VARIABLES THAT AFFECT THE INCIDENCE OF BILATERAL ANTERIOR CRUCIATE LIGAMENTS INJURIES

A Report of a Senior Study

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ABSTRACT

The most common knee injury is the rupturing of the anterior cruciate ligament (ACL). A bilateral ACL injury is sustained when a single ACL is ruptured followed by the rupturing of the opposite ACL later in time. The goal of this study is to determine if certain variables affect the incidence of bilateral ACL injuries. It was hypothesized that heavier patients and patients with a shorter duration of therapy would be more likely to sustain a bilateral ACL injury. Data was collected from both a survey sent to orthopedic clinics and from files located at Appalachian Therapy in Maryville, Tennessee. The information gathered included the date of the initial injury, the date of the second injury, which knee was injured first, height, weight, type of graft, dominance, and the duration of physical therapy. The difference in weight and duration of therapy for single and bilateral ACL injuries was not significant. When genders were combined for the duration of therapy, there was a significant difference with individuals experiencing a second ACL tear having longer durations of therapy after the first injury ($p=0.03$). This unexpected finding could be explained by increased focus on the injured leg leading to neglect of the bilateral leg, or a lack of self-confidence in individuals having longer therapies leading to a more susceptibility.

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CHAPTER I

INTRODUCTION

Anatomy of the Knee

The knee is a joint that is used endlessly everyday. Walking, standing, and squatting are movements that would not be possible without the help of the knee joints. In *Kinesiology and applied anatomy* Grabiner (1989) gives a full description of the knee joint. The knee joint is actually the largest joint in the body. This means that it must be very complex in its design and function. Therefore, there are many different bones, tendons, and cartilages that makeup the knee joint. There are three smaller joints that comprise the actual knee joint. These include two tibiofemoral joints and one patellofemoral joint.

The two tibiofemoral joints are made up of two main bones: the femur and the tibia. Another smaller bone, the fibula, is also included. The femur is the largest bone in the body and makes up the top part of the knee joint, while the tibia and fibula are smaller and located at the bottom part. The third joint, patellofemoral joint, is a combination of the patellar surface of the femur and the patella bone. The patella develops within the tendon of the quadriceps' femoris muscle. The function of the patellar is to protect the anterior or front part of the knee and aid in the quadriceps muscle function. Although

these joints are a crucial part, they would be useless without the tendons and ligaments that hold it together.

The patellar tendon is a tendon in the knees. It is located in the anterior part of the knee and holds the front part of the joint together. This is so well known because patella tendonitis is a common ailment for people that are aging. Its symptoms are an aching in the very front part of the knee.

The medial and lateral collateral ligaments also play a role in knee stability. Although it has been found that the medial plays a more crucial part, they both function to control the turning in, turning out, and tibia movement of the knee joint.

Two other important ligaments are the oblique popliteal and the arcuate popliteal. Their main function is to provide stability in the posterior part of the knee. This prevents injuries like hyperextension of the knee.

There are also four important cruciate ligaments in the knee: lateral, medial, posterior, and anterior (see Figure1). The lateral (outside) and medial (inside) ligaments prevent the knee joint from moving too far in the side-to-side motion. The posterior and anterior cruciate ligaments are located deep within the knee and provide coronal and sagittal plane stability.

The last part of the knee joint is the menisci or cartilage, specifically the lateral and medial cartilage. They are important in absorbing the shock of some movements of the knee. It is very important that the menisci are present; otherwise the friction between bones rubbing on bones can increase 20%.

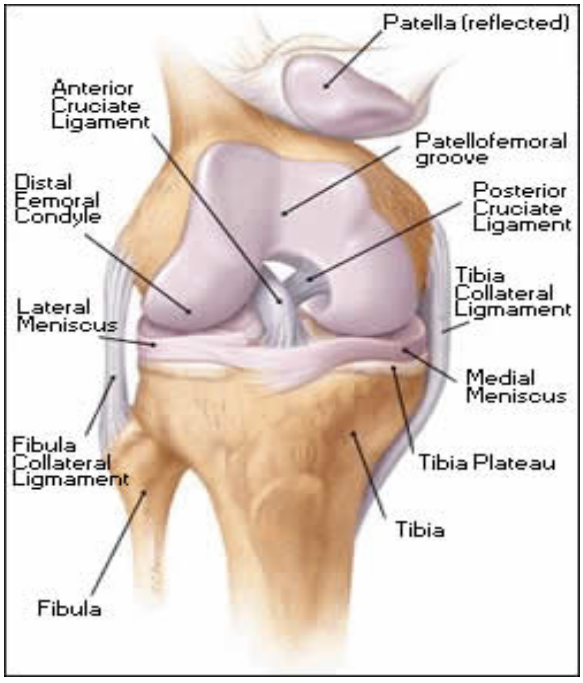

Figure 1. A diagram of the ligaments and bones of the knee. Source: *Bristol Orthopaedic and Sports Injury Clinic September 2003.*

The two major movements of the knee are flexion and extension. A normal knee joint should be able to straighten and bend from 0 to 140^{o}. The twelve muscles of the knee joint also aid in these movements. They are classified into three groups: hamstrings, quadriceps femoris, and unclassified.

The hamstring group includes three muscles: the semitendinosus, the semimembranosus, and the biceps femoris. Although they function some in the hip flexors, their main role is providing knee flexion. The semitendinosus and semimembranosus also help with the internal rotation of the knee.

There are four muscles in the quadriceps femoris group. These include the rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius. Together, these muscles provide the extensor motion and some internal rotations of the tibia.

The sartorius, gracilis, popliteus, gastrocnemius, and plantar muscles combine to form the unclassified group of muscles. These muscles play a larger role in the ankle and hip regions, but they have some functions in the knee. The popoliteus is an important muscle in the act of walking. Not only does it internally rotate on the tibia during the swing of the leg, but it also provides stability to the weigh-bearing leg.

Knee Injuries

The intricacy and complexity of the knee joint leaves much room for various injuries. Bones, tendons, ligaments, and cartilage are all subject to this and can lead to a dysfunctional knee. The obvious injuries that affect the knee joint are broken or fractured bones; however, the real detrimental injuries lie in the ligaments and cartilage.

Knee injuries can occur in both athletes and non-athletes; however, due to much more use and strain on their knees, athletes are more susceptible. This is because the knee is made to sustain everyday movements that are required for non-athletes. The trauma that athletes' bodies undergo sometimes leads to these types of injuries.

Injury to the lateral and medial menisci can have a large negative impact on the knee. The medial meniscus injuries are much more common and occur usually with a ligament sprain. Because the C-shaped medial meniscus is attached to the medial collateral ligament, spraining the ligament automatically damages the meniscus. The medial collateral ligament is sprained when too large of a force is directed laterally to medially on the knee. A sport scenario would be a player coming at another player and hitting his knee directly on the outside causing the knee to move too far inward. The lateral meniscus is not damaged near as much as the medial. It is usually subject to injury more from just overuse than anything else.

The most common knee injury is the rupturing of the anterior cruciate ligament (ACL) (Childs, 2002). This injury is common in most sports. It appears to be the easiest of the four cruciate ligaments to damage. Injuries to ligaments occur when the ligament is stretched to a point that it cannot return to its normal state. Sometimes the ligament is not completely torn but stretched or partially torn. In this case, the knee is still dysfunctional just not to the same level as a ruptured anterior cruciate ligament. Anterior cruciate ligament injuries often occur from too much lateral impact and too much internal tibial torque on a fully flexed or extended knee (Hame, Oakes, & Markolf, 2002). This type of tibial torque often occurs when landing from a jump.

Signs that a knee has sustained an ACL injury include excessive swelling and stiffness in the knee causing a reduction in range of motion (Sebastianelli & Black, 1995). Often, the patient will say that they heard and felt a pop. These are just signs of the injury. The way to determine if the ACL has been damaged is to perform several stability tests. The three main stability tests are the Lachman, drawer, and pivot shift tests.

The Lachman test is performed with the patient lying down with their knee at a 30^{o} angle. The femur is held in one hand and the tibia is pulled anteriorly with the other hand to perform the test. If there is any soft end point or "giving" reaction, then it suggests that an ACL tear is likely. When these tests are performed on perfectly functional knees, a sharp end point will occur indicating a tight and healthy ACL. The Lachman tests can diagnose 85% of ACL tears (Sebastianelli & Black, 1995).

The drawer test is done with the patient lying down with a bent knee. By applying anterior and posterior translation stress to the knee and feeling a soft end point,

the knee can test positive for an ACL injury. However, this test is only 25% accurate (Sebastianelli & Black, 1995).

The pivot shift test is conducted by lifting the tibia with the femur following posteriorly. The full extension of the knee causes it to flex which causes the iliotibial track to become tightened and move from an anterior to posterior position on the axis of knee flexion. If the relocation of the tibia is felt, then it is a sign that there is an ACL injury (Sebastianelli & Black, 1995). Although these tests can give a pretty good diagnosis, having a magnetic resonance image (MRI) can provide a clear-cut answer. The reason getting an X-ray would not be helpful is because it would only show bone damage. A MRI shows all the ligaments and tendons; therefore, it provides a more accurate diagnosis.

Prevention of ACL Injury

There are many different ideas about prevention of anterior cruciate ligament injuries. Some say that it is all in the genetics, while others have designed methods of prevention for both athletes and non-athletes. Tanji (1992) has outlined three things that an athlete can do to prevent knee injuries: the accelerated rounded turn, the bent-knee landing, and the three-step stop.

The purpose of the accelerated rounded turn is to prevent deceleration through the turn because that has been known to contribute to ACL tears. By turning initially with the inside foot and following through with the outside foot deceleration is avoided. Landing on a straight leg has been known to cause injuries. In order to land on a bent knee, the athlete must land with their feet at their hip's width apart and with their knees

bent from 60 to 90 degrees. The three-step stop is achieved by simply taking three steps when decelerating to help dispense the load on the knees so that it is bearable.

Although athletes are more prone to experience knee problems, non-athletes do not always have healthy knees. Common knees problems in non-athletes include bursitis, tendonitis, and osteoarthritis. Bursitis is commonly diagnosed in patients that put to much pressure on their knee in positions like kneeling. It is called bursitis because of the bursae sacs that are located in the knee to pad the joints and reduce friction. The most obvious symptom of bursitis is swelling in the front of the knee ("Six steps," 2004).

Tendonitis also causes swelling in the front of the knee, but it only hurts when the knee is moving, while knees that have bursitis are constantly in pain. Tendonitis occurs when a tendon is overstretched or overused. The most common type is patellar tendonitis. This tendon starts at the kneecap and goes down to the shinbone ("Six steps," 2004).

Osteoarthritis is a knee injury that involves cartilage. Usually chondromalacia is contracted before it turns into osteoarthritis. Chondromalacia is when the cartilage between the femur and shinbone soften. Once it softens, it is only a matter of time before it will begin to decay and break down and becomes osteoarthritis ("Six steps," 2004).

There are many things a non-athlete can do to prevent having knee problems in the future. One method is to just stay active. By staying active, the joint is being exercised and nourished. However, people must be smart before diving into a really intense workout. If something is uncomfortable or feels unstable, that should be a clear indicator that your body is not ready for that and may never be.

Treatment after an ACL Injury

Non-athletes that already have some knee problems have some things they can do to prevent it from getting worse. They can stay active without hurting their joints by walking in water ("Six steps," 2004). This exercise is good for the knees because there is no impact on the knee like there is when walking or running. It is also good exercise because the resistance of the water makes walking harder to do.

If a doctor's help is not immediately available, the best way to treat injuries for both athletes and non-athletes is to remember the acronym RICE. The "R" stands for rest. After an injury is sustained, the person should rest that part of the body to not make it worse. The "I" stands for ice. Ice is always a good treatment for injuries that involve a lot of swelling on the joint. Sometimes the doctor cannot tell what the injury is until the swelling is down, so it is an important treatment method. The "C" stands for compression. This can be achieved by wrapping the injured area tight so that the swelling does not get any worse. Lastly, the "E" stands for elevation. When the injured area is elevated above the heart it drains the blood from the injured area also helping with swelling. All these steps have to do with the swelling of the injured area. Swelling is really extra blood in the injured site, so swelling can be an indicator that there is a serious injury inside the joint.

If a serious knee injury is a possibility, for example a ruptured anterior cruciate ligament, then there are several options for treatment. For non-athletes, it is entirely possible to go on with everyday life without having the ACL repaired. As long as the person avoided movements like pivoting quickly, they should be able to function normally. For athletes, however, it is very unlikely that they would be able to return to

their sport and perform the same way they did before the injury. This means that a reconstructive surgery is really necessary before the athlete can return to play.

There are three different surgical methods for reconstructing an anterior cruciate ligament. The first type is the patellar graft. This method harvests a portion of your patellar tendon and uses it as the new ACL ligament. It requires two small screws to hold the graft in place while it is healing. A common problem with this type of graft is that patellar tendonitis often occurs after the graft has healed. The patient will also experience a great deal of front knee pain.

A study was performed on 100 patients that had this type of surgery to see what the long-term effects were. After waiting seven years, a follow up study showed that 47% developed patellofemoral osteoarthritis. Those that developed this had many problems with their knees including continuous swelling, poor range of motion, and weak quadriceps muscles. Those that did not develop the arthritis did not have any problems with their knees. Interestingly, it was found that the patellar graft seems to shorten some during the recovery process. This shortening had a strong correlation with the developing of osteoarthritis. Those with the shortest grafts seemed to experience the most severe kind of osteoarthritis (Jarvela, Paakkala, Kannus, & Jarvinen, 2001).

Another reconstruction method is the hamstring graft. This method is a more recent development. During this surgery, the orthopedic surgeon harvests a part of the patients hamstring using a long metal rod. He then braids the muscles fibers and reinserts it where the old ACL was located. This method requires one large screw to hold the graft in place. This method is not used as much as the patellar tendon graft because it tends to

be a little looser. When the graft is looser, the knee is not as stable and it increases the chances for reinjury.

The final method is the use of an allograft. This is also called a cadaver graft. Most doctors only use this if the other two methods are not an option due to already being used or are just not sufficient tissue. The main drawback with this method is the chance that the patient's body will reject the foreign tissue and result in infection, or that diseases could be transmitted. *Clostridium septicum* is the name of one type of infection that can be contracted from a contaminated graft (Barbour & Kling, 2003).

No matter what surgical procedure was used, the recovery time for the knee is still the same. This does not mean that all athletes return to their sport at the same time. Some athletes feel more comfortable earlier than others. Patients are usually told that they will return to play in six to nine months. For professional athletes this may be different due to the higher need for them to return. It takes at least six months for the graft to heal. Athletes that return before then are at a much greater risk of reinjury. Although it takes six months for it to heal, it really takes twelve months for the entire body to recuperate from the trauma it experienced.

For a while it was believed that ligament augmentation devices would help speed up the recovery and make the grafts heal faster and safer; however, a study found that there were no advantages in using these devices (Drogset & Grontvedt, 2002). Basically, the body is not going to heal faster in some patients. Although some patients' knees may feel better than others, the body needs time to heal, and nothing can speed that up.

There are many different factors that attribute to knee injuries. These factors can be divided into two categories: intrinsic and extrinsic. Intrinsic is personally related while

extrinsic is environmentally related. Examples of intrinsic factors include the type of body structure, which is the result of the individual's genetic makeup (Orchard, Seward, McGivern, & Hood, 2001). The anatomical and functional differences in a person make them more or less likely to injure their ACL.

Examples of extrinsic factors would be the type of shoe or cleat the athlete is playing in or the surface of the field. These types of factors have been studied and found to have some correlations with ACL injuries. One study found that the greater number of cleats on the shoe, the greater the chances are of injuring the ACL due to a higher torsional resistance. It was also found that more ACL injuries occurred on fields with dry conditions (Orchard et al., 2001). This is surprising because it is normally thought that in those rainy, wet, slippery games athletes would be more likely to injure themselves because the surface is not as stable. It could also be that there are more dry days than wet days so that the probability of an injury occurring during a dray day is higher simply because of the higher number of dry days.

Gender Differences in ACL Injury

For many years now, it has been known that females are more likely to rupture their ACL than men (Ireland, 2002). Countless studies have been performed, each drawing the same conclusions. One study found that women are two to eight times more likely to injury their ACL (Wojtys, Huston, Boynton, Spindler, & Lindenfeld, 2002). Because of these results, studies were then performed to find the reasons behind this. These studies have indicated that there are several different reasons, all of which are intrinsic.

The first intrinsic factor was the neuromuscular differences in males and females. Female athletes commonly have unbalanced strength in their legs. It is usually found that their quadriceps tend to be much stronger than their hamstring. Because of this unbalance, the knee is not properly protected making it more susceptible to an ACL tear (Saunders, 1998). Another muscular disadvantage is that women's fitness is usually at a lower level than men's, and therefore, women fatigue much quicker. Playing while fatigued leads to a much greater chance of injury.

Another intrinsic factor that leads to females tearing their ACL's is the difference anatomically. The femoral intercondylar notch is found to be smaller in females due to having a smaller height and weight. A smaller notch indicates a smaller anterior cruciate ligament, which is more likely to sustain an injury (Charlton, St. John, Ciccotti, Harrison, & Schweitzer, 2002). Also, because women have a wider hip region than men, there is a lot more outward pressure that female's knees must sustain. This extra load has also thought to be a disadvantage for females.

The third intrinsic factor is the effect of the menstrual cycle on ACL tears. The menstrual cycle is divided into three phases: follicular, ovulatory, and luteal. These three phases are found to have a correlation with ACL injuries. The follicular phase begins on the first day of menstruation and usually lasts about 9 days; however, it does vary. During this phase, numerous follicles begin developing in the ovary with eventually one ovary becoming larger than the rest. Also, during this phase, luteinizing hormone amounts rise. The ovulatory stage lasts only five days but also has a peak in estrogen output. The final phase, luteal, lasts from day 15 until the end of the cycle.

During this phase, the follicles collapse because no pregnancy occurred. A rise in progesterone occurs during this last phase (Wojtys et al., 2002).

A study was performed where they surveyed sixty-nine female athletes twenty-four hours after they sustained their injury to see the correlation between menstruation cycles and ACL tears occurred. By giving questionnaires to females that had recently injured their ACL's, they found that a very high percentage of these tears occurred during the ovulatory phase. Going into the study, it was believed that the greatest amount of injuries would occur during the luteal phase because it is the longest of the three phases. This was not what the results indicated. Because of this greater probability during the ovulatory phase, it leads scientists to believe that there is something about the rise in estrogen levels during that phase that causes these injuries (Wojtys et al., 2002). Studies are still being performed to find out how the increase in the levels of estrogens makes the ACL ligament more susceptible to injury (Wojtys et al., 2002).

Once an ACL injury has been sustained and reconstructed in one knee it is more likely that an injury would occur to the bilateral knee than the reconstructed knee. This is thought to be because returning athletes tend to favor their healthy knee causing an extra load to be carried on that knee. In one study using 94 patients, fifteen patients had to be excluded because they had injured their healthy knee, and eleven were also excluded because of reinjury to the same knee (Drogset & Grontvedt, 2002).

Purpose of this Study

Though some information is available about bilateral injuries, there are few studies that look at actual causes. A bilateral ACL injury is sustained when a single ACL is ruptured followed by the rupturing of the opposite ACL later in time. The goal of this

study is to see if certain variables affect the incidence of bilateral ACL injuries. It is hypothesized that heavier patients and patients with a shorter duration of therapy will be more likely to sustain a bilateral ACL injury. These discoveries will be very beneficial because it will show if a person who has already torn their ACL once will be likely to tear their bilateral ACL.

CHAPTER II

MATERIALS AND METHODS

A letter and survey were sent out to 206 different orthopedic facilities that were chosen from a list of clinics, hospitals, and universities that were members of the National Orthopedic Association. The addresses were chosen randomly from the list making sure to send a couple to each state. Each letter simply asked for the clinics help by filling out a very straight-forward survey that only asked for a few specifics which were easily answered by either a number or a simple word (see Appendix A). The desired information on the survey included the date of the initial injury, the date of the second injury, which knee was injured first, height, weight, type of graft, dominance, and the duration of physical therapy. Along with these letters and surveys were sent stamped self-addressed envelopes to make the process as easy and inexpensive as possible.

Thirteen percent of these letters were returned stating that the address had changed or the doctor that it was intended for was no longer there. Seven percent were mailed back only to apologize for not having any data that fit the criteria. Only 2% were sent back with patients that could be used in the study, with the remaining 78% of the surveys lacking any response.

It was decided to look locally at Appalachian Therapy in Maryville, Tennessee for more data to contribute to the study due to the small sample size. The criteria were also altered from just female basketball and soccer players to all males and females. Patients who had torn their ACL only once were added so there would be something to compare to the patients with bilateral ACL injuries. Archived files at Appalachian Therapy were examined, and the following variables noted: the date of the first injury, date of the second injury if applicable, weight, type of graft, which leg was injured first, patient's dominance, duration of therapy, and the flexion and extension percentages for 180 degree motion.

Permission was granted by the human research committee to look at patients' files (see Appendix B). Statistical tests were performed on the data collected. A two-tailed t-test was used to analyze the data.

CHAPTER III

RESULTS

Data were compiled in Microsoft Excel. Examination of the files at Appalachian Therapy indicated that more females incurred a bilateral injury. Of the total bilateral injuries, 57% were found to be females. Table 1 presents the percent of patellar graft and patient lateral dominance of individuals in the study.

Microsoft Excel was used to determine the basic statistics of each group. The resulting mean and standard error were used to create a graph. Weight and duration of therapy were the two variables put into a bar graph (see Figures 2 and 3). Two-tailed *t*-tests were performed on each of these results.

Table 1. Right lateral dominance and patellar graft for both males and females with single and bilateral ACL injuries.

	Single		Bilateral	
	Male	Female	Male	Female
% Right dominant	66.7	77.8	93.2	92.2
% Patellar graft	75%	91.7%	66.7%	88.9%

Effect of Weight on the Bilateral Injury

The results from the *t*-test for average weight for males showed a *p*-value of.81 and .35 for females. This means that the difference in weight for single and bilateral ACL injuries was not significant (see Figure 2).

Therapy Duration after First Injury

The results for the *t*-test for duration of therapy were also found to be insignificant. Both *p*-values were greater than 0.05 (males =0. 09, females=0. 23). When genders were combined however, there was a significant difference in duration of therapy with a *p*-value of 0.03, with individuals experiencing a second ACL tear having longer durations after the first injury (see Figure 3).

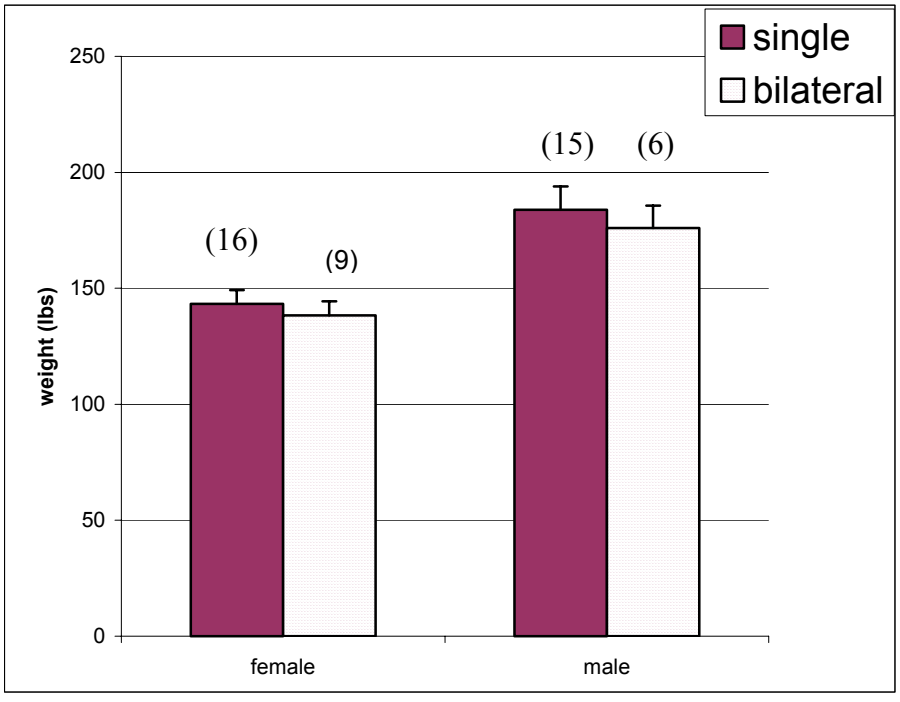

Figure 2. The average weight of females and males with single and bilateral ACL injuries.

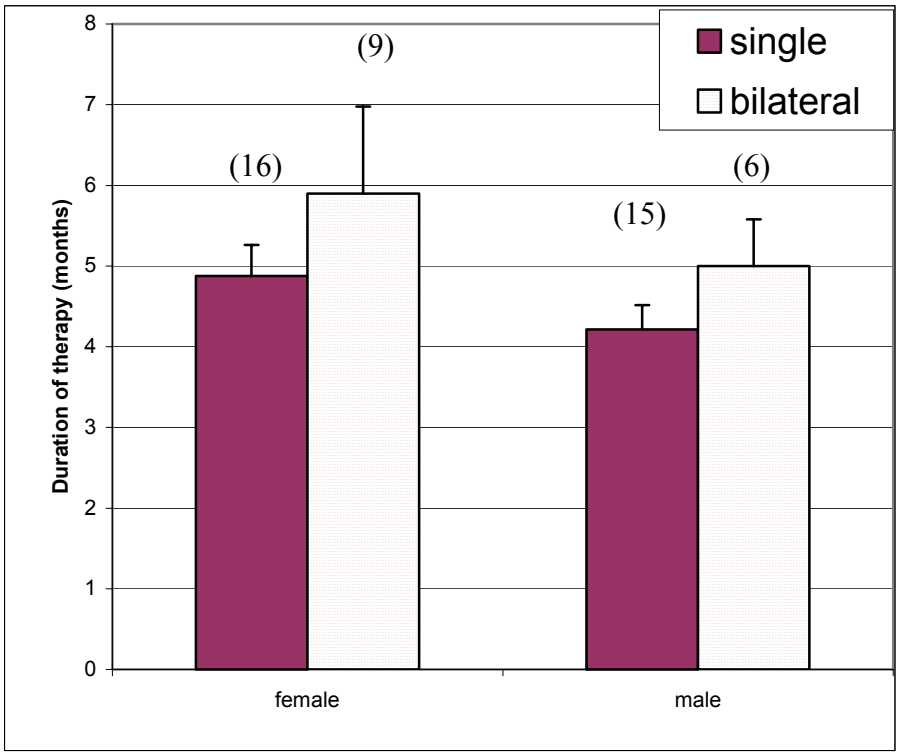

Figure 3. Average duration of physical therapy for males and females with single and bilateral ACL injuries.

Weight and Time between Injuries

The length of time between the bilateral injuries was compared to the weight of each bilateral patient to see if there was a correlation (see Figure 4). A linear regression test was performed on this data.

The R-squared value indicates that there is a very weak correlation between these two variables. When a *t*-test was performed, the result reported a *p*-value of .44. This shows that the results from this test were not significant.

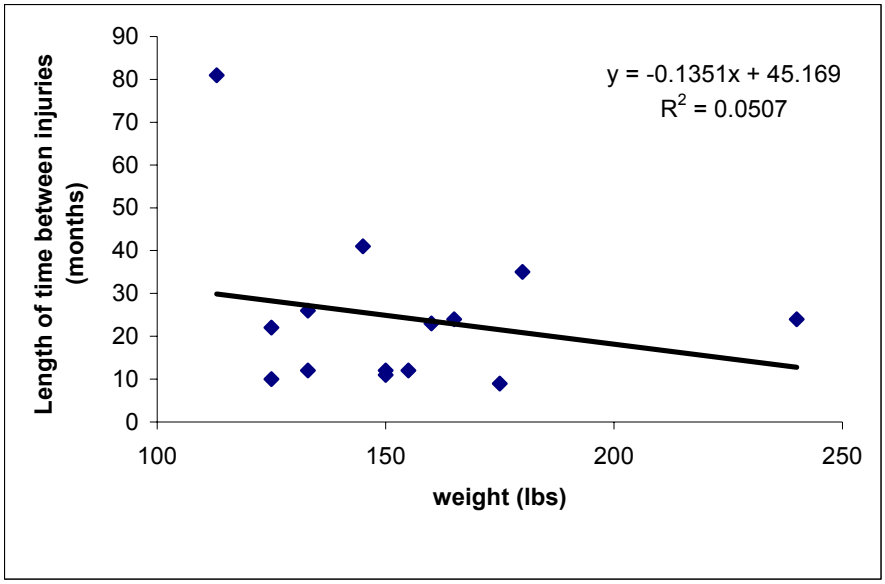

Figure 4. The time between bilateral ACL injuries for males and females depending on weight.

CHAPTER IV

DISCUSSION

The results show that there is not a significant difference in weight or duration of therapy for males or females between individuals with single or bilateral ACL injuries. This means that both hypotheses were rejected. Interestingly, when females and males were combined for the duration of therapy statistical test, a significant difference was found. This difference, however, was opposite of what was hypothesized. The results showed that people with bilateral ACL injuries actually attended therapy longer. While it makes more sense that people who attended therapy longer would be less likely to sustain a bilateral ACL tear, this was not the case. This unexpected finding could be explained by increased focus on the injured leg leading to neglect of the bilateral leg, or a lack of self-confidence in individuals having longer therapies leading to a more susceptibility.

A similar study was performed by Schickendantz and Weiker (1993) on 250 cases of surgically reconstructed anterior cruciate ligaments with 24 of them sustaining bilateral tears. The commonality of bilateral ACL tears is clear with approximately 10% of the patients having sustained them. Most of the patients with bilateral tears had reconstructive surgery on their initial ACL injury and half injured their other ACL performing the same activity that caused the first injury.

Unlike the results in the present study, Schickendantz and Weiker (1993) found more males with bilateral tears than females. This is unusual considering that females are more susceptible to sustaining ACL tears. The results from the present study found the average time between the initial and bilateral tears to be 24.4. This is about half the average that was found in the study with 250 cases (48.2). They did; however, find the average time between reconstructive surgery and the bilateral injury to be 29.3 months. This implies that the majority of patients used in this study had the surgery very soon after the actual injury.

Although the present study had a limited sample size, there are many studies available that have researched a similar topic with a much greater sample size. In one study on intercondylar notch width, a sample size of 45 bilateral ACL patients was used (Souryal, Moore, & Evans, 1988). Another study looking at notch width used a sample size of 90 men and 41 women with bilateral ACL injuries (Shelbourne, Facibene, & Hunt, 1997). It is clear that bilateral ACL injuries are not uncommon. These other studies indicate that a second ACL injury may be induced by: notch width, quadriceps muscle activation, the length of time before the patient returns to the activity, and gait accommodations.

The notch width is a common variable that is looked at as a predisposing factor of ACL injuries. Two studies measured the notch width of a control group, unilateral ACL tear group, and bilateral ACL tear group. Souryal et al. (1997) found that the mean notch width for the control group was slightly larger than the unilateral group, and the unilateral group was slightly larger than the bilateral group. There was a significant difference in notch width between the control group and the unilateral and bilateral ACL tears

combined; however, there was not a significant difference between the notch width of unilateral and bilateral ACL tears. A similar study recorded the same results. Even though the average notch width of the bilateral group was smaller than the notch width of the unilateral group, the results were still not significant. Based on the results of Souryal et al. (1997), it is likely that reduced notch width would have been a factor that predisposed individuals in this study to a second ACL injury.

A similar study was performed using computerized tomography analysis to determine lateral femoral condyle notch width. With their patients; however, they gathered various data including family history regarding knee injuries. This study found a significant difference in ACL tears regarding family history (Harner, Paulos, Greenwald, Rosenberg, & Cooley, 1994). These results show that there may be predisposing anatomic factors that contribute to ACL injuries. Harner et al. indicated that there might be factors determined at birth that are not hereditary that affect ACL tears.

There are some studies available that deal with variables affecting bilateral tears besides notch width. One study tested quadriceps muscle activation on unilateral ACL tear patients. The maximal voluntary activation was measured in both the injured and uninjured legs. The results showed that there was a moderately significant reduction in muscle activation in both legs (Urbach, Nebelung, Weiler, & Awiszus, 1999). These results are not what would be expected. Obviously the injured leg would have a reduction, but the uninjured side seems to contradict common thought. Most people would think that the uninjured size would stay the same if not increase. The patient is favoring the uninjured side, so it would seem to increase in voluntary quadriceps muscle activation. If patients with a unilateral ACL tear have decreased muscle activation in

both quadriceps, than the uninjured knee is less protected than it was before the initial injury. This could lead to a bilateral ACL tear.

Quadriceps strength is a common variable studied when looking at ACL injuries. One study looked at the impairments and disabilities that occur after ACL reconstructive surgery. Regarding quadriceps total work, it was found that it significantly improved up to two years after surgery (Risberg, Holm, Tjomsland, Ljunggren, & Ekeland, 1999). These findings have enormous implications to bilateral ACL injuries. Many patients return to their sport or activity that caused the intitial injury less than a year after surgery. This study is saying that it takes up to two years for the quadriceps muscle to perform at its normal level; meaning that patients who return to their activity before then are not yet at their normal strength. Thus, the results of Risberg et al. (1999) indicated that percent of quadriceps recovery could be a factor affecting bilateral ACL injuries.

Another variable that could be affecting bilateral ACL tears is the joint accommodations that the body makes when dealing with a unilateral ACL tear. One study specifically looked at gait accommodations. This study found that patients sustaining unilateral ACL tears showed symmetrical hip and asymmetrical knee joint motion. The control group showed exactly the opposite with asymmetrical hip and symmetrical knee joint motion (Ferber, Osternig, Woollacott, Wasielewski, & Lee, 2004). This study showed that these gait accommodations only lasted three months after reconstructive surgery. Maybe it is possible that these short-term alterations of gait could have some affect on the likelihood of sustaining a bilateral ACL tear.

From the present study and the others discussed, it is clear that there is much more to be learned about the variables causing bilateral ACL tears. Factors such as quadriceps

and hamstring strength at the end of therapy after surgery could indicate the likelihood of a bilateral injury. Many studies have indicated the deficit of quadriceps strength after ACL reconstructive surgery. Building up this strength in both legs and waiting up to two years before returning to the activity could decrease the chance of sustaining a bilateral ACL injury**.** One possible way to test the importance of duration of time before returning would be to gather the data from bilateral patients that show how long they waited to return to activity after the first reconstructive surgery. This could help present the ideal time period to return to the activity and be less likely to sustain a bilateral injury.

The results from the present study, while not significant, indicate that with a larger sample size, variables like weight and duration of therapy could affect the incidence of bilateral ACL injuries. Future research should be performed on similar variables such as the duration of time between returning to the activity after the first injury. As more studies become published many questions will be answers with the possibility of solutions to prevent these injuries from occurring.

APPENDICES

APPENDIX A

Survey Questions

	Case 1	Case 2	Case 3	Case 4
Date first ACL injury occurred				
Date contralateral ACL injury occurred				
Which ACL was first injured (right/left)				
Weight of patient				
Height of patient				
Patient's dominance (right of left handed)				
Type of graft procedure on first ACL injury				
Did the patient receive physical therapy after first ACL injury? -if so, the duration of the therapy				

*Make copies as necessary

APPENDIX B

Maryville College

Maryville, Tennessee
Human and Animal Subjects Review Committee

Response to Request to Conduct Research Involving Human or Animal Subjects

Date: September 28, 2004
Researcher: Elizabeth Rushworth

Faculty Supervisor: Dr. Drew Crain

Title: *"Anterior Cruciate Ligament Injuries and Reoccurrence in Females"*

Approval Status: Approved

Committee Approval: _____
* This completed form, along with the signed approval form, is to be included in the appendix of the research report.

REFERENCES

Barbour, S. A., & Kling, W. (2003). The safe and effective use of allograft tissue: An update. *The American Journal of Sports Medicine*, *31*, 791-797.

Charlton, W .P. H., St. John, T. A., Ciccotti, M. G., Harrison, N., & Schweitzer, M. (2002). Differences in femoral notch anatomy between men and women: A magnetic resonance imaging study. *The American Journal of Sports Medicine*, *30*, 329-323.

Childs, S. G. (2002). Pathogenesis of anterior cruciate ligament injury. *Orthopedic Nursing, 21*, 35-40.

Drogset, J. O., & Grontvedt, T. (2002). Anterior cruciate ligament reconstruction with and without a ligament augmentation device. Results at 8-year follow-up. *The American Journal of Sports Medicine*, *30*, 851-856.

Ferber, R., Osternig, L. R., Woollacott, M. H., Wasielewski, N. J., & Lee, J. H. (2004). Bilateral accommodations to anterior cruciate ligament deficiency and surgery. *Clinical Biomechanics (Bristol, Avon), 19*, 136-140.

Grabiner, M. D. (1989). The knee joint. In P. J. Rasch (Ed.), *Kinesiology and applied anatomy* (pp. 208-225). Philadelphia: Lea & Febiger.

Hame, S. L., Oakes, D. A., & Markolf, K. L. (2002). Injury to the anterior cruciate ligament during alpine skiing: A biomechanical analysis of tibial torque and knee flexion angle. *The American Journal of Sports Medicine*, *30*, 537-540.

Harner, C. D., Paulos, L. E., Greenwald, A. E., Rosenberg, T. D., & Cooley, V. C. (1994). Detailed analysis of patients with bilateral anterior cruciate ligament injuries. *The American Journal of Sports Medicine, 22*, 37-43.

Ireland, M. L. (2002). The female ACL: Why is it more prone to injury? *Orthopedic Clinics of North America, 33*, 637-651.

Jarvela, T., Paakkale, T., Kannus, P., & Jarvinen, M. (2001). The incidence of patellofemoral osteoarthritis and associated findings 7 years after anterior cruciate ligament reconstruction with a bone-patellar tendon-bone autograft. *The American Journal of Sports Medicine*, *29*, 18-24.

Johnson, D. P. (2003, September). Anterior Cruciate Ligament Reconstruction-ACL-Indications / Contra-indications. Bristol Orthopaedic and Sports Injury Clinic. Retrieved November 7, 2004, from the World Wide Web: http://www.orthopaedics.co.uk/boc/patients/anterior_cruciate_indications.htm/

Orchard, J., Seward, H., McGivern, J., & Hood, S. (2001). Intrinsic and Extrinsic Risk Factors for anterior cruciate ligament injury in Australian footballers. *The American Journal of Sports Medicine*, *29*, 196-201.

Risberg, M. A., Holm, I., Tjomsland, O., Ljunggren, E. & Ekeland, A. (1999). Prospective study of changes in impairment and disabilities after anterior cruciate ligament reconstruction. *Journal Orthopaedic and Sports Physical Therapy, 29*, 400-412.

Saunders, C. S. (1998). The active woman special health concerns. *Patient Care*, 32, 184.

Schickendantz, M. S., & Weiker, G. G. (1993). The predictive value of radiographs in the evaluation of unilateral and bilateral anterior cruciate ligament injuries. *The American Journal of Sports Medicine, 21,* 110-113.

Sebastianelli, W. J. & Black, K. P. (1995). Knee ligament injuries: A guide to 'hands on' diagnosis of anterior cruciate problems. *Consultant*, *35*, 163-170.

Shelbourne, K. D., Facibene, W. A., & Hunt, J. J. (1997). Radiographic and interoperative intercondylar notch width measurements in men and women with unilateral and bilateral anterior cruciate ligament tears. *Knee Surgery, Sports Traumatology, Arthroscopy, 5,* 229-233.

Six steps to help your knees. (2004). *Harvard Health Letter*, 1.

Souryal, T. O., Moore, H. A., & Evans, J. P. (1988). Bilaterality in anterior cruciate ligament injuries: Associated intercondylar notch stenosis. *The American Journal of Sports Medicine, 16,* 449-454.

Tanji, J. L. (1992). Advice that can reduce knee injury rates. *Consultant*, *32*, 100-101.

Urbach, D., Nebelung, W., Weiler, H. T., & Awiszus, F. (1999). Bilateral deficit of voluntary quadriceps muscle activation after unilateral ACL tear. *Medicine and Science in Sports and Exercise, 31*, 1691-1697.

Wojtys, E. M., Huston, L. J., Boynton, M. D., Spindler, K. P., & Lindenfeld, T. N. (2002). The effect of the menstrual cycle on anterior cruciate ligament injuries in women as determined by hormone levels. *The American Journal of Sports Medicine*, *30*, 182-188.