2019

LONGITUDINAL DESCRIPTIVE PROFILE OF COLLEGIATE PITCHERS PARTICIPATING IN A SUMMER BASEBALL LEAGUE

Isabelle Leslie Gillis
University of Kentucky, ilgi222@g.uky.edu
Digital Object Identifier: https://doi.org/10.13023/etd.2019.452

STUDENT AGREEMENT:

I represent that my thesis or dissertation and abstract are my original work. Proper attribution has been given to all outside sources. I understand that I am solely responsible for obtaining any needed copyright permissions. I have obtained needed written permission statement(s) from the owner(s) of each third-party copyrighted matter to be included in my work, allowing electronic distribution (if such use is not permitted by the fair use doctrine) which will be submitted to UKnowledge as Additional File.

I hereby grant to The University of Kentucky and its agents the irrevocable, non-exclusive, and royalty-free license to archive and make accessible my work in whole or in part in all forms of media, now or hereafter known. I agree that the document mentioned above may be made available immediately for worldwide access unless an embargo applies.

I retain all other ownership rights to the copyright of my work. I also retain the right to use in future works (such as articles or books) all or part of my work. I understand that I am free to register the copyright to my work.

REVIEW, APPROVAL AND ACCEPTANCE

The document mentioned above has been reviewed and accepted by the student's advisor, on behalf of the advisory committee, and by the Director of Graduate Studies (DGS), on behalf of the program; we verify that this is the final, approved version of the student's thesis including all changes required by the advisory committee. The undersigned agree to abide by the statements above.

Isabelle Leslie Gillis, Student

Dr. Mark Abel, Major Professor

Dr. Melinda Ickes, Director of Graduate Studies

LONGITUDINAL DESCRIPTIVE PROFILE OF COLLEGIATE PITCHERS PARTICIPATING IN A SUMMER BASEBALL LEAGUE

THESIS

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the College of Education at the University of Kentucky

By

Isabelle Leslie Gillis

Lexington, Kentucky

Dr. Mark Abel, Associate Professor of Kinesiology and Health Promotion

Lexington, Kentucky

2019

ABSTRACT OF THESIS

LONGITUDINAL DESCRIPTIVE PROFILE OF COLLEGIATE PITCHERS PARTICIPATING IN A SUMMER BASEBALL LEAGUE

The purpose of this study was to provide a longitudinal profile of pitching performance in a cohort of pitchers over two collegiate seasons and a summer league. Thus, this study utilized a longitudinal design to evaluate the impact of summer league participation on subsequent collegiate regular season pitching performance. Specifically, the performance of a cohort of Division 1 collegiate baseball pitchers during the 2018 Spring collegiate season, 2018 Summer League season, and the 2019 Spring collegiate season was evaluated and stratified by pitcher designation, arm dominance, and academic status. Analyses of variance were used to identify main and interaction effects on pitching outcomes. The level of statistical significance was set at $p < .05$ for all analyses. Data were publicly accessed from thirty-seven Division I collegiate baseball pitchers who participated in a summer baseball league. Collectively, all pitchers significantly improved earned run average ($p = .024$), number of strikeouts ($p = .011$), and strikeout efficiency ($p = .034$) from 2018 to 2019 collegiate seasons. Whereas, starting pitchers ($n = 15$) yielded fewer earned runs ($p = .039$) and enhanced hit efficiency ($p = .012$) from 2018 to 2019 collegiate seasons. Relief pitchers ($n = 16$) produced significantly more strikeouts from 2018 to 2019 collegiate seasons ($p = .012$). Finally, there were no differences in pitching outcomes for closers ($n = 6$) over time ($p > .05$). Regarding arm dominance, right-handed pitchers ($n = 23$) improved win average ($p = .001$), strikeouts ($p = .008$) and strikeout efficiency ($p = .031$) from 2018 to 2019 collegiate seasons. Left-handed pitchers ($n = 14$) significantly improved earned run average ($p = .015$), earned runs ($p = .048$), and hit efficiency ($p = .014$). Regarding academic stratification, the freshman to sophomore cohort ($n = 15$) significantly improved number of pitches ($p = .018$), innings pitched ($p = .019$), hits ($p = .029$), and strikeouts ($p = .003$). Whereas, the sophomore to junior cohort ($n = 21$) significantly improved losses ($p = .042$) and hit efficiency ($p =.028$). The findings from this study indicate that participation in a summer baseball league may have improved several critical pitching metrics with implications to enhance team performance.

KEYWORDS: collegiate pitchers, summer baseball, baseball, athletics

Isabelle Leslie Gillis
(Name of Student)

12/02/2019
Date

LONGITUDINAL DESCRIPTIVE PROFILE OF COLLEGIATE PITCHERS
PARTICIPATING IN A SUMMER BASEBALL LEAGUE

By
Isabelle Leslie Gillis

Dr. Mark Abel
Director of Thesis

Dr. Melinda Ickes
Director of Graduate Studies

12/02/2019
Date

ACKNOWLEDGMENTS

I would like to thank first and foremost my thesis committee, Dr. Abel, Dr. Bergstrom, and Dr. Morris for taking me on and helping me throughout this entire process. I'd also like to thank my parents, friends, and family, for supporting me throughout my master's degree program, and my thesis work.

Without the help of Keirce Kimbel and Phil DePase of Kentucky Baseball, and Tori Lomaka of CATS, most of the college information, and NCAA Bylaws would not have been included. Furthermore, I would like to thank Donny Gress who helped me gather information from the Cape Cod Baseball League (CCBL), especially from the Harwich Mariners during the Summer of 2018. I would also like to thank the Jim Lawler and the rest of Wareham Gatemen's coaches, and management for taking me on as an intern, and helping me gather information on pitchers and teams throughout the CCBL during the Summer of 2018.

Finally, to my Grandma, thank you for introducing baseball to me, and making me fall in love with it. This is for you.

To all of you, I would like to say, "thank you".

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Player development is critical to enhance baseball pitching performance. Thus, it is important that players are provided with feedback on pitching mechanics, are able to visualize the strike zone while pitching, and develop sport-specific muscular fitness while increasing level of play. Although collegiate baseball facilitates player development, elite summer baseball leagues offer additional opportunities to enhance player development, and help athletes prepare for professional baseball leagues (e.g., major league baseball: MLB).

There are an abundance of collegiate athletes participating in summer league baseball. Specifically, there are about 53 collegiate summer baseball leagues throughout the United States and Canada including the Northwoods League (NWL), Western Canadian Baseball League, and Cape Code Baseball League (CCBL) (The Baseball Observer, 2017). Thus, although not all collegiate baseball players participate in summer leagues, about 15,900 to 31,800 collegiate players participate in North American summer baseball leagues annually (The Baseball Observer, 2017). One of the most notable summer baseball leagues is the CCBL. In 2018, there were 294 collegiate pitchers who played in the CCBL league (Cape Cod Baseball, 2019). These pitchers include those who were on a temporary contract, full season contract, and pitchers who played in the CCBL during the CCBL playoffs. Of those 294 total pitchers, 119 pitchers came from Power 5 collegiate Conferences (i.e., Atlantic Coast Conference (ACC), Big 10 Conference (BIG 10), Big 12 Conference (BIG 12), Pacific-12 Conference (PAC-12), & Southeastern

Conference (SEC) (Cape Cod Baseball, 2019). Thus, approximately 40% of CCBL pitchers came from a Power 5 Conference school.

Although many collegiate baseball players participate in approximately 50 summer leagues, not all make it to the MLB level. However, one league, the CCBL has a significant number of alumni in MLB (Cape Cod Baseball, 2019). In 2018, the CCBL had 303 *active* alumni in MLB. (Cape Cod Baseball, 2019), indicating that CCBL alumni compose 34.6% of all MLB players (Gough, 2019). Furthermore, during the 2018 world series, there were 14 CCBL alumni on *active* MLB world series rosters (CCBL Public Relations Office, 2018). Another notable league is the NWL, where in 2017 180 alumni were *drafted* by MLB teams. In 2018, 163 current and NWL alumni were *drafted* by MLB teams (Northwoods League, 2019). Thus, it appears that participation in a summer baseball league enhances collegiate players' performance. However, there is a lack of research investigating the impact of participating in summer league baseball on subsequent collegiate pitching performance. Therefore, the purpose of this study was to evaluate the impact of summer league participation on subsequent collegiate pitching performance. We hypothesized that collegiate pitchers who participated in summer baseball league would enhance their pitching performance during the following college season.

Delimitations

This study was delimited to the following:

1. Student-athletes from Power 5 Conference schools who participated in the CCBL during the 2018 summer baseball league season and did not sign a professional baseball contract during the summer of 2018.
2. Student-athletes from Power 5 Conference schools who participated in the CCBL during the 2018 summer baseball league season and completed their team's CCBL season.
3. Student-athletes from Power 5 Conference Schools who were on their school's Spring 2018 and Spring 2019 active rosters and participated in the CCBL during the 2018 summer baseball league season.

Definitions

1. ERA – Earned runs average.
2. IP – Innings pitched.
3. ER – Earned runs given up by the pitcher.
4. K – Strikeouts.
5. NP/IP – season number of pitches divided by total number of innings pitched during the season.
6. NP/H – Season number of pitches divided by the total number of hits given up during the season.
7. NP/R – Season number of pitches divided by the total number of runs given up during the season.
8. NP/ER – Season number of pitches divided by the total number of earned runs given up during the season.

9. NP/K – Season number of pitches divided by the total number of strikeouts delivered during the season.

CHAPTER II

LITERATURE REVIEW

Starting in the 1840s, in New York, baseball was considered to be "America's Pastime". However, the sport did not grow into a league until 1871 when the first league, the National Association of Professional Baseball Players, was founded. In the early 1900s, baseball underwent a large expansion due to more Americans living in major cities, such as Chicago, Boston, and Atlanta. Baseball teams came to those major cities, so attendance and revenue could increase, as well as the trend of the sport (Helyar, 1994). Today, there are 30 professional teams, and two leagues – the American and National Leagues within Major League Baseball (MLB), with nine starting positions, and three secondary positions. The nine starting positions in baseball: pitcher, catcher, first baseman, second baseman, short stop, third baseman, left fielder, center fielder, and right fielder. The other three notable baseball positions are: designated hitter, pinch hitter, and pinch runner (Baseball reference: positions, 2017).

TYPES OF PITCHERS

There are different types of pitchers, including: starter, reliever (long, middle), and closer. The starter will start the game and is expected to pitch long into the 7^{th} or 8^{th} inning of the game. The reliever has three different types of pitchers. The long reliever is a reliever who also functions as a starting pitcher and is a great position for pitchers who are trying to transition into becoming a starting pitcher. This reliever usually relieves the pitcher early in the game, if the manager has decided to pull his starter for a variety of reasons. The long reliever's job is to keep the other team's lead to where it is at and ensure that no other runs are given. The middle reliever can also function as a closer, in which this reliever will come into the latter end of the baseball game, which is usually the 6th or 7th inning. The middle reliever's job is to maintain the lead or tie before the closer comes in. Finally, the closing pitcher is a reliever who comes into the game in the 8th inning and is expected to close out the 9-inning game (Baseball Reference: Pitcher, 2017).

On Field Performance Variables

On-field performance variables that influence how well a pitcher performs ranges from how many pitches and innings are pitched during one game. While there have been arbitrary pitch limits set for professional baseball players, the pitch limits set were not based on scientific evidence, and it is not enforced as the pitching coach and the general manager (GM) of the baseball team have final say on when and whether or not to keep a pitcher in the game (Karakolis, Bhan, & Crotin, 2013). Literature has indicated that the amount of innings pitched over the course of the season is a predictor for injury risk, prevalence, fatigue, and performance (Karakolis, Bhan, & Crotin, 2013; Love, Aytar, Bush, & Uhl, 2010; Chalmers, Erickson, Ball, Romeo, & Verma, 2016; Grantham, Byram, Meadows, & Ahmad, 2014).

The number of innings thrown by a pitcher is also dependent on the pitcher classification. For instance, Love, Aytar, Bush, and Uhl (2010) reported that, on average, Division 1 (D1) pitchers in the Southeastern Conference (SEC) pitch for approximately 6.0 innings each time they appear if they are a starting pitcher, while pitchers who are combined starters and relievers pitched approximately 4.0 innings per appearance. In addition, those who pitch as relievers only pitch for about 1.3 innings per appearance. Although Love, Aytar, Bush, and Uhl (2010) did not find a significant difference between number of innings thrown between all categories of pitchers, the data indicate that there is a dramatic difference between pitchers who are categorized as starting only pitchers, and reliever only pitchers; whereas there is only a slight decrease in the average amount of innings pitched between a starter only and a combined starter and reliever pitcher. These differences become important when discussing the volume of pitches thrown, and injury risk and prevalence among pitchers (Love, Aytar, Bush, & Uhl, 2010).

In the MLB (Major League Baseball), the amount of innings a pitcher throws is also an important performance variable. In a study that was conducted to find the relationship between injury and cumulative work metrics, it was reported that most MLB pitchers will throw for less than 20 innings in a single season. This alludes to the fact that most MLB pitchers are relievers and closers. In addition, the study also concluded that the pitchers with the lowest risk for injury were those who pitched approximately 2 to 3 innings per game, which reflects 21% of pitchers, while the pitchers with the highest injury risk pitched for approximately 6 to 7 innings per game, which reflects 39% of pitchers. Karakolis, Bhan, & Crotin, (2013) concluded that “starting pitchers who averaged 6-7 innings per game may be more likely to get injured the following season than relief pitchers who averaged between 0 and 3 innings per game” (p. 2117). This is an important relationship because both coaches and players want to be healthy, and if they are injured, they cannot pitch, and may hinder the team’s overall performance.

Unlike the amount of innings pitched, pitch count can provide a more complete picture of the pitcher’s performance by keeping track of how many pitches each pitcher throws per game appearance, and over the course of a season. Keeping track of pitch counts can also help determine when injury and fatigue occur, as well as giving us an idea of how many strikes and balls – or how the pitcher performs per game. In addition to this, coaches can use pitch counts to reduce injury risk, fatigue, and potentially relieve pitchers before or when they approach when injury and fatigue usually occur in a collegiate and/or MLB pitcher.

In accordance with the amount of innings pitched, collegiate baseball pitchers who are starters also threw more pitches per game (97 ± 10 pitches) (Love, Aytar, Bush, & Uhl, 2010). Collegiate pitchers who were combined starters and relievers threw approximately 68 ± 19 pitches per game (Love, Aytar, Bush, & Uhl, 2010). Over the course of a season, starters threw 1204 ± 387 pitches, while combined starter and reliever pitchers threw 613 ± 182 pitches, and finally, reliever pitchers threw for 254 ± 77 pitches (Love, Aytar, Bush, & Uhl, 2010). These pitch differences were all found to be statistically significant ($p<0.001$) (Love, Aytar, Bush, & Uhl, 2010). The study also concluded that based on this, it is evident that starting pitchers – which account for only 8% of D1 SEC collegiate pitchers – throw the greatest number of pitchers, while pitchers who combine to be starters and relievers – or about 92% of D1 SEC collegiate pitchers – throw significantly less (Love, Aytar, Bush, & Uhl, 2010).

In a study conducted on MLB pitchers, researchers found the number of pitchers who pitched between 901 and 1200 pitches per season was relative to the number of pitchers who threw 301 to 600 pitches per season. The number of pitchers that threw 901 – 1200 pitches in a season was 540, while the number of pitchers that threw 301 – 600 pitchers in a single season was 546, respectively (Karakolis, Bhan, & Crotin, 2013). This shows that while the number of pitches a pitcher throws may be significantly different, the number of pitchers who are starters compared to relievers and/or closers is very close, with a difference of 6 pitchers.

ERA, or earned run average, is another performance measure for pitchers. As the name implies, ERA implies on average, how many runs the pitcher allows in per pitching appearance. Therefore, the lower the pitcher's ERA is, the better the performance is against opponents. The greatest influence on ERA is the rate of injury a pitcher has, and whether or not he has undergone Ulnar Collateral Ligament (UCL) surgery, or commonly called "Tommy John" surgery, or, if the pitcher in question has undergone UCL revision (UCL-R) surgery. In a study conducted by Marshall, Keller, Lynch, Bey, and Moutzouros (2015), the authors compared pitchers in the MLB who had undergone UCL-R surgery to pitchers who were compared to a group of pitchers who had not undergone UCL or UCL-R surgery. The study concluded that pitchers who returned to the MLB after UCL-R surgery had similar ERAs compared with the control group, in which no significant differences were found between groups. Although no significant differences in ERA were found, overall the group that underwent UCL-R surgery had several declines in other areas of performance including but not limited to, innings pitched, wins and losses, and pitching workload, which indicates a lowered pitch count, playing time, and overall a shortened career. In terms of innings pitched, the control group pitched an average of 75.0 innings after 3 years after their original UCL revision surgery, while those in the UCL-R category pitched an average of 36.95 innings ($p < 0.01$). This indicates an average drop of over 50% of innings pitched, which also indicates that pitch count, gam es played, and wins/losses all decreased after UCL-R surgery and returned to play in MLB. In addition to the overall decline in performance, the rate of pitchers having UCL-R surgery and then returning to the majors or minors to continue their careers was 84.8%, however, only 65.5% of those pitchers ended up back in the MLB (Marshall, Keller, Lynch, Bey, & Moutzourous, 2015).

Both collegiate and major league baseball thrive off of pitching velocity. The faster the ball it thrown, the faster it reaches home plate and the catcher's glove 60.5 feet away, and the more likely the batter will not be able to hit the 90-mph (miles per hour) ball in the 0.9859 seconds it takes to reach home plate. Due to this relationship, it is crucial that collegiate and major league pitchers throw at a high velocity. It is not uncommon to see fastballs pitched at 95 – 100 miles per hour, which would reach home plate between 0.934 and 0.887 seconds; or have other pitches such as breaking and curveballs thrown at 85 – 90 mph, which would reach home plate between 1.0439 and 0.9859 seconds. Although this high velocity is crucial to striking out batters, keeping pitch count down and innings pitched up (if the pitcher continuously strikes out batters with a relatively low pitch count per inning), pitching at a constant high velocity is a risk factor for overuse injury, fatigue, and inferior kinematics for pitchers (Chalmers, Erickson, Ball, Romeo, & Verma, 2016; Marshall, Keller, Lynch, Bey, & Moutzourous, 2015; Grantham, Byram, Meadows, & Ahmad, 2014; Karakolis, Bhan, & Crotin, 2013).

With a high pitch velocity sustained over a long period of time, the elbow experiences routine stress in which the elbow is constantly exceeding the load to failure of the UCL. The excessive load to failure will result in UCL surgery, and UCL-R surgery (Chalmers, Erickson, Ball, Romeo, & Verma, 2016; Grantham, Byram, Meadows, & Ahmad, 2014; Marshall, Keller, Lynch, Bey, & Moutzourous, 2015). A study conducted in MLB pitchers found that a higher pitch velocity was the most predictive factor for

UCL-R surgery. The study concluded that among pre-injury pitchers, peak pitch velocity and average pitch velocity was higher than the control group of pitchers. Pitchers who threw an average of 81.4 mph or lower were found to need UCL-R surgery in 7.8% of those pitchers, while pitchers who threw an average of 91.0 mph or higher, 18.3% were found to need UCL-R surgery (Chalmers, Erickson, Ball, Romeo, & Verma, 2016). This indicates that in order to reduce injury, and keep a high level of performance, pitchers need to reduce the speed they are pitching at.

In terms of the relationship between high pitch velocity and kinematics, velocity and fatigue, and kinematics and fatigue, Grantham, Byram, Meadows, & Ahmad (2017) found that a high volume of playing time results in excessive throwing, which in turn predisposes pitchers to overuse injuries. When the pitcher has muscular fatigue during a game appearance, pitching mechanics will decrease because it is more difficult to maintain the correct movement patterns, which increases susceptibility to overuse injuries, and injuries in general (Barnett, 2006). Contrary to belief that as a pitcher's fatigue increases, his velocity decreases, there was not a significant decrease in velocity from the beginning of a pitcher's appearance to the end of that appearance, despite fatigue increasing (Grantham, Byram, Meadows, & Ahmad 2017). The researchers also concluded that velocity is a contributor to the high rate of baseball injuries (Grantham, Byram, Meadows, & Ahmad 2017).

Finally, kinematics and fatigue have the strongest relationship. Understanding kinematics is crucial to biomechanists, exercise physiologists, practitioners, coaches, and baseball players alike because it allows us to fully understand how the pitcher is pitching, and how his mechanics will influence all other pitching performance factors. As stated earlier, as a pitcher's muscular fatigue increases during his game, the optimal pitching mechanics decline. If this is broken down by innings, long innings (identified as more than 15 pitches per inning) saw impaired kinematics as a proponent of fatigue in which the pitcher has increased stride length at foot contact, increased hip flexion during maximum external rotation and when the ball was released (Grantham, Byram, Meadows, & Ahmad 2017). Over the course of a game, which was indicated by an average of 6.3 innings, with a standard deviation of 1.6 innings, fatigue increased, while, as stated before, pitching velocity did not decrease (Grantham, Byram, Meadows, & Ahmad 2017). However, we also know that while pitching velocity did not decrease, the kinematics to uphold ideal pitching mechanics may have decreased, resulting in an increased risk of injury, because with poor mechanics, the arm is strained more. In addition to this, the study concluded that if a pitcher were to throw more than 80 pitches in one game, their risk of surgery due to injury would increase 4 times (Grantham, Byram, Meadows, & Ahmad 2017).

Injuries

Baseball, like any other sport, has injuries associated with it, since repeated overhead throwing can alter player's range of motion (ROM) which contributes to shoulder injury. In fact, the shoulder is the most frequently injured body region in high school, college, and professional baseball players (Curcio et al., 2017).

The most prevalent injury among pitchers Ulnar Collateral Ligament (UCL) or "Tommy John" surgery. UCL surgery is a reconstructive surgery of the UCL which allows pitchers and other overhead throwing athletes to return and continue to play at an elite level, such as D1 or professional leagues (Marshall, Keller, Lynch, Bey, & Moutzouros, 2015). In a study conducted on MLB players who had undergone UCL and UCL-R surgery, pitchers who underwent their first UCL surgery were 28.5 ± 4.0 years old, and the average time in between surgeries was 4.73 years (Marshall et. al., 2015). The study concluded that pitchers who have UCL-R surgery have a limited return to play in the MLB which includes a decreased workload, meaning fewer innings pitched, pitch count, and overall games played (Marshall et. al., 2015). In addition, pitching performance for each player decreased after their UCL-R surgery, in which innings pitched significantly declined form an average of 67 to 39 innings, and overall games played also declined since both wins and losses both had a significant decline in them (Marshall et.al., 2015).

Since UCL and UCL-R surgeries are the most prevalent injuries in baseball pitchers, it is important to understand the rate at which these injuries occur at. One study done by Curcio et al. (2017) found that shoulder and elbow injuries are the leading causes of why players needed 21 or more days away from their sport. The study also found that almost 60% of shoulder injuries resulted from throwing, and 73% of those shoulder injuries occurred in baseball pitchers (Curcio et al., 2017). Therefore, if 60 baseball players had shoulder injuries, 43.8 of those 60 players would be pitchers, which is concerning for players, coaches, trainers, practitioners, and others involved in baseball. In addition to this, since starting college baseball pitchers throw for an average of 90 pitches per game and approximately 5.66 innings per game appearance, they are at a higher risk of injury. With this high pitch count, and how that relates to overuse injury, college baseball pitchers account for 21% of all injuries that occur in baseball (Love, Aytar, Bush, & Uhl, 2010).

Another study conducted by Karakolis, Bhan, and Crotin (2013), found a positive correlation between all cumulative work metrics, and injury days for the following baseball season. These cumulative work metrics were defined as games pitched during a single season (appearances), total innings pitched during a single season, total pitches thrown during a single season, average number of innings pitched per appearance during a full season, and average number of pitchers thrown per appearance during a full season. The study also found that peak injury rates occurred with 66 to 70 game appearances in MLB pitchers, which correlates to approximately one appearance every 2 to 2.5 games. With this injury rate, the authors concluded that when a pitcher throws to much, it can be detrimental to the pitcher's health (Karakolis, Bhan, & Crotin 2013).

With the large rate of injuries in baseball, with most occurring in baseball pitchers, it is imperative to explore how to first reduce these injuries in pitchers that are already in Division 1 or MLB and have shoulder and/or elbow injuries, and second how to prevent these injuries from occurring in future D1 and MLB pitchers, and pitchers who do not currently have any injuries. One way to reduce the rate of injury immediately is to reduce the amount of pitches that are thrown by each pitcher. Although limits have been set for professional pitchers of approximately 100 pitches for starting pitchers, these limits have been either decided arbitrarily, or based on thorough analyses not published in scientific literature. Due to this, current methods of limiting work is not an effective tool to prevent future injury (Karakolis, Bhan, & Crotin 2013). Other literature has determined that pitchers who throw at a high velocity need lower pitch counts, and are prime candidates for injury prevention (Chalmers, Erickson, Ball, Romeo, & Verma, 2016). Therefore, pitching coaches and general managers need to reduce the pitcher's pitch count, innings pitched, and overall pitches which may include pitches from practice, bull pen, and game appearance.

Another way to reduce the prevalence of injury is to reduce the velocity at which pitchers in Division 1 baseball and MLB pitchers throw at. As stated earlier, the higher the pitch velocity is, the more likely the pitcher is to have an injury occur. In fact, high pitch velocity is the most predictive factor of UCL-R surgery in MLB pitchers. In addition, pitchers who pitch an average of 81.4 mph or lower have a lower injury rate than those who pitch an average velocity of 91.0 mph or higher (Chalmers, Erickson, Ball, Romeo, & Verma, 2016). With this in mind, it may be suggested that by reducing pitch velocity, the rate of UCL surgery risk, and injury will also decrease.

In addition, recovery techniques are used frequently to reduce injury rates because techniques are used to enhance the rate of removal of blood lactate after high intensity exercise and reduce delayed onset muscle soreness (DOMS) (Barnett, 2006). The Spencer Technique in which the multistep process which uses muscle energy with post-isometric contraction and relaxation to stretch and go through the entire range of motion of the shoulder was used in one study to determine its effect on collegiate baseball players. The Spencer Technique was found to combat the potentially harmful effects of repeated throwing on the Glenohumeral joint (Curcio et al., 2017). Another study by Warren, Brown, Landers, & Stahura (2011) was aimed at between inning recovery methods in collegiate baseball pitchers. The study found that decreases in blood hydrogen ions (H^+) can allow for muscle recovery, which could allow for greater performance in subsequent activity. The results of three different in-between inning recovery methods determined that electromuscular stimulation (EMS) was the only method that had a significant decrease in blood lactic acid levels during the recovery period, and EMS was perceived by pitchers that is was the best recovery method (Warren, Brown, Landers, & Stahura, 2011). In addition, EMS provides the benefits of an active recovery without any cardiovascular strain on the body, which may allow the clearance of H^+ ions from the muscle without the use of glycogen stores to perform contractions (Warren, et. al., 2011). In addition to this, a study conducted by Barnett (2006) determined that a combination of both light recovery exercise and icing may lead to an enhanced 24-hour effect in shoulder strength for baseball pitchers. Therefore, by using the Spencer Technique, EMS, and light exercise recovery and icing the shoulder, the rate and risk of injury may decrease in baseball pitchers, which would ultimately increase performance.

With the age of pitchers who have UCL surgery becoming younger and younger, ages greater than the average UCL surgery age of 23.7 years old may be an indicator of greater performance because their bodies have not succumbed to needing reconstructive surgery. In addition to this, how long a pitcher has been pitching in the MLB can be an indicator of his performance. For instance, a New York Yankee, C.C. Sabathia, was drafted in 1998 by the Cleveland Indians and played with them until 2008 but has been playing with the New York Yankees since 2009. Due to his 19-year MLB pitching career, it is assumed that his performance is excellent, as his statistics show (MLB: CC Sabathia, 2017). Therefore, longer playing careers can be associated with greater performance in the MLB since it is uncommon for pitchers to have almost 20 years of consistent pitching.

With on field performance variables, it is important to remember that pitchers have a very demanding position in baseball where they are expected to pitch perfectly at a high velocity for about 100 pitches. However, while they are expected to do this for so long, their risk of overuse injury, UCL and UCL-R surgery risk increases, fatigue sets in, and their mechanics of pitching decrease. In order to reduce these negative effects associated with the cost of pitching, many injury prevention techniques have become available such as the Spencer Technique, electromuscular stimulation in between innings, passive recovery in which pitchers sit and relax, and multiple days off in between game appearances if the pitcher is a starting pitcher. In order to really reduce the rate and risk of injury, strict limits of pitch count and innings pitched need to be put in place based on scientific literature, and not arbitrarily like they are now. With these techniques to reduce the prevalence of injury, not only would we see more healthy pitchers, but their performance would also likely increase as well.

Although there is a substantial amount of literature on performance variables that influence MLB pitchers, there is not as much literature on variables that may or may not influence Division 1 collegiate baseball pitchers. This may be because few researchers want to study collegiate baseball, or they do not want to publish any research, and have it harm the draft status of certain baseball players. In addition to this, medical records which would indicate injury and surgery prevalence would be published, which again, could harm the draft status of collegiate baseball pitchers. Another limitation of this paper is that most literature associated with baseball comes from biomechanical studies, and not exercise physiology, or physiology studies on baseball players. Most literature from biomechanical studies will highlight injury rates and prevention of baseball pitchers, especially with UCL and UCL-R surgery, especially as it relates to fatigue and mechanics. Although this is very important, published literature is missing a large area in which physiologists and exercise physiologists can help determine how baseball player's performance can improved based on certain aspects of their game.

Other common limitations of studies were that although they had gathered data based on a season of college or MLB baseball, it was not representative of the entire year in which a baseball pitcher may throw. For instance, if a baseball player was a junior or senior in college and played fall ball, trained over the winter during pre-season, spring season, and went to a summer league before getting drafted in the MLB, certain studies would only look at his performance during the spring season, or when he threw his first pitch in the MLB without regards to what he did over the past year in terms of performance, and how to reduce injury risk and rate. In conclusion, the current literature reveals a lot of how to improve performance while reducing injury rates, however, more literature based on exercise physiology needs to be produced.

CHAPTER III

METHODS

Experimental Approach to the Problem

This study utilized a longitudinal design to evaluate the impact of summer league participation on subsequent collegiate regular season pitching performance. The researchers evaluated the performance of a cohort of Division 1 collegiate baseball pitchers during the 2018 Spring collegiate season, 2018 Summer League season, and the 2019 Spring collegiate season. Time served as the independent variable, whereas pitching performance outcomes served as the dependent variables. Specifically, the dependent variables included: pitch count per game, earned run average (ERA) per game, innings pitched per game, hits per game, runs per game, and strikeouts per game, ERA per season, number of wins and losses, total pitches per season, and relative metrics of pitching performance.

Subjects

The sample was composed of pitchers from the ACC, BIG 10, BIG 12, PAC-12, and SEC who were on a Division 1 baseball team roster during the 2018 and 2019 Spring seasons and played in the CCBL during the 2018 summer season. Out of 119 Power 5 Conference pitchers, 37 qualified for the study. Those 37 pitchers only participated in the CCBL during Summer 2018, with no prior summer league experience in Summer 2017. Additionally, players were removed from the study if the they left the CCBL to participate in other baseball activities (e.g., USA baseball team or private training).

Furthermore, to be eligible to participate in this study the collegiate student-athletes were required to meet NCAA academic requirements for eligibility (NCAA, 2019) (Appendix, A).

Procedures:

The following metrics were collected on every pitcher on a Power 5 Conference team that was active on a team roster for the 2018 and 2019 seasons and participated in the 2018 CCBL: pitcher's name, game date, opponent, number of pitches per game, earned runs average (ERA) per game, wins, loss, type of pitcher (starter, reliever, or closer), innings pitched per game, hits per game, runs per game, earned runs per game, and strikeouts per game. Since more than one pitcher typically pitched in each game, the principal investigator (PI) noted which player pitched first, second, third, etc. and each player's metrics were recorded (Appendix B). For data analysis, each player's name was removed, and a code was used to identify each player. Pitchers were also stratified by pitching designation (i.e., starter, reliever, or closer) and academic ranking (i.e., freshman, sophomore, or junior). Institutional Review Board approval was not required because these data were publicly reported by the players academic institution and summer baseball league.

The number of pitches, wins, losses, type of pitcher, innings pitched, hits, runs, earned runs, and strikeouts were determined by box scores posted online by the school at the conclusion of each game. ERA per game was determined by multiplying the earned runs variable by 9, then divided by innings pitched. For example: 1 Earned Run over 1 Inning Pitched would equal a game ERA of 9.0 [(1*9)/1]. The innings pitched and earned runs were determined from online publication or via a hard copy box score issued by the school. In the event that the online or hard copy box score output did not include number of pitches, the PI searched the opponent's athletic department's website to determine if that school reported number of pitches. Data were reported as missing if both schools did not report number of pitches thrown. 5.25% of the data were coded as missing.

Statistical Analysis

Basic descriptive statistics (mean $\pm$ standard deviation) were used to assess the central tendency and dispersion for all dependent variables. Separate mixed factor repeated measures analysis of variance were used to identify main effects for time (2018 vs. 2019) and group (i.e., time vs. pitcher category; time vs. academic cohort; and time vs. pitching handedness) and associated interaction effects for pitching outcomes (i.e., ERA, win to loss ratio, pitch count, strikeouts, pitches per strikeout, hits, pitches per hit, runs, pitches per run, earned runs, pitches per earned runs). In addition, repeated measures analyses of variance were used to compare pitching outcomes within the entire cohort, by pitcher category, and by academic rank across two collegiate baseball seasons. Partial eta squared was used to calculate effect sizes. Small, medium, and large effect sizes were defined as $\leq$ .01, .01-.13, and $\geq$.13, respectively. Statistical power was also reported for all ANOVA outcomes. Normality of dependent variables was assessed via Fisher's Coefficient of Skewness (i.e., Fisher's Coefficient of Skewness = skewness statistic / standard error of skewness). A Fisher's skewness coefficient less than the absolute value of 1.96 was defined as a normal distribution. The level of significance was set at $p < 0.05$ for all analyses. The smallest worthwhile change was used to determine if there was a favorable (F) or unfavorable (U) practical change over time for each pitching metric for each analysis. Smallest worthwhile change was calculated by taking the 2019 standard deviation of each metric and multiplying it by 1/5 (Hopkins, 2004). As an equation: $2019\ Standard\ Deviation\ x \left({}^{1}/_{5}\right)$ for each pitching metric. To calculate the relative change in pitching metrics from the 2018 to the 2019 collegiate baseball season percent change scores were used. Percent change was calculated by taking the mean of 2019 minus the mean of 2018, divided by the mean of 2018, and multiplied by 100. As an equation: $\left(\frac{(mean\ 2018 - mean\ 2019)}{mean\ 2018}\right) x\ 100$, for each individual pitching metric, for all analyses. The Statistical Software Package for Social Sciences (SPSS, version 26) was used to process all statistical analyses.

CHAPTER IV

RESULTS AND DISCUSSION

Results

Table 1 displays a between subjects' comparison of pitching outcomes by pitcher designation between 2018 versus 2019 collegiate seasons. Descriptive data are provided in subsequent tables. The analysis indicated a main effect of group for number of pitches thrown ($F(2,34) = 5.999$, $p = 0.006$), innings pitched ($F(2,34) = 5.82$, $p = 0.007$), and strikeouts ($F(2,34) = 7.681$, $p = 0.002$). Specifically, with the two time points collapsed, starters yielded more pitches, innings pitched, and strikeouts than relievers and.

Table 1. Comparison of between subjects effects of pitching outcomes by pitcher designation in 2018 and 2019 collegiate seasons.

Type of Pitcher: Starter, Reliever, Closer				
Variable	F stat	p-value	ES	Power
Number of pitches	5.999	0.006	0.261 (L)	0.852
ERA	2.388	0.107	0.123 (L)	0.449
Wins	0.51	0.605	0.029 (M)	0.127
Losses	0.01	0.99	0.001 (S)	0.051
Innings Pitched	5.82	0.007	0.255 (L)	0.84
Hits	3.422	0.044	0.168 (L)	0.604
Runs	1.613	0.214	0.087 (M)	0.317
Earned Runs	1.259	0.297	0.069 (M)	0.255
Strikeouts	7.681	0.002	0.311 (L)	0.929

ES: Effect Size; S: Small Effect Size; M: Medium Effect Size; L: Large Effect Size; ERA: Earned run average.

A longitudinal (within subjects) comparison of collegiate pitching outcomes over time in the entire sample (all pitching categories) are presented in Table 2. The results indicated that, despite no difference in pitch count per game, there were main effects for time as pitchers significantly decreased season ERA by 3.87 (F (37,1) = 5.589; p = 0.024; Large ES), increased the number of strikeouts per game by 0.96 (F(37,1) = 7.187; p = 0.011; Large ES), and decreased the number of pitches per strikeout (F(37,1) = 4.846; p = 0.034; Medium ES). Despite small to medium effect sizes, there were no significant differences among the remaining pitching outcomes.

Table 2. Longitudinal comparison of pitching performance outcomes in 37 collegiate baseball pitchers who participated in a 2018 summer baseball league.

	2018			2019					
	Mean	±	SD	Mean	±	SD	P-value	Effect Size (MD)	Power
Number of Pitches	47.07	±	22.75	52.89	±	29.14	0.263	0.035 (M)	0.198
ERA	12.54	±	12.40	8.67	±	6.79	0.024	0.134 (L)	0.633
W	2.97	±	2.05	3.43	±	2.51	0.340	0.025 (M)	0.156
L	2.38	±	1.83	2.00	±	2.08	0.375	0.022 (M)	0.141
Innings Pitched	2.57	±	1.47	3.06	±	1.94	0.153	0.056 (M)	0.295
Hits	2.78	±	1.60	2.80	±	1.65	0.946	0.001 (S)	0.051
Runs	1.60	±	0.91	1.60	±	0.89	0.996	0.001 (S)	0.050
Earned Runs	1.38	±	0.82	1.36	±	0.76	0.920	0.001 (S)	0.051
Strikeouts	2.48	±	1.24	3.44	±	2.12	0.011	0.166 (L)	0.742
NP/IP	16.56	±	3.90	16.68	±	2.53	0.861	0.031(M)	0.053
NP/H	17.11	±	5.82	18.95	±	3.99	0.096	0.075 (M)	0.383
NP/R	30.59	±	13.09	33.26	±	10.25	0.303	0.029 (M)	0.174
NP/ER	35.94	±	15.44	39.87	±	14.87	0.265	0.034 (M)	0.197
NP/K	18.02	±	6.41	15.86	±	4.90	0.034	0.119 (M)	0.572

MD: Effect size magnitude descriptor; S: Small effect size; M: Medium effect size; L: Large effect size. NP/IP: season number of pitches divided by season number of innings pitched; NP/H: season number of pitches divided by season number of hits given up; NP/R: season number of pitches divided by season number of runs given up; NP/ER: season number of pitches divided by season number of earned runs; NP/K: season number of pitches divided by season number of strikeouts.

The pitchers' performance outcomes over time were further analyzed by pitcher classification (starter, reliever, & closer). Table 3 displays a longitudinal comparison of pitching performance outcomes among 15 starting pitchers who participated in a 2018 summer baseball league. Despite no difference in pitch count per game, starting pitchers significantly decreased season earned runs by 0.46 ($F(1,14) = 5.17$, $p = 0.039$; Large ES). There was a large, but nonsignificant effect for decreased hits per game among starting pitchers ($F(1,14) = 4.45$, $p = 0.053$; Large ES). Despite medium to large effect sizes among other pitching outcomes, there were no significant differences among the remaining pitching outcomes.

Table 3. Longitudinal comparison of pitching performance outcomes in 15 collegiate starting pitchers who participated in a 2018 summer baseball league.

	2018			2019					
	Mean	±	SD	Mean	±	SD	P-value	Effect Size (MD)	Power
Number of Pitches	68.27	±	19.23	59.66	±	27.71	0.292	0.079 (M)	0.175
ERA	11.63	±	10.87	7.49	±	4.88	0.096	0.186 (L)	0.384
W	3.87	±	2.30	3.33	±	2.35	0.532	0.028 (M)	0.092
L	3.13	±	1.92	2.13	±	2.29	0.165	0.133 (L)	0.276
Innings Pitched	3.91	±	1.30	3.61	±	1.95	0.604	0.020 (M)	0.079
Hits	4.27	±	1.21	3.31	±	1.88	0.053	0.241 (L)	0.501
Runs	2.37	±	0.79	1.90	±	0.95	0.092	0.189 (L)	0.392
Earned Runs	2.04	±	0.73	1.58	±	0.77	0.039	0.270 (L)	0.562
Strikeouts	3.39	±	1.23	3.48	±	1.69	0.875	0.002 (S)	0.053
NP/IP	15.28	±	2.91	16.87	±	2.28	0.109	0.173 (L)	0.357
NP/H	15.72	±	5.51	19.35	±	3.32	0.012	0.372 (L)	0.764
NP/R	26.85	±	7.10	33.09	±	9.64	0.082	0.200 (L)	0.415
NP/ER	31.89	±	11.23	39.48	±	12.15	0.081	0.202 (L)	0.418
NP/K	19.67	±	4.57	17.72	±	4.57	0.235	0.099 (M)	0.212

MD: Effect size magnitude descriptor; S: Small effect size; M: Medium effect size; L: Large effect size. NP/IP: season number of pitches divided by season number of innings pitched; NP/H: season number of pitches divided by season number of hits given up; NP/R: season number of pitches divided by season number of runs given up; NP/ER: season number of pitches divided by season number of earned runs; NP/K: season number of pitches divided by season number of strikeouts.

Table 4 displays a longitudinal comparison of pitching performance outcomes among 16 collegiate relief pitchers who participated in a 2018 summer baseball league. Despite a nonsignificant trend of increased pitch count per game and innings pitched, relief pitchers significantly increased their strikeouts per game ($F_{(1,15)} = 9.57$, p =

0.007; Large ES). Although there were medium to large effect sizes among other pitching outcomes, there were no significant differences among the remaining pitching outcomes.

Table 4. Longitudinal comparison of pitching performance outcomes in 16 collegiate relief pitchers who participated in a 2018 summer baseball league.

	2018			2019					
	Mean	±	SD	Mean	±	SD	P-value	Effect Size (MD)	Power
Number of Pitches	32.89	±	10.30	44.87	±	29.10	0.105	0.165 (L)	0.365
ERA	14.18	±	14.38	10.19	±	8.62	0.202	0.106 (M)	0.239
W	2.56	±	1.71	3.38	±	2.47	0.191	0.111 (M)	0.250
L	1.81	±	1.47	1.63	±	2.03	0.788	0.005 (S)	0.058
Innings Pitched	1.66	±	0.61	2.44	±	1.73	0.064	0.211 (L)	0.465
Hits	1.77	±	0.99	2.31	±	1.45	0.250	0.087 (M)	0.202
Runs	1.05	±	0.57	1.32	±	0.86	0.292	0.074 (M)	0.176
Earned Runs	0.89	±	0.51	1.16	±	0.77	0.243	0.090 (M)	0.207
Strikeouts	1.80	±	0.79	3.15	±	2.27	0.007	0.389 (L)	0.824
NP/IP	16.15	±	3.00	16.41	±	2.57	0.799	0.004 (S)	0.057
NP/H	18.73	±	6.37	18.63	±	5.29	0.961	0.0 (S)	0.050
NP/R	33.36	±	16.98	33.34	±	12.25	0.997	0.0 (S)	0.050
NP/ER	39.26	±	18.95	40.59	±	19.18	0.848	0.003 (S)	0.054
NP/K	17.65	±	7.21	14.56	±	4.77	0.079	0.192 (L)	0.423

MD: Effect size magnitude descriptor; S: Small effect size; M: Medium effect size; L: Large effect size; NP/IP: season number of pitches divided by season number of innings pitched; NP/H: season number of pitches divided by season number of hits given up; NP/R: season number of pitches divided by season number of runs given up; NP/ER: season number of pitches divided by season number of earned runs; NP/K: season number of pitches divided by season number of strikeouts.

Table 5 displays a longitudinal comparison of pitching performance outcomes among 6 collegiate closers who participated in a 2018 summer baseball league. There were no significant differences in pitching outcomes in the closers between 2018 and 2019 collegiate seasons.

Table 5. Longitudinal comparison of pitching performance outcomes in 6 collegiate closing pitchers who participated in a 2018 summer baseball league.

	2018			2019					
	Mean	±	SD	Mean	±	SD	P-value	Effect Size (MD)	Power
Number of Pitches	31.85	±	10.11	57.35	±	32.50	0.084	0.480 (L)	0.413
ERA	10.45	±	11.86	7.55	±	5.36	0.398	0.146 (L)	0.118
W	1.83	±	1.47	3.83	±	3.37	0.144	0.375 (L)	0.291
L	2.00	±	2.10	2.67	±	1.75	0.363	0.167 (L)	0.130
Innings Pitched	1.64	±	0.75	3.33	±	2.28	0.101	0.447 (L)	0.371
Hits	1.76	±	0.44	1.83	±	1.41	0.148	0.368 (L)	0.285
Runs	1.16	±	0.54	1.61	±	0.71	0.342	0.181 (L)	0.138
Earned Runs	1.02	±	0.53	1.37	±	0.62	0.430	0.128 (M)	0.109
Strikeouts	2.05	±	0.83	4.11	±	2.83	0.119	0.413 (L)	0.332
NP/IP	20.84	±	5.58	16.92	±	3.36	0.063	0.530 (L)	0.484
NP/H	16.28	±	4.72	18.82	±	0.94	0.262	0.242 (L)	0.179
NP/R	32.52	±	12.53	33.47	±	6.73	0.893	0.004 (S)	0.052
NP/ER	37.23	±	14.11	38.95	±	8.49	0.794	0.015 (M)	0.056
NP/K	14.91	±	3.11	14.69	±	5.30	0.902	0.003 (S)	0.017

MD: Effect size magnitude descriptor; S: Small effect size; M: Medium effect size; L: Large effect size. NP/IP: season number of pitches divided by season number of innings pitched; NP/H: season number of pitches divided by season number of hits given up; NP/R: season number of pitches divided by season number of runs given up; NP/ER: season number of pitches divided by season number of earned runs; NP/K: season number of pitches divided by season number of strikeouts.

There were significant pitcher designation by time interaction effects for number of pitches ($F(1,29) = 5.999$, $p = 0.006$; Table 6), innings pitched ($F(1,29) = 5.82$, p =

0.007; Table 7), and strikeouts (F(1,29) = 7.681, p = 0.002; Table 8). Specifically, for number of pitches, starters threw more pitches than relievers and closers from 2018 to 2019 collegiate seasons (Table 6). For innings pitched, starters pitched more innings than starters and closers from 2018 to 2019 collegiate seasons (Table 7). Regarding strikeouts, starters accumulated more strikeouts than relievers and closers from 2018 to 2019 collegiate seasons (Table 8).

Table 6. Comparison of interaction effects for Pitches Thrown between starters, relievers, and closers from 2018 versus 2019 collegiate seasons.

	MD (2018 vs. 2019)	±	SD	Post hoc comparison (p<.05)
Starters	21.86	±	34.02	S > R,C
Relievers	-8.03	±	15.82	R < S
Closers	-12.29	±	24.86	C < S

MD: Mean difference. SD: Standard Deviation. S: Starters, R: Relievers, C: Closers.

Table 7. Comparison of interaction effects for Innings Pitched between starters, relievers, and closers from 2018 versus 2019 collegiate seasons.

	MD (2018 vs. 2019)	±	SD	Post hoc comparison (p<.05)
Starters	1.52	±	2.29	S > R,C
Relievers	-0.45	±	0.95	R < S
Closers	-0.59	±	1.34	C < S

MD: Mean difference. SD: Standard Deviation. S: Starters, R: Relievers, C: Closers.

Table 8. Comparison of interaction effects for Strikeouts between starters, relievers, and closers from 2018 versus 2019 collegiate seasons.

	MD (2018 vs. 2019)	±	SD	Post hoc comparison (p<.05)
Starters	2.17	±	2.35	S > R,C
Relievers	-0.07	±	0.68	R < S
Closers	-0.47	±	1.83	C < S

MD: Mean difference. SD: Standard deviation. S: Starters, R: Relievers, C: Closers.

Table 9 displays a between subjects comparison of pitching outcomes by academic cohort in 2018 and 2019 collegiate seasons. Descriptive data are provided in subsequent tables. The analysis indicated a main effect for group for losses ($F(1,34) = 5.76$, $p = 0.022$), hits ($F(1,34) = 6.374$, $p = 0.016$), and runs ($F(1,34) = 4.889$, $p = 0.034$). Specifically, the sophomore cohort yielded fewer losses, hits, and runs compared to the freshman cohort.

Table 9. Between subjects comparison of pitching outcomes by academic cohort from 2018 versus 2019 collegiate seasons.

	Academic Cohort: Fr to So, So to Jr			
Variable:	F stat	p-value	ES	Power
Number of Pitches	3.678	0.064	0.098 (M)	0.462
ERA	0.001	0.971	0.0 (S)	0.05
Wins	0.003	0.957	0.0 (S)	0.05
Losses	5.76	0.022	0.145 (L)	0.645
Innings Pitched	1.681	0.204	0.047 (M)	0.243
Hits	6.374	0.016	0.158 (L)	0.689
Runs	4.889	0.034	0.126 (L)	0.575
Earned Runs	3.973	0.054	0.105 (M)	0.491
Strikeouts	1.400	0.245	0.04 (S)	0.21

Fr to So: Freshman to Sophomore; So to Jr: Sophomore to Junior; ES: Effect Size; S: Small Effect Size; M: Medium Effect Size; L: Large Effect Size.

To evaluate the impact of summer league participation based on the academic classification of the pitcher, data were analyzed within academic cohorts. Table 10 displays a longitudinal comparison of pitching performance outcomes in 15 collegiate pitchers who participated in a 2018 summer baseball league who were classified as Freshmen in 2018 and Sophomores in 2019. The results indicated a significant increase in pitch count per game ($F(1,14) = 7.16$, $p = 0.018$; Large ES), innings pitched per game ($F(1,14) = 7.03$, $p = 0.019$; Large ES), hits ($F(1,14) = 5.91$, $p = .029$; Large ES), and strikeouts per game 1.48 ($F(1,14) = 12.47$, $p = 0.003$; Large ES). Despite throwing more pitches per game, there were no differences in runs or earned runs indicating enhanced pitching effectiveness.

Table 10. Longitudinal comparison of pitching performance outcomes in 15 collegiate pitchers who participated in a 2018 summer baseball league who were classified as Freshmen in 2018 and Sophomores in 2019.

	2018			2019						
	Mean	±	SD	Mean	±	SD	P-value	Effect Size (MD)	Power	Percent Change
Number of Pitches	43.98	±	22.04	61.22	±	27.11	0.018	0.338 (L)	0.702	39.2
ERA	12.78	±	10.61	8.60	±	6.51	0.113	0.169 (L)	0.350	-32.8 (F)
W	3.47	±	1.92	4.53	±	3.44	0.265	0.088 (M)	0.192	30.8 (F)
L	2.00	±	1.69	2.73	±	2.46	0.208	0.111 (M)	0.233	36.7 (U)
Innings Pitched	2.39	±	1.28	3.39	±	1.78	0.019	0.334 (L)	0.694	42.0 (F)
Hits	2.30	±	1.15	3.20	±	1.61	0.029	0.297 (L)	0.619	38.9 (U)
Runs	1.48	±	0.75	1.90	±	1.01	0.071	0.215 (L)	0.445	28.6 (U)
Earned Runs	1.33	±	0.75	1.66	±	0.83	0.110	0.172 (L)	0.356	25.0 (U)
Strikeouts	2.35	±	1.01	3.83	±	2.04	0.003	0.471 (L)	0.907	63.2 (F)
NP/IP	18.02	±	4.08	17.30	±	2.25	0.468	0.036 (M)	0.107	-4.0
NP/H	19.05	±	5.98	18.74	±	2.84	0.835	0.003 (S)	0.055	-1.6 (U)
NP/R	31.01	±	9.45	32.39	±	10.70	0.675	0.012 (M)	0.069	4.4 (F)
NP/ER	34.94	±	12.06	36.89	±	11.35	0.583	0.021 (M)	0.082	5.6 (F)
NP/K	18.57	±	6.40	16.70	±	4.27	0.134	0.143 (L)	0.317	-10.1(U)

F: favorable outcome direction; U: unfavorable outcome direction; MD: Effect size magnitude descriptor; S: Small effect size; M: Medium effect size; L: Large effect size; NP/IP: season number of pitches divided by season number of innings pitched; NP/H: season number of pitches divided by season number of hits given up; NP/R: season number of pitches divided by season number of runs given up; NP/ER: season number of pitches divided by season number of earned runs; NP/K: season number of pitches divided by season number of strikeouts.

Table 11 displays a longitudinal comparison of pitching performance outcomes in 21 collegiate pitchers who participated in a 2018 summer baseball league who were classified as Sophomores in 2018 and Juniors in 2019. The results indicated a significant decrease in losses ($F(1, 20) = 4.74$, $p = 0.042$; Large ES) and increased number of pitches relative to hits ($F(1,20) = 5.608$, $p = 0.028$; Large ES). Despite favorable trends and small to medium effect sizes, there were no significant differences among the remaining pitching outcomes from 2018 to 2019 seasons.

Table 11. Longitudinal comparison of pitching performance outcomes in 21 collegiate pitchers who participated in a 2018 summer baseball league who were classified as Sophomores in 2018 and Juniors in 2019.

	2018			2019						
	Mean	±	SD	Mean	±	SD	P-value	Effect Size (MD)	Power	Percent Change
Number of Pitches	49.54	±	24.00	47.06	±	30.43	0.740	0.006 (S)	0.062	-5.0
ERA	12.80	±	13.92	8.74	±	7.29	0.091	0.136 (L)	0.393	-31.7(F)
W	2.76	±	2.07	3.76	±	2.81	0.222	0.074 (S)	0.225	36.2 (F)
L	2.76	±	1.87	1.52	±	1.69	0.042	0.192 (L)	0.545	-44.8 (F)
Innings Pitched	2.71	±	1.64	2.82	±	2.09	0.824	0.003 (S)	0.055	4.3 (F)
Hits	3.16	±	1.82	2.53	±	1.71	0.165	0.094 (M)	0.279	-20.0 (F)
Runs	1.70	±	1.04	1.36	±	0.77	0.188	0.085 (M)	0.255	-19.6 (F)
Earned Runs	1.41	±	0.90	1.14	±	0.65	0.219	0.075 (M)	0.227	-19.4 (F)
Strikeouts	2.62	±	1.41	3.23	±	2.22	0.278	0.058 (M)	0.186	23.25 (F)
NP/IP	15.44	±	3.44	16.21	±	2.68	0.437	0.031 (M)	0.118	5.0
NP/H	15.63	±	5.37	19.11	±	4.75	0.028	0.219 (L)	0.615	22.2 (F)
NP/R	30.26	±	15.53	33.93	±	10.10	0.352	0.043 (M)	0.149	12.1 (F)
NP/ER	36.71	±	17.85	42.14	±	16.99	0.341	0.045 (M)	0.153	14.8 (F)
NP/K	17.60	±	6.55	15.22	±	5.34	0.128	0.112 (L)	0.327	-13.5 (U)

F: favorable outcome direction; U: unfavorable outcome direction; MD: Effect size magnitude descriptor; S: Small effect size; M: Medium effect size; L: Large effect size; NP/IP: season number of pitches divided by season number of innings pitched; NP/H: season number of pitches divided by season number of hits given up; NP/R: season number of pitches divided by season number of runs given up; NP/ER: season number of pitches divided by season number of earned runs; NP/K: season number of pitches divided by season number of strikeouts.

There were significant academic cohort by time interaction effects for losses ($F(1,35) = 0.852$, $p = 0.017$), hits ($F(1,35) = 2.762$, $p = 0.014$), and runs ($F(1,35) = 2.587$, $p = 0.026$). Specifically, for losses, the freshmen cohort accumulated a mean difference of .75 more losses from 2018 to 2019, whereas the sophomore cohort had 1.24 fewer losses from 2018 to 2019. For hits, the freshmen cohort allowed a mean difference of 0.88 more hits from 2018 to 2019, whereas the sophomore cohort decreased hits allowed by -0.63 from 2018 to 2019. Finally, for runs, the freshmen cohort allowed a mean difference of 0.43 more hits from 2018 to 2019, whereas the sophomore cohort allowed -0.33 fewer runs from 2018 to 2019.

Table 12 displays a longitudinal comparison of the percent change relative to the smallest worthwhile change (SWC) in pitching performance outcomes in 15 freshmen in 2018 and sophomores in 2019, and 21 sophomores in 2018 and juniors in 2019 collegiate pitchers who participated in a 2018 summer baseball league. These data indicate that ERA dropped for the F to S cohort, while W (wins) and Strikeouts increased. Additionally, it shows that ERA declined for the S to J cohort, as well as losses, hits, runs, and earned runs. While strikeouts increased for the cohort.

Table 12. Longitudinal comparison of the smallest worthwhile change (SWC) in pitching performance outcomes in 15 freshmen in 2018 and sophomores in 2019, to pitchers and 21 sophomores in 2018 and juniors in 2019 collegiate pitchers who participated in a 2018 summer baseball league.

	F to S Percent Change	S to J Percent Change	F to S SWC	S to J SWC
Number of Pitches	39.2	-5.0	5.4	6.1
ERA	-32.8	-31.7	1.3	1.5
W	30.8	36.2	0.7	0.6
L	36.7	-44.8	0.5	0.3
Innings Pitched	42.0	4.3	0.4	0.4
Hits	38.9	-20.0	0.3	0.3
Runs	28.6	-19.6	0.2	0.2
Earned Runs	25.0	-19.4	0.2	0.1
Strikeouts	63.2	23.3	0.4	0.4
NP/IP	-4.0	4.95	11.3	13.4
NP/H	-1.6	22.3	14.2	23.7
NP/R	4.4	12.1	53.5	50.5
NP/ER	5.6	14.8	56.7	85.0
NP/K	-10.1	-13.5	21.4	26.7

F to S: Academic Freshmen 2018 to Academic Sophomore 2019; S to J: Academic Sophomore 2018 to Academic Junior 2019; SWC: smallest worthwhile change.

Table 13 displays a comparison of pitching outcomes by arm dominance in 2018 versus 2019 collegiate seasons. Descriptive data are provided in subsequent tables. The analysis indicated a main effect of group for wins ($F(1,35) = 5.253$, $p = 0.028$) and earned runs ($F(1,35) = 5.689$, $p = 0.023$). Specifically, RHP yielded more wins and earned runs than LHP.

Table 13. Between subjects comparison of pitching outcomes by arm dominance from 2018 and 2019 collegiate seasons.

Pitching Hand: RHP, LHP				
Variable:	F stat	p-value	ES	Power
Number of Pitches	1.386	0.247	0.038 (M)	0.209
ERA	2.156	0.151	0.058 (M)	0.298
Wins	5.253	0.028	0.13 (L)	0.606
Losses	0.78	0.383	0.022 (M)	0.138
Innings Pitched	2.302	0.138	0.062 (M)	0.314
Hits	2.516	0.122	0.067 (M)	0.338
Runs	2.02	0.164	0.055 (M)	0.282
Earned Runs	5.689	0.023	0.14 (L)	0.64
Strikeouts	1.628	0.21	0.044 (M)	0.237

RHP: Right-handed pitcher; LHP: Left-handed pitcher; ES: Effect Size; M: Medium Effect Size; L: Large Effect Size.

Pitching performance by arm dominance was evaluated to determine if pitching performance following summer league baseball participation was similar in right versus left-handed pitchers. Table 14 displays a longitudinal comparison of pitching performance outcomes in 23 right-handed collegiate pitchers who participated in a 2018 summer baseball league. These results indicated that despite no change in pitch counts per game, RHP increased the number of innings pitched per game ($F(1,22) = 4.61$, $p = 0.043$; Large ES), season wins ($F(1,22) = 13.86$, $p = 0.001$; Large ES), and strikeouts per game ($F(1,22) = 8.49$, $p = 0.008$; Large ES). Despite small to large effect sizes, there were no significant differences among the remaining pitching outcomes.

Table 14. Longitudinal comparison of pitching performance outcomes in 23 right-handed collegiate pitchers who participated in a 2018 summer baseball league.

	2018			2019						
	Mean	±	SD	Mean	±	SD	P-value	Effect Size (MD)	Power	Percent Change
Number of Pitches	42.13	±	21.19	52.62	±	30.55	0.116	0.108 (M)	0.346	24.9 (F)
ERA	11.16	±	12.50	9.14	±	7.76	0.349	0.040 (M)	0.150	-18.1 (F)
W	2.65	±	1.85	4.65	±	2.76	0.001	0.387 (L)	0.945	75.4 (F)
L	2.22	±	1.78	2.13	±	2.05	0.859	0.001 (S)	0.053	-3.9 (F)
Innings Pitched	2.27	±	1.31	3.14	±	2.05	0.043	0.173 (L)	0.537	38.4 (F)
Hits	2.44	±	1.63	2.84	±	1.74	0.304	0.048 (M)	0.172	16.3 (U)
Runs	1.40	±	0.98	1.59	±	0.91	0.426	0.029 (M)	0.121	13.5 (U)
Earned Runs	1.13	±	0.81	1.38	±	0.81	0.205	0.072 (M)	0.239	22.1 (U)
Strikeouts	2.24	±	1.09	3.55	±	2.11	0.008	0.278 (L)	0.795	58.4 (F)
NP/IP	15.68	±	2.64	16.33	±	2.49	0.389	0.034 (M)	0.134	4.1 (F)
NP/H	18.43	±	6.41	18.60	±	3.67	0.899	0.001 (S)	0.052	0.9 (F)
NP/R	32.49	±	14.96	33.52	±	10.31	0.766	0.004 (S)	0.060	3.2 (F)
NP/ER	39.32	±	17.10	38.73	±	12.79	0.885	0.001 (S)	0.052	-1.5 (U)
NP/K	17.72	±	6.16	15.18	±	4.53	0.031	0.195 (L)	0.597	-14.4 (U)

F: favorable outcome direction; U: unfavorable outcome direction; MD: Effect size magnitude descriptor; S: Small effect size; M: Medium effect size; L: Large effect size; NP/IP: season number of pitches divided by season number of innings pitched; NP/H: season number of pitches divided by season number of hits given up; NP/R: season number of pitches divided by season number of runs given up; NP/ER: season number of pitches divided by season number of earned runs; NP/K: season number of pitches divided by season number of strikeouts.

Table 15 displays a longitudinal comparison of pitching performance outcomes in 14 left-handed collegiate pitchers who participated in a 2018 summer baseball league. The results indicated that despite no change in pitch count per game, pitchers significantly decreased ERA ($F(1,13) = 7.92$, $p = 0.015$; Large ES; Table 8), while decreasing earned runs per game ($F(1,13) = 4.76$, $p = 0.048$; Large ES; Table 8). Results also show that pitchers increased their number of pitches divided by hits ($F(1,13) = 8.05$, $p = 0.014$; Large ES; Table 8). Despite mostly medium to large effect sizes, there were no significant differences among the remaining pitching outcomes.

Table 15. Longitudinal comparison of pitching performance outcomes in 14 left-handed collegiate pitchers who participated in a 2018 summer baseball league.

	2018			2019						
	Mean	±	SD	Mean	±	SD	P-value	Effect Size (MD)	Power	Percent Change
Number of Pitches	55.18	±	23.64	53.32	±	27.78	0.827	0.004 (S)	0.055	-3.4 (F)
ERA	14.80	±	12.35	7.90	±	4.97	0.015	0.378 (L)	0.739	-46.7 (F)
W	3.50	±	2.31	2.93	±	3.34	0.625	0.019 (M)	0.075	-16.3 (U)
L	2.64	±	1.95	1.79	±	2.19	0.298	0.083 (M)	0.171	-32.4 (F)
Innings Pitched	3.08	±	1.62	2.93	±	1.79	0.789	0.006 (S)	0.057	-4.9 (F)
Hits	3.34	±	1.42	2.74	±	1.57	0.264	0.095 (M)	0.191	-18.0 (F)
Runs	1.94	±	0.69	1.63	±	0.90	0.215	0.116 (M)	0.227	-16.1 (F)
Earned Runs	1.79	±	0.67	1.34	±	0.69	0.048	0.268 (L)	0.524	-25.2 (F)
Strikeouts	2.89	±	1.39	3.26	±	2.19	0.522	0.032 (M)	0.094	13.1 (F)
NP/IP	18.00	±	5.16	17.25	±	2.57	0.596	0.022 (M)	0.080	-4.1 (U)
NP/H	14.94	±	4.03	19.52	±	4.55	0.014	0.382 (L)	0.747	30.7 (F)
NP/R	27.46	±	8.89	32.85	±	10.52	0.186	0.130 (L)	0.253	19.6 (F)
NP/ER	30.39	±	10.57	41.76	±	18.14	0.076	0.222 (L)	0.431	37.4 (F)
NP/K	18.52	±	7.01	16.99	±	5.42	0.436	0.047 (M)	0.116	-8.3 (U)

F: favorable outcome direction; U: unfavorable outcome direction; MD: Effect size magnitude descriptor; S: Small effect size; M: Medium effect size; L: Large effect size; NP/IP: season number of pitches divided by season number of innings pitched; NP/H: season number of pitches divided by season number of hits given up; NP/R: season number of pitches divided by season number of runs given up; NP/ER: season number of pitches divided by season number of earned runs; NP/K: season number of pitches divided by season number of strikeouts.

There were significant arm dominance by time interaction effects for wins ($F(1,35) = 3.875$, $p = 0.028$) and earned runs ($F(1,35) = 0.008$, $p = 0.023$). Specifically, for wins, the right-handed pitchers accumulated 2.00 more wins from 2018 to 2019, whereas the left-handed pitchers produced -0.57 fewer wins from 2018 to 2019. For earned runs, right-handed pitchers gave up 0.25 more earned runs from 2018 to 2019, whereas left-handed pitchers yielded -0.45 fewer earned runs from 2018 to 2019.

Table 16 displays a longitudinal comparison of percent change and the smallest worthwhile change (SWC) in pitching performance outcomes in 23 right-handed and 14 left-handed collegiate pitchers who participated in a 2018 summer baseball league. RHP had a percent change greater than the SWC for number of pitches, wins, innings pitched, hits, runs, earned runs, and strikeouts. RHP also had a percent change less than the SWC in earned runs average (ERA) and losses. This means that RHP increased their number of pitches, wins, innings pitched, and strikeouts which decreasing their ERA and losses which are all beneficial to the pitcher. However, RHP also increased their hits, runs, and earned runs which means that compared to 2018, in 2019, those pitchers gave up more hits, runs, and earned runs, despite decreasing their ERA. Results also showed that LHP had a percent change greater than the SWC in strikeouts and number of pitches divided by hits. LHP also had a percent change less than the SWC in ERA, wins, losses, innings pitched, hits, runs, and earned runs. This means that LHP beneficially decreased their ERA, losses, hits, runs, and earned runs while beneficially increasing their strikeouts and number of pitches divided by hits, which means that they increased their amount of pitches before a player got a hit.

Table 16. Longitudinal comparison of the smallest worthwhile change (SWC) in pitching performance outcomes in 23 right-handed and 14 left-handed collegiate pitchers who participated in a 2018 summer baseball league.

	RHP	LHP	RHP	LHP
	Percent Change	Percent Change	SWC	SWC
Number of Pitches	24.9	-3.4	6.1	5.6
ERA	-18.1	-46.7	1.6	1.0
W	75.4	-16.3	0.6	0.7
L	-3.9	-32.4	0.4	0.4
Innings Pitched	38.4	-4.9	0.4	0.4
Hits	16.3	-18.0	0.3	0.3
Runs	13.5	-16.1	0.2	0.2
Earned Runs	22.1	-25.2	0.2	0.1
Strikeouts	58.4	13.1	0.4	0.4
NP/IP	4.15	-4.14	12.5	12.9
NP/H	0.93	30.65	18.3	22.7
NP/R	3.16	19.61	51.5	52.6
NP/ER	-1.52	37.40	63.9	90.7
NP/K	-14.37	-8.26	22.7	27.1

RHP: right-handed pitcher; LHP: left-handed pitcher; SWC: smallest worthwhile change.

Discussion

The purpose of this study was to provide a longitudinal profile of pitching performance in a cohort of pitchers over two collegiate seasons and a summer league. We hypothesized that participation in summer league baseball would enhance subsequent collegiate pitching performance. Assessing the entire sample of pitchers indicated that earned run average, number of strikeouts, and strikeout efficiency significantly improved. These metrics can have a tangible effect on a team's performance. In addition, this study demonstrated that starting pitchers yielded more pitches, innings pitched, and strikeouts compared to relievers, and closers. Results also indicated that there was no difference in pitch volume metrics among relievers and closers. The notable changes with a pitching designation over time indicated that starting pitchers yielded fewer earned runs and enhanced run efficiency. Whereas, relief pitchers produced significantly more strikeouts. Finally, there were no differences in pitching outcomes for closers. However, despite large effect sizes for many of the outcome variables, the limited sample size for closers dramatically reduced statistical power to identify any potential differences.

On average, the present study's findings are similar to Love et al. (2010), in which they reported that starting pitchers threw more innings per appearance and number of pitches per appearance than relievers and closers. Love et al. (2010) also reported that "different types of pitchers throw significantly different amounts of pitches and participate in a significantly different number of innings over the course of a complete Spring collegiate baseball season" (p.198) (Love, Aytar, Bush, & Uhl, 2010). This agrees with Love et. al. (2010) and Karakolis, Bhan, & Crotin (2013) who indicated that the amount of pitches per season was relative to the pitcher's classification.

The present study descriptively compared pitching outcomes by academic status. There is no existing literature documenting changes in pitching performance by academic status. In regard to interaction effects, for academic cohort, the freshmen to sophomore cohort had more losses, hits, and runs, which means that they gave up more hits and runs, which could have attributed to more losses than the sophomore to junior cohort. The findings of the present study indicated that the freshmen cohort gave up an increased number of hits, however, they accumulated a greater mean game pitch count with no difference in (relative) pitching metrics accounting for this pitch count differential. Thus, it appears the increased absolute hit total was the result of throwing more pitches, not decreased pitching effectiveness. In fact, this cohort demonstrated similar pitching effectiveness despite an increased pitching volume. Regarding the sophomore cohort, they significantly decreased the number of losses per season. The magnitude of change was more than 1 loss per season, on average. This is a critical metric reflecting team performance and may indicate that more pitchers participating in summer league may augment the reduction in losses for a collegiate team in subsequent seasons.

To frame the present study's findings within the scope of meaningful and practical significance we conducted a SWC statistical analysis. As previously stated, unfavorable and favorable outcomes can help players and coaches know how their players can expect to play after participating in a summer baseball league, depending on academic cohort classification. As the results show, most pitching metrics in Table 10,11, 14, and, 15 were found to be in favorable outcome directions, despite only having one statistically significant outcome. This means that coaches who send players to the CCBL can expect similar results in their players who finished their sophomore year of academics before heading to summer collegiate baseball, and in the subsequent Spring season, are juniors. This may be more helpful for coaches and players when deciding what league to send their pitchers.

While there were no other significant findings, researchers noted that there were many favorable and unfavorable outcomes that players, coaches, and athletic administrators would view as valuable regarding how their players can expect to perform after participating in summer collegiate baseball league depending on academic cohort classification. Therefore, we categorized these trends as either F (favorable outcome direction) or U (unfavorable outcome direction). ERA (earned runs average), wins, innings pitched, and strikeouts were all favorable outcome directions because it shows that pitchers were trending towards decreasing their season ERA, increasing wins, and increasing innings pitched. Number of pitches was statistically significant but not a favorable outcome direction because researchers did not categorize the cohort of Freshman to Sophomores by pitching class (starting, relief, or closing) because the sample size to do this was too small. Therefore, if a Freshman to Sophomore pitcher was a closer but increased his number of pitches metric, it would not be favorable. However, if a Freshman to Sophomore pitcher was a starting pitcher and increased his number of pitches metric, it would be favorable. The unfavorable outcome directions indicate pitching metrics that may reduce the team's performance. These directional metrics include increases in losses, hits, runs, and earned runs (despite a statically significant decrease in overall ERA).

Regarding influence of handedness on pitching performance, for interaction effects, right-handed pitchers had more wins than left-handed pitchers over time.

However, left-handed pitchers had less earned runs than right-handed pitchers. This is beneficial because less earned runs means less runs given up by the pitcher. Therefore, left-handed pitchers gave up less runs than right-handed pitchers over time, despite right-handed pitchers increasing their number of wins over time. although there were only three statistically significant findings, when researchers looked that the percent changes to deem if it was a favorable (F) or unfavorable (U) outcome direction, they noticed number of pitches, ERA (earned runs average), wins, losses, innings pitched, and strikeouts all resulted in the favorable outcome direction. The smallest worthwhile change (SWC) also indicates that the number of pitches, wins, innings pitched, hits, runs, earned runs, and strikeouts were all favorable for RHPs, and this means that number of pitches, wins, innings pitched, and strikeouts showed favorable outcomes, while losses and ERA showed unfavorable outcomes. Hits, runs, and earned runs all had increasing trends which is unfavorable to the pitcher because it notes that he is giving up more hits, runs, and earned runs, despite overall ERA decreasing.

LHP produced a lower ERA and fewer runs allowed. Although there were only two statistically significant findings, when researches looked at the percent change to deem if it was a favorable (F) or unfavorable (U) outcome direction, they noticed number of pitches, ERA, losses, innings pitched, hits, runs, earned runs, and strikeouts all resulted in the favorable outcome direction, while wins was the only metric that resulted in an unfavorable outcome direction. The smallest worthwhile change also indicated that the number of pitches, strikeouts, and number of pitches divided by hits were all favorable for LHPs.

Given the exploratory nature of this study, additional research is warranted on the efficacy of summer league baseball participation on subsequent collegiate pitching performance. For instance, it would be interesting to compare performance outcomes due to participating in different summer leagues. This information would help coaches determine where they should send players to enhance their development.

Limitations

There are several limitations of the present study. First, a true control group was not utilized. Thus researchers cannot say for certain that changes in pitching performance are due solely to the effects of participation in a summer baseball league. It is possible that pitching outcomes may also be due to confounding factors such as individual coaching instruction, quality of collegiate competition, pitcher's physical maturation and experience, etc. Unfortunately, it was not feasible to create a control group for this study because it is almost impossible to identify collegiate pitchers who did not participate in other summer baseball leagues, individual and/or unstructured summer workouts and bullpen programs. In addition, several universities did not publish game pitch counts. In these cases, data for pitchers included in this study were coded as missing and not usable in the statistical analysis. In the present study 5.25% of game pitch count data were missing.

Practical Applications

The findings from this study indicate that most pitchers improved some pitching metrics due to participation in a summer baseball league, thus, it is important to note that participating in summer baseball league did not produce negative pitching outcomes. Although we are unable to parcel out the independent contribution of player maturation and experience on these improved performance outcomes, it seems reasonable to recommend that coaches should encourage their pitchers to participate in summer baseball leagues. These leagues provide players with access to coaches who can provide feedback on pitching mechanics and offer additional in-game experience. Despite the benefits of participating in summer league baseball, it is important that coaches apply appropriate loading parameters regarding pitch counts to minimize the risk of soft tissue injuries to these pitchers.

CHAPTER V

SUMMARY AND CONCLUSIONS

In general, participation in a summer baseball league may have enhanced pitching outcomes in the subsequent collegiate baseball season. Specifically, overall, pitchers participating in the summer baseball league improved their ERA and number of strikeouts per game. These are critical metrics that are related to the outcome of a game.

Although it was not measured, researchers can speculate based on past experience that many pitchers leave a summer baseball league and enter the subsequent Spring season (in this study it was the Spring 2019 season) with better command of their pitches, and better ability to control the game. As a result, pitchers may pitch more innings, produce more strikeouts, yield fewer less hits, runs, and earned runs, and decrease their earned runs average (ERA) over the course of the subsequent Spring season.

APPENDIX A

DIVISION 1 PROGRESS TOWARDS DEGREE REQUIREMENTS, VIA NCAA

- Home
- About

Division I Progress-Toward-Degree Requirements

Progress-toward-degree requirements are designed to guide student-athletes toward graduation. The standards help student-athletes take the appropriate steps toward earning their degree. Standards include minimum grade-point average, term-by-term and annual credit hour requirements, and percentage-of-degree requirements. Student-athletes who do not meet the requirements are not eligible for competition; however, a progress-toward-degree waiver may be filed to possibly regain eligibility (Academic Waivers). Two-year and four-year transfer student-athletes also are required to meet certain progress-toward-degree benchmarks at the time of transfer. Additionally, transfer student-athletes must have been academically eligible at their previous school to use the one-time transfer exception and be eligible for athletically related financial aid at the school to which they are transferring.

Progress-Toward-Degree Requirements

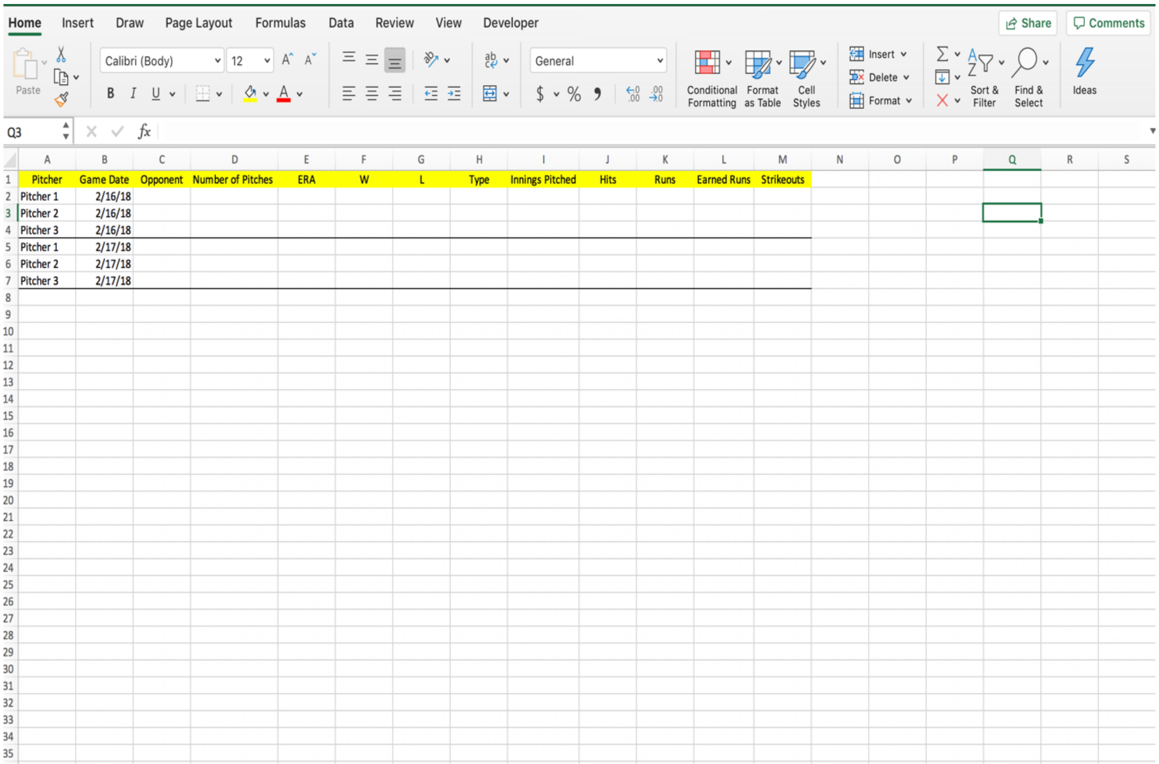
Academic Requirements	**Prior to the Second Year of Enrollment**	**Prior to the Third Year of Enrollment**	**Prior to the Fourth Year of Enrollment**	**Prior to the Fifth Year of Enrollment**
Regular Academic Term	6 semester/6 quarter hours of credit	6 semester/6 quarter hours of credit	6 semester/6 quarter hours of credit	6 semester/6 quarter hours of credit
Regular Academic Year	18 semester/27 quarter hours of credit	18 semester/27 quarter hours of credit	18 semester/27 quarter hours of credit	18 semester/27 quarter hours of credit
Degree Credit	Credits accepted toward any degree offered at the institution	Credits used must go toward the designated degree	Credits used must go toward the designated degree	Credits used must go toward the designated degree
Annual/Percentage-of-Degree	24 semester/36 quarter hours of credit	40-percent of the designated degree must be completed	60-percent of the designated degree must be completed	80-percent of the designated degree must be completed
Grade-Point Average	90-percent of the minimum GPA required for graduation (1.8 if a 2.0 is the minimum)	95-percent of the minimum GPA required for graduation (1.9 if a 2.0 is the minimum)	100-percent of the minimum GPA required for graduation (2.0 if 2.0 is the minimum)	100-percent of the minimum GPA required for graduation (2.0 if 2.0 is the minimum)

Application of Progress-Toward-Degree Legislation

Bylaw	**Description**	**Application**
14.4.3.1.3.1 14.4.3.1.4.2	Baseball student-athletes who fail to meet the credit hour requirements prior to the fall are ineligible for the remainder of the academic year	All baseball student-athletes
14.4.3.1.6	Football student-athletes who do not earn 9-semester/8-quarter hours during the fall term and fail to earn the eligibility point may not be eligible to compete during the first four games during the next season	All football student-athletes
14.4.3.1.7	Credit hours are based on hours earned or accepted for degree credit	All student-athletes

APPENDIX B

GAME METRICS



Pitcher	Game Date	Opponent	Number of Pitches	ERA	W	L	Type	Innings Pitched	Hits	Runs	Earned Runs	Strikeouts
Pitcher 1	2/16/18											
Pitcher 2	2/16/18											
Pitcher 3	2/16/18											
Pitcher 1	2/17/18											
Pitcher 2	2/17/18											
Pitcher 3	2/17/18											

This shows what each Power 5 Conference School's Game Data sheet would show. You can see that there are: Pitcher, Game Date, Opponent, Number of Pitches, ERA (per game), Win, Loss, Type (of pitcher), Innings Pitched, Hits, Runs, Earned Runs, and finally Strikeouts. Each game's data were recorded in the corresponding cells in Excel.

REFERENCES

Barnett, A. (2006). Using Recovery Modalities between Training Sessions in Elite Athletes: Does it Help? *Sports Medicine, 36(9)*, 781 – 796.

Blast Motion. (2019). What is Blast Factor. Retrieved from https://blastmotion.com/training-center/baseball/metrics/blast-factor/what-is-blast-factor/#testsimplebot

Cape Cod Baseball. (2019). Where the Stars of Tomorrow Shine Tonight! Retrieved October 2019, from http://www.capecodbaseball.org/archives/current-mlb-alumni/

Cape Cod Baseball. (2019). Where the Stars of Tomorrow Shine Tonight! Retrieved November 17, 2019, from http://www.capecodbaseball.org/stats/2018-statistics/

CCBL Public Relations Office. (2018, October 23). 14 CCBL Alumni on World Series Rosters. Retrieved November 2019, from http://capecodbaseball.org/news/?article_id=2531

Chalmers, P.N., Erickson, B.J., Ball, B., Romeo, A.A., & Verma, N.N. (2016). Fastball Pitch Velocity Helps Predict Ulnar Collateral Ligament Reconstruction in Major League Baseball Pitchers. *The American Journal of Sports Medicine, 44(8)*, 2130 – 2135. doi: 10.1177/0363546516634305

Curcio, J.E., Grana, M.J., England, S., Banyas, P.M., Palmer, B.D., Placke, A.E., Rieck, W.A.Jr., & Eade, A.M. (2017). Use of the Spencer Technique on Collegiate Baseball Players: Effect on Physical Performance and Self-Report Measures. *The Journal of American Osteopathic Association, 117*, 166 – 175. doi: 10.7556/jaoa.2017.031

Grantham, W.J., Byram, I.R., Meadows, M.C., & Ahmad, C.S. (2014). The Impact of Fatigue on the Kinematics of Collegiate Baseball Pitchers. *Orthapaedic Journal of Sports Medicine, 2(6)*, 1 – 10. doi: 10.1177/2325967114537032

Gough, C. (2019, October 23). MLB players on opening day rosters 2013-2019. Retrieved November 2019, from https://www.statista.com/statistics/639334/major-league-baseball-players-on-opering-day-rosters/

Helyar, J. (1994). *The Lords of the Realm: The Real History of Baseball*. New York: Ballantine Books.

Hopkins, W.G. (2004). How to Interpret Changes in Athletic Performance Test. *Sportscience, 8, 1 – 7*.

Karakolis, T., Bhan, S., & Crotin, R.L. (2013). An Inferential and Descriptive Statistical Examination of the Relationship Between Cumulative Work Metrics and Injury in Major League Baseball Pitchers. *Journal of Strength and Conditioning Research, 27(8)*, 2113 – 2118.

Love, S., Aytar, A., Bush, H., & Uhl, T.L. (2010). Descriptive Analysis of Pitch Volume in Southeastern Conference (SEC) Baseball Pitchers. *North American Journal of Sports Physical Therapy, 5(4)*, 194 – 200.

Marshall, N.E., Keller, R.A., Lynch, J.R., Bey, M.J., & Moutzouros, V. (2015). Pitching Performance and Longevity After Revision Ulnar Collateral Ligament Reconstruction in Major League Baseball Pitchers. *The American Journal of Sports Medicine, 43(5)*, 1051 – 1056. doi: 10.1177/0363546515579636

MLB. (2017). *CC Sabathia #52*. Retrieved from http://m.mlb.com/player/282332/cc-sabathia

Northwoods League. (2019). NWL Alumni. Retrieved November 2019, from https://northwoodsleague.com/about-nwl/nwl-alumni/#proball

Sports Reference. (2014, December 5). *Baseball Reference: Catcher.* Retrieved from https://www.baseball-reference.com/bullpen/Catcher

Sports Reference. (2006, June 23). *Baseball Reference: Center fielder.* Retrieved from https://www.baseball-reference.com/bullpen/Center_fielder

Sports Reference. (2016, December 24). *Baseball Reference: Designated hitter.* Retrieved from https://www.baseball-reference.com/bullpen/Designated_hitter

Sports Reference. (2015, November 1). *Baseball Reference: First baseman.* Retrieved from https://www.baseball-reference.com/bullpen/First_baseman

Sports Reference. (2006, February 26). *Baseball Reference: Left fielder.* Retrieved from https://www.baseball-reference.com/bullpen/Left_fielder

Sports Reference. (2017, October 9). *Baseball Reference: Pinch hitter.* Retrieved from https://www.baseball-reference.com/bullpen/Pinch_hitter

Sports Reference. (2009, July 28). *Baseball Reference: Pinch runner.* Retrieved from https://www.baseball-reference.com/bullpen/Pinch_runner

Sports Reference. (2017, April 26). *Baseball Reference: Pitcher.* Retrieved from https://www.baseball-reference.com/bullpen/Pitcher

Sports Reference. (2017, October 1). *Baseball Reference: Positions.* Retrieved from https://www.baseball-reference.com/bullpen/Positions

Sports Reference. (2006, February 27). *Baseball Reference: Right fielder.* Retrieved from https://www.baseball-reference.com/bullpen/Right_fielder

Sports Reference. (2017, March 19). *Baseball Reference: Second baseman.* Retrieved from https://www.baseball-reference.com/bullpen/Second_baseman

Sports Reference. (2017, March 3). *Baseball Reference: Shortstop.* Retrieved from https://www.baseball-reference.com/bullpen/Shortstop

Sports Reference. (2017, March 19). *Baseball Reference: Third baseman.* Retrieved from https://www.baseball-reference.com/bullpen/Third_baseman

The Baseball Observer. (2017). Summer Collegiate Leagues. Retrieved October 2019, from https://www.thebaseballobserver.com/summer-collegiate-leagues

Warren, C.D., Brown, L.E., Landers, M.R., & Stahura, K.A. (2011). Effect of Three Different Between-Inning Recovery Methods on Baseball Pitching Performance. *Journal of Strength and Conditioning Research, 25(3)*, 683 – 688.

Wayne Cavadi, N. (2019, June 17). *The complete printable College World Series bracket (PDF)*. Retrieved from NCAA: https://www.ncaa.com/news/baseball/article/2019-06-17/ncaa-college-baseball-bracket-2019-printable-college-world-series

Wilco, D. (2019, April 19). *The story of the first-ever college baseball game, in 1859*. Retrieved from NCAA: https://www.ncaa.com/news/baseball/article/2019-04-19/story-first-ever-college-baseball-game-1859

VITA

Isabelle Leslie Gillis

Place of Birth: Derry, NH

Education

Bachelor of Science, Kinesiology, University of Massachusetts – Amherst, Amherst, MA, December 2016.