x (Sportvision Inc./SportsMEDIA Technology, Durham, NC)<sup>11,12</sup> was introduced into MLB stadiums to track pitch characteristics, such as pitch type, velocity, release point, and movement. Several studies have used these data, along with conventional baseball statistics, to investigate the effects of UCLR on pitchers.<sup>6-9</sup> Studies investigating velocity have

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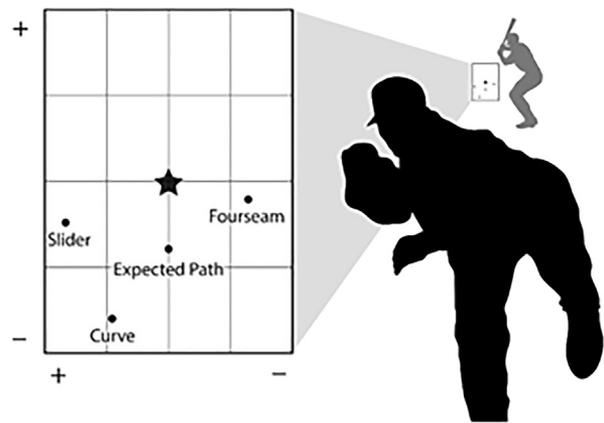
reported contradicting results, with some studies showing no change in fastball velocity,<sup>6,7</sup> whereas another showed a decrease in fastball velocity.<sup>8</sup> Another study reported that pitchers threw fewer pitches in the strike zone after surgery; however, performance after UCLR was similar to that seen in a control group over the same period of study.<sup>9</sup>

From these studies, it is difficult to determine the effect of UCLR on pitch characteristics and investigations on how UCLR affects pitch movement are limited. Pitch movement, as measured in inches by the PITCHf/x system (1 inch = 2.54 cm), is reported in horizontal and vertical vectors. Horizontal movement (Hmov) is the right or left movement of the pitch compared with the initial trajectory, with positive values to the left side of home plate and negative values to the right side of home plate from the pitcher's perspective (Fig 1). Vertical movement (Vmov) uses spin deflection of the baseball to determine movement of the pitch without the effect of gravity. A pitch with a positive vertical movement is a pitch with a high rate of backspin, which causes the pitch to "break up," whereas a pitch with forward spin does not resist the force of gravity and will break down. The 4-seam fastball has a high rate of backspin, which causes a positive Vmov. It also tends to move toward the same side of home plate as the pitcher's throwing arm. This would cause a negative Hmov value for a right-handed pitcher (Fig 1). The curve drops farther than would be expected due to gravity because of forward spin, and moves to the opposite side of home plate from the pitcher's hand. The curve therefore typically has a positive Hmov and a negative Vmov when thrown by a right-handed pitcher. The slider has a horizontal spin axis<sup>13</sup> that usually leads to a positive Hmov and Vmov when thrown by a right-handed pitcher. However, a small group of pitchers throw a slider with a negative Vmov (Figs 1 and 2).

The purpose of this study was to analyze the velocity and movement of the 4-seam fastball, curve, and slider thrown before and after UCLR in MLB pitchers using PITCHf/x data. We hypothesized that pitchers would return to their pre-UCLR velocity and pitch movement within 36 months after UCLR.

## Methods

A data set of pitchers who have undergone UCLR is established and maintained at MLB Reports ([www.mlbreports.com](http://www.mlbreports.com)) as described previously.<sup>14-16</sup> From these data, MLB pitchers who had UCLR from 2008 to 2015 were identified. Pitchers were excluded if they had undergone more than 1 UCLR in their careers, or if they did not have at least 20 pitches of 1 type in the 12- to 24-month preoperative, 12- to 24-month postoperative, and 24- to 36-month postoperative time

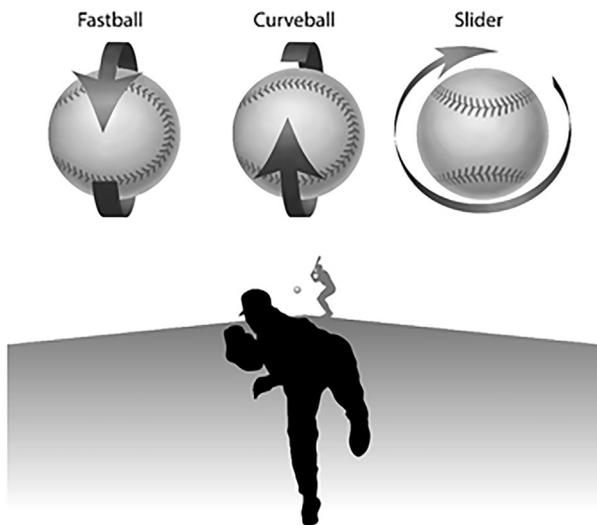


**Fig 1.** Demonstration of expected pitch movements for a right-handed pitcher. The 4-seam fastball tends to rise relative to the expected path and run in the direction of the pitcher's throwing arm. The curve tends to drop farther than the expected path and run away from the pitcher's throwing arm. The slider tends to drop less than would be expected due to gravity and it runs away from the pitcher's throwing arm.

frames. Due to the public nature of all data used, institutional review board approval was not required.

Demographic data recorded included handedness, type of pitcher (relief or starting pitcher), date of surgery, and age at surgery. Separately, pitch data were collected from a publicly available PITCHf/x database (DIY Baseball, LLC, Saratoga Springs, NY) and analyzed by pitch type (4-seam fastball, curve, slider).<sup>11,12</sup> Information related to the 4-seam fastball, curve, and slider pitches were collected for each pitcher in 3 distinct time frames: 12 to 24 months before surgery, 12 to 24 months after surgery, and 24 to 36 months after surgery. Measures collected for each pitch type included the number thrown, average velocity, average horizontal movement, and average vertical movement. For all left-handed pitchers, the horizontal axis was adjusted to match that of a right-handed pitcher for analysis purposes. Differences in velocity and movement of each pitch were compared between the preoperative time frame (12- 24 months before surgery), and the 2 postoperative time frames (12-24 months and 24-36 months after surgery) for each individual pitcher. To adjust for age, pitchers were separated into age groups, those who underwent UCLR before the age of 26, between 26 and 31, and after 31 years of age.

Statistical analyses were performed using paired t-tests for 2 means or using a repeated measures analysis with age group covariate using SASv9.4. Five different correlation structures were considered to capture change over time: unstructured, simple, compound symmetry, AR(1), and AR(1) with random intercept. Akaike information criterion, with small sample size correction, was used to determine the best model fit and final model estimates. Descriptive statistics for age



**Fig 2.** Demonstration of pitch spin for a right-handed pitcher. The 4-seam fastball has a backspin, while the curve has a forward spin. The slider has a clockwise spin for right-handed pitchers.

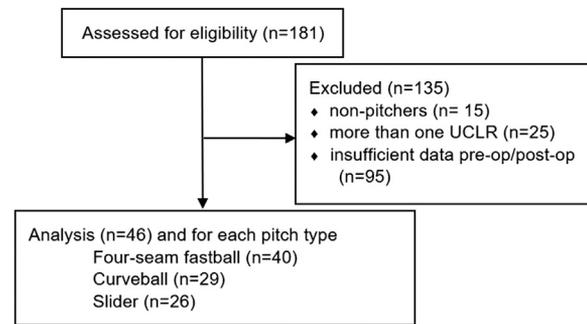
and outcome measures and final model fit are reported in [Appendix Tables 1 and 2](#), respectively, available at [www.arthroscopyjournal.org](http://www.arthroscopyjournal.org). Profile plots displaying movement trends among pitchers are reported in [Appendix Figure 1](#), available at [www.arthroscopyjournal.org](http://www.arthroscopyjournal.org).

## Results

A total of 46 pitchers were included in our study ([Fig 3](#)). Mean age at the time of surgery for pitchers was 28.0 years (age range 21-37 years old) and 34.8% (16/46) underwent surgery before the age of 26 years, whereas 50.0% (23/46) underwent surgery between the ages of 26 and 31 years. Of the 46 pitchers included in the study, 87.0% (40/46) met inclusion criteria for 4-seam fastball, 63.0% (29/46) met inclusion criteria for curve, and 56.5% (26/46) met inclusion criteria for slider.

### Overall Analysis

Velocity and horizontal movement did not change significantly for the 4-seam fastball pitch in either postoperative time frame when compared with preoperative values ([Table 1](#)). However, a statistically significant decrease was observed in 4-seam fastball movement in the vertical direction (9.46 inches [24.03 cm] vs 9.14 inches [23.22 cm],  $P = .032$ ) when comparing the preoperative time frame with the 24- to 36-month postoperative time frame. Vertical movement of the slider and curve did not change for either postoperative time frame, compared with preoperative values ([Table 1](#)).



**Fig 3.** Inclusion flowchart. (UCLR, ulnar collateral ligament reconstruction.)

### Determining the Influence of Pitcher Age

Pitchers who underwent UCLR between the ages of 26 and 31 years experienced a significant decrease in 4-seam fastball velocity at both 12 to 24 months and at 24 to 36 months after surgery (93.22 vs 92.53,  $P = .023$ , vs 92.41,  $P = .007$ ) ([Table 2](#)). However, players who underwent UCLR before the age of 26 years or after 31 years did not experience any significant change in their 4-seam fastball velocity. Pitchers with UCLR before the age of 26 years experienced a significant decrease in the amount of horizontal movement of their 4-seam fastball in both time frames, 12 to 24 months after surgery (5.84 inches [14.83 cm] vs 4.95 inches [12.57 cm],  $P = .020$ ) and 24 to 36 months after surgery (5.84 inches [14.83 cm] vs 5.03 inches [12.78 cm],  $P = .016$ ). Four-seam fastball vertical movement decreased for both 26- to 31-year-olds (9.39 inches [23.85 cm] vs 8.82 inches [22.40 cm],  $P = .014$ ) and those older than 31 years (9.51 inches [24.16 cm] vs 8.79 inches [22.33 cm],  $P = .001$ ) for the 24 to 36 months postoperative time frame. Pitchers who underwent UCLR between ages 26 and 31 years experienced a significant decrease in the amount of slider horizontal movement in the 12- to 24-month postoperative time frame (1.72 inches [4.37 cm] vs 1.21 inches [3.07 cm],  $P = .035$ , [Table 2](#)).

### Repeated Measures Analysis

Analogous results were observed across time periods. Decreases in the 4-seam fastball vertical movement were detected for both 12 to 24 months ( $P = .0475$ ) and 24 to 36 months ( $P = .0321$ ) postsurgery, after accounting for pitcher age at surgery.

## Discussion

In this study, there was no change in velocity or movement in the curve or slider after UCLR when compared with each pitcher's baseline before surgery in either time frame. After UCLR, the fastball had a statistically significant decrease in upward movement compared with a baseline 24 to 36 months postoperatively. The velocity and horizontal movement of the fastball was unchanged following UCLR in both time frames.

**Table 1.** Overall Velocity and Movement 12-24 Months Before Surgery Versus 12-24 Months After Surgery (First *P* Value) and 12-24 Months Before Surgery Versus 24-36 Months After Surgery (Second *P* Value)

Pitch	Measurement	Preoperative		Postoperative		
		12-24 Months	12-24 Months	<i>P</i> Value	24-36 Months	<i>P</i> Value
Four-seam fastball n = 40	Velocity (mph)	93.19 ± 5.75	92.92 ± 5.17	.309	92.95 ± 5.08	.305
	Hmov (inches)	-5.34 ± 2.19	-4.95 ± 5.40	.173	-4.99 ± 3.20	.093
	Vmov (inches)	9.46 ± 1.99	9.13 ± 2.40	.059	9.14 ± 1.94	<b>.032</b>
Curve n = 29	Velocity (mph)	78.87 ± 8.92	79.26 ± 8.61	.140	79.20 ± 8.51	.293
	Hmov (inches)	5.16 ± 4.39	5.07 ± 5.16	.704	5.14 ± 5.27	.968
	Vmov (inches)	-5.47 ± 4.63	-5.59 ± 6.22	.695	-5.59 ± 6.31	.743
Slider n = 26	Velocity (mph)	84.75 ± 6.00	84.40 ± 7.68	.359	84.46 ± 6.56	.329
	Hmov (inches)	1.87 ± 4.61	1.63 ± 3.39	.379	1.53 ± 5.10	.240
	Vmov (inches)	1.44 ± 4.27	1.69 ± 9.62	.533	1.14 ± 7.94	.396

NOTE. *P* values in bold are statistically significant.

Hmov, horizontal movement; Vmov, vertical movement.

When considering the pitcher age at surgery, the 26- to 31-year-old group experienced a significant decrease in 4-seam fastball velocity. It is possible this decrease is due to normal aging patterns. UCLR does affect the pitch movement for the 4-seam fastball, and this change does not appear to be due to age-related deterioration, as the pitchers who underwent surgery before 26 years of age were the most severely affected. This group of pitchers lost on average ~1 inch of 4-seam fastball horizontal movement in both postoperative time frames. In addition, pitchers in the older age groups displayed a significant decrease in vertical movement of their 4-seam fastball in the 24- to 36-month postoperative time frame.

Four-seam fastball movement derives from the magnitude of backspin placed on the ball by the pitcher, manifesting as horizontal movement and/or vertical movement depending on the orientation of the ball upon release. Variations of wrist and arm angle upon release are strongly correlated with the type of movement seen, whether more horizontal or more vertical.<sup>17</sup> The decreases in horizontal and vertical movement in the 4-seam fastball possibly derive from the loss of backspin exerted on the ball upon release. Improved technology has enhanced pitch tracking of MLB pitchers to include additional information such as spin rate and spin axis. Future studies could explore these tools to better understand how pitch characteristics are affected by injuries and surgery.

Wrist flexor-pronator muscle weakness is a potential mechanistic explanation for the effect of UCLR on backspinches. Combined flexor-pronator injury along with ulnar collateral ligament tear has previously been associated with poor outcomes.<sup>18</sup> In addition, the intimate association of the flexor-pronator mass with the ulnar nerve leads to a significant amount of manipulation of the muscle during transposition of the ulnar nerve.<sup>19</sup> It is possible such manipulation leads to weakness in the flexor-pronator mass that has not previously been detected. Alternatively, differences in

UCL tension preoperatively and graft tension postoperatively may lead to a difference in the ability to exert backspin, leading to the differences seen. The difference in 4-seam fastball movement is unlikely to derive from differences in overall mechanics preoperatively and postoperatively as a biomechanical study in active minor league baseball pitchers showed no differences between pitchers with a history of UCLR and those with no history of UCLR.<sup>20</sup>

### Limitations

As with all studies, this investigation has limitations. This study only included pitchers who returned to throw at least 20 pitches during a 12- to 24-month and 24- to 36-month time frame after surgery. A substantial portion of pitchers in the PITCHf/x database were excluded, many due to a lack of return to play at the MLB level, delayed return to play leading to insufficient data in the 12- to 24-month postoperative time frame, or transient return to play leading to insufficient data in the 24- to 36-month postoperative time frame. As such, selection bias may be introduced in this study. In addition, the operative methods, individual clinical findings, or surgeon may be influencing results; however, this information is not consistently available so could not be considered or analyzed. Finally, these results may not be generalizable to all professional or amateur pitchers as only those who returned to play within a defined period after UCLR were included. As a result, these results are likely the “best” overall results and may not reflect average anticipated results of UCLR.

### Conclusions

Following UCLR, MLB pitchers experienced no changes in horizontal or vertical movement or velocity of the curve or slider in either time frame. Decreased upward vertical movement of the fastball occurred after UCLR at final follow-up, but no change was observed in

**Table 2.** Velocity and Movement 12-24 Months Before Surgery Versus 12-24 Months After Surgery (first *P* value) and 12-24 Months Before Surgery Versus 24-36 Months After Surgery (second *P* value) by Age Group

Pitch	Measurement	Age Group (Years Old)	12-24 Months Preoperative	12-24 Months Postoperative	<i>P</i> Value	24-36 Months Postoperative	<i>P</i> Value
Four-seam Fastball <26, n = 15 26-31, n = 18 >31, n = 7	Velocity (mph)	<26	93.52 ± 4.37	93.65 ± 3.73	.800	93.63 ± 4.13	.806
		26-31	93.22 ± 5.94	92.53 ± 6.39	<b>.040</b>	92.41 ± 2.25	<b>.007</b>
		>31	92.43 ± 9.42	92.35 ± 4.67	.908	92.88 ± 6.97	.473
	Hmov (inches)	<26	-5.84 ± 2.69	-4.95 ± 4.00	<b>.020</b>	-5.03 ± 2.75	<b>.016</b>
		26-31	-5.11 ± 1.18	-4.83 ± 4.72	.485	-4.84 ± 2.83	.363
		>31	-4.90 ± 3.59	-5.27 ± 12.19	.744	-5.31 ± 6.19	.515
	Vmov (inches)	<26	9.53 ± 1.53	9.59 ± 1.21	.818	9.69 ± 0.840	.527
		26-31	9.39 ± 2.32	8.93 ± 3.22	.081	8.82 ± 2.50	<b>.014</b>
		>31	9.51 ± 2.77	8.68 ± 2.78	.139	8.79 ± 2.33	<b>.001</b>
Curve <26, n = 12 26-31, n = 13 >31, n = 4	Velocity (mph)	<26	79.11 ± 7.19	79.93 ± 7.30	.084	79.73 ± 7.13	.260
		26-31	79.04 ± 9.02	78.94 ± 9.43	.733	78.95 ± 10.76	.827
		>31	77.58 ± 18.21	78.29 ± 12.41	.512	78.39 ± 7.94	.510
	Hmov (inches)	<26	4.77 ± 4.75	4.48 ± 3.51	.426	4.79 ± 5.56	.978
		26-31	5.23 ± 3.29	5.24 ± 5.61	.982	5.19 ± 5.00	.917
		>31	6.07 ± 8.73	6.29 ± 9.31	.643	6.07 ± 7.18	.982
	Vmov (inches)	<26	-5.64 ± 4.41	-5.74 ± 7.25	.859	-5.47 ± 8.19	.802
		26-31	-5.37 ± 5.55	-5.43 ± 7.27	.898	-5.51 ± 6.55	.815
		>31	-5.26 ± 4.62	-5.66 ± 2.24	.618	-6.27 ± 1.95	.090
Slider <26, n = 10 26-31, n = 12 >31, n = 4	Velocity (mph)	<26	84.36 ± 7.64	84.99 ± 7.42	.277	84.37 ± 6.28	.987
		26-31	84.61 ± 5.18	84.04 ± 6.94	.261	84.29 ± 7.70	.434
		>31	86.14 ± 4.93	84.81 ± 10.29	.381	85.21 ± 6.67	.246
	Hmov (inches)	<26	2.19 ± 6.44	1.85 ± 1.88	.565	1.77 ± 4.15	.431
		26-31	1.72 ± 4.51	1.21 ± 5.65	<b>.035</b>	1.01 ± 7.49	.069
		>31	1.54 ± 2.00	2.34 ± 0.36	.330	2.45 ± 0.17	.287
	Vmov (inches)	<26	0.80 ± 7.27	1.17 ± 10.81	.485	0.44 ± 11.56	.581
		26-31	2.01 ± 2.33	2.75 ± 7.33	.241	2.32 ± 3.30	.414
		>31	1.31 ± 2.50	-0.18 ± 10.84	.318	-0.67 ± 7.86	.134

NOTE. *P* values in bold are statistically significant.

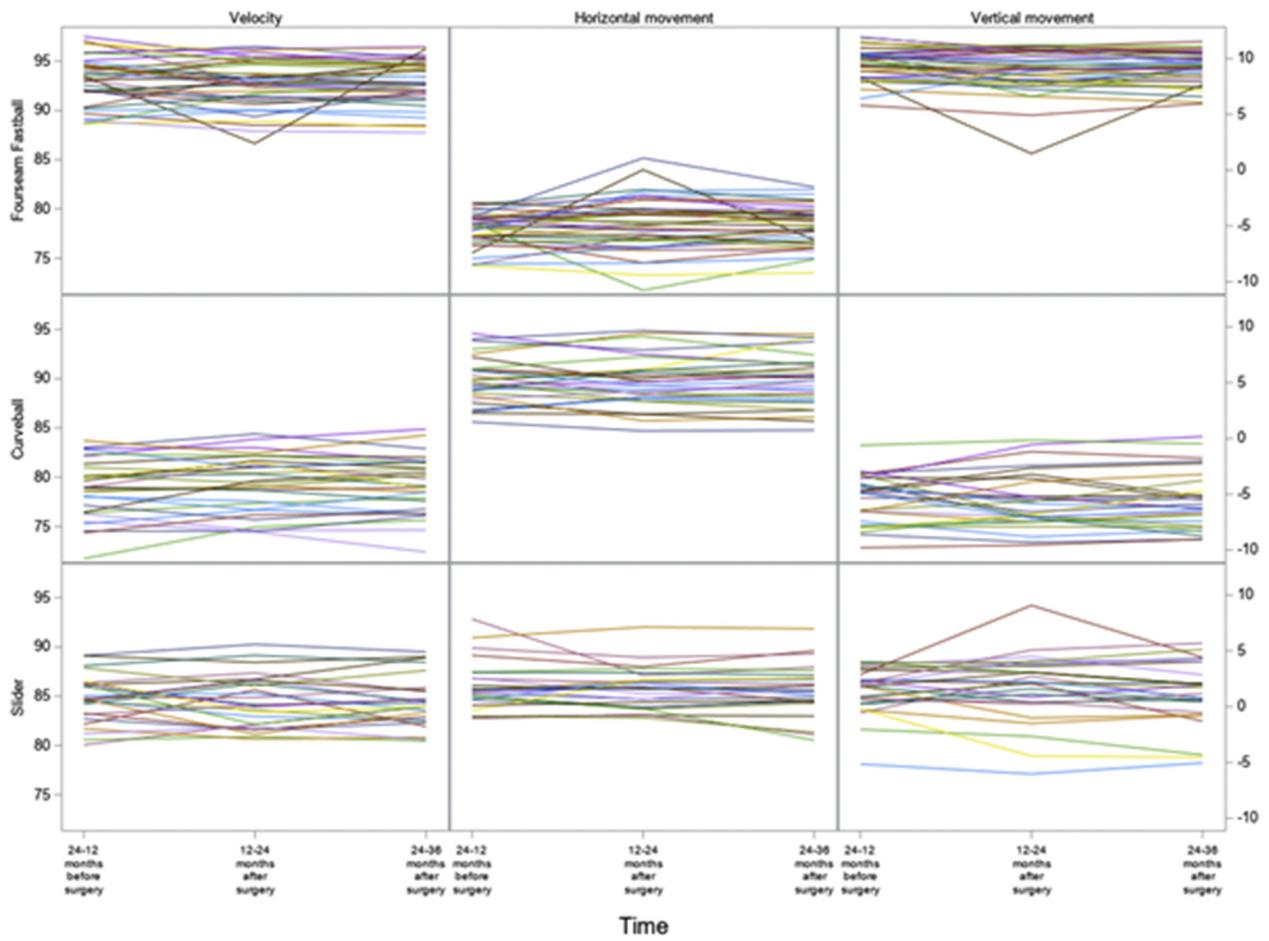
Hmov, horizontal movement; mph; miles per hour; Vmov, vertical movement.

velocity. Similar trends in pitch movement and velocity effects were observed regardless of age.

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**Appendix Fig 1.** Profile plot displaying the movement trends for each individual pitcher across all time frames.

**Appendix Table 1.** Descriptive Statistics for Age and Outcome Measures

Variable	Time	N	Mean	(SD)	Change From Baseline	(SD)
Age		46	27.98	(3.58)		
Four-seam fastball velocity	Baseline	40	93.19	(2.40)		
	Postoperative 1	40	92.7	(2.44)	-0.49	(1.92)
	Postoperative 2	40	92.95	(2.25)	-0.24	(1.48)
Four-seam fastball Hmov	Baseline	40	-5.34	(1.48)		
	Postoperative 1	40	-4.79	(2.44)	0.56	(2.1)
	Postoperative 2	40	-4.99	(1.79)	0.35	(1.28)
Four-seam fastball Vmov	Baseline	40	9.46	(1.41)		
	Postoperative 1	40	8.98	(1.95)	-0.48	(1.48)
	Postoperative 2	40	9.14	(1.39)	-0.32	(0.92)
Curveball velocity	Baseline	29	78.87	(2.99)		
	Postoperative 1	29	79.26	(2.93)	0.39	(1.4)
	Postoperative 2	29	79.2	(2.92)	0.33	(1.66)
Curveball Hmov	Baseline	29	5.16	(2.10)		
	Postoperative 1	29	5.07	(2.27)	-0.09	(1.22)
	Postoperative 2	29	5.14	(2.30)	-0.01	(1.45)
Curveball Vmov	Baseline	29	-5.47	(2.15)		
	Postoperative 1	29	-5.59	(2.49)	-0.12	(1.65)
	Postoperative 2	29	-5.59	(2.51)	-0.13	(2.09)
Slider Velocity	Baseline	26	84.75	(2.45)		
	Postoperative 1	26	84.52	(2.68)	-0.23	(1.92)
	Postoperative 2	26	84.46	(2.56)	-0.29	(1.5)
Slider Hmov	Baseline	26	1.87	(2.15)		
	Postoperative 1	26	1.63	(1.84)	-0.24	(1.35)
	Postoperative 2	26	1.53	(2.26)	-0.34	(1.45)
Slider Vmov	Baseline	26	1.44	(2.07)		
	Postoperative 1	26	1.69	(3.10)	0.25	(2.03)
	Postoperative 2	26	1.14	(2.82)	-0.3	(1.78)

Hmov, horizontal movement; SD, standard deviation; Vmov, vertical movement.

**Appendix Table 2.** Final Model (Correlation Structure) for Each Movement Measure, by Pitch Type, Showing Significant Differences in Four-Seam Fastball Metrics and No Significant Differences in Curve or Slider Metrics

Variable	Effect	Estimate	SE	t Value	P value
Four-seam fastball velocity (CS)	Intercept	94.49	2.67	35.39	<.0001
	Age	-0.05	0.09	-0.49	.6267
	Postoperative 1	-0.49	0.27	-1.81	.0749
	Postoperative 2	-0.24	0.27	-0.89	.3761
Four-seam fastball Hmov (UN)	Intercept	-6.41	1.9	-3.36	.0018
	Age	0.04	0.07	0.56	.5776
	Postoperative 1	0.56	0.33	1.67	.1024
	Postoperative 2	0.35	0.2	1.72	.0925
Four-seam fastball Vmov (UN)	Intercept	11.22	1.7	6.59	<.0001
	Age	-0.06	0.06	-1.04	.3036
	Postoperative 1	-0.48	0.23	-2.05	<b>.0475</b>
	Postoperative 2	-0.32	0.15	-2.22	<b>.0321</b>
Curveball velocity (CS)	Intercept	80.93	4.2	19.29	<.0001
	Age	-0.08	0.15	-0.5	.6230
	Postoperative 1	0.39	0.27	1.49	.1429
	Postoperative 2	0.33	0.27	1.25	.2181
Curveball Hmov (UN)	Intercept	3.6	3.25	1.11	.2780
	Age	0.06	0.12	0.48	.6338
	Postoperative 1	-0.09	0.23	-0.38	.7038
	Postoperative 2	-0.01	0.27	-0.04	.9677
Curveball Vmov (UN)	Intercept	-5.07	3.19	-1.59	.1238
	Age	-0.01	0.12	-0.13	.9006
	Postoperative 1	-0.12	0.31	-0.4	.6953
	Postoperative 2	-0.13	0.39	-0.33	.7432
Slider velocity (AR(1))	Intercept	82.41	3.69	22.33	<.0001
	Age	0.08	0.13	0.64	.5277
	Postoperative 1	-0.23	0.41	-0.55	.5843
	Postoperative 2	-0.29	0.31	-0.96	.3425
Slider Hmov (UN)	Intercept	2.08	3.01	0.69	.4974
	Age	-0.01	0.11	-0.07	.9453
	Postoperative 1	-0.24	0.27	-0.9	.3786
	Postoperative 2	-0.34	0.29	-1.2	.2402
Slider Vmov (UN)	Intercept	-1.81	3.43	-0.53	.6021
	Age	0.12	0.12	0.95	.3496
	Postoperative 1	0.25	0.4	0.63	.5334
	Postoperative 2	-0.3	0.35	-0.86	.3959

NOTE. P values in bold are statistically significant.

CS, compound symmetry; Hmov, horizontal movement; SE, standard error; UN, unstructured; Vmov, vertical movement.