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EFFECTS OF TOMMY JOHN SURGERY, DRAFT ORDER, AND MONETARY FACTORS ON THE VALUE OF PITCHERS IN MAJOR LEAGUE BASEBALL

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By

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DEDICATION

This thesis is dedicated to the many people that helped me finish grad school and throughout the years. From the faculty and staff of the Health and Exercise Sciences department to my parents and brother, I thank my family for being my lifelong support system and my HESP herd for being my scholastic support system. I wish I could name you all but know that there are only so many I could list before the names outweigh the thesis itself. The people I absolutely must acknowledge will be included in the following page, but of all the people I could dedicate this to, I dedicate the thesis in its entirety to my grandparents: Johnny Wong, Ming Wong, Mae Tiu, and Paul Tiu. They taught me the value of hard work and fostered my love for baseball and never giving up. This thesis would not have come to fruition if it was not for them.

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Abstract

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The purpose of this thesis is to determine what effects draft order, monetary earnings, and Tommy John Surgery (TJS) have on the perceived value of a pitcher in Major League Baseball (MLB). For the context of this thesis, value will be defined as a player's ability to contribute to their team's wins in a positive manner. TJS has become synonymous with MLB and baseball as a sport, and many are either skeptical of its effects or over-assuming of its benefits. The three aforementioned areas of concerns were used to structure the thesis, as each dependent outcome is analyzed in a chapter of its own. Multiple articles and studies pertaining to the effects draft order, financial earnings, and TJS may have on pitcher value were compiled and analyzed. Looking at studies between pitchers who underwent TJS prior to being drafted, their order by which they are picked by a team is not as affected as assumed, but the pitcher is more likely to return to the disabled/injured list during their career in MLB. A lens of economic value saw that pitchers who were paid more added to their teams' respective wins. However, the financial loss caused by a pitcher missing time to recover from TJS could outweigh the cost of wins. From a purely Tommy-John standpoint, there are significant changes both beneficial and detrimental to a pitcher's overall statistics. Further research and personal knowledge should be explored prior to receiving TJS as a pitcher. Overall, the factor of TJS seems to have a slightly negative influence on the other two factors and an overall stronger influence than draft order or monetary earnings.

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CHAPTER 1: INTRODUCTION

From its conception in 1876 to the present, Major League Baseball (MLB) has captivated audiences and entertained the masses of the United States of America and the world itself (History.com). As a sport contingent on perceived unpredictability, baseball scientists and spectators alike will often bridge the gap between projected and actual outcomes with misconceptions rooted in different unknowns. Of the multiple confounding variables, three major factors have seemed to become synonymous with pitcher value in baseball: amateur draft order, financial earnings, and ulnar collateral ligament (UCL) reconstruction surgery, also known as Tommy John surgery.

Efforts in quantitative data collection and analysis in MLB performance statistics have been made to help dispel some of these misunderstandings. The first comprehensive reference book of baseball statistics, "The Baseball Encyclopedia: The Complete and Official Record of Major League Baseball," was published by Macmillan in 1969 and dubbed "Big Mac" after the publisher's name and the alleged 6.5-pound weight of the first edition (Neyer, 2017). In August of 1971, the Society of Baseball Research, or SABR, was founded as an organization to extend and update the research that "Big Mac" pioneered to do, going so far as to naming the field of baseball analytics "sabermetrics" (SABR, 2022).

Through its members' endeavors, SABR would use "Big Mac" as the foundation for research-based books and references about baseball statistics, including the databases baseball-reference.com and fangraphs.com, Michael Lewis' book "Moneyball," and the statistic of wins above replacement, or WAR. These resources comprise most of the background information and data used to research the three unknowns and their effects on the value of a pitcher in MLB. Value of a pitcher in MLB will be quantified as a pitcher's performance-based and statistical contributions towards their individual success and their respective team's overall success.

Although the game of baseball itself has evolved since the days of simply jotting down statistics on paper, sabermetrics has compensated for the advance in recording skill and statistics to account for the physical and performance-based advancement. From baseball writers and analysts to medical doctors, many use the databases and resources to create studies revolving around physiological factors that may affect the pitcher's performance statistics beneficially or detrimentally. Despite the growth in literature accessible to those interested in baseball statistics, blanks and gaps in what is known often has led to the perpetuity of the unknowns.

After the first amateur draft in 1965, no one has been able to accurately determine if a pitcher being drafted with a higher pick or in a higher round will perform better than a pitcher in a lower round or with a lower pick. The managerial mindset of Moneyball created in 2002 questioned MLB teams and ownerships on their behaviors and approaches to financial expenditures and contracts given to players. Since the invention and application of Tommy John surgery, many studies have been initiated to find definitive and significant evidence that the surgery makes a pitcher perform better overall.

This thesis hopes to take that existing wealth of baseball statistics and sabermetrics to help clarify the three unknowns and help dispel the broad misconceptions used to patch the gaps between literature and what is publicly known about pitcher value and its relationships with draft order, financial earnings, and TJS. Through the research compartmentalized by chapters, each variable will be assessed in its positive and negative effects on an MLB pitcher's value.

CHAPTER 2: DRAFT ORDER AS A CONTRIBUTING FACTOR OF VALUE

Introduction

Prior to 1965, MLB teams would scout and scour the country on a first-come, first-served basis to recruit young high school and collegiate players to their minor-league affiliates and eventually to their major-league teams. The minor-league teams, often referred to as teams' farm systems, foster the skills of the drafted players and provide their major-league affiliations with new players and reserves for their active rosters. With the first-come, first-served ideal, the wealthier teams with more personnel and resources could collect all the top young talent before smaller teams with less payroll could have an opportunity to even observe them. The amateur draft was invented in 1965 to give losing teams a better chance at acquiring high-school and collegiate players with more value and potential to succeed at the major-league level (Manuel, 2010). The draft was initially structured so that each team had picks in the first round of the draft, with some supplementary picks given to different teams under certain circumstances based on team performance on contractual obligations. The teams would continue picking amateur players until a capacity was reached; the 1965 draft had 824 picks in 72 rounds, while the most recent draft in 2021 had 222 picks over seven rounds.

Once a player is drafted and signs a professional contract, that player is assigned to a minor-league team affiliated with the major-league team for which the player was drafted. The league levels ascend from rookie ball (Rk) to single-A level (A), double-A level (AA), and triple-A league (AAA). Most times, if not all the time, drafted amateur players are assigned to an Rk-league affiliate. As the player progresses in skill, that player will get promoted semi-sequentially until they reach the AAA level. Minor league-level statistics are not definitively indicative of a player's pre-draft statistics, but in terms of pre-Major League Baseball statistics, it is easier to uniformly compile and objectively compare minor-league statistics to MLB statistics than amateur or pre-draft statistics.

Scouting reports of the players about to be drafted and the draft itself usually adds misconception to player value. Players picked in the first round are thought to have more performance-based success in the MLB than players drafted in subsequent rounds. For example, here are career statistics and averages from some of the pitchers drafted in 1965, provided by Baseball-Reference.com:

Pitcher 1: 0.400 W%, 3.70 ERA, 0.8299 K/IP, -0.3 WAR, -0.10 WAR/season for 3yrs

Pitcher 2: 0.526 W%, 3.19 ERA, 1.0609 K/IP, 83.6 WAR, 3.10 WAR/season for 27yrs

Pitcher 1 was drafted with the second overall pick during the first round of the 1965 draft and the first pitcher drafted that year. Pitcher 2 is Nolan Ryan, the 226th overall pick in the 12th round of the 1965 draft. The latter pitcher, despite not being considered for the MLB until the double-digit rounds of the draft, went on to become the all-time leader in strikeouts and no-hitters, and he is considered to be one of the greatest pitchers in MLB history (National Baseball Hall of Fame). Statistics categories have since been developed for MLB players to assist in predicting performance outputs. Scouts who observe players before the draft may not have a large-enough sample size to fully evaluate a player's projected career performance.

Many variables contribute to the assumption of a pitcher's future successes or failures in a professional career. Scouts will often look to pitching-based outcomes for a superficial summary of value, like a pre-drafted pitcher's surgical history and/or fastball velocity. Although many surgeries can affect the physiological performance and draft value of a pitcher, Tommy John surgery stands out as the procedure with the most misconception surrounding its consequences, including one regarding its effect on fastball velocity. A poll ran by Dr. Chris Ahmad of the New York Yankees and reported on by physical therapist Dr. Mike Reinold found that within the sample, 32% of high school players, 53% of college pitchers, 33% of the players' coaches, and 36% of the players' parents believed that velocity would increase as a result of Tommy John surgery (Reinold, 2014).

About half of the potential recruits and the potential recruits' coaches for the minor-league affiliates of Major League Baseball teams and a third of the coaches overseeing them believe that UCL reconstruction can make the pitchers pitch at a higher velocity than their initial velocity. This way of thinking could make them look more attractive to professional scouts from different Major League Baseball organizations and increase their value in the drafts that recruit them into different teams' farm systems. On the other hand, amateur-draft scouts may have reservations about drafting a pitcher who had a particular procedure done prior playing in MLB.

Review of Literature and Methods

In my initial exploration of the topic, I analyzed the difference in performance between first-round pitchers' performances at the minor-league level and at the major-league level. I created a database consisting of 1,000 pitchers from the amateur draft with at least 3 complete seasons of play in the MLB. Terra et al. ran analyses for the study and found that 404 of the subjects were picked in the first round, while 396 of the subjects were drafted after the 2000 season. The total sample and subsamples of pitchers were created by coarsened exact matching (CEM). The subsamples divided the pitchers by draft status (i.e., first round) and number of seasons in the MLB that the subjects played. Through SPSS Statistics, linear regression models evaluated the MiLB and MLB-career performances of the pitchers in the sample and tested the effect of draft pick order on outcomes. Dependent variables in these tests included the following statistics: earned-run average (ERA), ERA+, unearned/earned runs allowed per 9 innings (RA9), winning percentage, fielding-independent pitching (FIP), and K/9, or strikeouts per 9 innings (Terra et al., 2022a).

A player's RA9 factors in all runs a pitcher is responsible for, both earned and unearned. A pitcher may acquire an unearned run if an opposing runner from the previous pitcher scores or if an error occurs by the pitcher's defense that allows the opposing team to score a run. Calculating RA9 is nearly identical to calculating ERA with the addition of unearned run totals to earned run totals prior to multiplying that sum by the 9-factor and dividing that product by the innings pitched. A modified metric of ERA, ERA+ is calculated by normalizing a player's earned-run average and factoring in differing ballparks or opposing batters' effects on ERA, converting it into a measure comparable to a league ERA based on the average MLB ERA (designated an ERA+ of 100). By that metric, a player with an ERA+ of 90 would have a personal ERA 10% less than the league average, whereas a player with an ERA+ of 201 would have a personal ERA 101% greater than league average. Strikeouts per nine innings (K/9), calculated by multiplying a pitcher's K/IP by 9, is the average of strikeouts a pitcher may accrue in the average number of innings in a baseball game, or nine innings.

Most of the literature regarding how draft order affects value is associated with pre-draft injuries and how it affects pitchers' paths to careers in MLB and their longevity once they get to the Major-League level. Some pitchers who have played in the MLB received UCL reconstruction surgery prior to being drafted, either from necessity or as a preventive measure and potentially to enhance performance, according to the misconception. A study published in *The American Journal of Sports Medicine* analyzed the performance and injury track record of MLB pitchers that received Tommy John surgery prior to being drafted (Wymore et al., 2016). Performance statistics analyzed included pitch velocities and cumulative averages of the pitchers' careers, annual values, and per-inning values. Injury statistics that were observed included risk of future injury by instances when a player was placed on the disabled list

(DL). The term "disabled list" is used in this study. To note, the term was updated prior to the 2019 season and renamed the "injured list (IL)" (Passan, 2019).

Results and Discussion

From Terra et al.'s descriptive statistics processed by SPSS Statistics on my database, the subjects in the analyzed groups averaged 10.1 ± 4.4 years in the minor-league baseball (MiLB) system and 8.0 ± 2.8 years in the MLB. Linear regression models were run holding the year of the draft and the type of pitcher (starter, reliever, starter-reliever, closer) constant as potential confounding variables. The table below illustrates the changes in statistics from first-round pitchers compared to pitchers picked in subsequent rounds (Terra et al., 2022a).

Table 1
Significant results of Terra et al. linear regression models

Variable	Change in points	95% CI	P
MiLB_ERA	+0.233	0.153 to 0.313	<0.001
MLB_ERA	+0.386	0.304 to 0.469	<0.001
MiLB_RA9	+0.217	0.129 to 0.306	<0.001
MLB_RA9	+0.398	0.308 to 0.489	<0.001
MiLB_W% (pct_pts)	-2.239	-3.393 to -1.085	<0.001
MLB_W% (pct_pts)	-2.435	-3.466 to -1.405	<0.001
MLB_ERA+	-8.304	-10.333 to -6.275	<0.001
MLB_FIP	+0.244	0.175 to 0.312	<0.001
MLB_K/9	-0.302	-0.492 to -0.113	0.002

The linear regression models showed that on average, the first-round subjects had a higher increase of ERA and RA9 at the Major-League level than at the minor-league level compared to subjects drafted in following rounds (+0.233 in minors vs +0.386 in MLB, P <

0.001 and +0.217 in the minors vs 0.398 in MLB, P < 0.001). Those results indicate that the study's first-round subjects allowed more runs, earned and unearned, during their MLB careers compared to subjects drafted in subsequent rounds. Subjects drafted in the first round also had a higher decrease in win percentage in the MLB (-2.435 percentage points, P < 0.001) than in the MiLB (-2.239 percentage points, P < 0.001) compared to pitchers drafted in the later rounds.

Following those analyses, a second round of linear regressions was processed, retaining subjects drafted after the year 2000 to account for potentially updated approaches to the drafting strategies (n=396). The direction of every relationship observed in the first linear regressions was preserved in following models. Significance was retained for the following statistics: MiLB ERA (p = 0.016), MLB ERA (p < 0.001), MiLB RA9 (p = 0.078), MLB RA9 (p<0.001), MLB ERA+ (p = 0.002), MLB FIP (p = 0.001), and MLB K/9 (p = 0.045). The differences are statistically significant from a P-value perspective and a baseball context. For example, the difference in MLB ERA+ (-8.304, P < 0.001) between first-round pitchers and subsequent-round pitchers could be the difference between a below-average ERA+ of 92 or an above-average ERA+ of 108.

From the drafts that took place between 2006 to 2010 in the Wymore et al. study, 38 pitchers were identified to have had Tommy John surgery before being drafted by a major-league team (UCLR group), with an additional 114 pitchers chosen to comprise the control group. Each control-group pitcher was chosen within 30 picks of a given pitcher in the UCLR group and matched for height and weight, with three control-group pitchers picked for each UCLR-group pitcher. Statistics were run using SPSS Statistics version 12 to calculate means and frequencies for the group, while two different types of tests were run to compare the performance and injury statistics of the UCLR group and the control group: chi-squared tests for categorical data and independent-samples *t* tests for continuous data. Continuous variables with abnormal distributions also underwent Mann-Whitney *U* tests. For all the tests, significance was set at $P < 0.05$. (Wymore et. al, 2016).

On average, the UCLR group was 21.8 ± 1.2 years of age and measured at 74.5 ± 2.3 inches and 209.6 ± 18.3 lbs. The control group measured at 21.4 ± 1.3 years of age, 74.3 ± 2.0 inches of height, and weighed in at 203.5 ± 15.7 lbs. P-values for age (0.050), height (0.612), and weight (0.046) were found using the descriptives analyses. Below are transcribed tables including significant and insignificant statistical findings from the tests run on the subject groups in the Wymore et al. study.

Table 2
Pitch Velocity in miles per hour, based off study's Table 6 (Wymore et al., 2016)

Velocity	**UCLR**	**Control**	***P* Value**
Average (mean ± SD)	92.7 ± 2.0	92.1 ± 2.3	0.148
Maximum (mean ± SD)	93.1 ± 2.6	92.4 ± 2.8	0.257

Note. Reproduced with permission from Dr. Lucas Wymore.

Table 3
Selected Performance Statistics per Inning, based off study's Table 9 (Wymore et al., 2016)

Statistic per Year	**UCLR**	**Control**	***P* Value**
Runs, median (range)	0.52 (0.32 - 1.60)	0.54 (0.22 - 1.15)	0.432
Home runs allowed, median (range)	0.07 (0.02 - 0.20)	0.08 (0.00 - 0.18)	0.022
Walked, median (range)	0.43 (0.19 - 1.00)	0.36 (0.19 - 1.22)	0.066
Struck batters, median (range)	0.05 (0.00 - 0.10)	0.06 (0.00 - 0.21)	0.189

Note. Reproduced with permission from Dr. Lucas Wymore.

Table 4
Risk of Future Injury, based off study's Table 10 (Wymore et al., 2016)

Future Injury	**UCLR**	**Control**	***P* Value**
DL assignment, n/N (%)	33/38 (86.8)	73/114 (64.0)	0.008
Days on DL, median (range)	103.0 (10-521)	94.0 (7-668)	0.316
DL for elbow, n/N (%)	15/33 (45.5)	32/73 (43.8)	0.877
Tear or retear, n/N (%)	4/38 (10.5)	18/114 (15.8)	0.425

Note. Reproduced with permission from Dr. Lucas Wymore.

The significant findings appear to be that of the difference between home runs allowed per inning (P=0.022) and IL assignment (P=0.008) when comparing the UCLR group to the control group. The analyzed data shows that the UCLR group allowed 0.07 home runs per inning (range: 0.02 - 0.20) and had 86.8% of its members return to the "disabled list" (33 of 38 group members). On the other hand, the control group allowed 0.08 home runs per inning (range: 0.00 - 0.18) and had 64.0% of its members return to the "disabled list" (73 of 114 group members). Pitchers from the UCLR group averaged fewer home runs per innings pitched but were more likely to return to the DL/IL for future injuries during their careers. They returned to the DL/IL due to unspecified elbow injury (15 of 33, 45.5%) or UCL tear or re-tear (4 of 38, 10.5%), but compared to the control group (32 of 73 for elbow, 43.8% and 18 of 114 for UCL, 15.8%), results were indicative but insignificant (P = 0.877 for elbow, P = 0.425 for UCL).

Although the UCLR group had a higher percentage of its members returned to the IL in their professional careers, a statistic showed that the average number of days spent on the IL by the UCLR group (103.0) and the control group (94.0) were not as drastic or significant (P=0.316) as one may assume. Another insignificant finding to note was the comparison of pitch velocities between groups, where the UCLR group averaged 92.7 ± 2.0 miles per hour against the control group's 92.1 ± 2.3 miles per hour (P = 0.148) and reached a maximum velocity of 93.1 ± 2.6

miles per hour in the UCLR group against 92.4 ± 2.8 miles per hour in the control group (P = 0.257). These results likely indicate that although there is a slight elevation in pitch velocities between the UCLR and control groups, the P-values may suggest alternative explanations for the increase in velocity thrown by UCLR pitchers.

Conclusion

The validity of draft order as a predictor of success in Major League Baseball and the accuracy of the criteria by which a pitcher is drafted in a high round is left to be further investigated. Pitchers drafted in the first round appeared to have not performed as well as pitchers drafted in subsequent rounds. The first-round pitchers had increases in statistics where higher numbers are not favorable and decreases in statistics where lower numbers are not favorable. However, if a pitcher receives Tommy John surgery prior to being drafted, they are most likely to return to an injured status while playing in MLB. Contrary to the implications of Ahmad's poll results, Tommy John surgery was not conclusively seen to increase fastball velocity.

CHAPTER 3: FINANCIAL EARNINGS AS A CONTRIBUTING FACTOR OF VALUE

Introduction

Like most professional sports, Major League Baseball is a financially demanding operation organized as a business and as a cog in the entertainment industry. For the main entertainers, the players, salaries are usually contingent on more than just one aspect of a player. On the business side of MLB, team owners and general managers have a fiscal scope into the value of players on their teams. From 2019 to 2021, MLB collectively decreased its total payroll across all teams by 4% (Brown, 2021). This deficit could be related to MLB shortening the 2020 season from 162 games to 60 games in response to the coronavirus pandemic. However, the team payrolls should not be considered miniscule. In 2021, the lowest team payroll was approximately $50.3 million, while 20 teams of 30 total teams had a payroll exceeding $100 million (Brown, 2021).

From the first contract they will sign out of the draft, players in MLB will have their careers mostly dictated by where they can make the most financial gain from their performance. Some skeptics could assume that if a player gets paid more, they will perform better, while others may also assume that a player who performs better will be paid more. From the business standpoint, it could be the spending trends of teams' front offices that could dictate how their players are paid. Negotiations for contracts strengthened in 1966 with the solidification of the MLB Players Association (MLBPA), a union of players from all active MLB teams that represents the all the players in business affairs with MLB. Spearheaded by Marvin Miller and the first MLBPA, the first collective bargaining agreement (CBA) in 1968 raised the minimum wage of $6,000 to $10,000 for players that year (Normandin, 2018).

In 2002, Billy Beane, then-general manager of the Oakland Athletics, used sabermetrics and quantitative analyses to utilize the team's payroll of around $40 million to perform at a competitive level while ranking 28th out of 30 teams in overall team payroll (*2002 MLB Payrolls - the Baseball Cube*, n.d.). Although Beane is credited with bringing "Moneyball" into public gaze of popularity, the idea was first developed by the then-general manager of the Athletics, Sandy Alderson. During his tenure in the 1980s and 1990s, Alderson wanted to rebuild the Athletics' minor-league farm system with young talent to have them ready to play for them in MLB efficiently and effectively. In addition to that, Alderson also utilized the free-agent market to find low-cost players that may positively contribute to the Athletics' success.

An article from Bleacher Report summarizes the idea of moneyball as the following equation: "moneyball equals low cost free agent players plus calling up minor league talent from one's farm system, with a hopeful end product of a successful MLB season" (Wright, 2011). Moneyball challenges the idea that more spending leads to more winning, and it can work for teams with lower budgets competing against teams with larger budgets. From a performance standpoint, teams want the most wins. From a financial standpoint, teams want the most wins while utilizing their budget or payroll the most efficiently. As a professional team sport, MLB and its teams with smaller markets can utilize moneyball to maximize their value while not bankrupting their teams.

With building or rebuilding a farm system, team front offices must navigate and interpret the scouting reports to draft players who can add value to their minor-league affiliates and, in turn, contribute to the major-league team. Eventually, these minor-league players may graduate to play in MLB and are then dependent financially on where they play next. It is difficult to predict how valuable draftees will become and how much they will be worth in a monetary sense. For the free-agent market, where MLB players once signed to a team contract may now receive contractual offers from other teams to play for them, the moneyball approach favors teams to pick the most cost-effective options that can collectively earn wins rather than sign the most-expensive star players. The condition of the players, whether their history of injury is extensive or frequent, can also affect the value of a player and the contracts which they are offered or can sign.

Review of Literature and Methods

Preliminary analyses by my research team reframed the focus from draft order and performance to fiscal earnings and performance, running descriptive statistics and frequencies, this time accounting for pitchers' wins above average (WAA), wins above replacement (WAR), and total earnings in millions of dollars (Terra et al., 2022b). WAA defines the wins a player contributes above the theoretical average player, and the sum of all the players' WAA values on a team should closely resemble the team's final win-loss record (WAA – BR Bullpen, 2020). Like WAA, WAR calculates the wins a player would contribute over a theoretical "replacement-level player." This replacement player would be considered "a AAA-quality player acquired by a team at any time for the league's minimum salary" (Wins above Replacement – BR Bullpen, 2020). A positive WAA or WAR value for a player indicates that the player contributed to the team's wins, while a negative WAA or WAR value for a player may equate to a player negatively affecting the team's wins or towards the team's losses.

The 1000 subjects were then divided two times for separate analyses. For the first of these analyses, the pitchers were coded from 1 to 3. Coding numbers were allocated as followed: 1 if the pitcher was drafted prior to the year 2000, 2 if the pitcher was drafted during the years 2000 to 2010, 3 if the pitcher was drafted following the 2010 season. Multiple comparison (MC) Tukey tests were run on the three groups to compare the means of the individual groups' WAA and WAR to the mean WAA and mean WAR of the whole database and the means of each group to one another. After that, the subjects who had salary values were divided by salary level into quintiles of 195 pitchers each, with the fifth quintile having 194. A one-way ANOVA test on the quintiles compared the means of each quintile based on level of earnings to each other. All monetary values for the Terra et al. study were adjusted for inflation to their 2019 values.

Since it is a common procedure performed on baseball players, a 2020 study by Dr. Jason Meldau et al. analyzed the economic effect of Tommy John surgery on MLB pitchers. The data needed for this study was obtained using public records to identify MLB pitchers who had undergone the surgery from 2004 to 2014. Inclusion criteria required the pitchers to have played in one MLB game before the surgery, had the surgery performed between 2004 and 2014, and had returned to play in at least one MLB or minor-league baseball (MiLB) game following surgery. Contract information and time used to undergo and recover from the procedure that they could have played in the regular season were used to evaluate financial loss. Since the data collection for the study occurred in 2017, fiscal earnings were adjusted for inflation to equate to 2017 value (Meldau et al., 2019).

Results and Discussion

From our findings, 36.2% of the subjects were classified as starting pitchers and 68.5% of the sample size were right-handed. Subjects were also analyzed by which decade they were drafted and can be seen in Table 5. The descriptive statistics calculated the averages for the following categories observed in the study: MLB wins (61.34 ± 54.780), MLB ERA (4.060 ± 0.682), MLB RA9 (4.229 ± 0.719). MLB WAA (2.733 ± 9.038), WAR (11.973 ± 14.740), and total earnings in millions (27.321 ± 38.628). From Table 5, it can be seen from a percentage perspective by decade that pitchers drafted in the 2000s comprise more than a quarter of the subjects (26.7%). For the MC Tukey tests, 604 pitchers were drafted prior to the year 2000, 296 pitchers were drafted during the years of 2000 and 2010, and 100 pitchers were drafted after the

2010 season. With significance set at P<0.05, the means for WAA and WAR were calculated within each of the three groups and are shown in Table 6:

Table 5
Percentages of subjects drafted in each decade, (Terra et al., 2022b)

Decade of Draft	**1960s**	**1970s**	**1980s**	**1990s**	**2000s**	**2010s**
Total (n=1000)	5.7%	13.7%	21.0%	20%	26.7%	12.9%

Table 6
WAA and WAR means for the divided sample groups, (Terra et al., 2022b)

	Prior to 2000 (n=604)	**2000-2010 (n=296)**	**After 2010 (n=100)**	**Significance**
MLB WAA	3.134 ± 10.215	2.404 ± 7.642	1.289 ± 3.367	P=0.127
MLB WAR	14.599 ± 16.548	9.163 ± 11.245	4.428 ± 4.951	P<0.001

MLB WAA within each group was not found to be significant (P=0.127), but it is noted that the standard deviations in MLB WAA are almost thrice as large as the calculated means. With P<0.001, MLB WAR found pitchers drafted prior to 2000 to have the highest average value and standard deviation (14.599 ± 16.548). The pitchers drafted after 2010 had the lowest average value, but they also had the lowest standard deviation (4.428 ± 4.951).

The standard deviation values are not as large of a difference compared to the standard deviation of the MLB WAA, but the WAR standard deviations are still larger in quantity than the means for WAR. From these means, a pitcher drafted prior to 2000 could have an MLB WAR as high as 31.147 and as low as -1.949, while a pitcher drafted after 2010 could have an MLB WAR as high as 9.379 and as low as -0.523. In the context of Table 6's results, a pitcher drafted before 2000 could add about 31 wins to their team but could also subtract almost two wins or add two losses to their team's record. A pitcher drafted after 2010 could contribute nine wins to their team's record or approximately one win against the team's record.

The linear regressions held "decade of draft" and "total monetary earnings in millions" as the independent variables. The dependent variables that were observed individually were MLB WAA and MLB WAR. Significance was set at P<0.001. The results for both regressions can be seen in Tables 7 and 8. With both linear regression models producing P<0.001, all findings in these analyses are significant.

Table 7
Linear Regressions of total monetary earnings predicting MLB WAA (Terra et al., 2022b)

Independent variable **($R^2 = 0.475$)**	**Unstandardized β**	**95% CI (lower to higher)**	**P-value**
Decade of Draft	-0.631	-0.929 to -0.333	P<0.001
Total Monetary Earnings in Millions	0.161	0.150 to 0.172	P<0.001

Table 8
Linear Regressions of total monetary earnings predicting MLB WAR (Terra et al., 2022b)

Independent variable **($R^2 = 0.637$)**	**Unstandardized β**	**95% CI (lower to higher)**	**P-value**
Decade of Draft	-3.247	-3.652 to -2.842	P<0.001
Total Monetary Earnings in Millions	0.287	0.272 to 0.301	P<0.001

For the WAA model, it seems that for every incremental increase in decade of draft, WAA decreases by 0.631 points on average. For every incremental increase in total monetary earnings by millions, the WAA increases, on average, by 0.161 points. Although this may suggest that more spending contributes to more WAA accrued, the variance or R^2 suggests that the independent variables account for 47.5% of the results' variance. This means that 52.5% of the results' discrepancies could be explained by other factors. The WAR model's R^2 value equates to 63.7% of the WAR-model results' variance is accounted for by draft decade and total monetary earnings in millions. For every incremental increase in decade of draft, WAR decreases by 3.247 points, while every increase in total monetary earnings in millions yields 0.287 points of WAR.

When looking at the independent variables of the linear regressions, the decade of draft negatively affects both WAA and WAR, and the total monetary earnings positively affects both WAA and WAR. Since it has a higher variance considered for its results, WAR seems to be more accurate in depicting the effect draft decade and total monetary earnings can have on wins a player could provide to their team. This is also confirmed by the MC Tukey test results, where the multiple comparisons analyzing WAA all had insignificant P-values and two of the three multiple comparisons analyzing WAR had significant P-values.

Table 9
Results of the MC Tukey tests comparing WAA values, (Terra et al., 2022b)

Decade groups being compared (coded number)	**Mean difference**	**P-value**
Prior to 2000 (1) vs 2000 – 2010 (2)	0.7302	P=0.490
Prior to 2000 (1) vs 2010 – present (3)	1.8449	P=0.141
2000 – 2010 (2) vs 2010 – present (3)	1.1147	P=0.535

Table 10
Results of the MC Tukey tests comparing WAR values, (Terra et al., 2022b)

Decade groups being compared (coded number)	**Mean difference**	**P-value**
Prior to 2000 (1) vs 2000 – 2010 (2)	5.4363	P<0.001
Prior to 2000 (1) vs 2010 – present (3)	10.1712	P<0.001

(Table 10 Continued)

Decade groups being compared (coded number)	Mean difference	P-value
2000 – 2010 (2) vs 2010 – present (3)	4.7348	P=0.12

The mean differences between 1 vs 2 and 1 vs 3 differ in significance from the mean difference of 2 vs 3, as can be seen in Table 10 above. Despite the adjustment for inflation, the differences could be explained by the trend of MLB teams spending more on player salaries. Reported numbers from Baseball Almanac show that the difference in minimum wage for MLB players increased from $6,000 in 1967 to $200,000 in 1999 (*Major League Baseball Minimum Wage | Baseball Almanac*, 2022). The same reports show that the period from 2000 to 2010 showed another increase from $200,000 to $400,000 respectively. The scope of the Terra et al. study, which saw the salary values get adjusted to 2019 value, would define 2011 to 2019 within group 3's parameters. Minimum wages from that timeframe would have increased $141,000, nearing $555,000 by 2019. In 2022, the newest CBA between MLB and the MLBPA granted raises in minimum wages for MLB players to $700,000 for the 2022 season and are projected to reach $780,000 by 2026, the last year of the newly negotiated CBA (Brown, 2022).

The one-way ANOVA revealed that salary quintiles had similar win percentages. Although the difference in win percentage between the highest-earning quintile and lowest-earning quintile is roughly 6%, none of the other win percentages differ from within either end of the range by about 3%. Those results can be seen in Table 11.

Table 11

One-way ANOVA results, win percentage to salary quintiles (Terra et al., 2022b)

Quintile	N	Win Percentage (as a %)
Top (1st) Quintile	195	0.5366047 (53.7%)

(Table 11 Continued)

Quintile	N	Win Percentage (as a %)
2nd Quintile	195	0.4968045 (49.7%)
Middle (3rd) Quintile	195	0.5019964 (50.2%)
4th Quintile	195	0.4975296 (49.8%)
Bottom (5th) Quintile	194	0.4679400 (46.8%)
Total	974	0.5002081 (50.0%)

With the total win percentage at 50.0% from this test, it is hard to argue if salary earnings have a significant effect on pitchers' win percentages. The top quintile of earning does have the highest win percentage, but the magnitude is marginal when comparing between quintiles. The argument could be made that more money spent on pitchers equates to more wins contributed, but since the percentages amongst quintiles are not vastly different, other factors could be contributing to the correlation of salary earnings and win percentages. As a team sport, pitchers in MLB are also successful by means of their teams' respective offensive production and defense fielding. Some metrics in baseball like fielding-independent pitching (FIP) and adjusted pitching wins can measure the sole impact a pitcher has on the team's wins.

Meldau et al. identified 194 pitchers that fit the study's criteria. Twelve of those pitchers underwent a revision surgery. Descriptive statistics showed the average age of the sample to be 27.8 ± 4.0 years of age, with the youngest pitcher at 20 years old and the oldest pitcher at 47 years old. The sample contained 92 starting pitchers, 97 relief pitchers, and 17 closers. Of those pitchers, 154 were right-handed and 52 were left-handed. The league affiliation was split evenly, with 103 pitchers representing the American League and 103 pitchers representing the National League. Looking at the surgery numbers by year, 11 total surgeries occurred in 2004 compared to 30 surgeries in 2014. The highest number of surgeries that took place in one year was 2012 with 35. Accounting for the revision surgeries, 206 total UCL reconstruction (UCLR) surgeries were performed in the observed timespan.

Total pitcher salaries were compiled, considering the number of players that earned certain earning thresholds. Economic losses were analyzed by the type of pitcher and year. All monetary values were adjusted for inflation to the year 2017.

Table 12
Total MLB pitcher salary and number of players earning at least $1, $5, and $10 million per year, (Meldau et al., 2019)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Pitchers	398	400	399	415	426	404	408	408	416	339	418
Total salary [a]	1.12	1.18	1.25	1.30	1.36	1.37	1.41	1.35	1.48	1.45	1.62
Average salary [b]	2.81	2.95	3.13	3.14	3.18	3.38	3.45	3.32	3.55	4.28	3.88
$1million	155	163	176	180	180	187	190	201	212	207	218
$5million	33	43	53	67	73	67	69	68	79	82	97
$10million	6	8	9	12	17	26	31	28	30	37	41

Note. Reproduced with permission from Dr. Eric Makhni.
[a] Values reported in billions of U.S. dollars, accounted for inflation. [b] Values reported in millions of U.S. dollars, accounted for inflation.

Table 13
Economic loss by type of pitcher and year (Meldau et al., 2019)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Starter	0.959	7.840	25.373	40.053	31.398	17.125	7.151	27.399	40.013	29.854	33.936
Relief	2.914	4.768	4.968	3.903	11.203	9.565	4.151	6.209	9.563	17.652	21.040
Closer	0.334	3.929	2.436	8.984	2.328	7.512	12.356	1.932	20.671	6.241	5.251
Total	4.207	16.537	32.777	52.940	44.929	34.202	23.658	35.540	70.247	53.747	60.227

Note. Reproduced with permission from Dr. Makhni.
Values were reported in millions of U.S. dollars, accounted for inflation.

Total pitcher salaries from Table 12 and economic losses from Table 13 showed upward trends, illustrating an increase in pitcher pay from 2004 to 2014 and an increase in corresponding losses as the years progressed. For total MLB pitcher salary, 2013 saw an average salary of $4.28 million, almost $0.4 million more than the 2014 value of $3.88 million. Between the years 2004 and 2014, the highest points of value in economic loss revolve around 2012, where the economic loss of starters in millions (40.013), economic loss of closers in millions (20.671), and total economic loss of pitchers who underwent UCLR (70.247) reach their maximum in the data set. Despite an average annual increase in salary, pitchers who underwent the procedure lost more annually.

Conclusion

Financial value of a pitcher is difficult to associate with one factor of a pitcher's overall performance. Even though the concept of moneyball has changed the way MLB teams utilize their payrolls and player management, player salaries have increased as a result of union efforts to compensate those on the field for their in-season performance. There is a correlation that points in WAA and WAR increases with total monetary earnings. However, the winning percentages do not differ as much as one may assume. The annual salary growth and economic losses experienced by pitchers who had UCLR shows that time away from the pitcher's mound has a negative effect on fiscal value of a pitcher. From the studies and articles observed, pitchers who are paid more may help their team win more games. The caveat of pitching too much to contribute more wins could place the pitcher at an economic loss should they require Tommy John surgery. As a pitcher recovered from the surgery during the regular season, the team was contractually obligated to pay them for that season, despite the pitcher not contributing to the team's wins or losses.

CHAPTER 4: UCL RECONSTRUCTION AS A CONTRIBUTING FACTOR OF VALUE

Introduction

Despite its novel presence in the history of baseball, Tommy John surgery has become a procedure synonymous with the sport and has since been a foundational point of contention in its contributions to pitcher value. If a player receives the surgery before being drafted, it could affect the order in which that player is drafted, and if a player receives it during their career in MLB, it could affect how long that player plays for and for how much. An important component of identifying value in a baseball player is the strength and durability of the player's arm. Pitching and throwing a baseball can cause considerable stress to the elbow and, more specifically, the ulnar collateral ligament (UCL). The ligament allows the throwing arm's elbow to be stabilized while absorbing the valgus stress inflicted as the elbow joint is pushed into an abducted position. If the stress experienced by the throwing elbow exceeds the ligament's physiological limit of endurance, injury may occur in the UCL or the elbow (Hibbard et al., 2015).

On September 25th, 1974, orthopedic doctor Frank Jobe performed a surgery he invented to reconstruct the UCL with a tendon graft. It was the first UCL reconstruction surgery of that design to be carried out and would change the course of history in sports medicine and baseball. The recipient of the surgery, who would later lend his name to the surgery's nickname, was Tommy John, a left-handed pitcher who had pitched 12 years prior to his UCL tear. Dr. Jobe had no definitive answer to whether John would be able to pitch after this surgery but knew that not performing the surgery would end John's career.

From Dr. Jobe's procedural perspective, the surgery consisted of obtaining a tendon graft, cleaning the joint, and securing the graft within the elbow. The tendon graft may be obtained from a donor or from the patient, most likely derived from the palmaris longus of the forearm, the hamstring tendon, or the big toe extensor tendon. The cleaning of the joint involved moving muscles and other tissues away from the affected joint and removing any damaged tissues. The surgeon proceeded to make holes in the humerus and ulna at the UCL's initial origin and insertion point. Once completed, the graft was threaded through the holes in the adjacent bones and secured by sutures or screws. The modern recovery process from UCL reconstruction surgery involves immobilization followed by months to a couple years of physical therapy and rehabilitation (Boston Children's Hospital, 2019). Failure to follow a recovery regimen or process personally made for the pitcher may result in re-injury or additional surgery.

Implementation of a post-operative recovery program may have stemmed from John's initial recovery; scar tissue from his procedure grew over the ulnar nerve of his left arm, causing involuntary curling of the arm and atrophy. To correct this, Dr. Jobe performed another surgery to remove the obstructing scar tissue and to reposition the nerve. When John removed his cast in January 1975 following the two procedures, he found an atrophied arm that would take over a year to rehabilitate before he returned to the mound on April 16, 1976. Fortunately for both John and Dr. Jobe, John played for 14 years after his return to play until his retirement in 1989. Although he waited two years before performing his next UCL reconstruction, Dr. Jobe and his pioneering surgery would assist more than 500 Major League Baseball (MLB) pitchers repair a strained or torn UCL (Landers, 2019).

Despite this, few investigations have explored the long-term effects of the surgery on the pitcher's performance, and preliminary results have often been misinterpreted and associated with a variety of misconceptions. A collective database on UCL reconstructions found that 78% of the surgeries performed prior to the end of 2013 returned to play (Roegele, 2015). Between John's recovery to the end of 2013, roughly four out of five pitchers who had their UCL reconstructed would return to play. The most common misconception is that the surgery will make you a better pitcher than before the repair. For example, the eponymous pitcher John saw improvements in most pitching categories. Prior to his surgery, John won 124 wins between Cleveland, Chicago, and the first half of his Los Angeles' tenure, averaging 10.3 wins per season over 12 seasons. However, John's post-surgery career saw him pitch 14 seasons with Los Angeles, New York, Anaheim, and Oakland, totaling 164 wins and averaging 11.7 wins per season (Baseball-Reference.com).

Review of Literature

To assist in the clarification of this misconception, there were a few studies analyzed to further understand possible explanations as to why these misconceptions about Tommy John surgery exist. The first study I performed with my team was conducted to evaluate the changes in pitching performances after the procedure and to identify if there were any distinct beneficial or detrimental effects on performance post-Tommy John surgery (Wong et al., 2019).

Across the board, not all the pitchers in the database may have experienced the same type of UCL tear, nor does it mean that every player was subjected to the same surgical procedure or used the same type of graft to repair the UCL. An additional study from Dr. Nathan Marshall et al. in 2019 explored how the type of tear, the surgical method, and the type of graft used might affect post-surgery statistics. The types of UCL tears (proximal, distal, midsubstance) and degrees to which the UCL had been torn (partially or completely) had the potential to be repaired using a modified Jobe technique or a docking technique, the latter of which had been the preferred method since 2013.

The two tendon grafts considered and analyzed in the study were of the palmaris and gracilis tendons from the forearm and inner thigh, respectively. From 2002 to 2016, 46 primary UCL reconstructions were performed on MLB pitchers and taken into consideration for this study's focus. Since revision surgeries would add more variance to the type of tear, surgical procedure, and graft, only primary reconstructions were counted (Marshall et al., 2019).

Methods

In the Wong et al. study, three groups of 50 pitchers in each were analyzed and compared. The first group (REC) consisted of 50 pitchers who had at least two years playing before and after undergoing UCL reconstruction surgery. These players were selected from a publicly available record of pitchers in MLB who are recipients of the surgery. The second group (INJ) had 50 players who sustained an injury tantamount to the impact of a UCL tear but did not experience the Tommy John surgery or undergo surgical intervention to heal. The last group (NON) served as the study's control group and was composed of 50 players who, as of 2019, had neither received UCL reconstruction surgery nor sustained a major injury similar to a UCL tear or strain. The latter two groups were picked using similarity scores of REC-group pitchers (provided by statistician Bill James and Baseball Reference) to find pitchers for the INJ and NON groups. Players from the INJ and NON groups also had the same play-time parameters as the first group to ensure a standardized window from which to analyze performance statistics.

Descriptive statistics identified population means and percentages. Binary variables were reported as percentages. Continuous variables were reported as means and standard deviations of the group. Mixed ANOVA with repeated measures and Greenhouse-Geisser corrections were used to measure the effect of group assignment when comparing statistics from the first and last seasons of play along with the means of the first two and final two seasons of play; these statistics included wins, win percentages, strikeouts per inning (K/IP), and earned-run averages (ERA).

The win percentage compared the amount of wins a pitcher has accrued to the total number of games that a pitcher has decidedly won or lost. Strikeouts per innings pitched (K/IP) refers to the average number of strikeouts a pitcher pitched over the innings in which they pitched. Earned-run average (ERA) is calculated by multiplying the number of runs a pitcher has earned by a factor of nine, and then that product is divided by the number of innings pitched by the pitcher. These statistics gave each pitcher in the sample size a superficial yet comprehensive summary of each pitcher's performances in their given scope or timeframe.

Pitching performance statistics for each subject in the Marshall et al. study were obtained from the same reference site as the Wong et al. study (Baseball-Reference.com) and additionally from fangraphs.com. Potential subjects were exempt from the study if the pitcher was a starting pitcher with fewer than 20 innings pitched in a year or a relief pitcher with fewer than 10 innings pitched in a year. These parameters were instilled to avoid small sample bias and skewing of the data. Each player's MLB statistics for three years before and after the UCL reconstruction were compiled and included the following categories: games, innings pitched (IP), win percentage, ERA, walks and hits per innings pitched (WHIP), walks per 9 innings, strikeouts per 9 innings, fastball velocity, runs above replacement (RAR), and wins above replacement (WAR). Walks per 9 innings is the average number of walks a pitcher would issue over the course of the length of a standard game: nine innings. WHIP equates to the sum of a given pitcher's walks and strikeouts dealt, divided by the total number of innings that pitcher has pitched.

The term "above replacement" in WAR and RAR refer to a theoretical reference player that approximates performance based on league averages. When calculating WAR for pitchers, either runs allowed per 9 innings (RA9) or fielding independent pitching (FIP) is used to comparatively analyze averages of the league to find how many wins that specific pitcher would acquire in the number of innings pitched (MLB.com). RAR is a similar metric to WAR, replacing wins with runs. A player's RA9 factors in all runs a pitcher is responsible for, both earned and unearned. A pitcher may acquire an unearned run if an opposing runner from the previous pitcher scores or if an error occurs by the pitcher's defense that allows the opposing team to score a run. Calculating RA9 is nearly identical to calculating ERA with the addition of unearned run totals to earned run totals prior to multiplying that sum by the 9-factor and dividing that product by the innings pitched.

Fielding-independent pitching (FIP) has some parallels to ERA and RA9, but the major difference is that it only accounts for outcomes for which the pitcher is most responsible. These outcomes for when the pitcher is most-responsible and are used to calculate FIP involve strikeouts, unintentional walks, hit-by-pitches, and home runs allowed. Outcomes resulting in the ball being put into the field of play by the opposing batter are not factored into FIP because the pitcher is thought to have limited control over the results produced by the fielding defense. A pitcher with a lower FIP than ERA may indicate that the pitcher's defense was not helpful in preventing the opposing runs scored, while a pitcher with a lower ERA than FIP may have had a defense that saved more runs than the pitcher could have control of preventing. Differences in ERA and FIP could help quantify the value of a given pitcher with an effective defense and a pitcher with an ineffective defense.

Results and Discussion

The pitchers in the Wong et al. study measured at 74.9 ± 2.4 inches, BMI of 26.8 ± 2.2 kg/m^2, and played 10.5 ± 4.5 years. From the whole sample, almost all the pitchers played 8.2 ± 4.8 years pre-injury while a little more than half of the sample (N = 82) played 4.2 ± 3.5 years post-injury. Of these pitchers, 67.34% of them currently are or were starting pitchers and 71.34% of them currently are or were right-handed pitchers. Spanning the entire careers of the subjects in the sample size, changes in wins and WAR (wins above replacement) yielded negative results (-0.04 ± 0.16 wins and -3.6 ± 8.5 WAR respectively), while changes in ERA (0.13 ± 1.6) and strikeouts (0.03 ± 0.18) yielded positive results (Wong et al., 2019).

Table 14
Descriptive statistics of entire sample, (Wong et al., 2019)

Variable	N	% of the Population
Tommy John Surgery	150	33.34%
Starter	150	67.34%
Reliever	150	16.00%
Both Starter and Reliever	150	8.67%
Closer	150	8.00%
Right Handed	150	71.34%
Variable	**N**	**Mean**
Years Pre-Injury	149	8.221 ± 4.812
Years Post-Injury	82	4.159 ± 3.547
Change Wins (Entire Career)	80	-0.044 ± 0.157
Change Wins (First and Last Season Only)	150	0.711 ± 6.151
Change Wins (First 2 and Last 2 Seasons Only)	150	-0.467 ± 10.424
Change ERA (Entire Career)	80	0.127 ± 1.624
Change ERA (First and Last Season Only)	150	0.377 ± 2.167
Change ERA (First 2 and Last 2 Seasons Only)	150	0.044 ± 1.442
Change K (Entire Career)	80	0.031 ± 0.177
Change K (First and Last Season Only)	150	0.044 ± 0.258
Change K (First 2 and Last 2 Seasons Only)	150	0.041 ± 0.205
Change WAR (Entire Career)	80	-3.603 ± 8.540
Change Winning Percentage (First and Last Season Only)	150	-0.069 ± 0.305
Change Winning Percentage (First 2 and Last 2 Seasons Only)	150	-0.030 ± 0.198

Multiple linear regression models with a P-value set at P<0.05 were used to determine the effect that UCL reconstruction had on pre- to post-injury changes between the first and last seasons' statistics and the first-two and last-two seasons' statistics. Confounding variables held constant for these analyses included years post-injury, total years active, and BMI. From the first two seasons, pitchers won 14.6 ± 7.8 games per season with a winning percentage of 53.6%. They totaled an ERA of 4.01 ± 1.14 ERA and struck out 0.88 ± 0.23 batters per inning. The more significant results involve the change in winning percentage between the first and last seasons and the winning percentage between the averages of the first two and last two seasons (P=0.026 and P=0.017 respectively). The following linear regressions analyzed the changes in performance statistics from the first and last seasons of each subject in the sample. Potential confounding variables were held constant.

Tables 15-18

Results of linear regression models used to determine the effect of UCL reconstruction on first-last season statistic (Wong et. al, 2019)

Model	Variable	Unst. β	95% CI Lower	95% CI Upper	t	Sig.
R^2 = 0.128	Tommy John Surgery	0.144	0.018	0.271	2.28	**P = 0.026**
F = 2.81	Years Post-Injury	-0.029	-0.050	-0.008	-2.75	P = 0.007
P = 0.031	Years Active	0.013	-0.003	0.028	1.65	P = 0.104
DF (regression): 4	BMI	-0.003	-0.033	0.026	-0.24	P = 0.814
DF (residual): 77 DF (total): 81	**Dependent Variable:** Change Winning % (First and Last Season Only)					

Model	Variable	Unst. β	95% CI Lower	95% CI Upper	t	Sig.
R^2 = 0.080	Tommy John Surgery	1.817	-0.995	4.628	1.29	P = 0.202
F = 1.66	Years Post-Injury	-0.375	-0.845	0.095	-1.59	P = 0.116
P = 0.168	Years Active	0.075	-0.265	0.414	0.44	P = 0.663
DF (regression): 4	BMI	-0.460	-1.117	0.198	-1.39	P = 0.168
DF (residual): 77 DF (total): 81	**Dependent Variable:** Change Wins (First and Last Season Only)					

Model	Variable	Unst. β	95% CI Lower	95% CI Upper	t	Sig.
R^2 = 0.062	Tommy John Surgery	-0.072	-1.120	0.976	-0.14	P = 0.892
F = 1.27	Years Post-Injury	0.120	-0.055	0.295	1.36	P = 0.176
P = 0.290	Years Active	-0.059	-0.186	0.067	-0.93	P = 0.354
DF (regression): 4	BMI	0.146	-0.099	0.391	1.18	P = 0.240
DF (residual): 77 DF (total): 81	**Dependent Variable:** Change ERA (First and Last Season Only)					

Model	Variable	Unst. β	95% CI Lower	95% CI Upper	t	Sig.
R^2 = 0.034	Tommy John Surgery	-0.067	-0.206	0.072	-0.96	P = 0.339
F = 0.68	Years Post-Injury	-0.012	-0.035	0.012	-0.99	P = 0.326
P = 0.609	Years Active	0.004	-0.012	0.021	0.52	P = 0.602
DF (regression): 4	BMI	0.008	-0.025	0.040	0.48	P = 0.630
DF (residual): 77 DF (total): 81	**Dependent Variable:** Change K (First and Last Season Only)					

From the first and last seasons, the only significant finding of note was the 14.4 percentage-point change in win percentage between the first and last season for players who underwent Tommy John surgery in the REC group (P=0.026). In the same analysis, the players in the INJ group underwent a decrease of 2.9 percentage points in their win percentages (P=0.007). Linear regressions were also used to compare statistics between the sample groups' first-two and last-two seasons of play, holding confounding variables constant.

Tables 19-20
Results of linear regression models used to determine the effects of UCL reconstruction on first-two and last-two season statistics, win percentages and wins (Wong et al., 2019)

Model	Variable	Unst. β	95% CI (Low/High)		t	Sig.
R^2 = 0.109	**Tommy John Surgery**	1.450	-3.020	5.921	0.65	P = 0.520
F = 2.34	**Years Post-Injury**	-0.308	-1.055	0.439	-0.82	P = 0.415
P = 0.062	**Years Active**	-0.448	-0.988	0.092	-1.65	P = 0.103
DF (regression): 4	**BMI**	-0.839	-1.885	0.206	-1.60	P = 0.114
DF (residual): 77 **DF (total): 81**	**Dependent Variable:** Change Wins (First Two Seasons and Last Two Seasons Only)					

Model	Variable	Unst. β	95% CI (Low/High)		t	Sig.
R^2 = 0.083	**Tommy John Surgery**	0.044	-0.050	0.138	0.94	P = 0.352
F = 1.75	**Years Post-Injury**	-0.019	-0.035	-0.004	-2.44	**P = 0.017**
P = 0.148	**Years Active**	0.006	-0.005	0.017	1.07	P = 0.289
DF (regression): 4	**BMI**	-0.003	-0.025	-0.019	-0.25	P = 0.801
DF (residual): 77 **DF (total): 81**	**Dependent Variable:** Change Winning % (First Two Seasons and Last Two Seasons)					

Although the regression models from the first-two and last-two seasons did not show any significant changes in the REC group, the decrease in win percentage of 1.9 percentage points (P=0.017) showed that INJ-group pitchers did not have a higher win percentage in their first two seasons or last two seasons. Changes in ERA and strikeout numbers from the first-two and last-two seasons are reported in Tables 21 and 22, despite there being no significant results from those models:

Tables 21-22
Results of linear regression models used to determine the effects of UCL reconstruction on first-two and last-two season statistics, ERA and strikeouts (Wong et al., 2019)

Model	Variable	Unst. β	95% CI		t	Sig.
			Lower	Upper		
R^2 = 0.050	**Tommy John Surgery**	-0.069	-0.794	0.655	-0.19	P = 0.849
F = 1.02	**Years Post-Injury**	0.076	-0.045	0.197	1.25	P = 0.214
P = 0.405	**Years Active**	-0.056	-0.144	0.032	-1.27	P = 0.207
DF (regression): 4	**BMI**	0.071	-0.098	0.241	0.83	P = 0.407
DF (residual): 77 **DF (total): 81**	**Dependent Variable:** Change ERA (First Two Seasons and Last Two Seasons Only)					

Model	Variable	Unst. β	95% CI		t	Sig.
			Lower	Upper		
R^2 = 0.023	**Tommy John Surgery**	-0.016	-0.127	0.096	-0.28	P = 0.782
F = 0.46	**Years Post-Injury**	-0.011	-0.030	0.008	-1.17	P = 0.245
P = 0.764	**Years Active**	0.006	-0.007	0.020	0.89	P = 0.377
DF (regression): 4	**BMI**	0.009	-0.017	0.035	0.70	P = 0.484
DF (residual): 77 **DF (total): 81**	**Dependent Variable:** Change K (First Two Seasons and Last Two Seasons Only)					

Based off the analyses and research done on this small sample size, it appeared that UCL reconstruction did not compromise pitching quality in a significantly positive or negative way. The mixed ANOVAs found no statistical differences between the REC group, the INJ group, and the NON group, while the linear regressions predicted minimal changes in pitching performances between pitchers in the pre- and post-operational phases of UCL reconstruction (Wong et al., 2019). The results of this study should not be a definitive conclusion, as the data did not include physiological effects or mechanical parameters like the likelihood of UCL re-injury in past patients (leading to a revision of the UCL reconstruction) or differences in rehabilitation programs.

Pitchers in the Marshall et al. study were analyzed according to the performance outcomes, with results being grouped into each factor of Tommy John surgery that was being evaluated. Time (in years) pre- and postoperative were reported as means, while continuous variables were represented as means with standard deviations and percentages. Comparison of means underwent *t*-test analysis, significance set at $P < 0.05$. Descriptive statistics from the study are summarized in the following table:

Table 23
*Pitcher Descriptives (*Marshall et al., 2019)

Category	Mean
Age	26.3 ± 4.5
Right-handed, Mean ± n (%)	31 (67)
Starting pitcher, Mean ± n (%)	27 (59)
Time to return from surgery (in months), Mean ± SD (range)	13.7 (10-23)
Return to play (n=45), Mean ± n (%)	43 (96)
Return to MLB (n=44), Mean ± n (%)	36 (82)

Note. N=46. Reproduced with permission from Dr. Nathan Marshall.

Noting the last two categories in the table above, one player in the sample size was still listed on the DL/IL for UCL reconstruction (n=45) and two players had either still been listed on the DL/IL, reassigned to minor-league rehabilitation, or received the surgery while playing in the minor leagues (n=44). When analyzing the sample grouped by procedural strategy (docking and modified Jobe), players who underwent the modified Jobe technique pitched longer in MLB than those who underwent the docking technique (3.4 years vs 1.1 years respectively, P = 0.001).

Compared to the docking group, subjects in the modified Jobe group pitched in more games preoperatively (32.6 vs 20.6 games, P = 0.024) and walked more batters post-operative (3.7 vs 2.8 walks, P = 0.044). Other results from this grouping analysis were found to be insignificant. In the scope of graft type, the palmaris graft group was younger than the gracilis graft group (25.7 vs 28.4 years, P = 0.043) and weighed more than the gracilis graft group (98.4 vs 93.0 kg, P = 0.032). Post-operative playing time was shown to be greater in the palmaris group (5.2 vs 2.7 years, P = 0.007) with the significant finding being time in the minors (MiLB) and MLB to be longer from the palmaris group (2.5 years vs 0.7 years in MiLB, P = 0.015).

Organizing the subject groups by location of the tear (distal, proximal, or midsubstance) and degree of the tear (partial or complete) yielded more performance-based differences between categories in each classification of scope, with significance set for both at P<0.05. For tear location, the following *t*-test results from the study are presented here:

Table 24
Significant relationship between difference of performance statistics and tear location (Marshall et al., 2019)

Category of Statistic	**Proximal tear (n=16)**	**Distal tear (n=24)**	**Midsubstance tear (n=3)**	***P* Value**
Pre-op fastball velocity, miles per hour	90.6	93.0	N/A	0.023

Note. Reproduced with permission from Dr. Nathan Marshall.

(Table 24 Continued)

Category of Statistic	**Proximal tear (n=16)**	**Distal tear (n=24)**	**Midsubstance tear (n=3)**	***P* Value**
Pre-op ERA	5.11	3.93	3.51	0.003
Pre-op WHIP	1.47	1.32	1.25	0.021
Pre-op strikeouts per 9 innings	6.6	8.3	6.3	0.016
Pre-op WAR	0.1	0.9	1.4	0.017
Pre-op RAR	2.1	9.3	13.7	0.016
Post-op win percentage	58.3	42.4	48.9	0.029
Post-op IP	58.9	97.9	84.6	0.042

Note. Reproduced with permission from Dr. Nathan Marshall.

Considering the differences in sample size, the midsubstance-tear group (n=3) showed better results in only preoperative statistics (ERA, WHIP, WAR, and RAR) over the proximal-tear group or the distal-tear group, which would indicate that the midsubstance-tear group had a significantly greater performance between groups prior to Tommy John surgery. Among the groups, the distal-tear group led in pre-op fastball velocity, pre-op strikeouts per nine innings, and post-op innings pitched. On average, this group pitched faster and pitched more strikeouts before the surgery but pitched more innings after receiving the surgery. The only notable statistic that the proximal-tear group had the superior value was in post-op win percentage, which notes that when looking at all the groups, the proximal-tear group would win more after repairing the UCL than the others.

Table 25

Significant relationship between difference of performance results and type of tear (Marshall et al., 2019)

Category of statistic	**Complete tear (n=14)**	**Partial tear (n=32)**	***P* value**
Years post-surgery, total	5.9	4.0	0.033

(Table 25 Continued)

Category of statistic	Complete tear (n=14)	Partial tear (n=32)	*P* value
Years post-surgery, minors	3.1	1.7	0.028
ERA, pre-surgery	3.82	4.70	0.041
WHIP, post-surgery	1.27	1.41	0.037
Strikeouts per 9 innings, post-surgery	8.9	7.0	0.025

Note. Reproduced with permission from Dr. Nathan Marshall.

When looking at the results comparing types of tears to performance-based results, t-tests found that pitchers with a complete tear had a lower average ERA before reconstruction (3.82) than pitchers with a partial tear before surgery (4.70, P=0.041). The other significant results showed that pitchers who suffered a complete tear and returned to surgery played more years overall, more years in the minors, and yielded better post-surgery statistics in WHIP and strikeouts per 9 innings than those who returned from surgery to repair a partial tear. The increase of playing time in the minor leagues could be part of the rehabilitation program for pitchers who played in MLB while suffering the UCL tear, as pitchers recovering from the surgery would need time to test out the arm once it had been cleared for physical activity.

Some evidence has been provided by a study from Dr. Joseph Liu et al. regarding the revision rate of UCL reconstruction. 235 MLB pitchers between 1999 to 2014 have undergone Tommy John surgeries. Within that sample size, 31 pitchers (13.2%) underwent revision surgery and 37% underwent revision within three years or less after the initial procedure. Of those pitchers that had a revision surgery, 65.4% (17 pitchers) of that sub-sample returned to pitch at least one game at the Major-League level, while 43.2% (11 pitchers) returned to pitch 10 or more games. From that group, the average recovery time was 20.76 months.

Pitchers recovering from revision surgery that returned to MLB performance played significantly less time post-revision surgery. With significance set as $P < 0.05$, pitchers that underwent revision procedures pitched 2.6 seasons compared to those who just had an initial UCL reconstruction, who played an average 4.9 seasons ($P=0.002$). Revised pitchers also showed significant signs of pitching fewer innings (36.95 innings vs 83.97 innings, $P=0.012$) and throwing fewer pitches (635.72 pitches vs 1355.98 pitches, $P=0.016$) than those who only had an initial Tommy John surgery with no revisional follow-up (Liu et al., 2016).

When analyzing these studies, there is ambiguous evidence supporting both sides of the argument that Tommy John surgery improves or worsens pitcher performance. Depending on which study is being analyzed, there are positive and negative results for pitchers before and after TJS. The Liu et al. study shows that more than a third of pitchers who receive UCL reconstruction will likely have another corrective surgery operated on them, and from that group comes shortened career longevity in MLB. Marshall et al. showed that Tommy John surgery had statistical improvements depending on the type and location of the UCL tear, what kind of graft and technique used to repair the tear. Conversely, my study showed that other than having a higher winning percentage from the first/last seasons and first-two/last-two seasons, there are not many significant differences between pitchers before and after UCL reconstruction (Wong et al., 2019).

Conclusion

From preliminary analyses of the literature, it is difficult to definitively state if UCL reconstruction surgery is beneficial or detrimental to a pitcher's value. Despite the few significant findings across the existing studies, there are still many insignificant findings that would require further research to validate or invalidate. The location of the tear on the UCL and the degree to which the UCL is torn can affect the postoperative results based on the placement and the severity of the tear. If a pitcher suffers damage to the UCL, surgery is recommended if the pitcher wants to continue a career in professional baseball but should also be cognizant of the additional risks and likelihood or undergoing corrective surgery.

CHAPTER 5: CONCLUSION

In MLB, pitcher value is a value that lends contribution from many variables in baseball, on and off the field. For the context of this thesis, pitcher value is defined by the positive contributions a pitcher has for their team and their wins. Between the three variables of pitcher value analyzed, the effect of Tommy John surgery (TJS) or UCL reconstruction seems to have the most prevalence on pitcher value and its comprising factors. In draft-order, TJS seemed to have as much of a significant effect as if a pitcher was drafted in the first round. When analyzed in the scope of pre-draft value, pitchers who underwent the procedure before being drafted had a higher likelihood of returning to the disabled/injured list. This may weigh negatively against a pitcher's perceived draft value and result in that pitcher being drafted in a lower slot. Additionally, performance statistics from pitchers drafted in the first round do not differ as drastically or significantly from performance statistics of pitchers drafted in successive rounds. Further research would have to be done regarding the accuracy of projecting future success and positive value in MLB with draft-round status. This may also include evaluating the metrics in which pitchers are scouted and weighed in the draft.

From the financial scope, pitchers who are recovering from TJS yield an average economic loss for their teams. Accounting for inflation and the increasing minimum wage of MLB pitchers, fiscal value of a pitcher quantified by WAA and WAR, has some positive correlation with salary dollars paid. Although it suggests that investing in pitchers can add to a team's cumulative win totals, the individual winning percentages do not vary as drastically when observing them as a dependent variable against salary paid to those pitchers. On the other hand, TJS represented an economic loss to pitchers and their respective teams. Those teams with pitchers recovering from TJS are essentially paying for the pitchers to rehabilitate and not directly paying for the pitchers to add to the teams' wins.

When looking at the performance-based statistics from pitchers who underwent TJS, each variable affected by TJS yields a different outcome that cannot be summarized as having an overall positive or negative effect on pitcher value. Whether it is the physiological variables affected by TJS as observed in Marshall et al.'s study or variables pertaining to preoperative and postoperative performance statistics like Wong et al.'s study, TJS is neither purely beneficial nor purely detrimental to overall pitcher value in MLB. TJS does have a negative influence when analyzing its effects against draft order and fiscal impact, which in turn can equate to an overall negative impression on a pitcher's win-based value. However, further research observing TJS as a sole factor of positive or negative influence on pitcher value would have to be done for a conclusive indication.

Observing these three variables and their contributions to an MLB pitcher's win-based value, all three have strong influences in the resulting totality of value. TJS status has a slightly negative influence on both draft order and monetary earnings but can also have some benefits in preserving career longevity, as seen with the case of the eponymous Tommy John. More research with respect to each variable's individual compositional factors should be utilized to fortify one's argument. As the current literature stands, no single variable can solely determine a pitcher's win-value and overall contributions to overall success. It is within each variable to have a positive or negative effect pending on what subcategory is analyzed.

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