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Abstract

This paper analyzes the literature surrounding the relationship between MLB pitcher velocity, pitcher injury time, and hit batsmen which indicate that pitcher velocity is likely the cause for higher injury rates and an increase in batters hit. Two linear regression models were used to examine both of these relationships. The data set included average pitcher fastball velocity, number of pitches, time injured, and the number of hit batters for pitchers who threw more than one hundred fastballs in any year between 2015-2022. The first regression found no significance between velocity and time injured however the relationship was positive. The second regression displayed a high negative significance which did not support the hypothesis. Given these results, this paper puts forth possible improvements to the data which could improve the results to align with the hypothesis.

1. Introduction

Major League Baseball teams spend over 1.5 Billion dollars per year on pitcher contracts which is the largest amount of money spent on a single position in any sport. Because of the importance of the position, MLB teams also spend extensive amounts of capital on pitcher development, in particular, velocity training. This search for velocity has become a widespread phenomenon in recent years at every level of baseball. However, studies such as O'Connell (2016) have found that gaining velocity also puts the pitcher's arm under greater stress which could mean an increased chance of injury. Additionally, higher velocity negatively impacts the pitcher's arm but also the quality of the pitches themselves. A pitcher must strain to throw harder which can result in less accurate pitches, in turn, resulting in more hit-by pitches. The question before us is whether gaining velocity is in the best interest of MLB teams or is it hurting their players' ability to play an entire 162-game season. With fan-favorite pitchers and hitters sitting on the bench due to injury, fans and owners should all be concerned with the direction the game is taking.

Sports media outlets have written at length about the increasing fastball velocity rate and how it impacts the game. Today's batters are striking out more than ever and the offense seems to be at an all-time low. Media sources have been quick to point out that increasing fastball velocities are to blame and want the league to make necessary changes to make hitting more prevalent. There is also an ample amount of literature that describes why pitchers are throwing harder and what happens to their arms at higher velocities.

But, while some writers have brought up the problems of rising velocity and its effects on batting averages, no one has looked at how velocity impacts MLB arms and potential hitter

injuries. The question of whether fastball velocity has increased the number of injuries to pitchers and batters has never been analyzed in an empirical study and has not been answered in any relevant study or paper.

Using linear regression analysis, this paper attempts to determine whether higher velocities are correlated with pitchers experiencing more injuries as well as more hit batters. This analysis is intended to give pitchers, coaches, and teams an understanding of the unintended impacts of gaining velocity. The second section of this paper will go over the literature relevant to this topic by explaining how and why velocity is increasing in MLB along with its impacts. The third section will cover the data, model, and estimation techniques used for regression. Section four will analyze the regression results and section five will conclude the findings.

2. Literature Review

The research on pitching velocity in baseball will help answer four questions: why velocity is increasing within MLB, how pitchers are gaining velocity, what is happening to the arm when players throw extremely high velocities, as well as what is happening to hitters as a result of the aforementioned questions.

How is velocity impacting baseball?

The single most important issue within MLB today is that pitchers are gaining pitch velocity every year making hitting more difficult. Sheinin (2019), found that rising pitching velocities

across MLB have changed the game immensely from the not-so-distant past. Hitters are now striking out more than ever and since 2018, there have been more strikeouts than hits in an MLB season. Not only are strikeouts up but hits are also at an all-time low. Data from Baseball Reference in Table 1 show that batting average, the ratio of hits to at-bats, has been decreasing since the 1999 season. Along with batting average, Table 1 also displays on-base percentage, the probability that a batter will get on base, and slugging percentage, the number of bases a batter gets per at-bat. Sheinin (2019) attributes this gradual decrease which can be seen in the table to increased fastball velocities.

Table 1. Batting Average, On-base Percentage, and Slugging percentage 1999-2022

Year	BA	OBP	SLG
2022	0.243	0.312	0.395
2021	0.244	0.317	0.411
2020	0.245	0.322	0.418
2019	0.252	0.323	0.435
2018	0.248	0.318	0.409
2017	0.255	0.324	0.426
2016	0.255	0.322	0.417
2015	0.254	0.317	0.405
2014	0.251	0.314	0.386
2013	0.253	0.318	0.396
2012	0.255	0.319	0.405
2011	0.255	0.321	0.399
2010	0.257	0.325	0.403
2009	0.262	0.333	0.418
2008	0.264	0.333	0.416
2007	0.268	0.336	0.423
2006	0.269	0.337	0.432
2005	0.264	0.33	0.419
2004	0.266	0.335	0.428
2003	0.264	0.333	0.422
2002	0.261	0.331	0.417
2001	0.264	0.332	0.427
2000	0.27	0.345	0.437
1999	0.271	0.345	0.434

(*Major League batting year-by-year averages*. Baseball Reference)

With increased pitch velocity, hitters are having a more challenging time getting hits for two reasons. First, because pitchers' fastballs are getting to them faster, hitters have less time to react, making it harder to discern balls from strikes. Secondly, a faster fastball has allowed offspeed pitches (changeups, curveballs, and sliders) to become more impactful. Batters have to react so quickly to a fastball that they are more likely to commit early to breaking balls that become impossible to hit. Because of this obvious relationship between velocity and lower hitting numbers, front offices have been investing money into their teams to try and increase the velocity of their pitchers at every level. Consequently, from 2008 to 2018 the MLB median pitch velocity jumped almost an entire mile per hour from 89.0 mph to 89.9 mph. Over this same timeframe, the number of pitches thrown over 100 mph went from 200 in 2008 to over 1500 in 2018. Along with more pitches being thrown over 100 mph, there was a 50% increase in the number of pitchers able to throw at that speed (Sheinin, 2019). Wilson (2018) looked into the impact of faster pitches and found that batting averages drop drastically with increasing velocity. The paper also found that faster velocities give up fewer home runs and extra-base hits.

How are velocities increasing?

Since it is widely known that higher velocities negatively impact batting statistics MLB teams and independent baseball companies have invested huge amounts of money to figure out how to throw harder. Driveline, a baseball development company based out of Seattle is one of the industry-leading facilities where high-level pitchers search for velocity. One aspect of Driveline's training program involves throwing weighted baseballs. According to Driveline

(2022), an 8-week weighted ball program will increase one's “arm fitness”, i.e. stronger muscles and tissue, that will allow pitchers to throw harder along with being able to “bounce back” faster after throwing. Reinold et al., (2018) found that a six-week weighted baseball throwing program did in fact see a 3.3% significant increase in velocity, but also found that injuries went up 24% when comparing the experimental to the control group. Another way in which pitchers attempt to gain velocity does not come from arm strength but by mobility. Stodden et al., (2005) looked at biomechanical factors that could increase throwing velocity. The study concluded that being more flexible, especially in the shoulders and trunk will allow a pitcher to throw harder. Together, strength and flexibility programs have facilitated the increase in pitching velocity.

What are the impacts on the arm when throwing at high velocities?

With the increase in pitching velocity established, scholars have questioned what effect higher velocity has on the health of pitchers. Several studies have pointed out that the rate of pitchers undergoing surgery is at an all-time high. Schoenfield (2015) found that there were more Ulnar Collateral Ligament surgeries performed in 2014 than in all of the 1990s combined. In a study done by the American Journal of Orthopedics, Conte (2015) found that 400 UCL reconstructions have been performed between 1974 and 2015 however one-third of them had been done within the last 5 years of the study 2011-2015. Clearly, the available literature indicates that both velocity and elbow injuries have been increasing at an exponential rate. Researchers at the American Sports Medicine Institute used capture software in order to figure out if velocity was responsible for greater elbow-varus torque, the force experienced when the arm stretches back

during a throwing motion (Jenkins, 2020). According to O'Connell (2016), elbow-varus torque is the leading cause of elbow injuries resulting in UCL reconstruction. Jenkins (2020) found that velocity accounted for 95.7% of the variance in elbow-varus torque. This strongly suggests that higher velocity increases the stress on a pitcher's elbow. Schoenfield also writes that Dr. Fleisig, a doctor at the American Sports Medicine Institute, stated directly that velocity is the leading factor in pitching injuries and that there is clear evidence that throwing 95 mph is more stressful on the arm than throwing 90 mph. It can be inferred from all of these studies that these two variables, pitch velocity and injury rate, may be highly correlated.

What is happening with hitters?

Not only are pitchers experiencing more injuries but Verducci (2021) addresses the increasing number of hit batsman injuries in MLB. Verducci states that the last three seasons have been the most dangerous ever for batters with 0.92 batters hit per game, which is up 12% from the full-length 2019 season. Verducci attributes this increase in hit-by-pitches (HBP) to two main factors. First, MLB teams are now valuing increased velocity over a pitcher's ability to control their pitch location. The second is that the current meta of pitching involves the high fastball. When a ball is thrown out of the pitcher's hand, the shortest amount of time it takes for the ball to cross the plate would be from a straight line from the release point. Therefore the high fastball for a strike is the fastest pitch in baseball because it takes the shortest amount of time to reach the plate. But with less control from trying to throw harder, these high fastballs are being miss-thrown and have resulted in pitches being thrown in areas that could seriously injure a

batter. Fink (2019) looked at the increasing number of batters being hit and suggested that velocity may not be a reason for the increase in hit-by-pitches. The paper supports this idea by saying that high-velocity throwers are not responsible for as many HBP as softer throwers. However, this study fails to take into account that there are many more pitchers throwing 90 mph fastballs than pitchers throwing 100 mph. Therefore we would always expect more batters to get hit by the many pitchers who throw low 90s than the few pitchers who are throwing 100. It makes sense to expect that we will find that higher velocity in general is correlated to an increase in HPBs since in the new meta of high velocity, every pitcher is overthrowing regardless of whatever maximum velocity he throws.

3. Data and Model

The data used for this study comes from Baseball Savant and SportTrac. Baseball Savant is an MLB-run website with public data on every player and every game. SportTrac is a website that tracks different statistics including injury time, contract information, as well as salary information from almost every major sport.

The data set that was constructed for this analysis consisted of a population of pitchers who threw at least 100 fastballs during the 2022 MLB season. The data consists of these players' statistics from 2015-2022 as well as their time injured from an arm injury. The main observations that are used are the average velocity of a pitcher's fastball, the number of fastballs thrown, the time they spent injured due to an arm injury, and the number of batters hit by pitches. All of the observations used in the regression can be seen in Table 2 below.

Table 2. Variable Names

Pitches	The total number of fastballs thrown by a pitcher
Velocity	The average fastball speed from a certain pitcher
Time_injured	The amount of time a pitcher spends on the injury list in a given season due to an arm injury
Hit by Pitches (HBP)	The number of times a pitcher hit a batter during a game

The strength of this data set is that all of the statistics are accurate to what happened on the field. Because Baseball Savant is run by MLB they always have the most accurate statistics. Sport Trac however, is not an MLB-sanctioned service so the data may not be as accurate. The collection of injury data began in 2015.

As stated above, since the injury data only goes back to 2015 the data may not represent a long enough picture through time to see the full relationship between velocity and Injuries. This is especially true because MLB saw the largest jumps in velocity during the 2000s. Because the injury data does not go back that far we are not seeing the time period where velocity really started to jump. Another feature that may affect this paper's results is that pitchers mainly try to gain velocity during the off-season when they do not have to pitch every five days at max intent. During the offseason is when pitchers have the time to train hard and try to throw harder meaning they are more likely to get injured then and not during the season. If an injury was

experienced during the off-season and they did not participate in the season, then their statistics were not recorded, meaning their injury and velocity would be excluded from the data set.

In order to assess the correlation between velocity, time spent injured, and hit by pitches This paper uses two linear regression models to determine if higher velocity is correlated with longer and more severe injuries as well as to see if higher velocities create more HBP. For the first equation, the dependent variable will be Time_injured/Pitches and the independent variable will be Velocity. The second equation will have HBP/Pitches as the dependent variable and the Velocity will stay as the independent variable. Both Time_injured and HBP will be divided by the number of pitches thrown by a given pitcher in order to standardize that data. The Two Models that will be used are as follows:

Equation 1:

$$Time\ Injured/Pitches = \beta_0 + \beta_1 \text{Velocity} + u$$

Equation 2:

$$HBP/Pitches = \beta_{0+} \beta_1 \text{Velocity} + u$$

In both of these equations β_0 represents the Y-intercept of the correlation line, β_1 is the slope of the correlation line, and u is an error term.

4. Results

The two tables below display the results from the regressions. Table 3 looks at how velocity impacts time spent on the injury list due to an arm injury for a pitcher. Table 4 displays how velocity impacts the number of batters pitchers hit in a year. The tables provide the P-values, standard errors, R^2, adjusted R^2, and F-stat for each regression.

Table 3. Time Injured and Velocity

	Dependent variable:
	I(time_injured/pitches)
velocity	0.001
	(0.001)
Constant	-0.095
	(0.094)
Observations	1,300
R^2	0.001
Adjusted R^2	0.001
Residual Std. Error	0.083 (df = 1298)
F Statistic	1.742 (df = 1; 1298)
Note:	*p<0.1; **p<0.05; ***p<0.01

Looking at table 3, the relationship between velocity and time_injured, it is immediately revealed that there is no significance within this data set for these two variables. A P-value of only 0.001 tells us that from the 2015-2022 season, velocity only accounted for 0.1% of arm injuries. We also see that the R^2 and adjusted R^2 values (0.001) are both insignificant as well as the F-stat (1.742). These results are unexpected but there is still a positive relationship between time_injured and velocity. This means that even though it is a very small factor, velocity does impact the health of pitchers' arms. As stated in section 3 one of the largest weaknesses of the data used for this regression is the time span. Because of the positive relationship between the two variables it can be inferred that a larger range of data could help the significance. This regression also could be falling victim to omitted variable bias (OVB). The variable that could have a major impact on the relationship between velocity and time_injured would be age. It is common knowledge that the older you get the more likely you are to get injured and this is also true when it comes to throwing velocity. When a pitcher gets older, they not only start to throw slower but are also at a higher risk of injury. A second variable that could impact the significance of this regression would be the type of pitcher. The two main types of pitchers, starting pitchers and relief pitchers, tend to have completely different philosophies when on the mound. Starters aim to not throw their hardest in order to try and pitch as many innings as possible, while the relief pitcher's job is to go into a game to get just three outs. Therefore relief pitchers tend to throw harder for shorter intervals of time which puts more strain on the arm. With many pitchers in the data set being starting pitchers the results may have become slightly skewed. In conclusion, if more years, pitcher age, and pitcher type were implemented in this regression, then the results would likely become more significant.

Table 4. HBP and Velocity

	Dependent variable:
	I(HBP/pitches)
velocity	-0.0003***
	(0.0001)
Constant	0.039***
	(0.007)
Observations	1,300
R^2	0.017
Adjusted R^2	0.016
Residual Std. Error	0.006 (df = 1298)
F Statistic	22.550*** (df = 1; 1298)
Note:	*p<0.1; **p<0.05; ***p<0.01

Unlike the first regression, Table 4's results were in fact significant, however in the opposite direction as this paper hypothesized. The p-value (-0.0003) is significant at the 0.01 level which is quite an odd result because the two variables are negatively correlated. While the R^2 (0.017) and adjusted R^2 (0.016) values are very low, the f-statistic is significant at the 0.01 level which is quite odd. The low R^2 value tells us that the model does not fit the data very well but the

f-stat conveys that the model fits the data better than a model with no variables. It was hypothesized that in order for pitchers to throw harder, they must in fact strain their bodies in the process, resulting in more inaccurate pitches. It is also known that the rate at which batters are getting hit has been steadily rising along with the average velocity as documented by Verducci (2021). But from the result of the regression it can be inferred that the data set does not provide a good look at the whole picture. One potential flaw lies in the fact that pitchers who can throw extremely high velocities (98-102), have the ability to not throw as hard but still reap the benefits of a high 90s fastball. A pitcher who only throws low to mid-90s (90-94), realizes that he will see a larger benefit trying to throw as hard as he can because the benefit of increased velocity outweighs the resulting loss of control. Therefore in order to obtain more accurate results, the data would have to group pitchers who throw similar velocities together to reveal potential significance.

5. Conclusion

In conclusion, we set out to answer two questions. First, to determine if increased velocity in MLB pitching is correlated with the increase in arm injuries. Second, to determine if increased velocity is correlated with the recent increase in the number of hit batsmen. Using data obtained from BaseballSavant.com and SprtTrac.com two linear regression models were created to answer these questions. In the case of the pitcher arm injuries, the regression displayed a positive relationship but with no significance. In the case of hit batsmen, the regression displayed a negative relationship which was the opposite of what was hypothesized. However, there are reasons to suspect that the dataset may be at fault for these conclusions. In the case of time

injured, player age and the type of pitcher are two variables that should have been accounted for. Likewise, for the HBP regression, the data could have been grouped so that different velocity ranges could be regressed. Given the large amount of existing evidence that connects velocity to injury and HBP rates, it is reasonable to believe that if the data is properly altered, then the regression results should support this paper's hypothesis.

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