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The Effects of Knee Injuries on Performance in NFL Quarterbacks



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by

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I hereby recognize and pledge to fulfill my responsibilities as defined in the Honor Code and to maintain the integrity of both myself and the College as a whole.

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Abstract

The purpose of this study was to determine how an injury to the knee affects an NFL quarterback's performance. Knee injuries included were sprains and partial or complete tears of the ACL, LCL, MCL, or meniscus. Performance statistics from the 2006 season to the 2022 seasons were collected for all quarterbacks from Pro Reference Football, with the most important statistic being total QBR. The season of injury was also recorded from various publicly available sources. Over the study period, 48 quarterbacks were found to have injured their knees. Eighteen athletes were excluded because they did not meet the inclusion criteria. The inclusion criteria included not having knee injuries in consecutive years, having performance data for the year prior and after injury, and being ranked above a 50. There was no statistically significant evidence to indicate knee injuries impacted the performance of the athlete in the year after injury or in the year of injury. However, while there was no statistical significance, in the year after injury it is indicated there is a slight decrease in performance. Thus, indicating surgeons and physical therapy are effective in returning athletes to nearly the same level of performance. Each type of knee injury, in the study, should be further investigated to analyze the differences each has on performance.

CHAPTER 1: Introduction

In the National Football League (NFL), players can suffer from a range of injuries throughout any given season, as football is an intense contact sport. Amongst all these injuries, shoulder, ankle, and head are considered the most frequent. Perhaps the most prevalent are injuries to the knee. Of all injuries suffered by NFL players, some estimate that knee injuries account for 20% of total injuries in the NFL [1]. Another study, which consolidated data from the 2012-2020 season, observed 8,293 knee injuries, far surpassing all other injury types (Fig. 1) [2]. In football, the knees are responsible for a range of actions such as sprinting, pivoting, and tackling, leading to an increased susceptibility to becoming injured. When an injury occurs due to performing these actions, it can hinder performance and cause severe pain not allowing the athlete to perform.

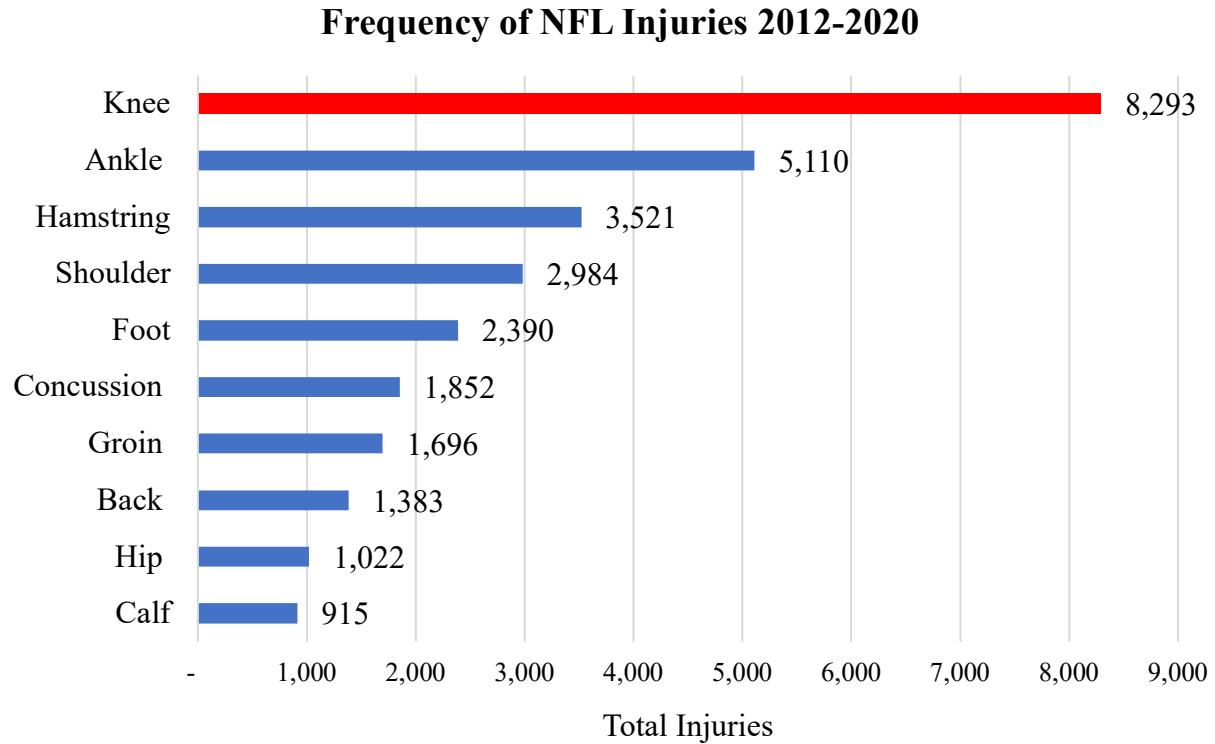


Figure 1. The frequency of different injury types acquired by players throughout the 2012 to 2020 seasons. The graphic has been edited from original source for comprehensibility [2].

The location of an injury in the knee depends mostly on the position of the knee at the time of injury. For example, when the direction of force comes from outside the knee, the medial collateral ligament (MCL) is at risk of injury. This is due to the MCL being located at the inner knee so when it becomes stretched out, it snaps. The lateral collateral ligament (LCL) is located at the outer knee, and both provide stability to the knee joint. At the center of the knee, the anterior cruciate ligament (ACL) and the posterior cruciate ligament (PCL) can be found forming an X-shape. The ACL is responsible for forward movements and rotation of the knee while the PCL controls backward movements. Sudden cutting or pivot in sports is a common way the ACL can be torn due to the twisting and stretching of the ligament [3]. An injury to any one of these ligaments can negatively affect an individual's everyday life. For an athlete, an injury to any of

these ligaments can hinder performance or completely suspend play for a range of weeks to months.

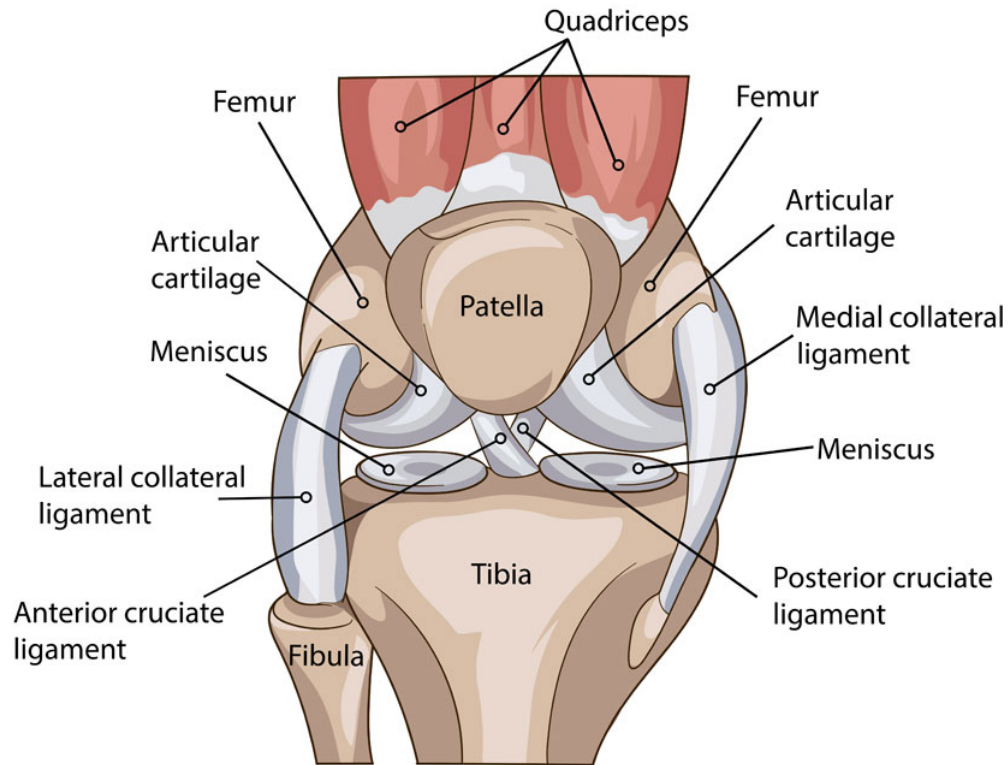


Figure 2. A diagram of the knee [4].

Quarterbacks play a key role in any NFL team's performance for the season, as they are the most important position on the field. Quarterbacks are the team's fundamental decision makers, they serve as a direct line of communication with the coaches. Their ability to make timely plays and efficiently manage the game routinely plays a part in determining the outcome of the game. If a starting quarterback were to suffer a knee injury, it would not only impact the team's performance, but more importantly, the athlete's own performance. Depending on the severity of the injury, the athlete could even require surgery on their knee to repair any damage that has occurred. If surgery is necessary, athletes are required to work with a surgeon and are further recommended to see a physical therapist post-operation in order to aid in recovery. The

recovery of a minor sprain can take around six weeks to heal, whereas a major sprain or tear can take several months to heal [5]. Surgery preparation and a timeline also add additional time to the recovery process.

In 2019, the NFL compiled a list of the top 25 quarterbacks of all time, ranking Tom Brady first, followed by Joe Montana, Peyton Manning, Johnny Unitas, and Otto Graham [6]. Tom Brady has become a well-known name in the NFL since he was drafted in 2000 by the New England Patriots. He spent his first 20 seasons, from 2001 to 2019, with the Patriots and finished his career with the Tampa Bay Buccaneers after the 2022 season. During Brady's time with the Patriots, he averaged 16 games per season, excluding his 2008 season [7]. In the first quarter of week one in 2008, he tore his left MCL and ACL while being tackled by a Kansas City Chiefs safety, Bernard Pollard. Brady missed all the remaining 2008 season games but was healthy by the 2009 season. However, in his final season with the Patriots in 2019, Brady again suffered from a fully torn MCL, but it is not publicly clarified how. Despite this, he continued to play. He did not have surgery to repair his MCL until the 2021 offseason.

A quarterback's performance can be measured by several different statistics such as passes attempted, passes completed, passing touchdowns, and yards gained per pass attempt. Of all the different statics, the most encompassing statistical measurement for quarterbacks is the Total Quarterback Rating (QBR). In 2006, ESPN created this measurement of performance to incorporate all of the quarterback's contributions to winning including how they impact the game on rushes, penalties, turnovers, and passes [8]. The total QBR is ranked on a zero to one hundred scale. In Brady's years of injury, his QBR dropped drastically. When comparing his season prior to injury and season after injury, his QBR dropped 12.9 points after the 2008 injury and 2.4 points after the 2019 injury (Fig. 3). While there could be other factors at play as to why total

QBR dropped, it appears that Brady's knee injuries could have influenced his overall performance in the seasons following injury.

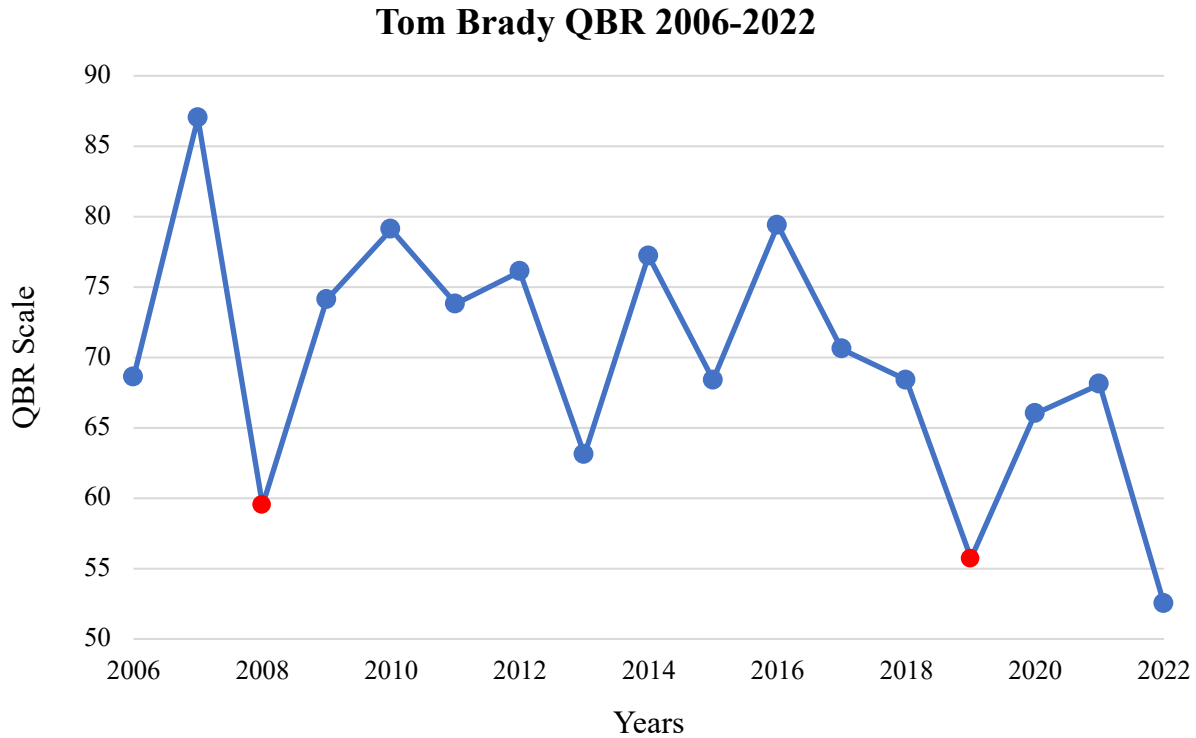


Figure 3. Tom Brady's total QBR from the 2006 season to the 2022 season. The red dots indicate the years of injury.

Tom Brady is but one individual case where a knee injury appears to affect his performance in the following year. In order to analyze if this trend is true for all quarterbacks, attention would need to be turned to observe if this trend is present across all quarterbacks who have suffered from a severe knee injury. If knee injuries were to influence the QBR of the majority of quarterbacks, a model could be created for football teams to utilize. The model would take data regarding the year of the knee injury, age of the athlete, total QBR for the year prior to injury, and the outcome would be the predicted QBR for the year after injury. This

would allow football programs to predict where their quarterback, with a knee injury, should be performing in the following year.

While it has been found that there is a difference in QBR the seasons prior to injury and in the season after injury, there is no evidence that injury caused this difference in QBR. To further understand why this might be it should be explored how each specific knee injury affects a quarterback's performance. For example, if an ACL injury impacts performance in the following season more than an MCL injury.

CHAPTER 2: Literature Review

BRIEF HISTORY OF ACL RECONSTRUCTION

Injuries to the anterior cruciate ligament (ACL) are one of the most common knee injuries in sports and are a common injury for active people. In a given year, it is estimated that there are about 150,000 new ACL ruptures [9]. Without surgery, a knee with an ACL injury is very limited and the patient's activities are limited as well. This can lead to further issues and degenerative changes. Currently, ACL reconstruction surgery is widely studied, partly due to professional sports where fast recovery and rehabilitation are essential and due to a greater awareness of the general public.

Davarinos, O'Neill, and Curtin provide a history of ACL beginning in old Egyptian times and their anatomy was described in the famous Smith Papyrus [9]. Claudius Galen, a Greek physician in the Roman Empire, was the first to describe the nature of the ACL. In 1836, the Weber brothers from Germany noted there was an abnormal anterior-posterior movement of the tibia after a tear of the ACL. They also were the first to describe that each bundle of the ACL was tensioned in different degrees of flexion of the knee joint. In 1845 France, the first cadaveric studies for mechanism of knee ligament injuries occurred and in 1850 the first description of an ACL rupture was recorded. In 1875 the technique for the Lachman test, a passive accessory movement test of the knee performed to identify the integrity of the ACL, was first described. The first report of an ACL repair was made in 1900, but no information was provided about the operation aside from the results being satisfactory.

Another report, the location unknown, was made about a 41-year-old-miner who had both cruciate ligaments repaired in 1903. An incision into the joint revealed that the ligaments had

been pulled away from their femoral attachments and were then repaired with catgut sutures. After some weeks of cast immobilization, the knee was able to move. Six years later, the patient reported having a perfectly strong knee. In 1913, Goetjes published a study dealing with ruptures of the cruciate ligaments and claimed that stitching ligaments was ineffective and that natural cicatricial tissue was the only reliable means of repair. These findings continued to advance through time and the methods for surgery have only become better.

A short case report regarding reconstruction of the ACL was published by Hey Groves in 1917 and in 1920. He was the first to clearly state that bending and extending of the knee affect tension within the ACL. The use of meniscal grafts aided Groves in this finding. Italian orthopedic surgeon, Riccardo Galeazzi, was the first to publish the usage of a hamstring tendon autograft in ACL reconstruction in 1934 and the knee was found to be stable 18 months after. In 1935, the first report of using a patellar tendon graft was done by Campbell, but this method did not achieve widespread approval. Jones, in 1963, published a new surgical technique, which had excellent clinical outcomes for eleven patients. This method was the bone-patellar tendon-bone graft, but at first there was criticism for this technique due to the graft being so short. However, this technique began to gain acceptance due to its simplicity and minimal surgical trauma. Jones' technique was taken into consideration in 1969 when the use of free bone-patellar tendon-bone graft was pioneered. This became the everyday standard by the 1990s due being relatively simple and yielding consistently good results. This procedure did have its drawbacks though, including pain at the graft donor site and stiffness within the extensor apparatus of the knee. Since 2003, there has been talk of a double-bundle gracilis and semitendinosus graft. The claim made was that it would guarantee a more anatomic ACL reconstruction and avoid the use of hardware for graft fixation. Research continues in this area, and there are many variations to this method being

used today. However, many ACL reconstructions today are still done using bone-patellar tendon-bone graft.

ACL INJURIES IN THE NBA

An analysis of the performance outcomes of ACL reconstruction in the National Basketball Association (NBA) was performed by Busfield et al. [10]. The purpose of the study was to determine the proportion of NBA players who underwent ACL reconstruction and returned to play in the NBA. Further, they quantify the effects of ACL surgery on statistical performance.

The research first calculates a player's efficiency rating (PER), and then creates statistical categories to compare pre- and post-injury. The use of the PER rating has been a common practice in evaluating a player's performance [11]. An NBA player's performance statistics were recorded in each of the following categories: games played, minutes per game, points per game, field goal percentage, 3-point field goal percentage, free throw percentage, rebounds per game, assists per game, steals per game, blocks per game, turnovers per game, and personal fouls. The player's PER was then calculated by summing positive performance measures and subtracting negative performance measures. The PER is an objective and standardized method of assessing a player's performance according to this paper. Players were also matched to a comparison group to create a control group in order to identify differences in the players PER pre- and post-injury. The control group allowed for a comparison of the injured players' expected performance.

The paper focuses on players who participated in the 1994-1995 season to the 2005-2006 season with the exclusion of the 1998-1999 season. In this period, 27 athletes experienced an ACL injury that required surgery and met the study requirements. Of these, six did not return to the NBA, twelve had a decreased PER, five had an unchanged PER, and four had an increase in PER. Of the 21 players who returned to competition, there was a statistically significant decrease in the number of games played, shot percentage, and turnovers per game when returning to play. The performance variables measured also decreased yet were not statistically significant.

As Busfield et al. note, it can be problematic and often difficult to calculate the return to play measure due to multiple confounding factors [10]. For instance, the team may bring on new players that perform better than the injured player, thus decreasing the playing time. It is important to note that the study does not use the typical orthopedic outcome measures. So, as the athlete returns to play, they may not be 100 percent back to where they were prior to the injury.

When investigating a basketball player's performance, the PER is a parsimonious measure of performance pre- and post-injury that could be utilized for any type of injury that may occur. The use of the control group to suggest where an athlete's projected performance may be compared to their actual performance can be applied to almost any sport and is helpful at inferring causality.

ACL INJURIES IN THE NHL

An analysis looking into the performance and return to sport after anterior cruciate ligament reconstruction (ACL) in the National Hockey League (NHL) was performed by

Erickson et al. [12]. The purpose of this study was to determine the return to sport rate in the NHL following the reconstruction of an ACL. This paper also investigated performance once an athlete had returned to the sport and the difference between players who underwent ACL reconstruction and their controls who did not.

One method behind this study was to explore the demographics of athletes that underwent ACL reconstruction. These demographics included age at injury, months from injury to return to play, position played, period of game which injury occurred, which side of the body the injury occurred on, body mass index (BMI), years played before and after injury, and whether the player returned to the NHL the season after the injury. The other method behind this study was to look into the average in-game performance data per season. This data included games played, goals, assists, points, positive and negative goal differential, penalty minutes, even-strength goals, power-play goals, short-handed goals, shots, shooting percentage, total time on ice, and average time on ice per game. These variables were then analyzed pre- and post-injury of the players' careers. A control group was created and matched to each player based on sex, BMI, age, the position they play, years of experience in the NHL, and all the measured performance variables.

This paper focused on the hockey players who participated in the years between 1990 and 2013. Of this population of NHL players, it was found that thirty-six were able to return to sport after ACL reconstruction. However, one of these did not return to the NHL but returned to play internationally in the Kontinental Hockey League. Of the thirty-five players, nineteen of these players continued to be active in the NHL. It was found in the demographic data that 68% of the ACL tears were left-handed shooters, and ACL tears occurred 55% of the time in the right knee.

Prior to the reconstruction of the ACL, the control cohort and players who tore their ACLs had no statistically significant differences in any performance or demographic variables. In the first year after ACL reconstruction, there was no statistically significant difference in player performance from preinjury performance. In the following two years of playing in the NHL, the players who underwent ACL reconstruction performed better than their controls. The ACL reconstruction group performed better in means goals and points per season, mean shots, mean shooting percentage per season, and mean power play. To aid in finding these results single variable analyses for all continuous variables within the groups were performed using paired sample student t-tests.

When evaluating a hockey player's performance during the season this paper does a good job of classifying which characteristics to investigate. It also shed light on the idea of comparing the injured player's knee to the side that more dominantly use in play. The use of the control group was once again put into play and allowed for comparison to where the injured player should ideally be performing.

ACL INJURIES IN NFL LINEMEN

An analysis was done looking into the return to sport (RTS) and performance after anterior cruciate ligament (ACL) reconstruction in National Football League (NFL) linemen by Cinque et al. [13]. The purpose of this study was to define the percentage of NFL linemen who RTS after ACL reconstruction. This study also looked into what the mean time to RTS was and the impact the reconstruction had on performance compared with matched controls.

The study group for this paper was NFL offensive and defensive linemen who sustained and underwent ACL reconstruction between 1980 and 2015. Players were identified through extensive searches of publicly available information that could be found on search engines. Linemen were included if the tear of the ACL was unilateral and reconstructed. Meniscal tears, cartilage injuries, lateral collateral injury, or medial collateral ligament injury to linemen were also included in the study. If multiple ACL injuries were present, participants were only included if there was sufficient data for the first injury. Players were excluded for three reasons and the first was if they had incomplete or unavailable data. The second was if multiligament injuries were present. The final exclusion was if they did not play at least one NFL season prior to injury or if the injury had occurred in the past year due to insufficient data.

Demographic information was taken for each player, and this included position, league, age at injury, side of injury, body mass index (BMI), draft year, draft round, months from injury to RTS, total number of Pro Bowl appearances, total number of seasons splayed before and after the injury, and total number of games started before and after the injury. Average in game performance data was collected for defensive players which included sacks, tackles, assists, interceptions, interceptions returned for touchdowns, pass deflections, forced fumbles, fumble recoveries, and fumble recoveries for touchdowns. Performance variables were analyzed as averages for pre- and postinjury over the course of the athlete's career and three subsequent seasons after returning from construction.

This paper used a control group to be able to compare a healthy group playing performance data to the study group's data on several parameters. This group was created based off the following parameters: age, sex, BMI, position, draft year, draft round, number of Pro Bowl appearances prior to injury, and all measured performance variables prior to injury. Using

this information, the control group was created. The data from these two groups was compared using a linear regression for the continuous variables and a Poisson regression for the categorical variables during the three years before and three years after injury.

Of the 73 linemen who met the criteria for the study, 47 returned to play after reconstruction surgery. All offensive linemen returned to play after injury and when compared to controls were found to have no differences when it came to number of seasons, total number of games played, mean number of games played, or mean number of games started per season. Among the defensive players who RTS the majority returned the season after the injury had occurred. There was no difference when matched with controls with regards to any performance metrics as an average over their career. However, when defensive linemen who tore, their ACL were compared to their controls, they played fewer total seasons. Overall, 64.3% of offensive and defensive linemen who underwent ACL reconstruction returned to play.

This paper does an excellent job of providing a regression example to see how an ACL injury affects a certain position in football. It not only provides the example of a linear regression, but also a Poisson regression which sheds more light on how to compare non numerical data. It also provides specific examples of how a healthy cohort group can be used to compare the performance of individuals to how the NFL would expect them to perform.

Chapter 3: Physical Therapy

ANTERIOR CRUCIATE LIGAMENT INJURY

The anterior cruciate ligament (ACL) is one of the major ligaments in the knee connecting the thigh bone to the shin bone. This ligament aids in the stability of the knee. When a tear of this ligament occurs one might feel a sharp, intense pain or hear a loud popping or snapping sound. The knee area will swell and walking might be difficult due to the area's instability. An ACL tear can be diagnosed by a physical therapist, athletic trainer, or orthopedic surgeon. Surgeons may order further tests, such as an MRI, to confirm the diagnosis and assess whether there is other possible damage. The majority of people who sustain an ACL tear will undergo surgery to repair the tear. Although some are able to avoid surgery by modifying their physical activity to relieve the stress placed on the knee.

Anterior Cruciate Ligament Injury

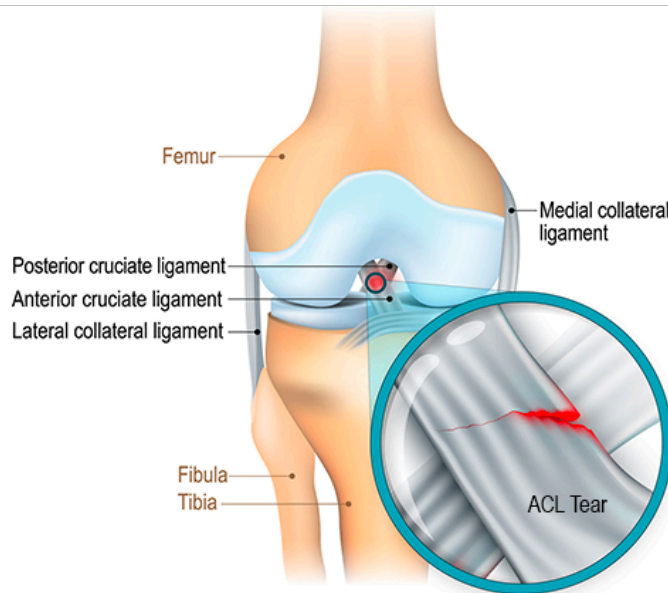


Figure 4. Diagram of the ACL and visual of how a tear appears [14].

Prior to surgery, some surgeons refer ACL tear patients to physical therapists to decrease swelling of the area, increase the range of movement of the knee, and strengthen the quadricep muscles. After surgery, the surgeon and physical therapist communicate to create a treatment program based on the patient's specific needs and goals.

Following surgery, some surgeons will provide the patient with a brace that physical therapists will help fit to the patient in order to limit knee movement. Ice and compression will be used to aid in minimizing swelling of the knee. During the first few weeks following surgery, physical therapists will help the patient to regain motion in the knee area and provide gentle exercises that can be performed at home. The focus is to regain full movement of the knee and increase blood flow. Electrical stimulation may also help restore thigh muscle strength and help regain the remaining range of motion in the knee.

After the first few weeks, physical therapists will then help the patient's ability to place weight on the knee. This is accomplished by using a combination of non-weight-bearing and weight-bearing exercises. The exercises focus on the quadricep and hamstring muscles. In the following weeks, the intensity of the exercises is increased and balance exercises are added to the program. As the patient regains strength and balance, physical therapists then design a more personalized plan to get the patient back into life. If the patient is an athlete a return to sport treatment program is created to fit the individual's specific goals and needs.

MEDIAL COLLATERAL LIGAMENT INJURY

The medial collateral ligament (MCL) is located on the inner side of the knee joint and is a small, thick band of tissue. It connects the thigh bone and shin bone, preventing the knee from bending inward toward the other knee. When a tear of this ligament occurs, one might feel pain on the inner side of the knee, have swelling and bruising on the inner side of the knee, have stiffness in the knee, or the knee may feel unstable. One might also hear a loud popping sound as the injury occurs. Physical therapists will perform several tests to assess the MCL of the patient to try to reach a diagnosis. The physical therapist might work with an orthopedic doctor or other health care provider so further tests, such as an MRI, can confirm a diagnosis and rule out other damage. The physical therapist may recommend a knee brace to prevent bending of the knee or crutches to aid in reducing pain. Most MCL injuries can resolve without surgery however there are instances where surgery is the best treatment option.

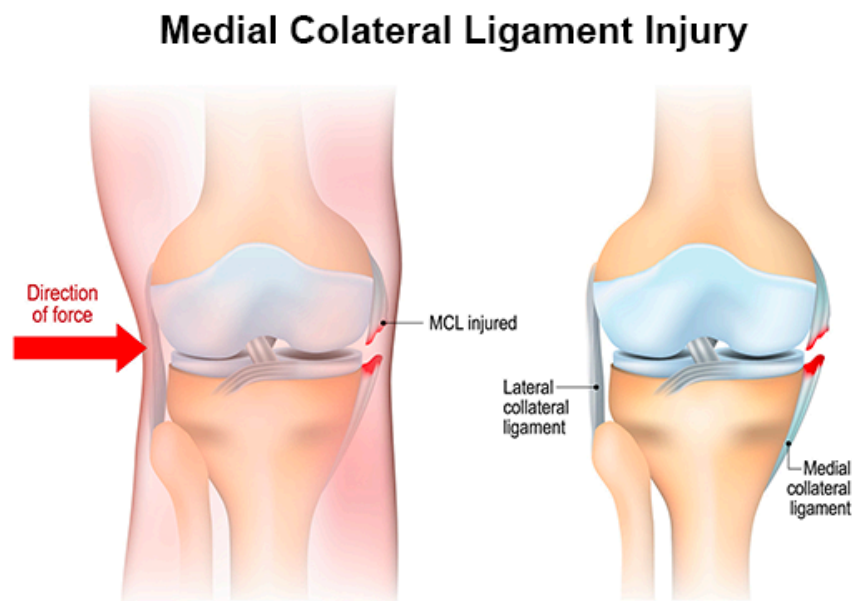


Figure 5. Diagram of the MCL and visual of how a tear appears [15].

Physical therapists will work with the patient to design a treatment program that will help the patient return to normal activities. This program will include exercises and treatments that can be done with the physical therapist and at home.

In order to reduce pain in the beginning the physical therapist may use a combination of different treatments and technologies such as ice, heat, ultrasound, electrical stimulation, taping, hands-on therapy, and exercises. The improvement of motion is the next step in the recovery of the MCL. The physical therapist will choose passive motions in order to gently move the leg and knee joint. These later will progress to active exercises and stretches that can be done by the patient on their own. The improvement of strength and agility is the next area of focus for the patient. Physical therapists accomplish this by selecting exercises that utilize cuff weights, elastic bands, weight lifting equipment, and cardio exercise equipment. Improvement of balance is also a focus while working on these exercises. At this point, a specific return to activities program is curated to best fit the patient's lifestyle. If surgery is required, a recovery program will be created and follow the same outline as if surgery were not required.

MENISCAL INJURY

The meniscus is a cartilage disc that cushions the knee and two can be found in each knee. There is one on the inner and outer portion of the knee, and together they act to absorb shock and stabilize the knee joint. There are two types of meniscus tears and they can be classified as acute or degenerative. When a tear of this cartilage occurs one might experience sharp, intense pain in the knee, swelling, difficulty walking, or a pop or tearing sensation in the knee area. Physical therapists will perform several tests to assess the meniscus of the patient to

try to reach a diagnosis. The results of the tests may indicate a need for further diagnostic tests, such as an MRI, or a referral to an orthopedic surgeon. Meniscal tears can often be managed without surgery and a short course of treatment from a physical therapist can determine whether surgery is necessary or not.

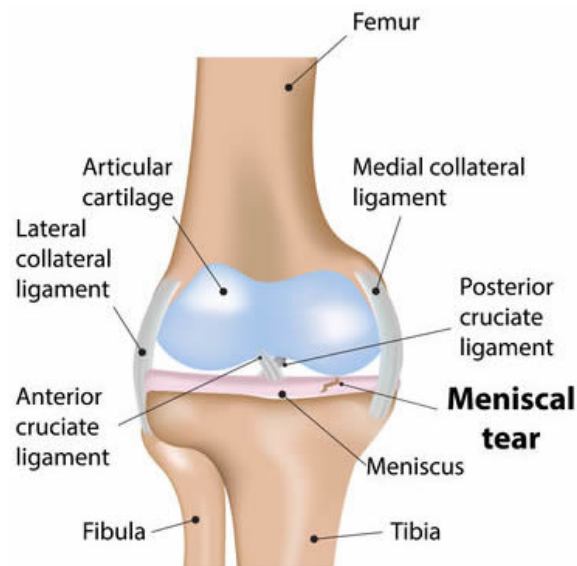


Figure 6. Diagram of the meniscus and visual of how a tear appears [16].

Physical therapists will work with the patient to curate the best program possible to return them back to their normal daily lives. Patients can either have no surgery, meniscus removal, or a meniscus repair. Treatment for all cases will closely follow the same program.

In the beginning, assistive devices such as crutches, canes, or walkers may be necessary to take pressure off of the knee. Physical therapists will begin with icing and compression to reduce swelling due to swelling being an important indicator of the level of the patient's ability to recover. Manual therapy will also be used to aid in reducing swelling and stiffness. Physical therapists will also use manual therapy to help restore muscle function around the knee.

Neuromuscular electrical stimulation (NMES) may also be used to gently stimulate/ contract the

muscles around the knee to help improve strength. Following the use of these techniques, strengthening exercises will be put in place at the appropriate time by the physical therapist. These exercises will be done to strengthen the muscles around the knee and throughout the leg in order to help ease pressure on the healing tissue on the knee. As recovery continues, the physical therapist will advise the patient on ways to improve and maintain fitness and decide whether the patient is ready to return to full activity. If the patient is an athlete a more extensive course of rehabilitation is required before returning to sport.

Chapter 4: Results

METHODS

Pro Football Reference maintains a database with ranging information regarding the NFL. It is a complete source for professional football history, including complete league, team, and player stats, rookies, leaders, awards, records, and scores. Data on NFL quarterbacks' statistics from the 2006 season to the 2022 season were collected from Pro Football Reference. The 2006 season was chosen as the beginning of the time period due to the total quarterback rating (QBR) statistic being developed in that year. According to ESPN, total QBR is unique in that it incorporates all a quarterback's contributions to winning, including how they impact the game on rushes, penalties, turnovers, and passes [8]. The total QBR system is based on a zero to one hundred scale set up so a 50 QBR represents a league average. For a factor of relevance, the data was chosen to end at the latest season completed in the NFL being 2022. The data taken from Pro Football Reference included age, total games played in the season, and total QBR for seasons before the injury, after the injury, and the season of the injury.

In order to identify players who had suffered from a knee injury, an extensive search of publicly available online information was utilized. Knee injuries included were grade 2 and 3 strains and partial or complete tears of the ACL, LCL, MCL, or meniscus. The searches were first performed on Draft Sharks which provides a range of information, but their most valued information is regarding injuries [17]. Draft Sharks has an injury index tool which uses historical health information and four other factors to predict the level at which the athlete is at risk for another injury [18]. The other four factors are probability of injury per game, probability of injury during the season, projected games missed, and the athletes' ability to perform taking into

account minor injuries [18]. Draft Sharks has a vast accumulation of injury data from the past decade to be able to run their Injury Index. If reports of injury could not be found on Draft Sharks, the query “suffer from a knee injury during time in the NFL” as well as the specific athlete's name was extensively searched on publicly available online information.

Public databases that were searched included NFL.com, ESPN.com, Google.com, and CBSSports.com. From these sources, information such as press releases and injury reports were used to identify quarterbacks who experienced a knee injury during their career in the NFL, in addition to Draft Sharks. This included quarterbacks who suffered injuries during the preseason and regular seasons. Players were excluded from the study if they had less than three years of data, as these players did not have sufficient time to determine how a knee injury would impact their performance. If a player suffered from knee injuries in consecutive years, they were also excluded from the study due to not having a healthy year both before and after injury. On Pro Football Reference, quarterbacks were ranked, per season, by the most yards gained by passing and if their rank was greater than 50, they were not included. The data collected for quarterbacks was then analyzed.

STATISTICAL ANALYSIS

Statistical analysis was conducted in Stata. The variables were compared by taking the averages, and a paired T-test was performed to compare the season before an injury occurred to the season after an injury occurred. Time series regressions with robust error variance and time fixed effects were run to analyze how quarterbacks QBR were affected by differing variables. For these regressions, the dependent variable is QBR, while the independent variables include

total games played in the season, age, injury status, and QBR for the year prior and year of injury. The QBR in the year prior to injury is utilized to effectively establish a player's baseline level of performance. Age squared was included in the regression due to age having a non-linear effect on performance. Model 1 represents the regression equation used which demonstrates the effect of injury and other variables on a quarterback's QBR. Each player was included in the model multiple times in each regression, due to this the model included adjustment for clustering around each specific player. The significance level was set to $P < 0.10$ for these statistical tests rather than the standard $P < 0.05$, due to no statistical significance found at this former level.

Model:

$$QBR_{it} = \beta_0 + \beta_1 Injury_{it-1} + \beta_2 QBR_{it-1} + \delta_i + \delta_t + \epsilon_{it}$$

δ_t = time fixed effects

δ_i = player fixed effects

RESULTS

Yearly, on average, 5.76% quarterbacks will suffer from a knee injury based on the 2006 to 2022 season data (Table 1). During this time period, all quarterbacks on average played in 11.15 games and had an average QBR of 50.23. The average age for quarterbacks during this time period is 29 years old.

Variable	Obs	Mean	Std. Dev.	Min	Max
Injury	833	0.057623	0.2331693	0	1
QBR	832	50.28858	15.98096	4	97.3
Games	833	11.15366	4.71958	1	17
Age	833	28.64826	4.665743	21	45

Table 1. Summary statistics regardless of injury status.

In total, 48 knee injuries were identified to have occurred between the 2006 season and the 2022 season; of these, 30 injuries did meet the inclusion criteria (Table 2). Of the 18 that did not, nine did not have data for the year prior to injury, five did not have data for the year after injury, and two sets of injuries occurred in consecutive years. Of the 30 injuries, it's found that a quarterback's QBR rating drops 3.28 on average from the year prior to injury to the year after injury (Table 2).

Variable	Obs	Mean	Std. Dev.	Min	Max
QBR Year Before Injury	39	55.88205	15.147	15.9	87
QBR Year of Injury	48	52.3125	14.87566	5.3	83.5
QBR Year After Injury	43	52.6	16.39914	22.4	82.3

Table 2. Summary statistics for quarterbacks that sustained knee injuries.

A paired t-test was utilized to analyze the relationship between the means of the total QBR in the year prior to a knee injury and the total QBR in the year after a knee injury. There is a statistically significant relationship, but it is weak and only appears in the one-sided test at a 90% confidence level (Table 3). This relationship does not appear at a 95% confidence level or in the two-sided t-test. This is likely due to the small sample size of only 30 knee injuries which makes it difficult to find statistically significant patterns.

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
QBR Year Before Injury	30	56.33333	2.367026	12.96474	51.49222	61.17445
QBR Year After Injury	30	51.94333	3.263292	17.87378	45.26915	58.61751
Difference	30	4.39	3.11472	17.06002	-1.980317	10.76032
mean(diff) = mean(QBR Before Injury - QBR After Injury)						t = 1.4094
Ho: mean(diff) = 0					degrees of freedom = 29	
Ha: mean(diff) < 0		Ha: mean(diff) != 0			Ha: mean(diff) > 0	
Pr(T < t) = 0.9153		Pr(T > t) = 0.1693			Pr(T > t) = 0.0847	

Table 3. Paired t-test.

A regression was run to analyze how the total QBR is affected by controlling for performance the seasons prior and performance the year after. While holding all else constant, there is a 0.65 decrease in performance the year after a knee injury (Table 4). While the injury variable does suggest performance decreases in the year after injury, it is not statistically significant.

QBR	Coef.	Std. Err.	t	P > t	[95% Conf. Interval]	
Injury Year Prior	-0.6481718	1.995471	-0.32	0.746	-4.589801	3.293457
QBR Year Before Injury	-0.1263943	0.0460919	-2.74	0.007	-0.217439	-0.0353495
Age	1.098124	2.106238	0.52	0.603	-3.062301	5.25855
Age Squared	-0.0332404	0.0327978	-1.01	0.312	-0.0980254	0.0315447
Number of Obs						642
Number of Groups						157
R-sq within						0.0693

Table 4. Regression 1A.

Total games were added to the regression as an additional control variable. The additional variable accounts for more variance in the model and alters the values from the first regression. In this regression the injury variable is still not statistically significant but does indicate a 1.39 decrease in performance (Table 5). Once again suggesting performance decreases in the year

after injury even though it is not statically significant. However, the new variable of games played does cause the possibility of simultaneity. This raises concerns because while games played can affect the outcome of total QBR, total QBR can also affect the number of games played in the season. If a quarterback were to have a low QBR they are less likely to play in games which in turn affects their QBR even further.

QBR	Coef.	Std. Err.	t	P > t	[95% Conf. Interval]	
Injury Year Prior	-1.394979	1.811044	-0.77	0.442	-4.972311	2.182353
QBR Year Before Injury	-0.1370504	0.0424711	-3.23	0.002	-0.220943	-0.0531578
Age	2.053217	1.974085	1.04	0.3	-1.846169	5.952602
Age Squared	-0.0433029	0.0315515	-1.37	0.172	-0.1056262	0.0190204
Games Played	25.08435	30.64596	0.82	0.414	-35.45023	85.61892
Number of Obs						642
Number of Groups						157
R-sq						0.153

Table 5. Regression 1B.

Another regression was run to analyze how the total QBR is affected by controlling for performance in the year of injury and performance the year before the injury. While holding all else constant, there is a 0.05 decrease in performance the year after knee injury (Table 6).

Although the injury variable is not statistically significant, it does suggest performance decreases the year of injury. Knee injuries could have occurred at any point in the season which would have athletes missing different portions of the season. Any one or multiple of these scenarios could be contributing to why the variable is not statistically significant and why its coefficient changes minimally.

QBR	Coef.	Std. Err.	t	P > t	[95% Conf. Interval]	
Injury	-0.052444	2.352479	-0.09	0.931	-4.852066	4.441578
QBR Year Before Injury	-0.1260158	0.0461584	-2.73	0.007	-0.217192	-0.0348396
Age	1.089142	2.104041	0.52	0.605	-3.066945	5.245229
Age Squared	-0.0330899	0.0327611	-1.01	0.314	-0.0978024	0.0316226
Number of Obs						642
Number of Groups						157
R-sq						0.0691

Table 6. Regression 2A.

Once again total games were added to the regression as an additional control variable and accounted for more variance in the model than the first regression. In this regression the injury variable is still not statistically significant but does indicate a 0.66 increase in performance whereas before it indicated a decrease in performance (Table 7). Presumably, because the effect is not negative or significant, it implies surgery and physical therapy do aid in rehabilitation of quarterbacks' knees as they perform nearly just as well as they were prior to the injury. The concern of simultaneity is once again at play in this regression (Table 5).

QBR	Coef.	Std. Err.	t	P > t	[95% Conf. Interval]	
Injury	0.6639657	2.210666	0.3	0.764	-3.702736	5.030667
QBR Year Before Injury	-0.1370925	0.0427784	-3.2	0.002	-0.2215922	-0.0525927
Age	2.034799	1.980425	1.03	0.306	-1.877109	5.946707
Age Squared	-0.0429173	0.0316994	-1.35	0.178	-0.1055328	0.0196982
Games Played	1.035068	0.1726469	6	0	0.6940408	1.376095
Number of Obs						642
Number of Groups						157
R-sq						0.1523

Table 7. Regression 2B.

Chapter 5: Conclusion

Based on a small sample of knee injuries, the results failed to find that knee injuries have a statistically significant long-term effect on quarterbacks' performance. The work of surgeons and rehabilitation of the knee by physical therapists appears to have a positive impact on returning the athlete to play in the following year. However, there is no way to control the quality of rehab an athlete receives and how it affects their performance as some athletes return to play not being as healthy as possible. Athletes suffer from injuries constantly, and while some are more severe than others, it is beneficial in the sports world to know athletes can return to sports performing nearly identically to their performance before the injury.

The category of knee injuries range from several different types in this study, such as ACL, LCL, MCL, or meniscus injuries. In the future, it would be beneficial to analyze the effects of each type of knee injury separately whereas this study analyzes them all together. It is possible that one of these types of injuries effects the knee worse than others, in turn, effecting performance differently. This would be important to analyze because if true then teams could have a better idea of how a specific injury could affect their quarterback for not only that season, but seasons to come.

Although there was no statistical significance when analyzing if injury impacted performance, the coefficient for the variable did decrease in three of the regressions. It would be intriguing to create a group of athletes that could be used as controls for the injured athletes. These athletes would match the injured athlete as closely as possible in terms of performance and demographics in order to create a predicted measurement of performance had the athlete not been injured.

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About the Author

Cheyenne Wilson is a Business major with a minor in Biology. She is the daughter of Pamela and Marty Wilson and sister to Chase and Shane Wilson. Wilson was a four-year starter and two-year captain for the Allegheny's Women Volleyball program. She has earned several awards during her time and helped lead the Gators through many victories. Wilson also partook in Greek Life on campus. She is a three-year member of the sorority Kappa Kappa Gamma where she held the position of Vice President of Finance during. During her year in this position, she was responsible for keeping all financials in order as well as ensuring members paid their dues in a timely manner. Cheyenne's love for sports has directed her on a path to pursue a Doctor of Physical Therapy. This love has also inspired the idea behind her comp to analyze how injuries affect athletic performance and the role physical therapy plays in returning the athlete to sport. Upon graduation, Cheyenne plans to take a gap year and apply to Doctorate programs.