

Association of Maximum Pitch Velocity and Elbow Injury in Professional Baseball Pitchers

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Background: Recent literature has explored the association of upper extremity injury in baseball players with various aspects of the pitching motion. To our knowledge, no study has directly evaluated the connection between maximum pitch velocity and elbow injury in professional baseball pitchers.

Hypothesis: Professional pitchers throwing at higher maximum ball velocity will have a higher risk of elbow injury.

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

Methods: Twenty-three professional pitchers were analyzed during spring training games and the ball velocity of the fastest pitch thrown for a strike (maximum pitch velocity) was recorded. This group was then followed prospectively over the following 3 seasons for elbow injury significant enough to warrant inclusion on the disabled list and/or require surgery. The association between maximum pitch velocity and elbow injury was then analyzed using an unpaired Student *t* test.

Results: There were 9 players with elbow injuries in the group of pitchers studied, including 4 pitchers with an elbow muscle strain and/or joint inflammation and 5 pitchers with an ulnar collateral ligament sprain or tear. Three of the ulnar collateral ligament injuries required surgery. For the 14 pitchers in the noninjured group, the mean pitch velocity was 38.09 m/s (± 1.45) or 85.22 mph (± 3.24). For the 9 players in the injured group, the mean pitch velocity was 39.88 m/s (± 2.39) or 89.22 mph (± 5.36). There was a statistically significant association between maximum ball velocity and elbow injury ($P = .0354$). The injured group had a longer average career length (9.7 years) than the noninjured group (6.5 years; $P = .0248$). The 3 pitchers with the highest maximum ball velocity had the injuries requiring surgery.

Conclusion: A statistically significant association between maximum pitch velocity and elbow injury was noted in this study, providing further support of existing theories about injury in baseball.

Keywords: professional baseball; elbow injury; pitch velocity; professional pitcher; pitching motion

Elbow overuse injuries are common in baseball pitchers. Multiple studies have analyzed various factors that contribute to throwing-related injury, including pitching form variations,²⁶ sex,² ethnicity,⁷ level of competition,¹¹ rotator cuff strength (Byram I, et al, unpublished data, July 2009), wind-up versus stretch,⁴ pitch type (fastball/curveball/changeup),^{5,15,19} fatigue,⁶ length of play,¹⁸ and other factors.

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Some studies have focused on pitch count as a risk factor for injury, especially in populations of younger athletes.^{15,24} Other studies have identified increasing pitch velocity as an independent risk factor for injury, but these studies have involved adolescent or college-level pitchers and not professional pitchers.^{20,30} The purpose of this study was to investigate the association of maximum pitch velocity and elbow injury in professional pitchers. It was our hypothesis that pitchers throwing with higher maximum pitch velocity would have a greater risk of elbow injury.

MATERIALS AND METHODS

Twenty-five professional baseball pitchers were analyzed during spring training games of the 1998 Cactus League.

TABLE 1
Demographic and Workload Information^a

Patient No.	Age, y	Height, in	Weight, lb	BMI	R/L	Starter/Reliever	Games Played	Innings Pitched	Total Pitches	Pitches/Game	Career Length
Injured Group											
1	24	74	175	22.52	R	Reliever	54	72.1	1261	23.4	8
2	25	75	205	25.68	R	Reliever	181	222	3722	20.6	11
3	29	77	190	22.58	R	Starter	18	95	1489	82.7	12
4	28	73	192	25.38	L	Starter	83	446.2	7369	88.8	13
5	23	74	200	25.73	R	Starter	20	110	1784	89.2	6
6	30	73	236	31.20	R	Reliever	158	165	2672	16.9	13
7	26	73	180	23.80	R	Reliever	61	227.2	4112	67.4	3
8	28	74	200	25.73	R	Reliever	169	188.2	2955	17.5	10
9	20	77	225	26.74	R	Starter	49	303.2	5200	106.1	11 ^b
Avg	25.9	74.4	200.3	25.5	1L/8R	4St/5Re	88.1	203.2	3396.0	56.9	9.7
Noninjured Group											
1	30	74	200	25.73	R	Reliever	148	170.5	2871	19.4	8
2	23	76	225	27.45	R	Starter	105	498.1	7565	72.0	7
3	30	72	180	24.46	R	Reliever	202	238	3970	19.7	11
4	23	79	200	22.58	R	Reliever	12	21	319	26.6	3
5	30	77	198	23.53	R	Starter	102	653.1	10385	101.8	12
6	26	72	170	23.10	R	Starter	62	119.5	1966	31.7	7
7	27	74	213	27.40	R	Starter	31	77.2	1349	43.5	7
8	26	74	195	25.09	R	Reliever	6	7.2	168	28.0	4
9	26	77	205	24.36	R	Reliever	7	7	120	17.1	5
10	30	74	210	27.02	R	Reliever	61	185.2	3227	52.9	3
11	26	72	175	23.78	L	Starter	76	275.1	4701	61.9	6
12	25	73	155	20.49	R	Reliever	7	8	165	23.6	3
13	30	71	160	22.36	R	Reliever	191	270	4486	23.5	9
14	28	75	205	25.68	L	Reliever	108	165.4	3105	28.8	6
Avg	27.1	74.3	192.2	24.5	2L/12R	5St/9Re	79.9	192.5	3171.2	39.3	6.5
<i>P</i> Values	.3121	.8586	.3640	.3243			.7716	.8819	.8446	.1819	.0248

^aDemographic data obtained at the time of velocity measurement. Workload data obtained over the following 3 seasons (1998-2000). BMI, body mass index; R, right-handed; L, left-handed; Avg, average; St, starter; Re, reliever; *P* values represent statistical significance analysis between injured and noninjured group data.

^bStill playing in Majors at time of writing.

There were 21 right-handed pitchers and 4 left-handed pitchers. The average age was 26.8 years (range, 19-30 years). The average height was 74.16 inches (range, 70-79 inches) and the average weight was 195.56 pounds (range, 155-236 pounds). Pitches were thrown from a standard Major League mound (11 inches in height) to home plate, a distance of 60 feet and 6 inches. Regulation baseballs with a mass of 5 ounces and circumference of 9 inches were used. Using a standard pitch velocity radar gun, the ball speed was recorded for the fastest pitch thrown for a strike during the game, measuring the pitcher's maximum possible velocity.

For each pitcher, demographic information, the number of subsequent professional games played, and information about workload (pitch counts, innings, games) was determined using www.baseball-reference.com for the years of 1998, 1999, and 2000. Two pitchers were excluded from the sample because they did not pitch in the major league during any regular-season game after their data were recorded, leaving 23 pitchers for final analysis. The official Major League Baseball disabled list injury report for each year was used to track the injury history for a given pitcher over the 3

seasons after pitch speed data were collected. Injuries not directly related to the elbow were excluded; these injuries included groin cellulitis, gout, a strained calf, hand/wrist injuries, shoulder injuries, and spinal injuries. The presence of an elbow injury was used to divide the pitchers into the injured and noninjured groups, and the types of elbow injury and treatment were also characterized and recorded. Statistics were evaluated using an unpaired Student *t* test, with significance set a priori at $< .05$. The study protocol was approved by our institutional review board.

RESULTS

Of the 23 pitchers studied, 9 suffered elbow injury over the 3 seasons according to the pitch data collected. These injuries included 1 elbow inflammation, 2 elbow muscle strains, 1 combined elbow inflammation/muscle strain, and 5 ulnar collateral ligament injuries. Three pitchers required ulnar collateral ligament reconstruction for a full tear, and 2 were successfully treated for minor sprains with a rehabilitation program. Analysis of demographic and workload

TABLE 2
Pitching Velocity in the Noninjured Group^a

Patient No.	Velocity, m/s	Velocity, mph
1	36.21	81
2	36.21	81
3	36.65	82
4	37.10	83
5	37.10	83
6	37.10	83
7	37.55	84
8	38.00	85
9	38.89	87
10	38.89	87
11	39.34	88
12	39.78	89
13	40.23	90
14	40.23	90
Avg	38.09	85.22

^aR, right-handed; L, left-handed; Avg, average.

TABLE 3
Pitching Velocity and Injury Information
for the Injured Group^a

Patient No.	Velocity, m/s	Velocity, mph	Year of Injury	Type of Injury	Treatment
1	37.55	84	1998	Strain	Rehab
2	37.55	84	1999	UCLS	Rehab
3	38.00	85	1998	Strain/Inflam	Rehab
4	38.44	86	2000	Strain	Rehab
5	38.89	87	1998	UCLS	Rehab
6	40.23	90	1999	Inflam	Rehab
7	42.02	94	2000	UCLT	Surgery
8	42.02	94	1999	UCLT	Surgery
9	44.25	99	1999	UCLT	Surgery
Avg	39.88	89.22			

^aR, right-handed; L, left-handed; Strain, strain of one or more of the muscles at the elbow; Rehab, nonoperative treatment with a focused elbow rehabilitation program; UCLS, ulnar collateral ligament sprain; Inflam, inflammation of the elbow joint; UCLT, ulnar collateral ligament tear; Surgery, ulnar collateral ligament reconstruction; Avg, average.

information of the injured and noninjured groups revealed no statistically significant differences, with the exception of career length (Table 1). The injured group had a longer average career length (9.7 years) than the noninjured group (6.5 years, $P = .0248$).

For the 14 pitchers without an elbow injury, the mean pitch velocity was 38.09 m/s (± 1.45 ; range, 36.21-40.23 m/s) or 85.22 mph (± 3.24 ; range, 81-90 mph) (Table 2). For the 9 pitchers with an elbow injury, the mean pitch velocity was 39.88 m/s (± 2.39 ; range, 37.55-44.25 m/s) or 89.22 mph (± 5.36 ; range, 84-99 mph) (Table 3). There was a statistically significant association between higher pitch velocity and injury ($P = .0354$). The 3 pitchers with the fastest pitches (with speeds of 42.02, 42.02, and 44.25 m/s) were the 3 who had ulnar collateral ligament tears that required reconstruction.

DISCUSSION

Injury to the elbow from pitching a baseball can occur as either a culmination of chronic microtrauma, as an acute event, or as an acute-on-chronic phenomenon. The concept of valgus extension overload from throwing a baseball is well established as a cause of muscle strains and joint inflammation.^{1,14,31} Tension on the ulnar collateral ligament from elbow valgus torque can cause chronic or acute failure of the ligament, often resulting in the need for repair or reconstructive surgery.^{25,27} Multiple studies have examined the risk factors for injury to players at the adolescent and college levels.^{5,10-13,15-17,19,20,23,24,26,28,30} Professional pitchers, however, have an even higher risk of overuse injury because of the higher levels of force involved, when internal rotation velocities at the shoulder range from 6100 to 7510 deg/sec with concomitant elbow extension velocities of 3000 deg/sec.^{3,8,9,21,29} One recent study identified a 4- to 6-fold increase in the number of surgeries performed on baseball pitchers over the past decade.¹² The purpose of our study was to focus on the single variable of pitch velocity as an independent risk factor for elbow injury in the professional population.

Our study indeed showed that higher maximum pitch velocity is statistically significantly associated with elbow injury, and that the pitchers with the highest maximum ball velocities are the ones who sustained injuries requiring surgery. To our knowledge, no other study has directly established this connection in the professional population. In a 2002 comparison of American and Korean professional pitchers, Escamilla and colleagues⁷ found a 10% greater ball velocity in the American group and hypothesized that the greater kinetics underlying this difference might account for a higher risk of shoulder and elbow injuries. In a 2004 survey study, Petty and coworkers²² found that 72% of high school baseball players undergoing ulnar collateral ligament reconstruction had pitch speed greater than 80 mph. A 2006 study of adolescent pitchers by Olsen et al²⁰ found that pitching a fastball with a speed over 85 mph increased the risk of injury 2.58 times. This study, like that of Escamilla et al,⁷ dealt with both shoulder and elbow injuries, whereas our study focused only on elbow injuries.

Although pitch velocity was the primary variable analyzed in this study, the type of pitch thrown may also influence injury risk. Traditionally, the curveball has been considered a higher risk pitch than the fastball because of the complex rotational forces created throughout the upper extremity when it is thrown. Recent studies, however, have called this long-standing dogma into question. Fleisig et al¹² found no significant difference in joint loads between fastballs and curveballs in a study of collegiate pitchers. Dun and colleagues,⁵ however, showed that elbow and shoulder loads are greater in throwing the fastball than the curveball in youth baseball pitchers. These findings were confirmed by Nissen et al,¹⁹ who also found that shoulder and elbow moments were less with throwing a curveball than a fastball. These authors also determined a direct correlation between the magnitude of moments at the shoulder and elbow with ball velocity.¹⁹ Although our study did not analyze

curveball versus fastball as a variable, our findings are consistent with these studies in that the higher ball velocities (and thus the higher joint moments) were associated with injury.

Multiple additional factors such as pitch count, body size, age, and experience may also theoretically influence the risk of injury in a pitcher. Our analysis of such factors revealed a trend toward a higher workload in the injured group, with more games, more innings, more pitches, and more pitches per game than the noninjured group. These differences, however, were not statistically significant. We also noted a trend toward younger age and greater height, weight, and body mass index in the injured group but, again, none of these differences were statistically significant. It is unclear whether these trends represent risk factors for injury or, conversely, are predictive of the pitchers' performance ability (ie, bigger pitchers are able to throw faster and thus see more action). Future studies with a larger study sample may clarify these trends noted in our study.

We did observe a statistically significant difference in overall career length between the 2 groups, with the injured group having a longer average career length. Most likely, this difference is because the injured group had a higher overall ball velocity and thus a competitive edge over the noninjured group. Pitchers who can throw faster and maintain that velocity over the years, even when returning from injury, are more valuable to a baseball club and thus are more likely to have longer careers. Although we did not analyze velocity during additional seasons or velocity obtained after recovery from injury, it seems logical that the longer careers noted in the injured group are probably because their higher velocity rates made them a more valuable commodity.

This study did have certain limitations. We did not use data from multiple pitches over the course of a game or a season, thereby opening the possibility that the pitcher had an increase or decrease in ball speed over time, or even that the pitcher may have had an exceptionally "good day" or "bad day" at the time of data collection. Multiple factors obviously affect ball speed, and we did not seek to perform a complex analysis of these factors or to control for them. We simply thought that the fastest recorded pitch from a game situation was a reliable indicator of a pitcher's maximum ball velocity, and that it could be used to analyze injury risk. Another potential weakness was that we used injury data from 3 subsequent seasons, again opening the possibility that ball velocity in the second or third season (when injury occurred) may have been drastically different from the data measured in the first season (when injury did not occur). However, we chose to follow the athletes for 3 seasons because of the temporal requirement for overuse injuries to manifest, again assuming that pitchers would maintain their level of maximum ball velocity.

An additional issue was that our study did not seek to analyze fatigue as a factor related to injury, only the maximum ball velocity. A 2001 study by Murray et al¹⁸ showed a decrease in ball velocity and changes in kinetic

parameters over the course of a game. Other studies have shown, however, that no significant change in pitching biomechanics occurs as a pitcher approaches fatigue.^{6,19} Future studies should focus on the effect of fatigue on pitch velocity over the course of a game as a separate risk factor. In spite of these and other limitations, our study had a simple design enabling a clear identification of higher ball velocity as an individual risk factor for elbow injury.

In conclusion, this study showed that pitchers capable of throwing at higher maximum ball velocity had a higher risk of elbow injury and that the players throwing at the highest velocity had injuries requiring surgical reconstruction. These findings can be used to identify players at risk for injury and to design appropriate injury-prevention programs.

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