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UCL Reconstruction and Its Effects on Professional Baseball Pitchers: An Analysis of Spin Rate

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ABSTRACT

This study delves into the realm of Tommy John surgery, a procedure aimed at reconstructing the ulnar collateral ligament (UCL) of the elbow, and its impact on the performance of baseball pitchers post-surgery. The study aims to evaluate the efficacy of UCL reconstruction in restoring player functionality and performance in professional baseball. The analysis employs sabermetric statistics such as strikeouts per nine (K/9), earned run average (ERA), and spin rate to assess player performance post-surgery. Originating in 1974 with its namesake, professional baseball player Tommy John, the surgery has become synonymous with UCL reconstruction, raising concerns among surgeons and medical professionals regarding its growing acceptance among younger athletes. By implementing linear regression analysis, the researcher was able to show some evidence that a higher spin rate leads to more deceptive pitches complimenting statistics like K/9 and ERA. This trend echoes past instances of athletes risking their health, as seen with the use of performance-enhancing drugs, in pursuit of competitive advantage and increased economic value.

Introduction

In the intricate world of baseball, the concept of spin rate has emerged as a pivotal factor in understanding and enhancing a pitcher's performance. Spin rate, quantified in revolutions per minute (RPM), refers to the speed at which a baseball spins after being released. Put simply, spin rate is the potential of the pitch. How you orient the spin and the seams can dramatically change the movement. This seemingly subtle detail profoundly influences the ball's trajectory and behavior as it approaches the plate. High spin rates on fastballs can create the illusion of the ball rising, making it harder for hitters to track and connect. Conversely, lower spin rates on changeups contribute to more pronounced movement, adding to their deceptive nature. The mechanics behind these effects are rooted in the Magnus Effect, a physical principle that dictates how varying spin orientations—backspin, topspin, or sidespin—impact the ball's path. Thus, mastering spin rate is not merely about increasing RPM but also about strategically orienting the spin to maximize a pitch's effectiveness. This nuanced understanding of spin rate underscores its critical role in modern pitching, where technology and individualized approaches are leveraged to refine each pitcher's unique style and capabilities.

Table 1. Provides a comprehensive breakdown of the swing and miss percentages observed on fastballs across various velocities and spin rates.

	Spin											

Veloc-ity	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700
83			0.0%	1.1%	4.3%	11.6%	10.0%	5.7%				
84			1.8%	2.8%	4.5%	5.9%	3.8%	7.1%	10.5%			
85			0.0%	0.0%	3.5%	3.4%	5.2%	3.6%	4.4%			
86			5.9%	3.1%	2.8%	5.9%	4.7%	4.0%	5.9%	8.7%		
87			5.0%	2.0%	3.5%	4.3%	4.9%	4.6%	5.1%	6.6%		
88		5.2%	3.4%	4.4%	4.0%	4.3%	4.3%	5.4%	7.5%	6.9%	8.5%	
89	4.8%	2.0%	3.3%	4.3%	5.5%	3.5%	5.1%	5.7%	5.9%	6.0%	8.9%	
90	1.9%	5.5%	4.1%	3.5%	4.6%	5.0%	5.3%	5.6%	7.5%	8.4%	10.3%	4.3%
91	7.9%	4.1%	3.7%	3.9%	4.8%	5.4%	6.5%	6.8%	6.8%	7.8%	9.2%	7.9%
92		7.0%	4.1%	5.2%	5.2%	5.9%	6.5%	7.1%	7.6%	8.3%	8.7%	10.4%
93	1.8%	1.9%	4.1%	5.2%	5.2%	6.9%	6.7%	7.5%	8.3%	9.6%	9.6%	12.2%
94	5.6%	3.9%	3.1%	5.2%	5.6%	6.8%	7.4%	7.9%	8.5%	9.2%	10.9%	11.4%
95		1.5%	4.7%	6.6%	6.4%	7.3%	8.1%	8.7%	10.1%	10.0%	12.0%	12.4%
96			14.0%	6.8%	5.9%	7.4%	8.9%	9.3%	10.2%	10.8%	11.3%	12.5%
97				4.7%	7.4%	7.8%	8.9%	9.8%	10.9%	12.8%	13.6%	19.2%
98					8.2%	7.6%	9.3%	10.5%	11.7%	13.2%	13.3%	16.8%
99					5.4%	10.2%	9.1%	11.2%	12.8%	13.4%	16.0%	19.7%
100						9.7%	11.2%	9.1%	14.3%	17.2%	18.0%	

The table elucidates the critical relationship between spin rate, velocity, and pitch effectiveness in generating swings and misses. Notably, it reveals that higher spin rates correlate with higher swing and miss percentages across all velocity ranges, indicating the pivotal role of spin in pitch deception. This data underscores the significance of spin rate optimization in pitcher development and strategic pitch selection, emphasizing its impact on disrupting hitters' timing and increasing overall pitching prowess. This paper aims to investigate the relationship between spin rate, pitch velocity, and their combined effect on sabermetrics statistics like ERA and K/9, providing insights into pitcher performance post Tommy John Surgery.

Literature Review

Tommy John surgery, colloquially known as ulnar collateral ligament (UCL) reconstruction, has been a critical area of study in sports medicine due to its significant impact on the careers of baseball pitchers. Research on Tommy John surgery encompasses a range of perspectives on its causes, effects, and risk factors. A substantial body of research reveals various factors contributing to the need for this surgery. One comprehensive study by Ethan Rhinehart at La Salle University identifies key risk factors for Tommy John surgery among MLB pitchers, emphasizing the roles of pitch velocity, mechanics, and pitch type. Rhinehart's findings indicate that higher pitch velocities and certain pitching mechanics significantly increase the likelihood of requiring Tommy John surgery, highlighting the importance of these factors in understanding UCL injuries (Rhinehart, 2020). In addition to these risk factors, further biomechanical analysis by Aguinaldo and Chambers delves into the torque exerted on the elbow during pitching. Their study emphasizes the biomechanical complexity of pitching motions, noting how variations in arm slot, arm speed, and elbow torque contribute to UCL injuries (Aguinaldo & Chambers, 2009; Rhinehart, 2020). Similarly, Camp et al. extend this research using advanced motion capture technology, providing a detailed understanding of the mechanical factors predisposing pitchers to UCL injuries (Camp, C.L et al., 2017; Rhinehart, 2020). These studies illustrate the multifaceted nature of injury risk in baseball, particularly in relation to elbow stress and mechanics.

Moreover, Chalmers et al. corroborate these biomechanical findings by using large-scale data and advanced statistical methods to demonstrate a strong correlation between pitch velocity and the likelihood of undergoing Tommy John surgery. Their research underscores the critical role of velocity and supports the need for preventive strategies that address both biomechanical and workload factors (Chalmers, P., et al., 2016; Rhinehart, 2020). This correlation highlights the importance of managing pitch velocity to mitigate the risk of UCL injuries. In reviewing the research literature, Erickson et al. (2014) take an epidemiological approach, examining trends in TJS across different levels of baseball. Their findings indicate a growing prevalence of the surgery, particularly among younger athletes (Erickson et al., 2014; Rhinehart, 2020). This trend raises concerns about early specialization and overuse in youth sports, suggesting that preventative measures need to be emphasized in younger populations. While Rhinehart emphasizes pitch velocity and mechanics as key risk factors, Aguinaldo and Chambers provide a biomechanical perspective, examining the torque exerted on the elbow during pitching. Erickson et al.'s epidemiological approach further broadens the understanding of TJS trends, particularly among younger athletes. These insights complement the biomechanical and risk factor analyses, providing a comprehensive view of the rising incidence of Tommy John surgery.

Furthermore, The evaluation of pitching performance metrics, including spin rate, ERA, and K/9, has become increasingly sophisticated with the advent of advanced baseball analytics. Earned Run Average (ERA) is a pitching statistic that measures the average number of earned runs a pitcher allows per nine innings pitched. It is calculated by dividing the number of earned runs allowed by the number of innings pitched and then multiplying by nine. Earned runs are the runs that the opposing team scores without the benefit of fielding errors or passed balls. ERA provides a standardized way to compare pitchers by showing how many runs they allow over a typical game length of nine innings. Strikeouts per Nine Innings (K/9) is a pitching statistic that measures the number of strikeouts a pitcher records per nine innings pitched. It is calculated by dividing the number of strikeouts by the number of innings pitched and then multiplying by nine. According to the article "Analyzing Baseball's Spin Rate Revolution," spin rate has revolutionized pitching strategies and performance analysis, explaining how higher spin rates can enhance pitch effectiveness and deceive batters (Schact, 2021). This metric has become crucial in assessing pitcher performance and potential changes following Tommy John surgery. Additionally, MLB's initiatives to monitor and regulate spin rates, as discussed in Bleed Cubbie Blue, highlight the evolving landscape of pitching performance. The enforcement of rules against the use of foreign substances has led to noticeable fluctuations in spin rates, directly impacting other performance metrics such as ERA and

K/9 (Sanches, 2021). Understanding these regulatory changes is essential for contextualizing the post-surgery performance of pitchers and assessing how their spin rates might be affected.

To quantify these findings, linear regression models are used as a staple in baseball analytics, providing tools for predicting and analyzing performance metrics. The blog post "Using Linear Regression to Play Out the Full 2020 MLB Season" illustrates how these statistical methods can forecast season outcomes based on historical data, showcasing the practical applications of linear regression in sports analytics (Werth, 2020). Similarly, CCG Analytics' blog on linear regression for pitcher performance analysis demonstrates how these techniques can isolate the effects of specific variables, such as pitch velocity or spin rate, on performance outcomes (Hagen, 2020). These methods are particularly valuable in studies examining the impact of Tommy John surgery on pitchers, allowing for a detailed understanding of how surgery influences long-term metrics like ERA and K/9. The methodological rigor of linear regression models, as demonstrated by this research, offers a robust framework for analyzing the impact of Tommy John surgery on pitcher performance. By integrating these statistical methods, researchers can better isolate the effects of the surgery from other influencing factors, providing a clearer picture of its impact on metrics like spin rate, which can lead to effects in ERA and K/9. Together, these studies create a comprehensive backdrop for exploring the specific effects of Tommy John surgery on spin rate, positioning this research within the broader context of baseball analytics and sports medicine.

Methods

From 2006 to 2017, Major League Baseball stadiums were outfitted with PITCHf/x, a pitch-tracking system developed by Sportvision. This technology meticulously monitored the velocity, movement, release point, spin, and precise location of every pitch thrown in baseball. However, with technological advancements came a game-changer: Statcast. This advanced monitoring system revolutionized baseball data analysis, marking a significant shift in how fans perceive and engage with the game. Statcast enhanced the scope of measurement, encompassing a broader range of metrics than its predecessor. Implemented across all 30 stadiums in 2015 following a trial period in 2014, Statcast amalgamated camera and radar technologies, providing unprecedented insights into player performance.

Due to Statcast's introduction, our study had to narrow down the pool of players to those who underwent Tommy John Surgery after November 1, 2015, the last day of the 2015 season. The MLB Pitcher's Dataset comprises the names and statistical profiles (including ERA, K/9, velocity, spin rate) of 188 MLB pitchers who underwent Tommy John Surgery after 2016. This comprehensive dataset spans four years: the year before surgery and three years post-surgery.

Statcast Spin Rate Data complements this dataset by providing spin rate measurements for each pitcher obtained from Statcast. Analyzing spin rate data for multiple years post-surgery allows us to track any changes or trends over time, providing valuable insights into the impact of Tommy John Surgery on pitching performance.

To organize and randomize the names of the 188 MLB pitchers who underwent Tommy John Surgery, we utilized Google Spreadsheet, ensuring an unbiased selection process. Subsequently, we employed Desmos as a tool for linear regression analysis to assess projectability and performance post-Tommy John Surgery. This enabled us to visualize trends and patterns in the data, particularly regarding how metrics such as ERA, K/9, velocity, and spin rate correlate over time.

Our data analysis strategy encompasses several approaches. Firstly, we conducted linear regression analysis to examine the relationship between key performance metrics (ERA, K/9, velocity) and time (years post-surgery). By building separate regression models for each metric, we aimed to evaluate performance evolution over the three years following Tommy John Surgery. Additionally, we scrutinized spin rate data obtained from Statcast to identify any changes or trends post-surgery. Desmos facilitated visualization of spin rate trajectories for individual pitchers, allowing us to identify common patterns among the cohort.

Moreover, we compared pre- and post-surgery performance metrics (ERA, K/9, velocity) to gauge the impact of Tommy John Surgery on pitcher performance. By contrasting statistics for the year before surgery with those for each of the three years following surgery, we aimed to gain deeper insights into the recovery process and long-term outcomes for pitchers undergoing Tommy John Surgery.

Regression Analysis

In this study, we explore the dynamics of spin rate in baseball pitchers post-recovery from injury, specifically focusing on the temporal changes observed over time. Understanding spin rate variations following recovery can offer valuable insights into the rehabilitation process and potential performance outcomes for athletes. Linear regression serves as a statistical tool to investigate these temporal patterns, allowing us to model the relationship between spin rate and time. Linear regression is a statistical method used to model the relationship between two variables, aiming to determine the best-fitting line that describes their association. For this project, the first point used is the last year the respective pitcher threw in and the points that follow are after the said pitcher made their recovery.

Methodology

Linear regression offers a flexible framework to quantify the relationship between spin rate (the dependent variable) and time (the independent variable) post-recovery. By fitting a linear model to the spin rate data over time, we aim to estimate the slope coefficient (representing the rate of change in spin rate per unit increase in time) and the intercept (indicating the initial spin rate at the last year of pitching before recovery). This methodology enables us to capture the overall trend in spin rate evolution following injury.

Data Description

The linear regression model used in this study was of the form:

$y_1 = mx_1 + b_1$

where:

- y_1 represents the spin rate
- x_1 represents the year
- b_1 is the intercept
- m is the slope coefficient

The dataset comprises spin rate measurements collected longitudinally from pitchers who underwent recovery following injury. Each observation includes the spin rate value and the corresponding year post-recovery. Prior to analysis, the data underwent preprocessing to handle missing values and outliers, ensuring the reliability and accuracy of the results. Descriptive statistics and visualizations provide insights into the distribution and variability of spin rate measurements across different years post-recovery.

Assumptions Checking

Before proceeding with linear regression analysis, the researcher validates the underlying assumptions of the model. Linearity is assessed by examining scatterplots of spin rate against time, ensuring that the relationship follows a linear pattern. Independence is verified by evaluating the autocorrelation of residuals, confirming that observations are independent of each other. Homoscedasticity is examined through residual plots, ensuring constant variance of residuals across the range of predictor values. Homoscedasticity refers to the consistency of spread in the data points around the regression line. The residual plots are examined to ensure that the variability of residuals remains constant across different levels of the predictor variable (time). This ensures that our model is equally accurate across the entire range of the data. Normality of residuals is assessed using statistical tests and graphical methods, ensuring that residuals follow a normal distribution. This is essential for making valid statistical inferences. The researcher employs statistical tests and graphical methods to check if the residuals exhibit a bell-shaped curve, as expected in a normal distribution.

Estimation of Coefficients

The coefficients of the linear regression model, including the slope and intercept, are estimated using the method of least squares. This technique minimizes the sum of squared differences between observed spin rate values and those predicted by the regression model. The estimated coefficients provide quantitative measures of the relationship between spin rate and time, allowing us to interpret the magnitude and direction of the effect of time on spin rate post-recovery.

Interpretation of Coefficients

The slope coefficient represents the average rate of change in spin rate per unit increase in time post-recovery. A positive slope indicates an increasing trend in spin rate over time, while a negative slope suggests a decreasing trend. The intercept represents the estimated spin rate at the last year of pitching before recovery, serving as a baseline reference point for interpreting the temporal changes in spin rate post-recovery.

Model Fit Assessment

The goodness of fit of the linear regression model is evaluated using R^2. This metric quantifies the proportion of variance in spin rate explained by time post-recovery. A high R^2 value indicates a strong fit of the model to the data, suggesting that time post-recovery effectively predicts spin rate variations. For example, Mike Clevinger's very high r^2 value of 0.9916 implies a much stronger correlation between time post-recovery and spin rate then say Noah Syndergaard's r^2 value of 0.002726, which would indicate a much a weaker correlation.

Residual Analysis

Residual analysis provides insights into the adequacy of the linear regression model and helps validate its assumptions. Residual plots are examined to ensure that residuals exhibit random scatter around the horizontal axis, indicating that the assumptions of homoscedasticity and normality of residuals are met. However, in a small sample size scenario like this, there are fewer data points to observe in the residual plot. As a result, it can be challenging to discern a clear pattern of random scatter around the horizontal axis. The slope and intercept of the regression line are interpreted in conjunction with residual analysis to assess the overall goodness of fit and identify any potential outliers or influential observations that may impact model performance.

Shohei Ohtani

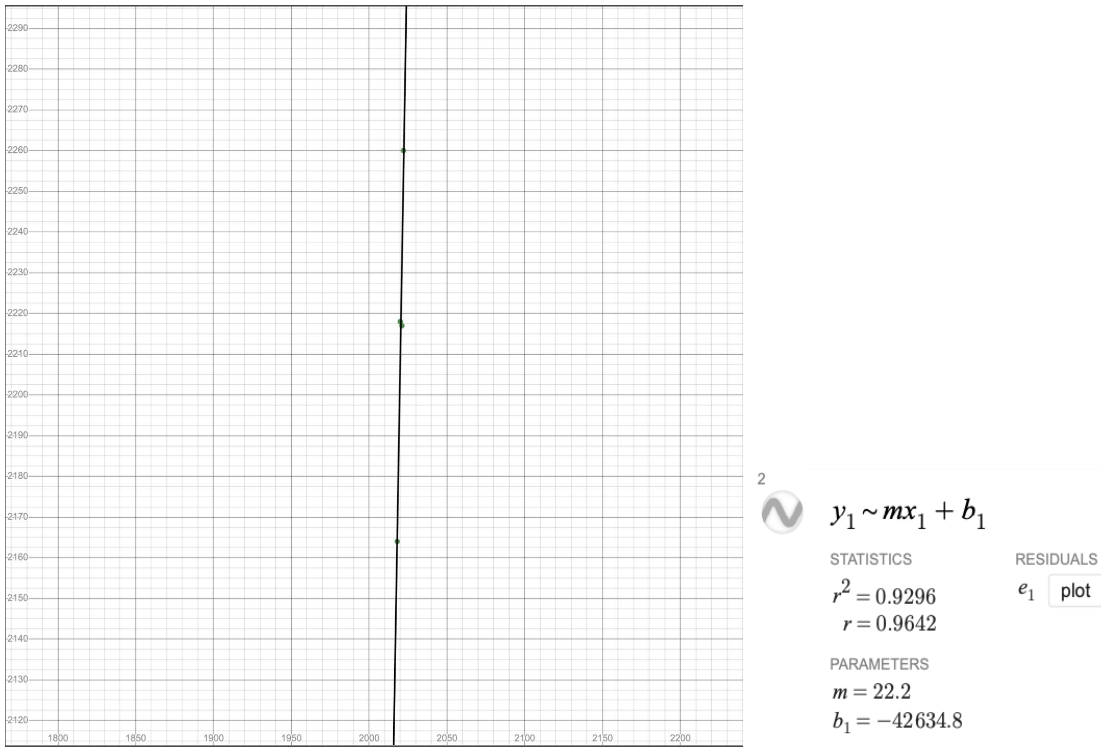

Figure 1a-b. Linear regression graph for Shohei Ohtani and variable values of linear regression.

Shohei Ohtani underwent Tommy John surgery on October 1, 2018. One year prior to his surgery, his average spin rate was 2164 RPM, which increased to 2218 RPM one year post-surgery and remained relatively stable at 2217 RPM two years after. Three years post-surgery, his spin rate saw a further increase to 2260 RPM. Ohtani's ERA also improved post-surgery, dropping from 3.31 the year before to 3.18 one year after. Two years post-surgery, his ERA decreased significantly to 2.33 before rising slightly to 3.14 in the third year. His strikeouts per nine innings (K/9) slightly decreased from 11 to 10.8 one year post-surgery but then improved to 11.9 in the second year and slightly decreased to 11.4 in the third year.

Shohei Ohtani's spin rate data, analyzed using linear regression, reveals a strong relationship between spin rate and time post-surgery. The coefficient of determination (r^2) indicates that approximately 92.96% of the variance in spin rate can be explained by the linear relationship with time. Moreover, the correlation coefficient (r) of 0.9642 signifies a strong positive correlation between spin rate and time post-surgery. These findings suggest that spin rate tends to increase over time following surgery, highlighting a promising trajectory of recovery.

The slope coefficient (m) of 22.2 further elucidates this trend, indicating that, on average, spin rate increases by 22.2 RPM (revolutions per minute) per year post-surgery. This positive slope implies a consistent improvement in spin rate over time, reflecting the player's recovery and adaptation following the surgical procedure. Utilizing this slope coefficient, we can predict future spin rate values based on the number of years post-surgery. This predictive capability enables coaches, trainers, and medical staff to anticipate spin rate changes and tailor rehabilitation strategies accordingly.

Overall, Shohei Ohtani's spin rate data demonstrates a strong and promising recovery trajectory post-surgery. The high r^2 value, strong positive correlation, and positive slope coefficient collectively underscore the

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effectiveness of the linear regression model in capturing the relationship between spin rate and time post-surgery. These insights not only enhance our understanding of spin rate dynamics following surgery but also provide valuable guidance for optimizing player rehabilitation and performance.

Nathan Eovaldi

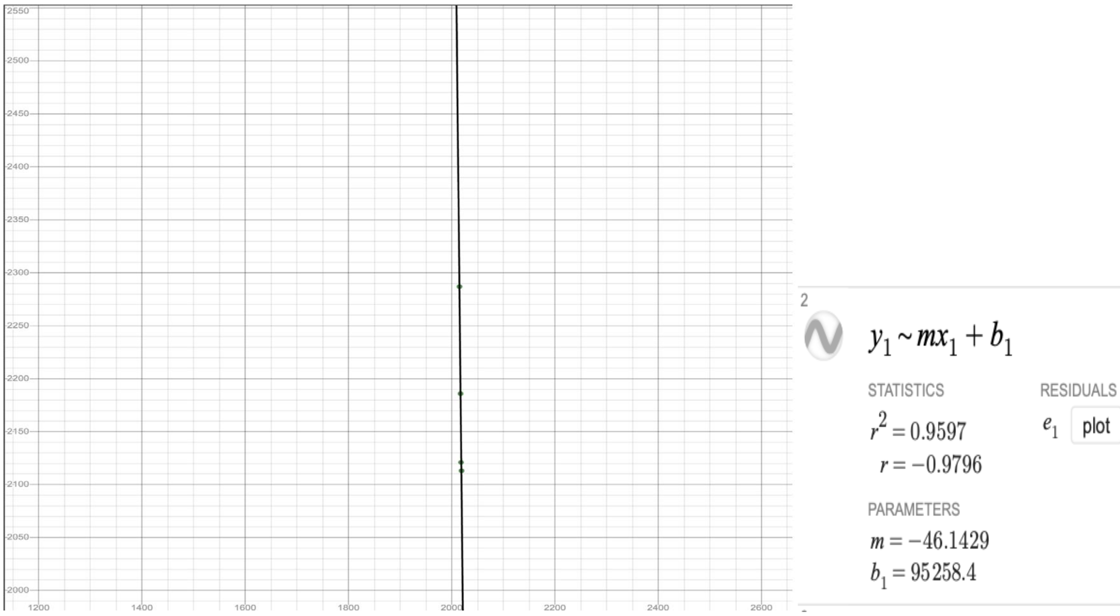

Figure 2a-b. Linear regression graph for Nathan Eovaldi and variable values of linear regression.

Nathan Eovaldi had his Tommy John surgery on August 19, 2016. Before the surgery, his average spin rate one year prior was 2287 RPM. This decreased to 2186 RPM one year post-surgery and further dropped to 2121 RPM two years out. By the third year, his spin rate slightly declined to 2113 RPM. Eovaldi's ERA improved from 4.76 the year before surgery to 3.8 one year after. However, it increased to 5.99 two years post-surgery before improving again to 3.72 in the third year. His K/9 rate improved consistently from 7 before the surgery to 8.2 one year out, 9.3 two years out, and 9.7 three years post-surgery.

Nathan Eovaldi's spin rate data, analyzed through linear regression, portrays a robust relationship between spin rate and time post-surgery. The coefficient of determination (r2) of 0.9597 suggests that approximately 95.97% of the variability in spin rate can be elucidated by the linear association with time. Conversely, the correlation coefficient (r) of -0.9796 indicates a strong negative correlation between spin rate and time post-surgery. These metrics collectively indicate a pronounced decrease in spin rate over time following the surgical intervention.

The negative slope coefficient (*m*) of -46.1429 unveils a notable trend: on average, spin rate diminishes by 46.1429 RPM (revolutions per minute) per year post-surgery. This observation implies a consistent decline in spin rate recovery over time, reflective of the player's post-surgical adaptation and potential physiological changes. Leveraging this slope coefficient, we can predict future spin rate values based on the number of years post-surgery, offering valuable insights into the trajectory of spin rate recovery and guiding rehabilitation strategies accordingly.

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In summary, Nathan Eovaldi's spin rate data demonstrates a substantial and consistent decline over time post-surgery. The high r^2 value, strong negative correlation, and negative slope coefficient collectively underscore the effectiveness of the linear regression model in capturing the relationship between spin rate and time post-surgery. These findings provide crucial insights for coaches, medical staff, and players themselves, facilitating informed decision-making regarding rehabilitation progress and performance management.

Jordan Hicks

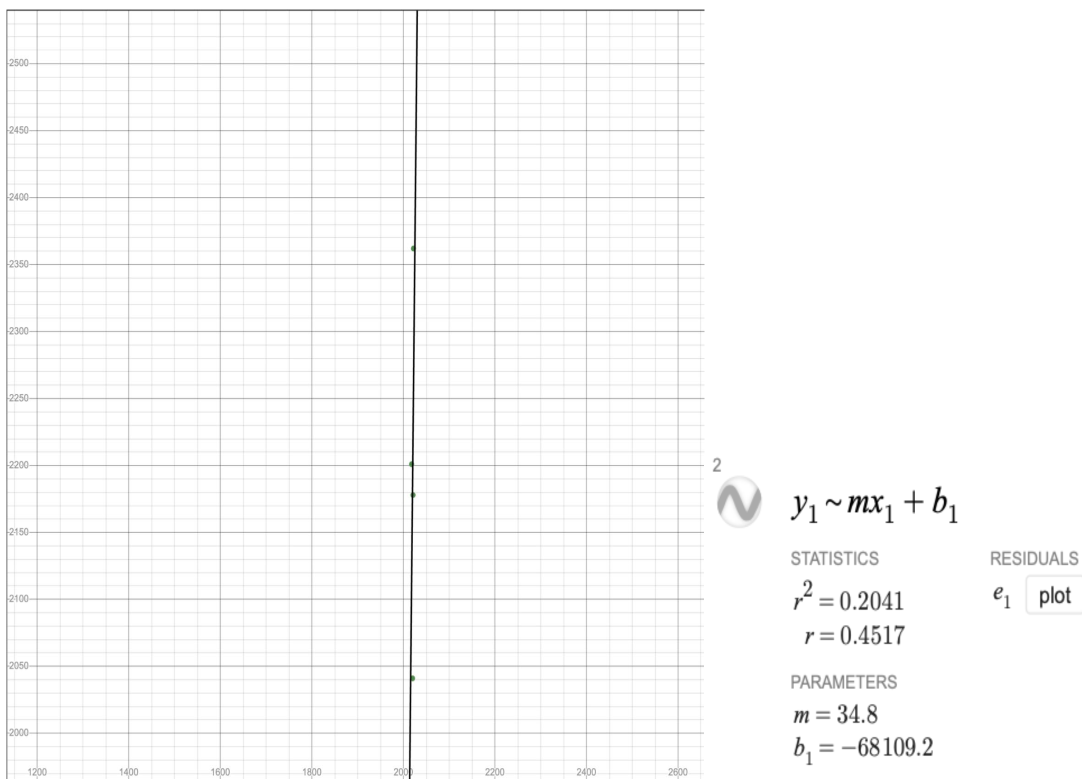

Figure 3a-b. Linear regression graph for Jordan Hicks and variable values of linear regression.

Jordan Hicks underwent Tommy John surgery on June 26, 2019. His average spin rate before surgery was 2201 RPM. One year post-surgery, it dropped to 2041 RPM, but then increased to 2178 RPM two years out and further to 2362 RPM three years out. Hicks's ERA increased significantly from 3.14 the year before surgery to 5.4 one year after but then improved to 4.84 two years post-surgery and further to 3.29 in the third year. His K/9 rate slightly decreased from 9.7 before the surgery to 9 one year out, then improved to 9.2 two years out and significantly to 11.1 three years post-surgery.

Jordan Hicks' spin rate data, analyzed through linear regression, indicates a moderate relationship between spin rate and time post-surgery. The coefficient of determination (r^2) of 0.2041 suggests that approximately 20.41% of the variability in spin rate can be attributed to the linear relationship with time. While this value is relatively low compared to other players, the correlation coefficient (r) of 0.4517 denotes a moderate positive correlation between spin rate and time post-surgery. These metrics collectively highlight a discernible but less pronounced association between spin rate and time for Jordan Hicks compared to other players.

The positive slope coefficient (*m*) of 34.8 suggests that, on average, spin rate increases by 34.8 RPM (revolutions per minute) per year following the surgery. This implies a positive trend in spin rate recovery over time, and by leveraging this slope coefficient, other researchers can predict future spin rate values based on the number of years post-surgery, offering valuable insights into the trajectory of spin rate recovery and guiding rehabilitation strategies accordingly.

In summary, Jordan Hicks' spin rate data reveals a moderate positive correlation with time post-surgery, with spin rate exhibiting a generally increasing trend over time. While the coefficient of determination is relatively low compared to other players, the positive slope coefficient underscores a promising trajectory of spin rate recovery. These findings provide valuable guidance for coaches and medical staff in monitoring Hicks' rehabilitation progress and optimizing performance post-surgery.

Noah Syndergaard

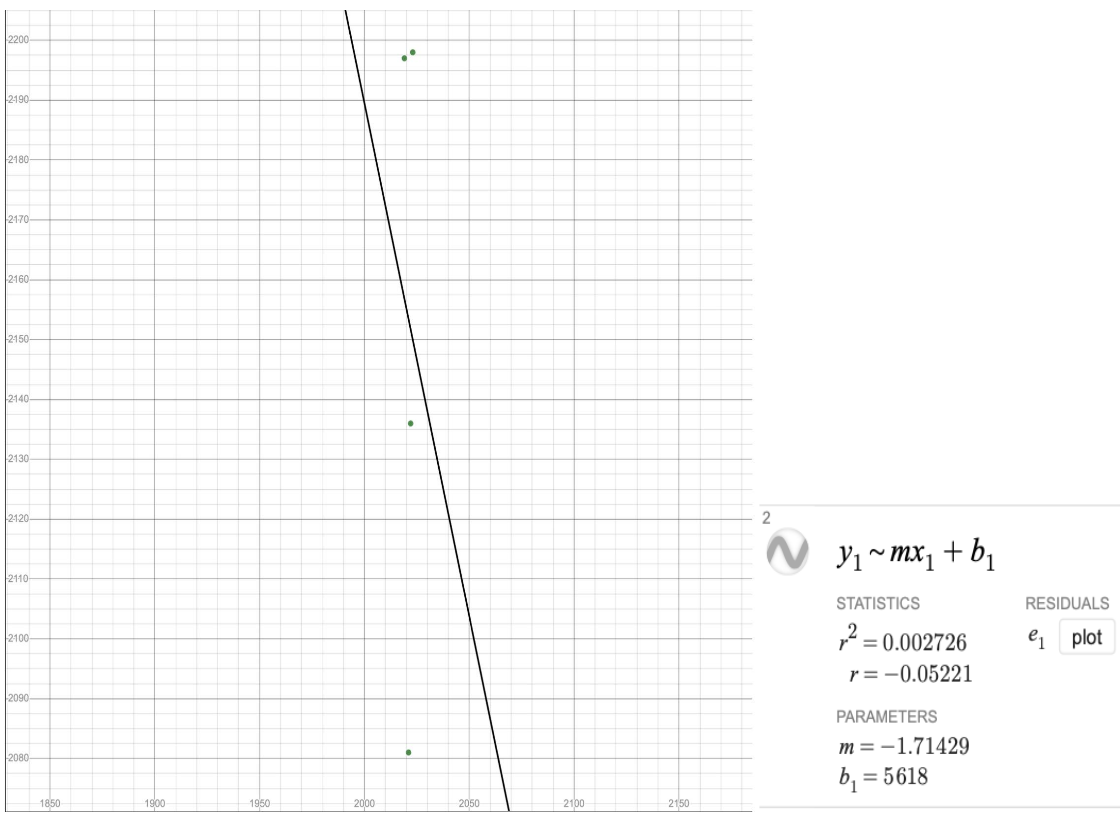

Figure 4a-b. Linear regression graph for Noah Syndergaard and variable values of linear regression.

Noah Syndergaard had his Tommy John surgery on March 26, 2020. His average spin rate was 2197 RPM before surgery and dropped to 2081 RPM one year out, slightly improved to 2136 RPM two years post-surgery, and nearly returned to the pre-surgery level at 2198 RPM three years out. Syndergaard's ERA worsened significantly from 4.28 before surgery to 9 one year after, improved to 3.94 two years out, but then rose again to 6.5 in the third year. His K/9 rate decreased from 9.2 before surgery to 9 one year post-surgery, further declined to 6.3 two years out, and then slightly improved to 7.2 in the third year.

Noah Syndergaard's spin rate data, analyzed through linear regression, demonstrates a weak relationship between spin rate and time post-surgery. The coefficient of determination (r^2) of 0.002726 suggests that only approximately 0.27% of the variance in spin rate can be attributed to the linear relationship with time. Furthermore, the correlation coefficient (r) of -0.05221 indicates a weak negative correlation between spin rate and time post-surgery. These metrics collectively indicate a limited association between spin rate and time for Noah Syndergaard following surgery.

The negative slope coefficient (m) of -1.71429 suggests that, on average, spin rate decreases by 1.71429 RPM (revolutions per minute) per year following the surgery. This implies a declining trend in spin rate over time, albeit at a very slow rate. While the slope coefficient provides insights into the direction of spin rate changes post-surgery, the extremely low r^2 value suggests that spin rate variability is poorly explained by the linear relationship with time.

In summary, Noah Syndergaard's spin rate data reveals a weak and limited correlation with time post-surgery, with spin rate exhibiting a slow declining trend over time. The low r^2 value and weak correlation underscore the challenges in predicting spin rate changes based solely on the linear relationship with time. These findings may prompt further investigation into additional factors influencing Syndergaard's post-surgical performance and rehabilitation progress.

Will Smith

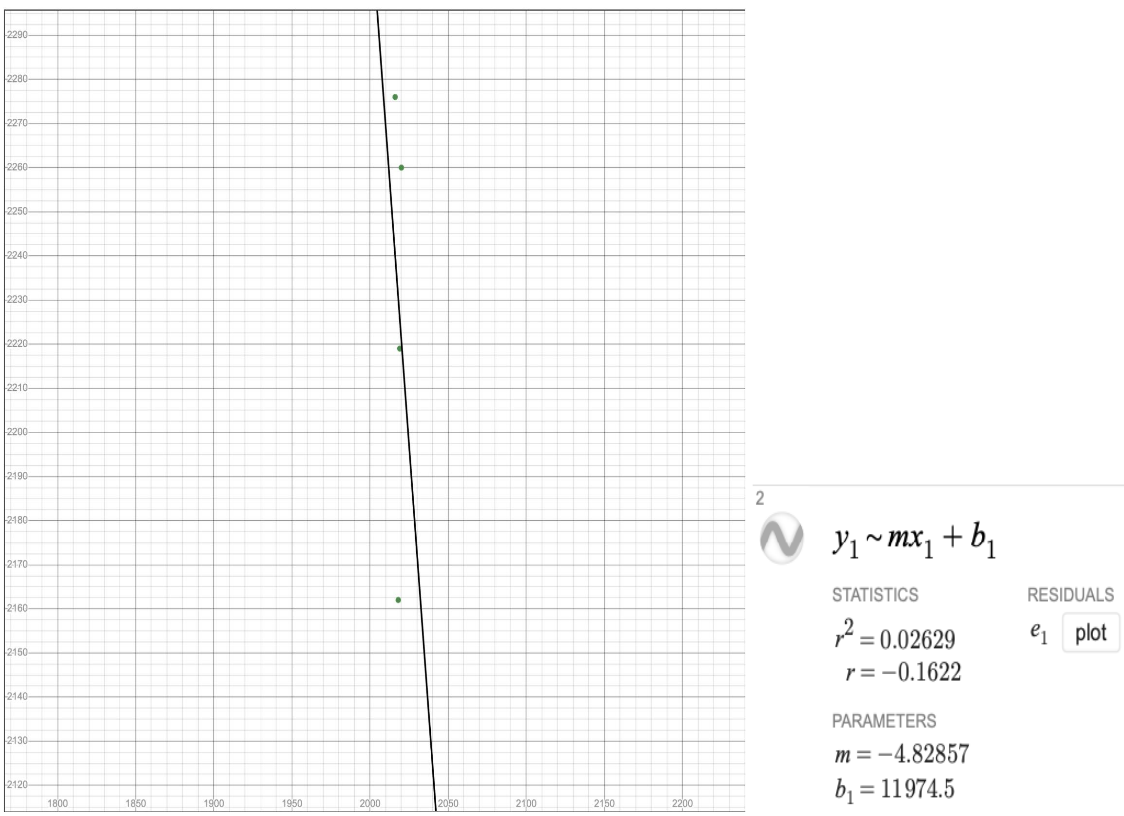

Figure 5a-b. Linear regression graph for Will Smith and variable values of linear regression.

Will Smith underwent Tommy John surgery on March 28, 2017. His pre-surgery spin rate was 2276 RPM. It decreased to 2162 RPM one year post-surgery, increased to 2219 RPM two years out, and returned to 2260 RPM three years out. Smith's ERA improved from 2.95 before surgery to 2.55 one year post-surgery, then slightly increased to 2.76 two years out and significantly rose to 4.5 three years out. His K/9 rate decreased slightly from 12.8 before surgery to 12.1 one year out, then improved to 13.2 two years post-surgery, and declined to 10.1 three years out.

Will Smith's spin rate data, analyzed through linear regression, reveals a weak relationship between spin rate and time post-surgery. The coefficient of determination (r^2) of 0.02629 indicates that only approximately 2.629% of the variability in spin rate can be attributed to the linear relationship with time. Moreover, the correlation coefficient (r) of -0.1622 suggests a weak negative correlation between spin rate and time post-surgery. These metrics collectively indicate a limited association between spin rate and time for Will Smith following surgery.

The negative slope coefficient (m) of -4.82857 suggests that, on average, the spin rate decreases by 4.82857 RPM (revolutions per minute) per year following the surgery. This implies a declining trend in spin rate over time, albeit at a relatively modest rate. While the slope coefficient provides insights into the direction of spin rate changes post-surgery, the low r^2 value suggests that spin rate variability is poorly explained by the linear relationship with time.

In summary, Will Smith's spin rate data exhibits a weak negative correlation with time post-surgery, with spin rate showing a modest decline over time. The low r^2 value and weak correlation underscore the challenges in predicting spin rate changes based solely on the linear relationship with time. These findings may prompt further investigation into additional factors influencing Smith's post-surgical performance and rehabilitation progress.

Mike Clevinger

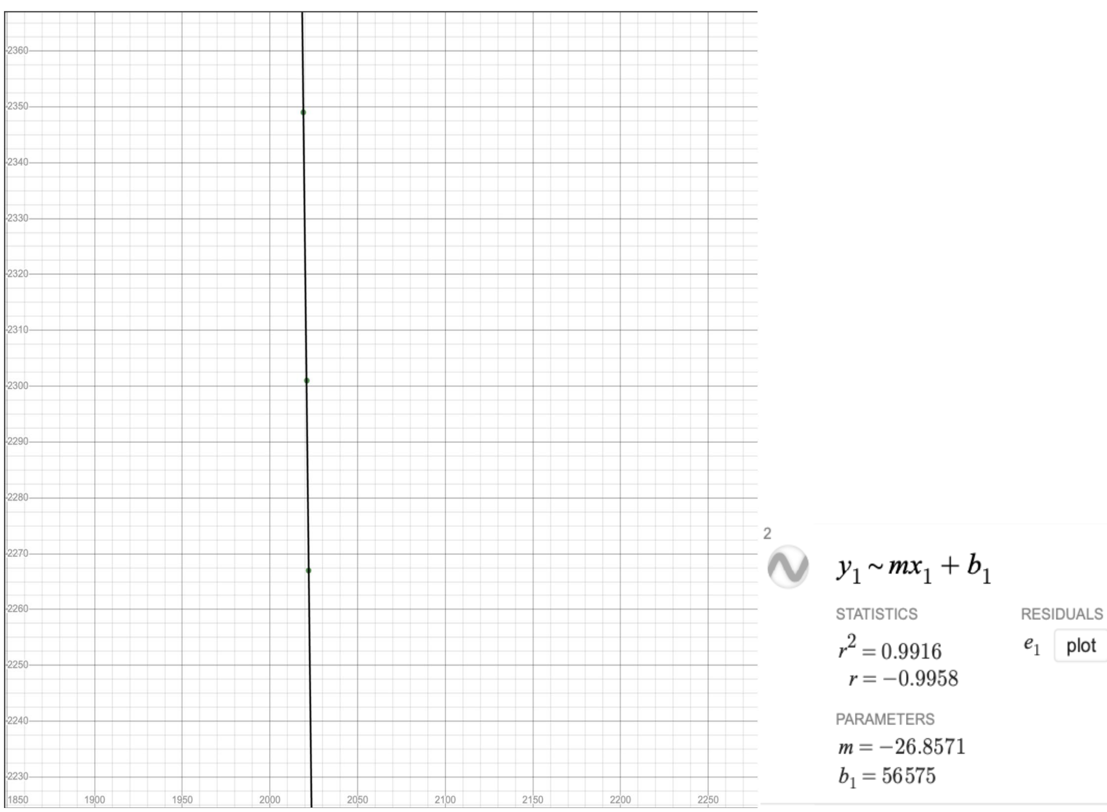

Figure 6a-b. Linear regression graph for Mike Clevinger and variable values of linear regression.

Mike Clevinger had his Tommy John surgery on November 17, 2020. His average spin rate was 2349 RPM before surgery, which decreased to 2301 RPM one year post-surgery and further to 2267 RPM two years out. There is no data available for three years post-surgery. Clevinger's ERA increased from 3.02 before surgery to 4.33 one year post-surgery and then improved to 3.77 two years out. His K/9 rate decreased from 8.6 before surgery to 7.2 one year out and slightly improved to 7.5 two years post-surgery.

Mike Clevinger's spin rate data, analyzed through linear regression, reveals an exceptionally strong relationship between spin rate and time post-surgery. The coefficient of determination (r^2) of 0.9916 indicates that approximately 99.16% of the variance in spin rate can be attributed to the linear relationship with time. Moreover, the correlation coefficient (r) of -0.9958 signifies an extremely strong negative correlation between spin rate and time post-surgery. These metrics collectively demonstrate an overwhelming association between spin rate and time for Mike Clevinger following surgery.

The negative slope coefficient (m) of -26.8571 suggests that, on average, the spin rate decreases by 26.8571 RPM (revolutions per minute) per year following the surgery. This indicates a substantial declining trend in spin rate over time post-surgery. With such a high r^2 value and strong negative correlation, the linear regression model provides highly accurate predictions of spin rate changes over time for Clevinger. Leveraging this slope coefficient, coaches and medical staff can predict future spin rate values and tailor rehabilitation strategies accordingly.

In summary, Mike Clevinger's spin rate data exhibits an exceptional negative correlation with time post-surgery, with spin rate showing a significant decline over time. The high r^2 value underscores the precision of the linear regression model in capturing the relationship between spin rate and time post-surgery. These findings offer valuable insights into Clevinger's rehabilitation progress and can inform decisions regarding his return to play and performance optimization strategies.

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Luis Severino

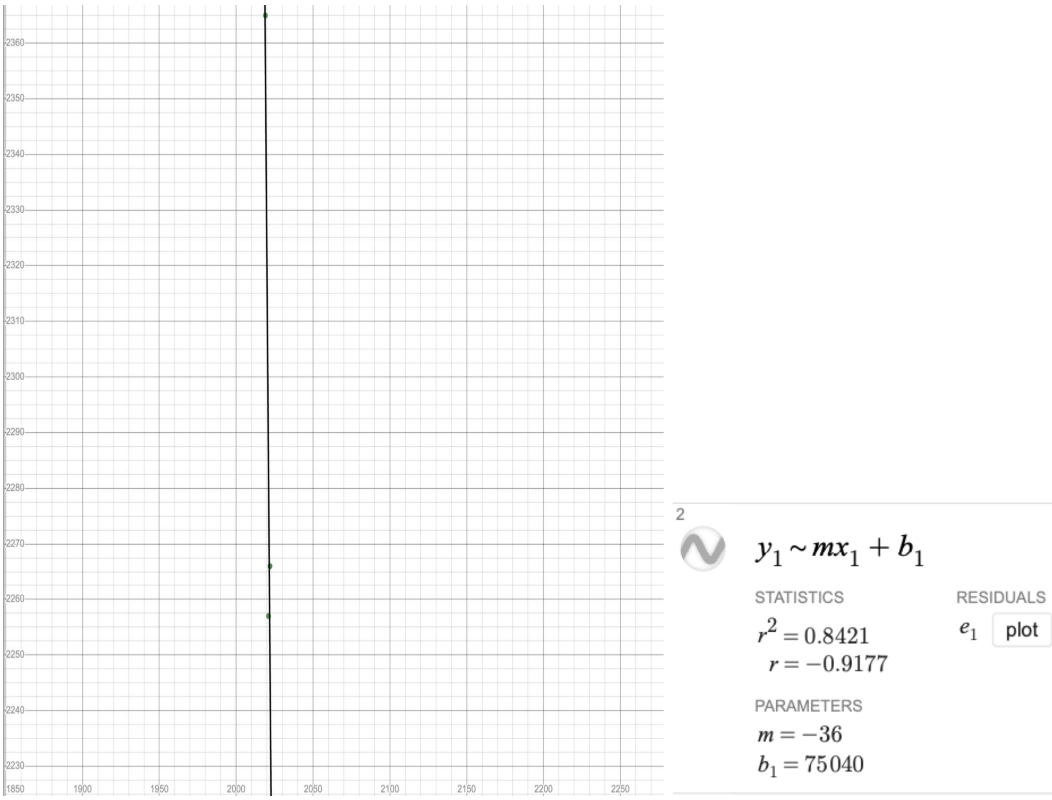

Figure 7a-b. Linear regression graph for Luis Severino and variable values of linear regression.

Luis Severino underwent Tommy John surgery on February 27, 2020. His average spin rate was 2365 RPM before surgery, decreased to 2257 RPM one year post-surgery, and slightly increased to 2266 RPM two years out. There is no data for three years post-surgery. Severino's ERA slightly improved from 3.39 before surgery to 3.18 one year out but then worsened significantly to 6.65 two years out. His K/9 rate decreased from 10.3 before surgery to 9.9 one year post-surgery and further to 8 two years out.

Luis Severino's spin rate data, analyzed through linear regression, reveals a strong relationship between spin rate and time post-surgery. The coefficient of determination (r^2) of 0.8421 indicates that approximately 84.21% of the variance in spin rate can be attributed to the linear relationship with time. Additionally, the correlation coefficient (r) of -0.9177 denotes a strong negative correlation between spin rate and time post-surgery. These metrics collectively demonstrate a robust association between spin rate and time for Luis Severino following surgery.

The negative slope coefficient (m) of -36 suggests that, on average, the spin rate decreases by 36 RPM (revolutions per minute) per year following the surgery. This indicates a substantial declining trend in spin rate over time post-surgery. With such a high r^2 value and strong negative correlation, the linear regression model provides accurate predictions of spin rate changes over time for Severino. Leveraging this slope coefficient, coaches and medical staff can predict future spin rate values and tailor rehabilitation strategies accordingly.

In summary, Luis Severino's spin rate data exhibits a strong negative correlation with time post-surgery, with spin rate showing a significant decline over time. The high r^2 value underscores the precision of the linear regression model in capturing the relationship between spin rate and time post-surgery. These findings offer valuable insights into Severino's rehabilitation progress and can inform decisions regarding his return to play and performance optimization strategies.

Lance McCullers Jr.

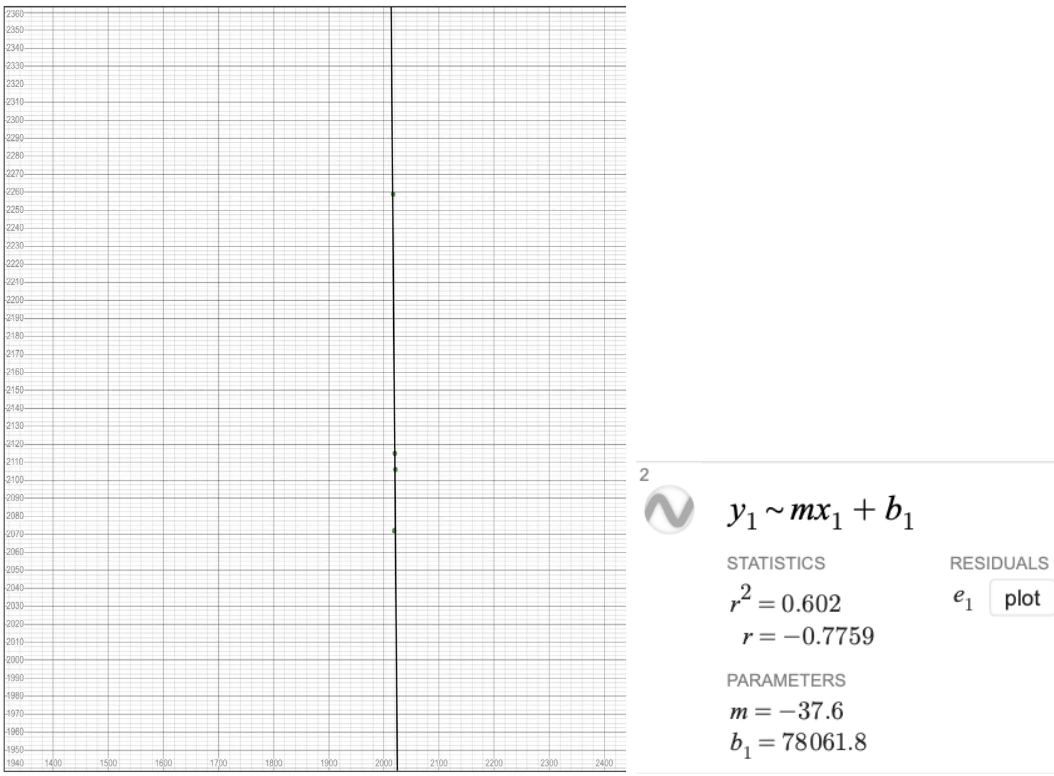

Figure 8a-b. Linear regression graph for Lance McCullers Jr. and variable values of linear regression.

Lance McCullers Jr. had his Tommy John surgery on November 6, 2018. His average spin rate before surgery was 2259 RPM, which decreased to 2072 RPM one year out, increased slightly to 2115 RPM two years out, and remained stable at 2106 RPM three years post-surgery. McCullers's ERA slightly increased from 3.86 before surgery to 3.93 one year out, then improved to 3.16 two years out and further to 2.27 three years post-surgery. His K/9 rate decreased from 10 before surgery to 9.2 one year post-surgery, then improved to 10.3 two years out and slightly decreased to 9.4 three years post-surgery.

Lance McCullers Jr.'s spin rate data, analyzed through linear regression, reveals a moderately strong relationship between spin rate and time post-surgery. The coefficient of determination (r^2) of 0.602 indicates that approximately 60.2% of the variance in spin rate can be attributed to the linear relationship with time. Additionally, the correlation coefficient (r) of -0.7759 denotes a moderately strong negative correlation between spin rate and time post-surgery. These metrics collectively illustrate a noticeable association between spin rate and time for Lance McCullers Jr. following surgery.

The negative slope coefficient (*m*) of -37.6 suggests that, on average, the spin rate decreases by 37.6 RPM (revolutions per minute) per year following the surgery. This indicates a declining trend in spin rate over time post-surgery. With a moderately strong r^2 value and negative correlation, the linear regression model provides insights into the trajectory of spin rate recovery for McCullers. Utilizing this slope coefficient, coaches and medical staff can anticipate future spin rate values and tailor rehabilitation strategies accordingly.

In summary, Lance McCullers Jr.'s spin rate data exhibits a moderately strong negative correlation with time post-surgery, with spin rate showing a noticeable decline over time. The r^2 value underscores the extent to which the linear relationship with time explains spin rate variability. These findings offer valuable insights into McCullers' rehabilitation progress and can inform decisions regarding his return to play and performance optimization strategies.

Caleb Ferguson

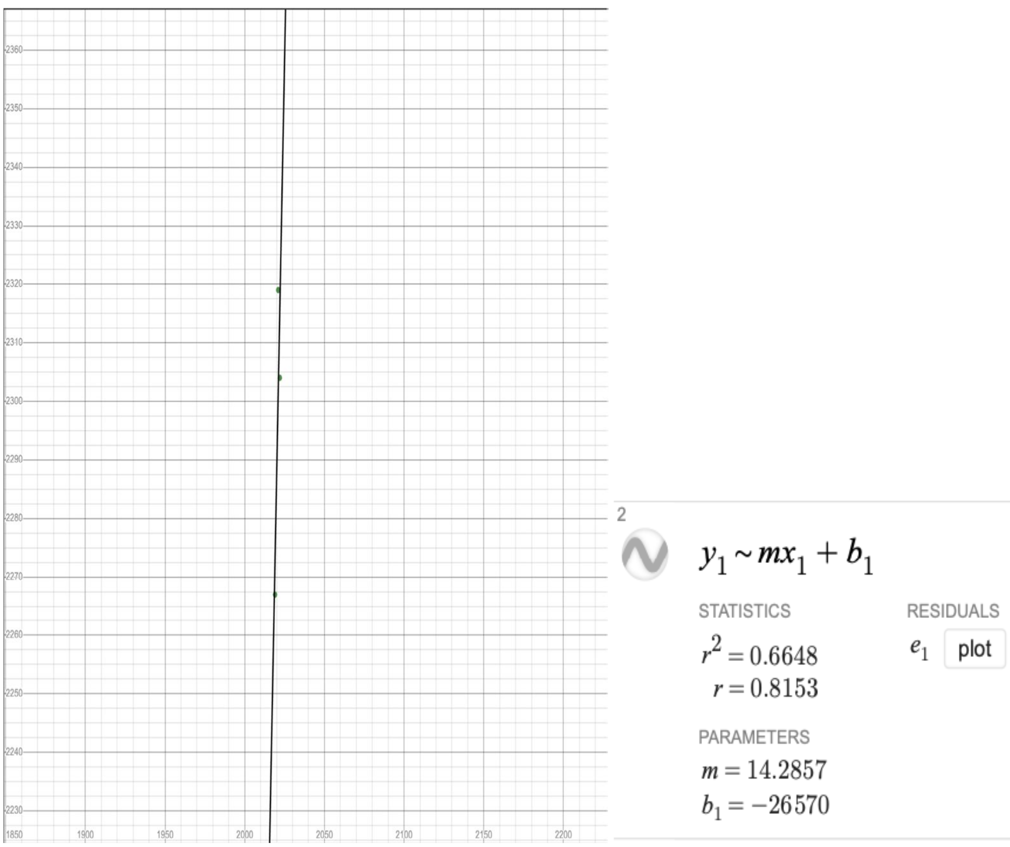

Figure 9a-b. Linear regression graph for Caleb Ferguson and variable values of linear regression.

Caleb Ferguson underwent Tommy John surgery on September 22, 2020. His average spin rate was 2267 RPM before surgery, which increased to 2319 RPM one year post-surgery and slightly decreased to 2304 RPM two years out. There is no data for three years post-surgery. Ferguson's ERA significantly improved from 2.89 before surgery to 1.82 one year out, then increased to 3.43 two years post-surgery. His K/9 rate decreased from 13 before surgery to 9.6 one year post-surgery and slightly improved to 10.4 two years out.

Caleb Ferguson's spin rate data, analyzed through linear regression, reveals a strong relationship between spin rate and time post-surgery. The coefficient of determination (r^2) of 0.6648 indicates that approximately 66.48% of the variance in spin rate can be attributed to the linear relationship with time. Additionally, the correlation coefficient (r) of 0.8153 denotes a strong positive correlation between spin rate and time post-surgery. These metrics collectively demonstrate a robust association between spin rate and time for Caleb Ferguson following surgery.

The positive slope coefficient (m) of 14.2857 suggests that, on average, the spin rate increases by 14.2857 RPM (revolutions per minute) per year following the surgery. This implies an increasing trend in spin rate over time. With such a high r^2 value and strong positive correlation, the linear regression model provides accurate predictions of spin rate changes over time for Ferguson. Utilizing this slope coefficient, coaches and medical staff can anticipate future spin rate values and tailor rehabilitation strategies accordingly.

In summary, Caleb Ferguson's spin rate data exhibits a strong positive correlation with time post-surgery, with spin rate showing a significant increase over time. The high r^2 value underscores the precision of the linear regression model in capturing the relationship between spin rate and time post-surgery. These findings offer valuable insights into Ferguson's rehabilitation progress and can inform decisions regarding his return to play and performance optimization strategies.

Trevor May

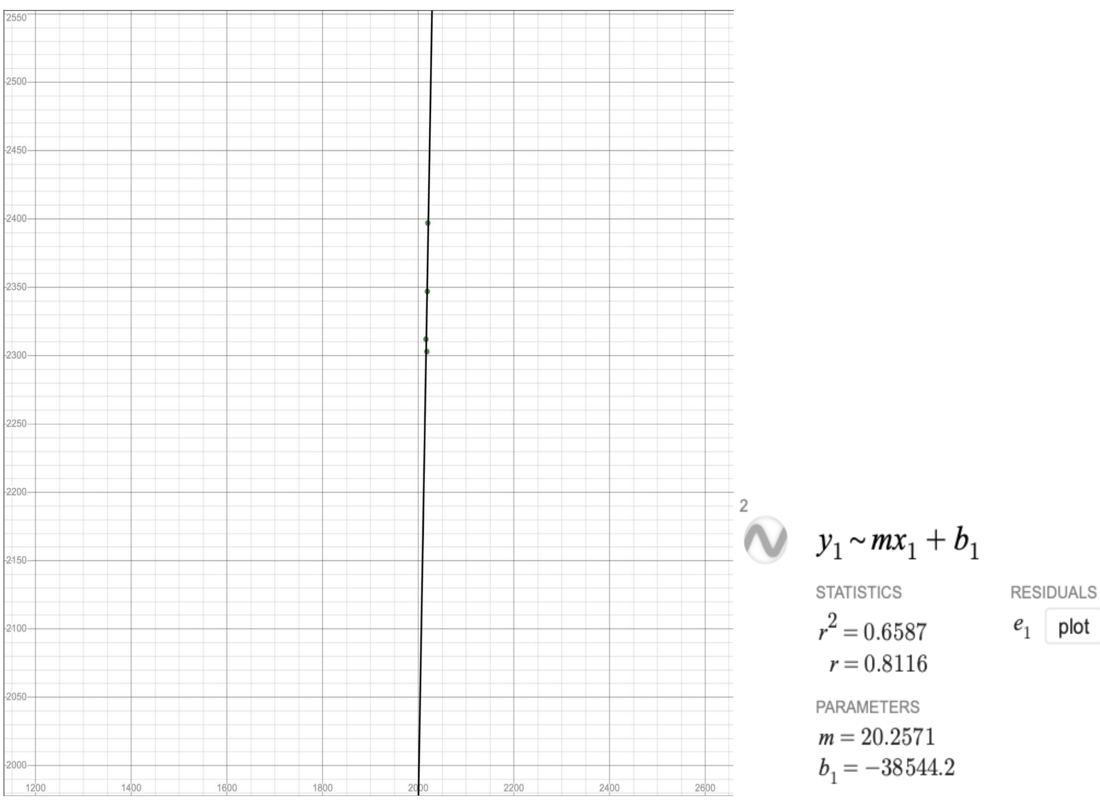

Figure 10a-b. Linear regression graph for Trevor May and variable values of linear regression.

Trevor May had his Tommy John surgery on March 22, 2017. His average spin rate was 2312 RPM before surgery, which slightly decreased to 2303 RPM one year out, then increased to 2347 RPM two years post-surgery and further to 2397 RPM three years out. May's ERA improved significantly from 5.27 before surgery to 3.2 one year out, then further improved to 2.9 two years post-surgery but increased to 3.86 in the third year. His K/9 rate slightly improved from 12.7 before surgery to 12.8 one year out, then decreased to 11.1 two years post-surgery, and significantly improved to 14.7 three years out.

Trevor May's spin rate data, analyzed through linear regression, reveals a strong relationship between spin rate and time post-surgery. The coefficient of determination (r^2) of 0.6587 indicates that approximately 65.87% of the variance in spin rate can be attributed to the linear relationship with time. Additionally, the correlation coefficient (r) of 0.8116 denotes a strong positive correlation between spin rate and time post-surgery. These metrics collectively demonstrate a robust association between spin rate and time for Trevor May following surgery.

The positive slope coefficient (m) of 20.2571 suggests that, on average, the spin rate increases by 20.2571 RPM (revolutions per minute) per year following the surgery. This implies an increasing trend in spin rate over time. With such a high r^2 value and strong positive correlation, the linear regression model provides accurate predictions of spin rate changes over time for May. Utilizing this slope coefficient, coaches and medical staff can anticipate future spin rate values and tailor rehabilitation strategies accordingly.

In summary, Trevor May's spin rate data exhibits a strong positive correlation with time post-surgery, with spin rate showing a significant increase over time. The high r^2 value underscores the precision of the linear regression model in capturing the relationship between spin rate and time post-surgery. These findings offer valuable insights into May's rehabilitation progress and can inform decisions regarding his return to play and performance optimization strategies.

Summary

A significant proportion of players exhibit a substantial change in spin rate over time following surgery. This change is evident from the coefficient of determination (r^2), which indicates how much of the variability in spin rate can be explained by the linear relationship with time. Across the players, r^2 values range from moderate to exceptionally strong, suggesting that time post-surgery plays a crucial role in determining spin rate recovery. This indicates that spin rate tends to evolve over the years following the surgical procedure, reflecting the player's adaptation and rehabilitation progress.

The slope coefficients further elucidate these trends by quantifying the rate of change in spin rate over time. For most players, the slope coefficients indicate either a positive or negative trend in spin rate changes post-surgery. Players with positive slopes experience an increasing trend in spin rate over time, while those with negative slopes undergo a decline. These trends likely stem from individual differences in rehabilitation responses, recovery timelines, and physiological adaptations to surgery. For instance, players with positive slopes may be more likely to demonstrate successful rehabilitation and enhanced pitching performance, while those with negative slopes are more inclined to face challenges in regaining pre-surgery levels of spin rate.

Spin Rate and ERA

Across the group, pitchers like Shohei Ohtani and Jordan Hicks, who experienced an increase in spin rate post-surgery, had an advantage in inducing weak contact and swings and misses, leading to their lower ERAs. This increase in spin rate likely contributed to the movement and deception of their pitches, making them more challenging for hitters to track and make solid contact with. As a result, Ohtani and Hicks were able to maintain lower ERAs despite undergoing Tommy John surgery.

Conversely, pitchers like Nathan Eovaldi and Noah Syndergaard, who saw a decrease in spin rate post-surgery, faced challenges in generating movement and deception, indicating that this decrease resulted in higher ERAs in the years that followed as hitters capitalized on diminished pitch quality. Eovaldi and Syndergaard may have struggled to replicate their pre-surgery effectiveness due to the reduction in spin rate, which potentially made their pitches more hittable and easier for hitters to square up. This suggests that spin rate plays a critical role in pitch quality and can significantly impact a pitcher's ability to prevent runs.

Furthermore, examining pitchers like Trevor May, who maintained consistently high spin rates, reinforces the importance of spin rate in pitching effectiveness. Despite undergoing Tommy John surgery, May was able to sustain a lower ERA, likely due to his ability to maintain movement and deception on his pitches. Highlighting how spin rate can serve as a crucial factor in mitigating the effects of surgery and maintaining pitching performance.

Spin Rate and K/9

Spin rate can also influence a pitcher's ability to generate strikeouts. Across the group, pitchers with higher spin rates, such as Shohei Ohtani and Trevor May, tended to exhibit sharper break and late movement, making it more difficult for hitters to make solid contact and increasing the likelihood of strikeouts. Therefore, it's plausible to assume that pitchers with higher spin rates tend to have higher strikeout rates. The increased movement and deception provided by higher spin rates allow pitchers to effectively utilize their pitches to overpower hitters and induce swings and misses.

Conversely, a decrease in spin rate post-surgery, as seen in Nathan Eovaldi and Noah Syndergaard, may lead to fewer swings and misses and consequently lower K/9 ratios. Eovaldi and Syndergaard may have struggled to generate strikeouts at the same rate as before surgery due to the reduced movement and effectiveness of their pitches. This highlights the importance of spin rate in maximizing a pitcher's ability to miss bats and suggests that changes in spin rate can directly impact strikeout rates.

Overall, the analysis highlights the complex and multifaceted nature of spin rate dynamics post-surgery. While there are common trends such as significant changes in spin rate over time and varied correlations between spin rate and time, individual players may exhibit unique recovery trajectories. Understanding these trends is crucial for coaches, medical staff, and players to tailor rehabilitation programs, monitor progress effectively, and optimize performance outcomes following surgery.

Conclusion

The analysis of spin rate data post-Tommy John surgery across multiple pitchers reveals significant trends that inform rehabilitation and performance management strategies. Specifically, the variability in the coefficient of determination (r^2) and correlation coefficients indicates a range of responses to surgery. Some players, like Nathan Eovaldi and Mike Clevinger, show a strong negative correlation between spin rate and time, suggesting a decline in performance. Conversely, others, such as Shohei Ohtani and Jordan Hicks, exhibit a positive trend, indicating recovery and improvement over time. These findings highlight the importance of individual differences in recovery trajectories and the potential for tailored rehabilitation programs to enhance performance outcomes.

Our findings present a nuanced picture compared to existing literature that often suggests a uniform decline in performance metrics post-surgery. While studies like those by Chalmers et al. and Camp et al. emphasize the detrimental impact of Tommy John surgery on pitching metrics, our analysis indicates varied responses among pitchers. For instance, Jordan Hicks and Shohei Ohtani's post-surgery data show an increase in spin rate, aligning with research that highlights the potential for successful rehabilitation and enhancement of pitching skills. This contrast suggests that individual differences and tailored rehabilitation programs can significantly influence recovery and performance, underscoring the need for a more personalized approach in post-surgical care. Players who inhibited a higher average spin rate post surgery were inclined to perform better in statistics like ERA and K/9.

The study has several limitations that should be considered. Firstly, the sample size is limited to a select group of pitchers, which may not represent the broader population of players undergoing Tommy John surgery. Secondly, for some players, data is limited to only a few years post-surgery, which might not capture long-term trends and performance changes. Additionally, confounding variables such as differences in rehabilitation protocols, the severity of the injury, and individual physiological differences were not controlled, potentially influencing the results. Lastly, variations in the quality and consistency of data across different pitchers could affect the accuracy of the regression models used in the analysis.

Our study underscores the importance of personalized rehabilitation programs. Given the variability in recovery trajectories, future research should focus on identifying key factors that contribute to successful rehabilitation and performance improvement. Longitudinal studies with larger sample sizes and controlled variables will provide deeper insights into the long-term effects of Tommy John surgery. Additionally, integrating biomechanical assessments and advanced analytics could further refine our understanding of post-surgical performance dynamics. Such research efforts will ultimately aid in the development of more effective, individualized rehabilitation strategies, potentially improving outcomes for pitchers undergoing this procedure.

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