Tommy John Surgery's Impact on Pitch Load Values in Major League Baseball Players

Original Research

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Abstract

Introduction: Pitch load (PL) is an alternative to baseball metrics. PL may better monitor overtraining and injury risk. PL is the summation of the product of pitch types thrown multiplied by their respective velocities over a single game or season. This study examined whether PL is impacted by ulnar collateral ligament (UCL) damage, which is treated with Tommy John surgery.

Methods: With publicly accessible retrospective data from 222 MLB pitchers, UCL damage's influence was assessed. PL was calculated with an expanded formula that is the summation of all pitch types thrown, as well as individual formulas per pitch type (fastball, breaking ball, off-speed) examined. In addition, pitch velocity and distribution, two more traditional baseball metrics, were calculated and analyzed. Each pitcher's calculated PL for their first available complete (>100 pitches) season before and after surgery were collected and analyzed. Data analysis entailed paired t-tests, with an $\alpha \leq 0.05$ denoting significance.

Results: There were no pre- to post-surgery changes to pitch distribution, but significant losses to fastball and breaking ball velocities. In contrast, PL values declined significantly for the expanded formula (pre: 113,470 ± 82,577, post: 62,045 ± 56,902, $p < 0.001$), as well as those per pitch type.

Conclusions: Compared to pitch velocity and distribution, PL demonstrates a greater sensitivity and precision to Tommy John surgery. Results imply PL may better serve MLB pitchers as a metric to monitor overtraining, injury risk, and perhaps a tool to construct return-to-play guidelines after Tommy John surgery.

Key Words: ulnar collateral ligament, shoulder internal rotation, elbow extension

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Introduction

Baseball is a time-honored American sport that for too long relied on antiquated beliefs and dogma to train and develop athletes. Among those athletes are pitchers, who have the pivotal role of putting the ball into play each time it is thrown from the pitcher's mound. Injury concerns for pitchers stem from performing many overhead throws with very high should internal rotation and elbow extension velocities, which necessitate high rates of force development for the engaged upper extremity muscles and can culminate in extreme repetitive stresses over time[1]. Large valgus forces are also created across the ulnar collateral ligament (UCL) from overhead pitching; over time this may evoke repetitive microtrauma to the area that ultimately elicits ligament damage[2]. Consequently, pitcher injury rates are higher than for other baseball positions and continue to be a subject of interest and inquiry[3-5]. Traditional metrics to monitor overtraining and injury risk in pitchers include tracking their number of pitches thrown and innings played[6]. While youth pitch count guidelines are well documented, appropriate workloads for professional pitchers are unclear[6-9]. Traditional metrics to identify a successful season for starting Major League Baseball (MLB) pitchers include 32 game appearances and more than 200 innings played, which allows them to accrue impactful statistics like total strikeouts and wins. While traditional baseball metric

offer a general assessment of the volume of activity over a season, modern technology allows a more comprehensive understanding of workloads experienced by MLB pitchers.

Though relationships between the number of competitive appearances and an athlete's value to their team seem intuitive, the interplay between workload and performance require deeper analysis to understand how a combination of pitch repetition, intensity, and frequency determine the level of success throughout a baseball season. Unlike traditional baseball metrics, modern technology now includes Pitch Load (PL), which is quantified as the summation of the product of pitch types thrown by their respective average velocity. With no units of measurement, the expanded PL formula, to account for multiple pitch types, is calculated as follows: Σ [(fastballs thrown x average velocity) + (breaking balls thrown x average velocity) + (off-speed pitches thrown x average velocity)]. What may make PL superior to traditional metrics is it accounts for the intensity of effort, denoted by average velocity, for different pitch types thrown over the course of a game or season. PL values for MLB pitchers have received little attention and warrant inquiry. Presumably, many things influence PL values, with injuries likely having the biggest impact as they also undermine a MLB pitcher's longevity in the sport. As previously noted, the most debilitating injury to pitchers is the rupture of the UCL to their throwing arm, which is treated operatively as Tommy John surgery. Up to 25% of MLB pitchers underwent UCL reconstruction[10,11]. A retrospective cohort study, with public records from 2004 to 2014, revealed pitchers (n = 206; age range 20-47 years) with UCL injuries missed an average of 180.2 days of MLB regular season games[12]. The aggregate cost of their recovery totaled $395 million, or $1.9 million per MLB pitcher[12].

Approximately 70-80% of pitchers return to their sport after Tommy John surgery, albeit with performance impairments[11,13]. A strategy adopted for such pitchers is to limit their workloads during games, yet no specific literature exists that offers proper workload guidelines for a successful return to MLB pitching after UCL surgery[11]. Before guidelines are created for MLB pitchers, research must identify changes in PL that occur after Tommy John surgery. This study's purpose is to quantify PL changes to MLB pitchers before and after Tommy John surgery. Given our sample, we hypothesize a significant decline in PL for MLB pitchers after their Tommy John surgery. Future research may utilize PL to identify a pitcher's risk of overtraining and risk of injury. In addition, once workload guidelines based on PL values are established, the metric may identify return-to-play guidelines after Tommy John surgery.

Methods

Participants

This retrospective study examined MLB pitchers who underwent Tommy John surgery between the 2008 and 2023 MLB seasons. During that period, 352 MLB pitchers were identified to have undergone this procedure. Data were collected and partitioned from Fangraphs, a publicly accessible internet website, by a member of the investigative team. To be included in the current analyses, a pitcher must have thrown at least 100 pitches in both the MLB season prior to, and after, their Tommy John surgery. This pitch count threshold aligns with prior research and ensures pitchers recorded a sufficient sample to generate reliable values[14]. Based on this criteria, 222 MLB pitchers were available for analysis while another 130 were excluded due to not meeting the 100 pitch per season criteria both before and after UCL surgery. From the 222 pitchers analyzed, most (211; 95.0%) recorded 100 or more pitches in their final complete season immediately before the season of their surgery, with the remaining 11 pitchers achieving this mark two season prior to their surgery. The post-surgery season represents the first season a pitcher met the 100-pitch threshold after surgery. There was more variance in this observation than the pre-surgery season. Almost half the subjects (106; 47.8%) recorded 100 or more pitches in the first full MLB season after their Tommy John surgery. Yet 94 pitchers (42.3%) needed an extra season to fully recover and achieve a 100+ pitch season post-surgery. The remaining 22 pitchers (9.9%) required 3-5 seasons to recover from UCL surgery before they recorded 100 or more pitches in an MLB season.

Data Collection

Pitch tracking data were extracted from the Fangraphs website. Fangraphs utilizes PITCHf/x technology to track the velocity of pitches and categorize each pitch thrown into a specific pitch type based on its velocity, movement, and trajectory[15]. This technology was implemented in every MLB stadium during the 2007 season and relies upon two mounted high-speed cameras to track each pitch thrown and measure its aforementioned characteristics[15]. Data on pitch counts and average velocity were collected for each pitcher and classified into three distinct pitch types: fastball, breaking ball, and off-speed. Specific pitches categorized as fastballs included four- and two-seam fastballs, cutter, and sinker. Specific pitches categorized as breaking balls included curveballs, sliders, and knuckle-curves. Off-speed pitches included both changeups and forkballs. Data on screwballs and knuckleballs were extracted from Fangraphs yet, due to their low pitch counts, were excluded from the current analyses.

Statistical Analysis

To address the study's purpose and hypothesis, paired t-tests examined differences to three outcome variables before and after Tommy John surgery. The main outcome variable was the expanded PL formula, defined as Σ [(fastballs thrown x average velocity) + (breaking balls thrown x average velocity) + (off-speed pitches thrown x average velocity)] and approximated the cumulative workload over a game or season. In addition to the expanded PL formula, pre-to-post surgery changes were examined per pitch type (fastballs, breaking balls, off-speed) to identify statistically significant differences. Secondly, differences in average ball velocity by pitch type were assessed to isolate the potential effect of UCL surgery on pitch speed. Finally, potentially significant differences in pitch distribution by type were examined. To do this, the percentage of pitches classified as fastballs, breaking balls, and off-speed per MLB pitcher before and after surgery were calculated to assess if they significantly altered their pitch type repertoire. Prior to conducting paired t-tests, distributions for difference scores were assessed for normality and outliers via visual inspection of Q-Q plots. All analyses conducted for this study used IBM SPSS software (Version 31.0.1.0) with an $\alpha \leq 0.05$ to denote statistical significance.

Results

Demographics

The current study's age for MLB pitchers was 27.8 ± 3.7 years. Approximately 75% (n = 162) were classified as right-handed pitchers, which mirrors the distribution of pitcher's handedness in MLB overall[16]. There was a relatively even distribution of pitchers in the data set that progressed to MLB from the college ranks (54.5%) compared to those drafted out of high school or joined an MLB franchise after beginning their career in another country (45.5%).

PL

The study's primary purpose examined PL changes before and after Tommy John surgery. Each pitcher's calculated PL for their first available complete (>100 pitches) season before and after the operation were collected for analysis. The PL metric before surgery was 113,470.0 ± 82,577.3, and 62,044.6 ± 56,902 after surgery. A paired t -test revealed this difference as statistically significant with a medium effect size, $t(221) = 9.9$, $p < 0.001$, $d = 0.7$. The identification of PL discrepancies by pitch type yielded further suggestions of statistically significant differences. For fastballs, there as a significant difference in PL for the pre-surgery season (73,691.4 ± 56,198.9) compared to the post-surgery season (41,395.4 ± 42,411), $t(221) = 9.3$, $p < 0.001$, $d = 0.6$. For breaking balls, pitchers exhibited a significantly higher PL before Tommy John surgery (28,412 ± 24,896.7) compared to after Tommy John surgery (14,851.9 ± 14,832.9), $t(221) = 9.0$, $p < 0.001$, $d = 0.6$. Finally, similar results were reported for off-speed pitches, where the pre-surgery PL (11,366.7 ± 15,386.6) was significantly higher than the post-surgery PL (5,797.4 ± 8,654.7), $t(221) = 6.3$, $p < 0.001$, $d = 0.4$.

Pitch Velocity

In addition to Tommy John's impact on PL, a pitch velocity per pitch type was also assessed before and after surgery. This helps isolate the effects of UCL reconstruction on how hard a pitcher can throw the ball, given that the PL metric accounts for both velocity and volume. The results of this analysis suggest Tommy John surgery had a statistically significant and small-to-medium effect on pitch velocity for fastballs and breaking balls, but no discernable impact on off-season pitches. For fastballs, pitchers had significantly lower velocities when comparing pre- (92.8 ± 2.9 mph) to post-surgery data (92.3 ± 3.0 mph), $t(221) = 4.2$, $p < 0.001$, $d = 0.3$. Pitchers also incurred a significant decrease to their breaking ball's pitch velocity, with pre-surgery speeds (81.9 ± 4.0 mph) roughly 0.3 miles per hour faster than post-surgery speeds (81.6 ± 3.9 mph), $t(221) = 1.9$, $p = 0.03$, $d = 0.13$. Yet there was no significant difference among off-speed pitch velocities based on pre- (84.6 ± 3.3 mph) and post-surgery data (84.7 ± 3.7 mph), $t(221) = -0.26$, $p = 0.4$.

Pitch Distribution

Finally, data were analyzed for potential differences in pitch distribution based on the percentage of fastballs, breaking balls, and off-speed pitches thrown before and after surgery. Prior to surgery, they threw 63 ± 11.8% of their pitches as fastballs, 27.1 ± 11.9% as breaking balls, and 9.9 ± 10.0% as off-speed. After surgery, fastballs accounted for 62.2 ± 13.9% of their pitches thrown, breaking balls were 27.5 ± 13.6 of their pitching repertoire, and off-speed accounted for 10.3 ± 12.2% of all pitches thrown. In each case, paired t-tests revealed no statistically significant pitch distribution differences between time periods examined (fastballs: $t(221) = 1.14$, $p = 0.12$; breaking balls: $t(221) = -0.54$, $p = 0.29$; off-speed pitches: $t(221) = -0.84$, $p = 0.19$). Table 1 below presents descriptive statistics and full results of each paired t-test conducted for this study.

Table 1. Descriptive statistics and paired T-test results for pitch load, velocity, and distribution

	Pre-Surgery			Post-Surgery					
	Mean (SD)	**Max**	**Min**	**Mean (SD)**	**Max**	**Min**	**t**	**p**	**d**
Pitch Load									
Expanded**	113470.0 (82577.3)	313694.7	9172.8	62044.6 (56902.0)	285403.5	8990.6	9.9	<.001	0.7
Fastballs**	73691.4 (56198.9)	255209.2	6969.6	41395.4 (42411.0)	257941.0	3828.0	9.3	<.001	0.6
Breaking Balls**	28412.0 (24896.7)	125751.5	0.0	14851.9 (14832.9)	103290.2	0.0	9.0	<.001	0.6
Off-Speed**	11366.0 (15386.6)	86813.1	0.0	5797.4 (8652.7)	62700.8	0.0	6.3	<.001	0.4
Velocity									
Fastballs**	92.8 (2.9)	100.5	80.7	92.3 (3.0)	100.2	77.6	4.2	<.001	0.3
Breaking Balls*	81.9 (4.0)	91.5	68.8	81.6 (3.9)	89.5	68.8	1.9	.03	0.1
Off-Speed	84.6 (3.3)	95.7	74.6	84.7 (3.7)	92.2	70.9	-0.3	.39	0.0
Distribution									
Fastballs	0.6 (0.12)	1.0	0.3	0.6 (0.14)	1.0	0.2	1.1	.12	0.1
Breaking Balls	0.3 (0.12)	0.6	0.0	0.3 (0.14)	0.8	0.0	-0.5	.29	0.0
Off-Speed	0.1 (0.10)	0.5	0.0	0.1 (0.12)	0.8	0.0	-0.8	.19	0.1

Notes: SD = Standard Deviation; Max = Maximum; Min = Minium; ** = $p < .01$; * = $p < .05$; Velocity measured in miles per hour (mph)

Discussion

Results offer interesting interpretation on Tommy John surgery's impact on performance from a large sample of MLB pitchers. It is important to first understand, while current fastball and breaking ball data had a significant decline in pitch velocity after Tommy Joh surgery, the magnitude of such changes are so small that they are of little practical importance. With such small changes, and the time points that current study data were collected and used for analysis, pitch velocity appears to be of little value to assess the severity of UCL injury and the challenges associated with post-injury recovery. In contrast, not only were expanded formula and individual PL values by pitch type significant, they had large post-surgery decrements. As some MLB pitchers required multiple post-surgery seasons to accrue 100 pitches, percentage declines across average PL values show -45.3% (expanded), -43.8% (fastballs), -47.7% (breaking balls), and -49.0% (off-speed) losses. PL loss magnitudes are consistent across and expanded and individual pitch types and far exceed those for pitch velocity and pitch distribution. The current hypothesis was affirmed by the large and significant PL losses after Tommy John surgery.

The PL metric offers a deeper understanding of workload's impact on pitching performance than traditional baseball metrics. While PL has received little prior attention, it is important to compare current results to those of related studies. Predictors of UCL injury include pitch velocity, with body mass and age acting as secondary correlated[5,17]. Other impactful UCL injury predictors included the amount of rest between starts, small pitch repertoires with a reliance on fastballs, an athlete's height, a less prominent horizontal ball release location, a higher average pitch velocity, and pitch count per game[18,19]. In a related study, a multivariate analysis of predictors of UCL surgery included less rest between games, more pitches per outing, higher throwing velocity, a more overhand delivery, and a shorter stature were the strongest correlates to the likelihood of UCL surgery[20].

Yet the results of Whiteside et al. contrast with those of Aguinaldo and Chambers, whereby the latter study noted sidearm deliveries led to more elbow stress[18,20]. Elbow torque during pitching is affected by external shoulder rotation,

elbow flexion, and trunk rotation[18]. Greater elbow flexion upon ball release, as well as trunk rotation after foot contact with the pitcher's mound, reduced elbow torque[18]. Biomechanical differences among pitchers was suggested as a possible reason for the inter-study differences[18,20]. Finally, another investigation deemed average fastball velocity the best predictor of pre- and post-injury pitching performance[21]. It is interesting to speculate, given the current results, how strong a predictor of UCL injury a metric that accounts for cumulative workload, such as the PL formula, would have been in those prior studies[5,17-21].

Interpretation of current results imply PL, unlike pitch velocity and distribution, may offer greater sensitivity and precision to monitor overtraining and injury risk for MLB pitchers. In addition, and perhaps more importantly, PL values may help construct return-to-play guidelines after Tommy John surgery. Yet before PL can be validated for such purposes, its large current study decrements speak to UCL injury's impact on pitching. Some current results contrast with those that tracked pitch velocity changes in MLB pitchers before and after Tommy John surgery[22]. As part of a cohort study to monitor pitch velocity in 28 MLB pitchers from 2008-2010 who previously underwent Tommy John surgery, a pair-matched control group of pitchers with no prior UCL injury were also investigated. The authors claimed 79% of injured pitchers returned to the same level of play after Tommy John surgery[22]. There was no significant difference in pitch average velocity after surgery and no significant performance differences between the experimental and control groups. However, in agreement with the current study, fastball and changeup pitch velocities after Tommy John surgery declined from pre- to post-injury years[22]. However, in contrast to the current study, Jiang and Leland relied solely on pitch velocity to assess performance[22]. In addition, they had fewer subjects and a control group, which may help explain why their results differed from the current study's.

Research that used traditional baseball metrics to identify injury risk also saw little benefit to such measures. Using traditional baseball metrics (number of starts, total season pitch counts, total season inning counts, and average pitch count per game started) a recent study assessed their association with subsequent injury risk to pitchers that led to placement on the disabled list (DL)[5]. MLB pitchers (n = 161) who made at least five starts between the 2010 and 2015 seasons had their data accessed from publicly available websites. Exclusionary criteria included an injury that led to their placement on the DL with a year prior to the time points their data were accessed. Results showed, except for total innings pitched from 2010-2011 being significantly associated with DL placement in 2012, there were no significant correlation between traditional pitch metrics and an athlete's subsequent DL placement[5]. Thus, traditional pitch metric at best have limited ability to change in response to injury resulting in DL placement. The influence of pitch metrics on subsequent performance showed each pitch thrown led to a 0.007 higher ERA for the next game[23]. It was concluded pitch number negatively influenced next-game performance and could foretell overtraining or injury, but the effect was small[23].

In contrast, since the current study's PL metric declined significantly after Tommy John surgery, it may have the sensitivity and precision necessary to detect overtraining or injury risk in MLB pitchers, but presently that is only speculation. Continued research is required before PL is accepted by the baseball community for such reasons. What makes PL superior to pitch velocity and distribution, is its' expanded formula accounts for the type, number, and velocity for each type of pitch thrown by an athlete and offers insights as to their cumulative workload. Repetitive overuse injuries, such as those for UCL, are hardly the result of an occasional high velocity pitch, but rather occur gradually over time as the result of repetitive trauma associated with the overhead pitching motion that is the trademark for the sport of MLB.

Conclusions

The current study is not without limitation. Since the study employed a within-subjects design, pitchers served as their own (pre-surgery) control condition. Despite our sample size, there was a large amount of variability as shown by Table 1 SD values. In addition, complications associated with their UCL reconstruction that include, but were not limited to, the injury's severity, and the length of time required to accrue 100 post-surgery pitches, are other potential sources of data variability. Factors such as a pitcher's role (starter, reliever, middle reliever, etc.), additional/confounding injuries, etc. may also impact PL, pitch velocity, and pitch distribution outcomes. Yet current results show the greater sensitivity and precision of PL over traditional baseball metrics. Pl may prove useful to monitor overtraining and injury risk for MLB pitchers, as well as help construct their return-to-play guidelines after Tommy John surgery.

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Conflict of Interest. The authors declare no conflicts of interest.

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