An Investigation into the Longevity of Major League Pitchers

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Introduction

Survival analysis is a branch of statistics practiced in medical fields, engineering, and economics. Though less common, survival analysis can also be utilized in sports through the investigation of career length. Regardless of the sport, coaches and front offices want to know how long a player will be a successful professional before they draft, sign, or trade for them. Some sports, such as baseball, have implemented statistics into decision-making more than others. In this study, we want to investigate and predict the career length of Major League pitchers. Specifically, we look to explore relationships between velocity, spin rates, handedness, pitch usage, and draft status in order to discover what impacts career length. To quantify career length, measured in total innings pitched in the Major Leagues, our initiating event will be defined as the date of a pitcher's MLB debut and the terminating event will be defined as the end of their Major League career.

We recognize that there is a discrepancy in innings pitched based on whether a pitcher is a starting pitcher or a relief pitcher. Starting pitchers naturally pitch more innings because of their role on the team. Traditionally, starting pitchers start the game and throw between five and seven innings in successful appearances. Also of note, these pitchers usually only pitch once every five games. Relief pitchers pitch less innings and finish what remains of the game once the starting pitcher is done pitching. Relievers appear more frequently than starters, but commonly only pitch for an inning or two in each appearance. Because of this, we planned to stratify our study based on position.

As we sorted through potential variables of interest, one of our main goals was to build models that provide relevant information to MLB teams and possibly aid in decision making. With this in mind, we concluded that some of the most important decisions a team has to make are on draft day. Scouts are primarily interested in physical features such as a player's mechanics and "stuff", which is a baseball term for the type and quality of pitches they throw. In addition, scouts dig deeper to find out if a player has a personal pitching coach, how often they throw during the year, what their bullpen routine is, and what kind of competitor they are. However, we wondered if scouts and front offices value pitchers over position players in early rounds or if there is a pattern of pitchers drafted in earlier rounds performing better and longer than those drafted a round or two later. In short, is there worth in drafting a pitcher on the first day of the draft because they traditionally have longer careers? This is a question we looked to answer in this investigation.

As we continued to consider potential variables of interest, we began to consider which abilities and types of pitches come at the expense of a pitcher's arm health. When thinking about the physical effects of throwing a high-velocity fastball, Noah Syndergaard, who averages 97.2 MPH on his fastball, immediately comes to mind. Syndergaard has been plagued with multiple arm injuries, which could be the result of the wear and tear caused by how hard he throws. These injuries have caused him to miss the majority of multiple seasons, reducing his career innings pitched. Focusing more on breaking balls, Little League pitchers have been limited and sometimes even banned from throwing these pitches because the torque needed to create spin wears on their elbows. However, this seems to be a common misconception and these claims about curveballs specifically were proven inaccurate in a study reported by Sports Illustrated. Furthermore, in a 2016 study from Shoulder and Elbow Surgery, pitchers who underwent Tommy John Surgery, the treatment of a UCL tear in the elbow, were more likely to have thrown more high-velocity pitches. Therefore, fastballs seem to create more wear on the elbow than breaking balls, no matter the age. Based on all this information, we decided to further investigate the effects of both velocity and spin rate (how fast the ball is spinning, measured in RPMs) on career length.

Lastly, data collected since the beginning of the Statcast Era (2015-present) suggests that the league-wide fastball usage rate has decreased by approximately 10% in the last eight years. Pitchers today seem to value horizontal break and changes in velocity more than throwing hard with a looping curveball mixed in as a strikeout pitch. This could be due to biomechanical advances, which in turn would lead to longer careers, so we were curious if pitchers who throw their fastball a certain percentage of the time are predicted to have shorter careers. We explain what constitutes a fastball-primary pitcher in the Pitcher Type section of Results.

Data

Our data was obtained from Baseball Reference and Baseball Savant. Baseball Reference is a historical database for a majority of common baseball statistics. We extracted cumulative data for pitchers that started their career anywhere between 2000 and present-day, as well as information regarding their handedness and draft status. Any pitchers that pitched in 2022 are considered censored data points since they could still be active players. For more advanced stats, we utilized Baseball Savant, which possesses data from the Statcast Era. Statcast was originally a combination of radar and camera systems that tracked spin rate, exit velocity, pitch location, and pitch types. This technology now uses the HawkEye system, which is also used in tennis.

Specific to our study, the first core dataframe we built is called *joinall*, which contains 36 different career statistics for 3138 different players who pitched more than 10 innings in the Major Leagues from 2000-2022. We chose this threshold of 10 innings to remove position players who only pitched a few innings in their career. Based on whether or not a player appeared as the starting pitcher in more than 5 games, we also created a categorical variable SP, where SP = 1 denotes a starting pitcher. Our second core dataframe is called *savant_avg*, which is the condensed version of Baseball Savant data once we grouped players by name and then summarized their Statcast metrics. Specifically, Statcast metrics were summarized as career averages. This dataframe contains 20 different Statcast statistics for 1548 pitchers. By joining these two core dataframes, we created *fullset*, the complete dataframe consisting of all 3138 players from Baseball Reference with the extra 20 Statcast-related variables added.

The rest of the dataframes used for modeling were built from *fullset*. First, *statcast* is a condensed version of *fullset* that only includes the 1469 players who pitched during the Statcast Era. From *statcast*, we created *statcast_SP* and *statcast_RP*, which separate starters and relievers. Next, *fullset_draft* contains six additional draft-related variables and only contains the players from *fullset* that had draft information available. Because of the lack of available data, only players drafted between 2000 and 2019 are in this dataset. Lastly, *handedness* removes pitchers from *fullset_draft* who did not have information regarding which arm they throw with. For a summary of the data frames we specifically use in our models, see Figure 1. Note: FB_x variables can also be Breaking_x and Offspeed_x, but for those types of pitches.

Dataframes Summary

Dataframe	Number of Pitchers	Number of Variables	Important Variables
statcast_SP statcast_RP	734 735	59	FB_Spin: Spin Rate, Measured in RPM FB_MPH: Velocity, Measured in MPH FB_Primary: Binary, 1 = Above Average Usage
handedness	1700	62	Throws: Right-Handed(R) or Left-Handed(L) SP: Binary, 1 = Starter
fullset_draft	1704	62	Overall_Pick: Overall Draft Position Round1_Pick: Binary, 1 = Drafted in 1st Round First10_Pick: Binary, 1 = Drafted in First 10 Rounds

Figure 1

Methods

First, to verify that there is in fact a difference in the predicted career length of a Major League pitcher dependent on whether they are a starting pitcher or a relief pitcher, we utilized non-parametric Kaplan-Meier survival models. With these models, we were able to examine the two survival curves and carry out a log-rank test, which provided the statistical significance needed to conclude that there is a difference between the two groups.

Next, and for much of our modeling process, we started by selecting a set of variables that we deemed could have an impact on career innings pitched. We then built models assuming parametric survival distributions, namely Normal, Exponential, Weibull, and Log-normal distributions. To check the adequacy of each parametric assumption, we created Cox-Snell residual plots and checked for linearity. Log-normal and Weibull always fit the data the best according to the residual plots and produced the lowest AIC values. Generally, our log-normal models had the most accurate hazard functions as well because they are allowed to be non-monotonic. After finding which distribution fit best, we then tested different variables for significance. Generally, we used a p-value of 0.05 to determine significance, but it is important to mention that we did not define a hard cutoff because making this decision binary can potentially exclude important information.

Finally, for a few variables of interest, we utilized semi-parametric Cox Proportional Hazard models. This technique models hazard ratios instead of survival times and assumes a hazard ratio is constant over time. Hazard is found by dividing a density function by a survival function and quantifies risk of failure given survival up to a certain time point. Cox PH models produce coefficients with a "flipped sign" compared to survival models because they measure the risk of failure instead of chance of survival. Furthermore, we checked whether the PH assumption was valid by running formal tests and examining plots of the Schoenfeld Residuals.

Results

Statcast Metrics

The goal of our first inquiry was to determine which Statcast metrics have the most significant effect on career length. In total, we built six models, one for each type of pitch, stratified by starters and relievers. The three pitches we explored were fastballs, breaking balls, and offspeed pitches.

Aside from the fastball model for starters, which assumed a Log-normal distribution, we assumed Weibull distributions as they produced the lowest AIC value and fit the Cox-Snell residuals best. For all models, we assumed a significance level of 0.05 and used career innings pitched as the outcome variable. For starting pitchers, we found that fastball spin rate (FB_Spin), breaking ball spin rate (Breaking_Spin), and offspeed velocity (Offspeed_MPH) were all statistically significant predictors of career length, while fastball velocity (FB_MPH) had a nearly significant p-value. An increase in the value of any of these metrics led to an increase in career length, with breaking ball spin rate having the most statistically significant impact. In our fastball model, a 100 RPM increase in spin rate predicted an 11.4% increase in career length. In our breaking ball model, a 100 RPM increase in spin rate predicted an 11.1% increase in career length. In our offspeed model, a 1 MPH increase in velocity predicted a 4.7% increase in career length, while a 5 MPH increase in velocity predicted a 25.5% increase in career length. Additionally, if considered significant, a 1 MPH increase in fastball velocity predicted a 4.2% increase in career length, while a 5 MPH increase in velocity predicted a 22.7% increase in career length. Figure 2 summarizes these findings.

Significant Starting Pitcher Variables

Variable	Coefficient	p-value	Impact on Career Length
FB_Spin	0.001081	0.010	100 RPM increase, ≅ 11.4% increase in career length
FB_MPH	0.040895	0.099	5 MPH increase, ≅ 22.7% increase in career length
Breaking_Spin	0.001045	2×10^{-6}	100 RPM increase, ≅ 11.1% increase in career length
Offspeed_MPH	0.0455	0.015	5 MPH increase, ≅ 25.5% increase in career length

Figure 2

For our relief pitcher models, we also assumed Weibull distributions as they produced the best-fitting Cox-Snell residuals and the lowest AIC values. Innings pitched is also the outcome variable for career length in our relief pitcher modeling. In these models, we found the same variables to be statistically significant or near significant, with the addition of the breaking ball velocity. We found that fastball velocity (FB_MPH) had a greater significance level for relief pitchers, but the predicted impact on career length was nearly identical to starters (4.2% increase with a 1 MPH increase, 22.6% increase with a 5 MPH increase). Breaking ball spin rate (Breaking_Spin) was still significant for these pitchers, but not as extreme compared to the starters. Numerically, a 100 RPM increase in spin rate only predicted an increase in career length by 5.5%, which is about half of what it was for starting pitchers. Figure 3 is a complete summary of these findings.

Significant Relief Pitcher Variables

Variable	**Coefficient**	**p-value**	**Impact on Career Length**
FB_Spin	0.000799	0.0260	100 RPM increase, ≅ 8.3% increase in career length
FB_MPH	0.040672	0.0547	5 MPH increase, ≅ 22.6% increase in career length
Breaking_Spin	0.000533	0.00856	100 RPM increase, ≅ 5.5% increase in career length
Breaking_MPH	0.037430	0.01488	5 MPH increase, ≅ 20.6% increase in career length
Offspeed_MPH	0.027675	0.05520	5 MPH increase, ≅ 14.8% increase in career length

Figure 3

Handedness

Using both parametric survival interaction models and semi-parametric Cox PH interaction models, we investigated the effects of handedness and position (starter or reliever) on career length. Both models found corresponding results. Using AIC and Cox-Snell residuals for assessment, the Weibull distribution was the best approach to parametrically model handedness. Both the survival model and Cox PH model predicted that right-handed relievers had the shortest career length and that the difference in their predicted career length compared to left-handed relievers was significant. We theorized that right-handed (RH) relievers are more expendable than left-handed (LH) relievers because they are easier to replace, and conversely, LH relievers are scarce. The interaction term in the survival model possesses a positive coefficient, claiming that the difference in career length between opposite-handed starting pitchers is less than the difference in career length between opposite-handed relievers. Starting pitchers are not needed for niche roles or for pitching in particular situations like relievers are, so while there are benefits of having both RH and LH pitchers in the starting rotation, this is less of a necessity than having situational LH relievers in the bullpen. Stated differently, starters by nature would not platoon against same-handed batters, as a quality appearance leads to the starting pitcher facing the entire lineup of hitters multiple times.

Pitcher Type

To determine whether certain archetypes of pitchers have differing effects on career length, we created a new binary variable to separate “flamethrowers” and “finesse pitchers”. This variable, FB_Primary, places a pitcher into one of two categories based on whether or not their fastball usage rate is greater than 57.7%. Intuitively, pitchers with a fastball usage rate greater than 57.7% were considered fastball-primary pitchers, and those with a fastball usage rate less than 57.7% were considered non-fastball-primary pitchers. This threshold represents the average fastball usage rate of the Statcast Era.

Our models predicted that risk is slightly higher for fastball-primary starting pitchers, but at a statistically insignificant level. Figure 4 is the Schoenfeld Residuals plot associated with the Cox PH model for starting pitchers, predicting career length in innings pitched. Because of the horizontal trend and near-zero slope of the coefficient, we conclude that a proportional hazard assumption is adequate. Further, formal testing resulted in a p-value of 0.21, confirming the conclusion that assuming proportional hazard is acceptable.

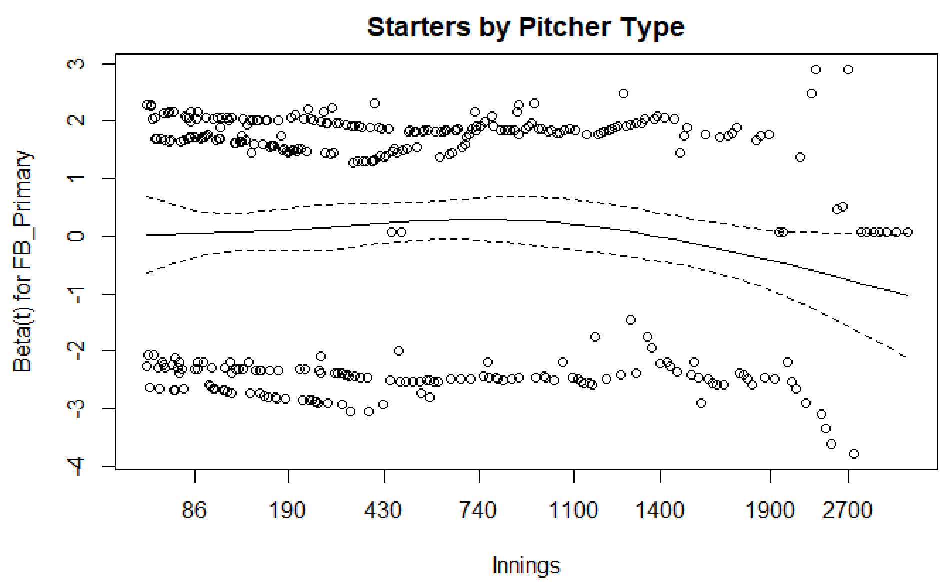

Figure 4

When modeling FB_Primary with a Cox PH model for relief pitchers, we received output predicting an increase in hazard for non-fastball-primary pitchers, but these results were also statistically insignificant. Figure 5 is the corresponding Schoenfeld Residuals plot, which shows a horizontal trend and near-zero slope of the coefficient. Once again, we conclude that a proportional hazard assumption is adequate, further supported by a formal test p-value greater than our significance threshold of 0.05.

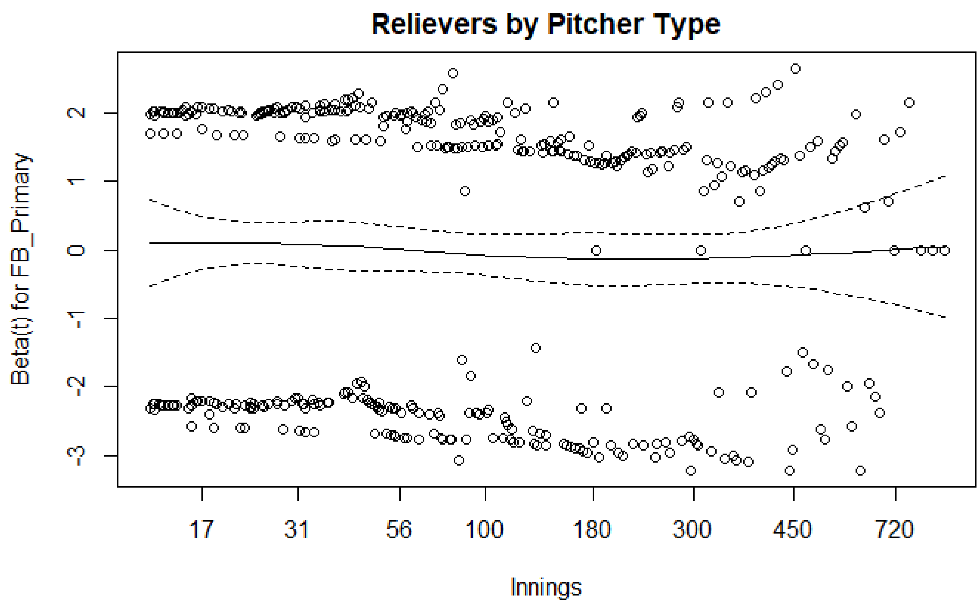

Figure 5

In conclusion, there does not appear to be sufficient evidence to reject the adequacy of the proportional hazard assumption. We recognize a shortcoming of this investigation is the broad generalization of pitcher archetypes, which could be further explored in the future.

<u>Draft Status</u>

Our last research question was whether or not draft status has an effect on career length. In addition to a player's overall draft position, we created three variables: Day1_Pick, Round1_Pick, and First10_Pick. Those drafted on the first day of the draft are picked between 1st and 60th overall, those drafted in the first round are picked between 1st and 30th overall, and those drafted in the first ten rounds are picked between 1st and 301st overall. Of the four models we created, only Overall_Pick was modeled with a Weibull assumption, while the rest were assumed to have a Log-normal distribution. Unfortunately, none of these four variables were significant at a threshold of 0.05, but the most significant variable of the four was if a player was drafted in Round 1 (p-value = 0.11).

We would expect pitchers drafted in the first round to have significantly longer career lengths, but this was not the case, so we searched for confounding factors. After investigating our data and thinking about the nature of the MLB Draft, we concluded that this problem is the result of our data only accounting for players that have pitched in the Major Leagues. Therefore, our model did not compare the career lengths of all pitchers drafted in the first round to all pitchers drafted in other rounds. Rather, we investigated if there is a relationship between draft status and career length given a player reached the Major Leagues. The MLB Draft is much more random and unpredictable than other professional sports drafts due to the number of rounds and the existence of the Minor Leagues. Major League teams have multiple scouts, departments, and resources focused on the assessment of all players in their organization post-draft, regardless of draft status. With that being said, the near significant p-value associated with first round picks could be due to the fact that MLB teams are more eager to elevate higher picks to the Major Leagues sooner, potentially because of the sunk-cost fallacy. In summary, pitchers that reach the Major Leagues are generally deserving of the accomplishment based on advances in analytics and scouting that help identify true quality.

Discussion

We have already discussed the nature of the MLB Draft and how that affected our draft status investigation. We have also recognized the need and importance for left-handed relievers and how that impacts and prolongs career length. Specific to our Statcast metrics investigation, there is an important takeaway in regards to the sign of the spin rate coefficients. Based on our own intuition, the results of the Shoulder and Elbow Surgery study referenced in the introduction, and the positive correlation between spin rate and velocity, we expected a negative coefficient for the fastball spin rate variable. However, it can be understood that pitchers who throw their fastball in the most biomechanically efficient way create higher spin rates. Moreover, pitchers who create more spin throw pitches that are faster and break harder. Therefore, pitchers with the highest spin rates and velocities are the most successful and dominant, which intuitively has a positive, lengthening effect on career innings pitched.

In recognition of this phenomenon, we included WHIP in our Statcast metric models to adjust for pitcher quality. WHIP is a popular baseball statistic that assesses baserunner prevention and is equal to the number of walks and hits allowed per inning pitched. As a quantitative variable in each of our six Statcast metric models, WHIP was a strongly significant predictor with a large, negative coefficient. In context, as WHIP decreases, career length is predicted to increase. We also created a categorical version of WHIP, as shown in Figure 6, that further supported that a decrease in WHIP predicts an increase in career length.

Categorical WHIP

Rating	WHIP
Excellent	1.00
Good	1.20
Average	1.40
Poor	1.60
Awful	1.80

Figure 6

As expected, in the presence of WHIP, most Statcast metrics became insignificant. This was true except for one metric for both starters and relievers, fastball velocity, which reported a p-value of 0.06. Although not directly supported by publicly available literature, we suggest that there is a bias towards pitchers who possess a high-velocity fastball in their repertoire. Stated differently, pitchers who can throw a fastball over 95 MPH seem to be given more leniency and permission to struggle because of their potential. With this leniency comes more career innings pitched, supported by the nearly significant p-value and positive coefficient on FB_MPH in the presence of WHIP.

Conclusion

We identified three potential improvements to expand this investigation. First, we are interested in assessing the impact of throwing a certain amount of pitches or innings before a certain age, whether in college or the Minor Leagues. Not only could this information be utilized in our draft status models, but also in new models that explore general wear and tear before becoming a professional and how that impacts career length. Second, injuries can both shorten and lengthen careers depending on the type and severity of an injury as well as the effectiveness of the rehab. Because of this, it would be interesting to examine whether or not the presence of Tommy John surgery has a significant effect on career length. Third, we want to gather data in a way that tracks changes in pitch usage over time so that fastball usage rate can be explored as a time-varying covariate. Furthermore, we want to know if any of the Statcast metrics have time-varying effects as one's career progresses.

In summary, we were able to examine the effects of Statcast metrics, handedness, pitcher type, and draft status on Major League pitcher career length. Of the many Statcast metrics available, our models conclude that spin rate is the most important predictor of career length. Sports Science departments across the Major Leagues are working with their pitchers to increase spin rates and spin efficiencies to improve their short-term effectiveness and performance, but there could also be long-term biomechanic benefits as well. Though this is true, we must recognize the confounding nature of quality and the overall importance of velocity. In addition, although players cannot control their dominant hand, our models capture the value of left-handed relievers and support the claim, “There is always a job for a lefty in the bullpen.” We also learned that our data cannot provide enough evidence to conclude that there is significant impact on career length given a certain draft position. However, we understand that this issue is the result of how our data was gathered and that there is unpredictability and randomness to the MLB Draft unlike other professional sports drafts.

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