Retrospective Analysis of Ulnar Collateral Ligament Reconstructions in Major League Baseball Pitchers

A Comparison of the "Tall and Fall" Versus "Drop and Drive" Pitching Styles

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Background: Previous pilot research has investigated differences in elbow valgus torque between the "tall and fall" (TF) and "drop and drive" (DD) pitching styles. Whether one of these pitching styles is associated with a greater rate of ulnar collateral ligament reconstruction (UCLR) is currently unknown.

Purpose: To determine the proportion of Major League Baseball (MLB) pitchers using the TF and DD pitching styles who underwent UCLR over a 10-year period.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: The demographic characteristics of pitchers who underwent UCLR between 2007 and 2017 were obtained via the open-source database MLB Player Analysis Tommy John Surgery List. Other information, such as previous UCLR and pitching videos and graphics, was obtained from other open-source databases. A comprehensive, 2-dimensional, kinesiology-based multicomponent definition of each pitching style was formulated and used to categorize the included pitchers into the TF and DD groups. Statistical comparisons and contrasts were made using chi-square and Pearson correlation tests.

Results: Included were 223 MLB pitchers (mean ± SD age, 27.5 ± 3.6 years; body mass index [BMI], 27.6 ± 2.2; throwing velocity, 92.9 ± 2.6 mph [149.5 ± 4.2 km/h]) who underwent UCLR between 2007 and 2017. Of these pitchers, 162 were categorized as TF pitchers (72.6%) and 61 as DD pitchers (27.4%). Pitching velocity for injured pitchers was significantly correlated to BMI ($P < .001$). We found no significant associations of pitching style with year of UCLR ($P = .941$), BMI ($P = .549$), age ($P = .647$), handedness ($P = .501$), or average pitch velocity ($P = .921$).

Conclusion: The study findings demonstrated that a higher proportion of UCL-injured MLB pitchers (72.6%) used the TF pitching style. Further research is needed to explore the potential association between pitching style and UCL injury.

Keywords: elbow; Major League Baseball; pitching style; ulnar collateral ligament reconstruction

Baseball pitching produces extraordinarily high upper extremity joint-reaction forces, most notably at the elbow.[1,2,6,7,11,22,23] The ulnar collateral ligament (UCL) in the elbow provides stabilization during high angular velocity performance and valgus stress overload.[1,2,6,11] Rupture of the UCL is a debilitating injury, and many patients elect to undergo ulnar collateral ligament reconstruction (UCLR). Over the past 15 years, the number of UCLR surgeries performed on baseball pitchers has increased and has even been referred to as an "epidemic" in the sport of baseball.[5,9,11,15] Professional baseball pitchers are 3 times more likely to sustain an upper extremity injury in comparison to their positional player counterparts.[26] UCL injury during pitching most often occurs during transition from rapid eccentric loading to explosive concentric contraction.[1,2,6,11] Several studies have investigated pitching mechanics and incurred valgus torque on the involved elbow joint.[**] Despite the identification of various

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predictive factors involving the kinetic chain that increase a pitcher's likelihood of incurring a UCL injury (trunk tilt, arm slot, arm angle, stride length), the precise cause of the current UCL injury "epidemic" remains largely unknown.

Two traditional stride phase (ie, lead pitching leg) pitching styles have been used in the baseball industry, "tall and fall" (TF) and "drop and drive" (DD). Historically, the TF pitching style is considered the more popular Western (ie, pitchers in the United States) pitching style.[7,27,28] In 1991, Ryan and House[28] described TF as "staying tall," or maintaining a higher center of gravity during the stride phase, allowing the pitcher to benefit from the earth's natural gravitational forces. At stride-foot contact (SFC) during TF pitching, the pelvis is higher than the knee of the drive-leg, resulting in the ball being released at a slightly vertical trajectory off the pitching mound.[27,28] The DD pitching style is more often used in Eastern (ie, Japanese and Korean pitchers) pitching.[7] The hallmark of this style is the lunge-like stride phase, in which the pitcher lowers his center of gravity by striding forward, resulting in flexing of the drive-leg while the patella and lower portion of the back leg depress toward the ground. At SFC during DD pitching, the leading knee assumes a flexed position.[7,27,28] The combination of these DD motions results in a longer, faster stride motion toward home plate when compared with TF. Both the TF and DD pitching styles strive to maximize pitching velocity but are visually and biomechanically different.[3,7,27,28]

Recently, our group conducted a pilot study that investigated TF versus DD pitching styles in collegiate baseball pitchers.[8] A total of 24 noninjured National Collegiate Athletic Association (NCAA) Division II and III baseball pitchers were categorized as using the TF and DD pitching styles via 2-dimensional (2D) kinematic motion capture analysis using the Hudl technique mobile application.[20] Elbow valgus torque was measured with a Motus Global sensor and compression sleeve.[21] The results of this pilot study demonstrated that elbow valgus torque was significantly greater in the TF group versus the DD group for the following fastball pitches: pitch number 3 (62.7 ± 13.5 vs 52.9 ± 10.5 N m, respectively; $P = .05$), pitch number 6 (64.3 ± 12.8 vs 49.9 ± 13.2 N m; $P = .01$), pitch number 8 (63.5 ± 15.5 vs 51.3 ± 11.0 N m; $P = .03$), and pitch number 9 (63.0 ± 9.6 vs 49.6 ± 15.7 N m; $P = .02$). These findings suggest that greater elbow valgus torque may occur when the TF pitching style is used compared with the DD pitching style.[8]

To the best of our knowledge, the use of these pitching styles among Major League Baseball (MLB) pitchers who have undergone UCLR has not been explored. Thus, the main purpose of this study was to explore the proportion of MLB pitchers (having undergone UCLR between 2007 and 2017) who used the TF versus DD pitching styles. We also sought to compare average throwing velocity and demographic characteristics (ie, body mass index [BMI] and age) between the 2 styles.

METHODS

Participants

The research team used the Baseball Reference website[4] to conduct a retrospective cohort study of rostered MLB pitchers who underwent UCLR between 2007 and 2017.

Data Sources

Player characteristics (age, BMI, velocity) were obtained via the open-source database "MLB Player Analysis Tommy John Surgery List."[30] Other information, such as the total number of MLB pitchers between 2007 and 2017, previous UCLR, and pitching video and graphic information, was obtained from other open-source databases.[4,12,16]

Defining the TF and DD Pitching Styles

The procedural protocol used to distinguish the 2 pitching styles was adapted from current literature.[7,8,17,27,28] As is largely accepted, there are 6 phases of the pitching motion: phase 1, wind-up; phase 2, stride; phase 3, arm cocking; phase 4, arm acceleration; phase 5, arm deceleration; and phase 6, follow-through.[31] Historical references suggest that delineation between TF and DD can be made at SFC.[27,28] Thus, pitching style was determined during phase 2. Location of the drive-leg knee was examined with respect to the pelvis at SFC. Pitchers whose drive-leg knee landed in a flexed (90°-130°), lunge-like position relative to the pelvis (ie, pelvis in line or below the knee level) during SFC were designated DD pitchers (Figure 1A). Pitchers whose drive-leg knee landed in an extended (140°-180°) position relative to the pelvis (ie, pelvis above the knee level) during SFC were designated TF pitchers (Figure 1B). In the event a pitcher's drive-leg

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Figure 1. Experimental setup and kinematic parameter measurements. (A) Drop and drive (DD) pitchers captured, 90°-130° of knee flexion. (B) Tall and fall (TF) pitchers captured, 140°-180° of knee flexion. (C) TF pitcher captured, ~130°-140° of knee flexion with pelvis above the drive-leg knee level. (D) DD pitcher captured, ~130°-140° of knee flexion and pelvis in line with the drive-leg knee level.

Tall and Fall (TF)	Drop and Drive (DD)
Drive-leg knee landed in an extended position relative to the pelvis during SFC (140°-180°)	Drive-leg knee landed in a flexed position relative to the pelvis during SFC (90°-130°)

*If the drive-leg knee landed between 130°-140°, pitch type was assigned based on pelvis location
- TF: pelvis above knee
- DD: pelvis in line with or below knee

Figure 2. Delineation of tall and fall (TF) and drop and drive (DD) pitching styles. SFC, stride-foot contact.

knee kinematic angle fell between 130° and 140°, we placed the MLB pitcher in the TF or DD group based on location of the pelvis in relation to the drive-leg knee (pelvis above [TF] or in line with or below [DD] the lead knee level) (Figure 1, C and D). A comprehensive, 2D kinesiology-based multicomponent definition of each pitching style was formulated (Figure 2).

Procedure

Pitchers were assigned to the TF and DD groups through the use of pitching videos attained from open media sources. Two independent video recordings of the player throwing a fastball pitch were used per subject and were analyzed by 2 raters (M.F.B. and G.H.). Each video was collected from the same athletic year and before the player underwent UCLR. A 2D lateral orthogonal view was used to examine all pitchers. For each pitch, the primary and secondary raters used Hudl technology to examine kinematic drive-leg knee angle and pelvic position. The video was paused at SFC, and then the kinematic angle tool was used to generate an angle from the anterior superior iliac spine to the inferior pole of the patella and down through the medial malleolus.[20] The average of the 2 drive-leg knee angles was then calculated. The box tool was used to capture the position of the pitcher's pelvis.[20] The arrow tool was used to determine the position of the pelvis in relation to the drive-leg knee. Pitching style was determined based on average drive-leg knee angle and pelvis positioning. The described procedure was completed by the primary and secondary raters for each MLB pitcher, in order to mitigate error and enhance reproducibility. If there were any discrepancies between raters, a third pitching video was assessed (Figure 3).

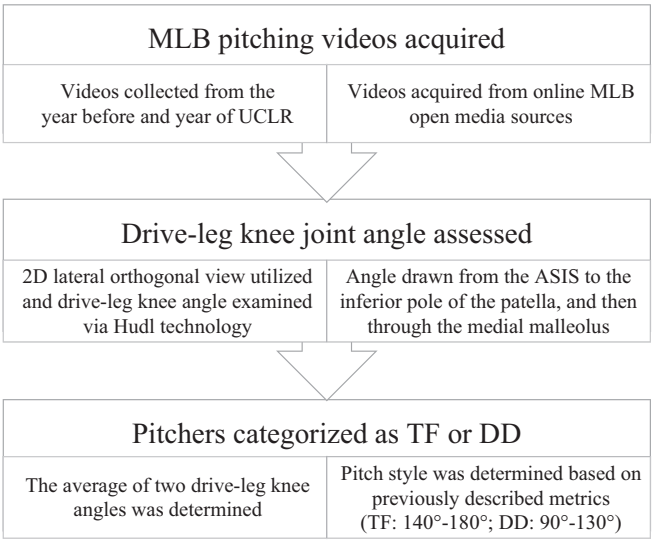

Figure 3. Procedure for the categorization of Major League Baseball (MLB) pitchers into tall and fall (TF) and drop and drive (DD) pitching styles. Two independent raters assessed both pitching videos of each MLB pitcher. ASIS, anterior superior iliac spine; TD, two-dimensional; UCLR, ulnar collateral ligament reconstruction.

Statistical Analysis

Data were analyzed and reported using descriptive statistics where appropriate. Two-tailed independent-sample t tests were used to assess normally distributed data. Statistical comparisons and contrasts were made using chi-square and Pearson correlation tests. A significance level of $P < .05$ was used. All data were analyzed using the IBM Statistical Package for the Social Sciences 28 (IBM SPSS Statistics), and figures were compiled using GraphPad Prism.

RESULTS

According to the Baseball Reference website,[4] a total of 2166 MLB pitchers were identified between the years 2007 and 2017, and 223 MLB pitchers (mean ± SD age, 27.5 ± 3.6 years; BMI, 27.6 ± 2.2; throwing velocity, 92.9 ± 2.6 mph [149.5 ± 4.2 km/h]) underwent UCLR between 2007 and 2017. Based on this statistic, 9.7% of all MLB pitchers during this time underwent UCLR. Of the 223 pitchers who underwent UCLR, 162 were categorized as TF pitchers (72.6%) and 61 as DD pitchers (27.4%) (Figure 4A). We found that 13 pitchers had more than 1 UCLR procedure (Figure 4B). The demographic and pitching characteristics are shown in Table 1 and Figure 4.

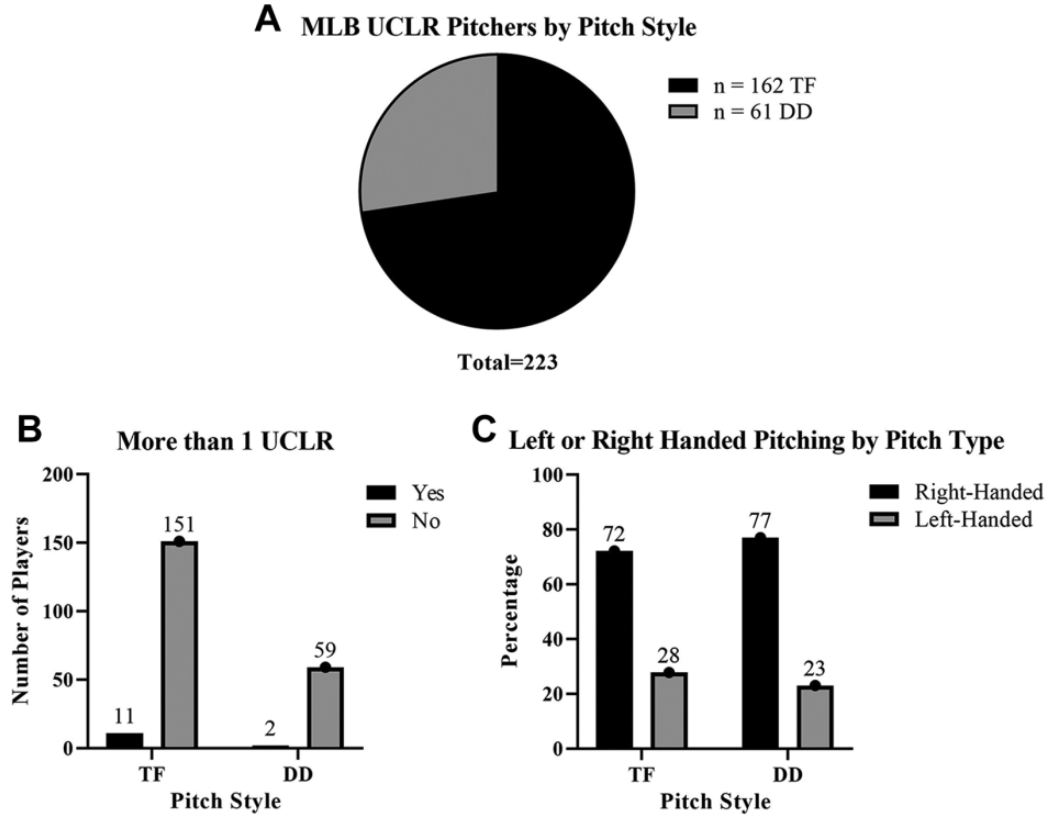

Figure 4. (A) Major League Baseball (MLB) pitchers who underwent ulnar collateral ligament reconstruction (UCLR), by pitching style. (B) MLB UCLR pitchers, by pitching style with or without more than 1 UCLR. DD, drop and drive; TF, tall and fall. (C) MLB UCLR pitchers, by pitching style and handedness.

TABLE 1
Demographic and Performance Variables by Pitching Style[a]

	Tall and Fall (n = 162)	Drop and Drive (n = 61)
Age, y	27.6 ± 3.8	27.5 ± 3.8
Body mass index	27.5 ± 2.2	27.4 ± 2.2
Fastball velocity, mph (km/h)	92.5 ± 2.5 (148.9 ± 4)	92.1 ± 2.6 (148.2 ± 4.2)

[a]Data are reported as mean ± SD.

TABLE 2
Ulnar Collateral Ligament Reconstruction in Major League Baseball Pitchers by Pitching Style (2007-2017)[a]

Year	Pitching Style	UCLR, n	Percentage
2017	TF	11	61
	DD	7	39
2016	TF	15	79
	DD	4	21
2015	TF	16	67
	DD	8	33
2014	TF	24	80
	DD	6	20
2013	TF	12	63
	DD	7	37
2012	TF	27	77
	DD	8	23
2011	TF	13	87
	DD	2	13
2010	TF	9	69
	DD	4	31
2009	TF	13	72
	DD	5	28
2008	TF	10	77
	DD	3	23
2007	TF	12	63
	DD	7	37
Total		223	

[a]DD, drop and drive; TF, tall and fall; UCLR, ulnar collateral ligament reconstruction.

Pitching velocity for injured pitchers was significantly correlated to BMI ($r = 0.24$; $P < .001$). Year of UCLR ($t = –0.074$; $P = .941$), BMI ($t = 0.600$; $P = .549$), age ($t = –0.459$; $P = .647$), handedness ($\chi^2 = 0.531$; $P = .501$), and average velocity ($t = –0.111$; $P = .921$) were not associated with pitching style. The proportions of TF and DD pitchers who underwent UCLR each year of the 10-year timeframe are provided in Table 2.

DISCUSSION

In this study, we sought to explore the proportion of MLB pitchers (having undergone UCLR between 2007 and 2017) who used the TF versus DD pitching style. Of the 223 MLB pitchers who underwent UCLR, nearly three-fourths used the TF pitching style (73%). This is an interesting finding and suggests the need for further research exploring the potential association between pitching style and UCL injury.

During SFC, the drive-leg of TF pitchers lands in an extended position, whereas the drive-leg of DD pitchers lands in a flexed position.[7,8,27,28] Recently, Oi et al[23] investigated the biomechanical differences between American and Japanese professional baseball pitchers. Interestingly, the extended drive-leg knee angle used by most American pitchers was found to result in significantly higher elbow varus joint stress and elbow injury rates. Conversely, the flexed drive-leg knee angle used by most Japanese pitchers was found to correlate with increased kinetic stress at the shoulder and higher shoulder injury rates. The results of our previously mentioned collegiate pilot study affirm these results; that is, landing with the drive-leg knee in an extended position (TF) results in greater elbow joint forces and elbow injury rates versus landing with the drive-leg knee in a flexed position (DD). Similarly, Dowling et al[13] evaluated 11 American and 11 Japanese collegiate pitchers and found that the American pitchers landed with the drive-leg knee in an extended position, resulting in greater throwing arm peak kinetics versus the Japanese group. Anz et al[2] demonstrated a strong correlation between elbow injury and higher elbow valgus torque throughout the entire pitching motion. Additionally, a previous retrospective study involving 104 MLB pitchers who underwent UCLR found that arm slots closer to the midline of the body (an overhead position) resulted in a higher upper extremity injury rate.[32] As previously mentioned, the TF pitching style uses a greater vertical ball release when compared with DD. The summation of these findings suggests that pitching style selection warrants further attention and may be a potential area for intervention to prevent UCL injury.

We defined the TF and DD pitching styles based on previous literature.[3,7,8,27,28] These definitions are based on drive-leg knee kinematics and pelvic position during SFC of the pitching motion (phase 2), and these defining parameters can be used to aid the conduct of further research exploring the potential association between pitching style and UCL injury. We suggest that researchers consider using three-dimensional (3D) motion capture technologies to further define and assess the TF and DD pitching styles.

Limitations

The present investigation is not without limitations. MLB data regarding individual training and medical history, playing experience, practice workloads, and individual pitching kinematics were not available for evaluation. Individual elbow valgus torque measures were not obtainable for pitchers in this retrospective study; thus, association with UCLR could not be explored. Additionally, we were unable to break down pitching styles by pitcher position (starter, reliever, closer). The primary and secondary raters for this study were both sports medicine professionals (certified physician assistant [PA-C] and certified athletic

trainer [ATC], respectively). There was no formal training session for delineation of pitching styles, which may add to the propensity for error and make replication of our findings difficult. Further, interrater and intrarater reliabilities were not assessed. Given the retrospective nature of the study, data from a homogeneous control group (noninjured MLB pitchers) during the specified 10-year period were not available. As such, direct comparison of injured versus noninjured MLB pitchers was not possible. This retrospective study lacked the use of 3D motion capture analysis to determine the exact drive-leg knee kinematics occurring in relation to the pelvis.

CONCLUSION

In this retrospective study, we demonstrated that a significantly larger proportion of UCL-injured MLB pitchers (2007-2017) used the TF pitching style. Approximately 10% of all MLB pitchers during this 10-year timeframe underwent UCLR. In this article, we have comprehensively defined the TF and DD pitching styles. Further research is needed to explore the potential association between pitching style and UCL injury. Specifically, an experimental design that directly compares UCL-injured versus noninjured pitchers using 3D motion capture should be used.

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