

ACL PREVENTION PROGRAMS AND
IT'S EFFECTIVENESS IN REDUCING THE RATE
OF INJURY IN THE COLLEGE AND
HIGH SCHOOL ATHLETE

By

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ABSTRACT

ACL PREVENTION PROGRAMS AND IT'S EFFECTIVENESS IN REDUCING THE RATEOF INJURY IN THE COLLEGE AND HIGH SCHOOL ATHLETE

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Purpose: The purpose of this study was to examine the absence or utilization of ACL injury prevention programs at NCAA universities, NAIA, junior colleges, and high schools.

Methods: A survey was used to determine if the use of an ACL injury prevention program could be considered useful to decrease the rate of ACL injury. Demographics were distributed to 1,000 certified members of the National Athletic Trainers Association who were currently employed at the collegiate or high school level.

Results: Results showed that non-contact ACL injuries were more frequent ($t = 3.749$, $p=.000$) than contact ACL injuries. The study found significance with those participants who stated 'some of their athletes' participated in a program compared to all athletes ($p=.006$) and no athletes. No significance was found if the instructor of the program had received any type of education in ACL injury prevention ($t=-0.686$, $p=0.495$), and at what time the program was utilized ($F_{(2, 61)}=.15$, $p=.862$). The study was unable to determine if certain exercises were beneficial when included in an ACL injury prevention program.

Conclusion: The results of this study provided further evidence that non-contact ACL injuries are more frequent than contact ACL injuries. The study exemplifies that there needs to be further research committed to determining what stretches, activities, and exercises are the most effective in reducing the frequency of ACL injuries in the high school and collegiate athlete.

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW OF THE PROBLEM

Injury to the anterior cruciate ligament (ACL) in the knee is an all too common injury among athletes, in spite of the increased awareness of the common mechanisms of injury. In recent years, there has been an increase in the amount of research dedicated to determining those factors that predispose athletes to an ACL injury. From 1988-2004, approximately 5,000 ACL injuries were reported among 15 NCAA sanctioned sports that were participating in Hootman's (2007) observational study; with an escalation in ACL injury by 1.3% each year. There are an estimated 80,000 ACL injuries that occur among the athletic population within the United States each year (Shimokochi, 2008), amounting to an approximately 1.7 billion dollars spent on surgery and rehabilitation services (Quatman, 2009). The athletes at greatest risk for injuring their ACLs are those who play sports which involve excessive cutting or pivoting in combination with a sudden change in speed. These movements are estimated to result in about 70% of all acute ACL injuries (Micheo, 2010).

According to the research, females are at the highest risk for incurring an ACL injury (Hewitt, 1999; Quatman, 2009). Hewitt (1999) states that female athletes have a 4 to 6 times greater chance of suffering from a general knee injury than male athletes. In Hootman's (2007) study, women's gymnastics had the highest rate of ACL injury. Female sports were reported to have three of the top four highest rates of ACL injury; which included women's gymnastics, women's soccer, women's basketball, in addition to men's spring football. An ACL injury is a significant injury that usually results in not only anatomical injury, but also emotional, psychological, and financial tolls on the athlete and their family. With the increasing number of

ACL injuries that are being diagnosed each year, there is an increased demand for an efficient way of managing and preventing ACL injuries.

ACL injuries are most frequently a result of a non-contact mechanism, usually in combination with a fast change in direction or speed. When the knee is in a slightly flexed position there are anterior tibial forces placed upon the knee resulting in the ACL being placed in a vulnerable position for injury. The ACL becomes even more susceptible to injury with the addition of internal tibial rotation to the already pre-existing anterior tibial forces (Markolf, 1995). An ACL rupture or injury frequently transpires when a valgus knee collapse occurs, which is classified as a non-contact mechanism. This occurs when the knee collapses in a valgus direction with internal tibial rotation, while the hip internally rotates. Female athletes have a 5.3 times greater risk of injuring their ACL than males, due to the valgus knee collapse mechanism (Quatman, 2009).

There are many extrinsic and intrinsic factors that are thought to contribute or predispose an individual to ACL injury. Extrinsic factors are those factors in which the athlete, coach, and athletic trainer have direct control of the situational factors. Some of these factors would be the level of play, a game or practice, level of skill, fitness level, type of shoe worn, wearing an ACL brace, weather, and the field conditions. Intrinsic factors are those factors that the athlete, coach, or athletic trainer cannot control and/or predisposing anatomical factors. Some of these factors would include the athlete's hormone levels, muscular strength, proprioceptive awareness levels, biomechanical awareness, and the individual's anatomical makeup and genetics. The awareness of these predispositions to ACL injury can help reduce the incidence and/or risk of injury by utilizing proper preventative measures.

One of the most influential aspects in regards to the stability within the knee is the athlete's efficiency of their neuromuscular control. It has been proposed that the hamstrings aid in decreasing the stress from the tibia sliding anteriorly on the femur, reducing hyperextension of the knee, and producing a posterior shearing force that aids in knee stability. In a study conducted by Renstrom (1996), it was found that the hamstrings can aid in limiting the stresses on the ACL when the knee is flexed past 60 degrees. If the muscle activation communication pathways are interrupted due to muscular imbalance compensation, the knee can become unstable and increase in laxity (Rozzi, 1999). Hewitt (1999) states that if there's a 60% difference in the quadriceps to hamstrings strength ratio the ACL is more susceptible to injury. In addition to Hewitt's findings, Myer (2008) found that anteroposterior tibiofemoral laxity can also contribute to ACL injury. It is important to find a balance between strength and flexibility; the hamstrings need to be strong enough to limit stresses that are placed upon the ACL, but also need to be flexible enough so that when contracted there isn't an increased strain on the ACL or impair its function. According to Boden (2010), a decrease in hamstring flexibility causes an increase in the compressive tibio-femoral joint forces also adding to ACL injury susceptibility. The quadriceps counteract the over stimulus of the hamstrings in order to decrease the stress and the strain placed on the ACL. When the knee is in slight flexion (hamstrings are activated), the angle between the infrapatellar tendon and tibia is largest, thus when in full knee extension (quadriceps activated) the shearing forces on the tibia anteriorly increase with a compressive tibiofemoral joint force; increasing the strain placed on the ACL (Shimokochi, 2008). Shimokochi's findings reiterate why it is important to make sure that the quadriceps do not put the knee into extreme extension since it can contribute to an increased tensile load placed upon

the ACL (Boden, 2010). It is therefore imperative to maintain the proper strength ratio and balance between the contraction forces of the hamstrings and quadriceps.

Poor biomechanics also contribute to ACL injury. A common biomechanical fault is when the athlete's foot is in a flat-footed position. Boden (2010) stated that when the athlete lands with a flat foot or near flat foot position, the lower extremity becomes a two part segment. This doesn't allow for the proper dispersion of the ground reactionary forces and increases the compressive forces on the lower extremity and a buckling within the joint. When landing from a jump an athlete should land with their foot in a forefoot position; this will increase the body's ability to absorb the ground reaction forces (Boden, 2010).

After sustaining an ACL injury, the risk for injuring the contralateral ACL increases by approximately 2 to 4% (Sward, 2010). According to Sward, the increased susceptibility to contralateral ACL injury exists because the opposing uninjured knee possesses the same biomechanical and material properties of the injured ACL and knee joint. The imbalances and genetic predispositional factors are usually equivalent and symmetrical thus an injury that occurs because these factors on one side of the body are risk factors that predisposes the contralateral side to injury as well. The body's anatomical makeup and tendency of the stresses and strains put on the ACL are equal to or greater than the injured ACL due to compensation (Sward, 2010). It has also been a recent area of interest of how often an ACL re-injury occurs after being surgically repaired and the athlete has returned to the level of play they were engaged in prior to the initial ACL injury. Hewett (2009) stated that the risk for a female athlete to reinjure their ACL after repair is between 12-28%. Myklebust and Holm (2003) found that the risk for reinjuring the ACL is approximately 22%. The risk of re-injury to the ACL is actually higher than the risk for sustaining a contralateral ACL injury, which was found to be around 9%.

There has been a recent increase in the amount of research dedicated to identifying individuals who are at risk of sustaining an ACL injury. Due to the increased attention to ACL injury, ACL injury prevention programs have become a topic of interest among the athletic population. There has been an even bigger interest especially within female athletics due to the increased risk factors women possess. There are many predisposing factors that can contribute to an individual's susceptibility to ACL injury. Becoming more aware of these factors and utilizing education, strengthening, and increasing an athlete's flexibility within an ACL injury prevention program can potentially help reduce the incidence of ACL injury.

1.2 SIGNIFICANCE OF THE PROBLEM

Females are 2 to 8 times more likely to injure their ACL than males (Boden, 2010; Quatman, 2009). Hewitt (1999) stated that females are 4-6 times at greater risk to injure their ACL than males. It is estimated that 10,000 female collegiate athletes will injure their knee within a one year period and that 2,200 of these injuries will be diagnosed as ACL ruptures (Hewitt, 1999). The contributing factors that increase females' susceptibility to ACL injuries are believed to be the anatomical makeup of women, neuromuscular efficiency, physiological contributions, conditioning levels, training exercises, and hormone levels (Wojtys, 2002). Boden (2009) stated that females have a wider hip and pelvis angle, this causes the knee to be in a more valgus or knock-kneed position. An increase valgus stress means that the lateral load on the knee joint increases, thus, there is more strain on the ACL (Boden, 2009). Females also have anteverted hips, placing the hamstrings in a shortened position decreasing knee joint stability (Shimokochi, 2008). When the female body decelerates, the hips antevert causing an increased load on the anterior tibial force; thus increasing the tensile force placed upon the ACL. Women

also tend to have smaller intercondylar notch widths increased joint laxity with anterior tibial translation in relation to the femur; all predisposing women to ACL injury.

One of the main topics of interest in recent years has been the impact of the female menstrual cycle on the susceptibility of the ACL to injury. Females have higher estrogen levels than men do, this is significant because estrogen has the ability to control and effect the relaxation of soft tissue such as the ACL (Boden, 2000). Estrogen's main function in the body is to promote fibroblast production and to reduce the synthesis of collagen. It has been suggested that if the soft tissue does become weaker due to collagen synthesis levels and decreases in its ability to perform at its needed strength, then females could be predisposed to ACL injury. Boden (2000) and Shultz (2005) found that knee laxity increased when estrogen and progesterone levels were elevated during menses. Numerous researchers have concluded that the use of oral contraceptives may release synthetic hormones that could decrease the likelihood of sustaining an ACL injury (Wojtys, 2002; Liu, 1997; Nielsen & Hammer, 1989; Hewitt, 2000).

ACL injury prevention programs have become a topic of discussion, especially within the female sports arena. These programs need to consider many different aspects including, education and athlete awareness, neuromuscular training, increasing the athlete's fitness level, increasing skill level, strengthening and increasing hamstring to quadriceps strength ratios, and identifying those athletes who are at a higher risk of ACL injury. An ACL injury prevention program needs to be set into place at a point in time when muscular fatigue will not negatively affect the benefits or outcomes of the programs goals. There is no one universally accepted ACL injury prevention program. The prevalence of ACL injury may be reduced by being aware of the factors that predispose an athlete to injury, be aware of the research dedicated to ACL injury prevention, and by utilizing an ACL injury prevention program.

Athletes should be educated on the proper neuromuscular and proprioceptive techniques, especially in the areas of pivoting and cutting maneuvers. The universally accepted elements to an ACL injury prevention program are stretching to increase flexibility, educating not only the athlete but also the coach, athletic trainer, and staff of higher risk maneuvers and positions, strengthening of the athlete's core and lower extremity; critiquing techniques (such as landing), increasing conditioning levels, sport specific agility, balancing, and plyometrics. It is vital to every prevention program to incorporate all activities and exercises in a multi-plane arena because of the non-specific dimensions and planes in which an ACL injury can occur (Renstrom, 2008).

There are a couple of widely accepted and used ACL injury prevention programs and educational techniques. Henning (1990) introduced the 3 step stop deceleration break down. A 3 step breakdown will decrease the impact forces and excessive loads placed on the knee joint and limit the rotational forces and ground reaction impact stresses on the ACL (Mandelbaum, 2005). Myklebust administered a program that aimed to improve the athlete's control of their movements in conjunction with controlling balance in a standing, jumping, and landing position. Although the results of Myklebust's prevention program were not statistically significant his ideas were utilized by other researchers. In 2007, Zazulak conducted a study that incorporated a program to increase proprioceptive awareness in order to decrease knee injuries. It was found that those who had poor core proprioception were at an increased risk for ACL injury, especially among those females who participated in the study (Zazulak, 2007).

Hewitt (1999) used a program that concentrated on educating the athlete on how to properly land from a jump, thus to reduce excessive valgus and varus stresses on the knee. The program consisted of muscular strengthening, stretching, and plyometric training. The program

did increase the participants' muscular strength and power of the hamstrings, decreased muscular imbalances between contralateral hamstrings, and decreased the hamstring to quadriceps torque ratios. The program's success led Hewitt to use it again in a study conducted on high school athletes, and the results demonstrated that the program was again successful. Hewitt's results showed that those athletes who were not part of the injury prevention program were 2.4 to 3.6 times more likely to have a serious knee injury compared to those who had participated in the program. The female athletes who did not use the ACL injury prevention program were 4.8 to 5.8 times at a higher risk of serious knee injury than male athletes. Females who had participated in the program were at a greater risk of injury than males, but the risk declined to females being only 1.3 to 2.4 times more likely to injure their ACL (Hewitt, 1999). Another widely accepted ACL injury prevention program is the Prevent Injury and Enhance Performance Program (PEP). This program contains a warm up, stretching, plyometrics, strengthening, and sport specific agilities that all focused on improving the athletes neuromuscular and strength coordination (Gilchrist, 2008). To date, there is no consensus on the benefit of one specific ACL injury prevention program over another. Moreover, it is important to keep in mind that sex and sport greatly impact the predisposition of the athlete to ACL injury. Therefore, further research is warranted on the effectiveness of ACL injury prevention programs and what these programs encompass in relation to specific sports.

1.3 PURPOSE STATEMENT

The main purpose of this study is to examine the absence or utilization of an ACL injury prevention program at NCAA colleges and universities (Division I, II, and III levels), NAIA universities, junior colleges, as well as at the high school level. It will assess what their ACL injury prevention program exercises and protocol consist of and determine if the training

program in use reduces the rate of ACL injuries by considering their ACL injury rate (non-contact vs. contact).

1.4 HYPOTHESES

The study will examine the following hypotheses:

H1: ACL injury prevention programs will be effective in reducing the incidence of ACL injury.

H2: Noncontact ACL injuries will be more prevalent than ACL injuries that result from contact.

H3: There will be an inverse relationship between the amount of time dedicated to the ACL injury prevention program and the incidence of ACL injury.

H4: ACL injury prevention programs that are conducted by ACL educated instructors will have a decreased number of ACL injuries compared to ACL prevention programs not conducted by an ACL educated instructors.

H5: Athletes who participant in an ACL injury prevention program prior to practice will have a lower incidence of ACL injury then those who participate in a program during practice.

H6: The most utilized screening tool used to determine if an athlete is at risk of ACL injury will be sex and the sport in which they participate.

1.5 RESEARCH QUESTION

R1: Will there be certain activities of an ACL injury prevention program (i.e., agility training, plyometrics, and education of proper techniques) that could decrease the incidence of an ACL injury?

1.6 OPERATIONAL DEFINITIONS OF TERMS

ACL Injury Prevention Program- A regime that commonly consists of stretching, strengthening, sport specific exercises, agility drills, and educational proper technique instruction with the goal of reducing the probability of sustaining an ACL injury.

Agonist – The muscles that stimulate contraction in relation to the muscles that are relaxing at the same time (Prentice, 2006).

Agility Drills- Exercise that improves an individual's balance, coordination, speed, endurance, strength, and reflexes usually in combination with a change of direction or velocity within a sport specific domain.

Antagonist – The muscles that counteract the muscles that are undergoing contraction (Prentice, 2006).

Anterior Cruciate Ligament (ACL) – Knee ligament; origin is proximal anterior middle tibia, insertion is medial surface of the lateral condyle. Prevents against anterior tibial translation, internal rotation, valgus and varus stresses (Prentice, 2006).

Articular (Hyaline) Cartilage – A connective tissue that acts to stabilize and reduce or reduce forces between joints. It receives no direct blood supply (Prentice, 2006).

Biomechanics – Pertains to the relation between the laws of mechanics to living organisms and biological tissue (Prentice, 2006).

Certified Athletic Trainer (ATC) – Healthcare professional, who has attained a bachelor's degree in athletic training, passed the board of certification, is a member of the National Athletic Trainers Association, and in the states that require it have acquired a state licensure. Specializes in the prevention, care and rehabilitation of injuries in the physically active population as well as providing general medical attention to illness.

Contact ACL Injury- Occurs when an excessive load is applied from an external force, usually another competitor that results in injury to the ACL.

Core Stability and Strengthening Exercises- Exercises and stretches that increase the strength, endurance and stability of the abdominal, trunk, and pelvic muscles.

Graduate Assistant Athletic Trainer- Usually a certified athletic trainer who has already attained his or her bachelor's degree. He or she are concurrently working towards receiving a master's degree while receiving teaching, clinical, and/or research opportunities and responsibilities.

K-T 2000 Arthrometer – Objective instrument used to measure knee laxity.

Lateral Collateral Ligament (LCL) – Knee ligament; origin lateral femoral epicondyle of the femur, insertion head of fibula. Prevents against varus forces (Prentice, 2006).

Laxity – Instability or a loose joint caused by stretched ligaments or tendons that predisposes the athlete to injury.

Posterior Cruciate Ligament (PCL) – Knee ligament; origin is post middle tibia, insertion is anterior lateral surface of the femoral medial condyle. Prevents against internal rotation and hyperextension (Prentice, 2006).

Magnetic Resonance Imaging (MRI) – Uses a magnetic field to take pictures of the body's tissues and organs, used as a diagnostic tool.

Medial Collateral Ligament (MCL) – Knee ligament; origin superior to joint line of femoral medial epicondyle, insertion is proximal medial tibia. Prevents against valgus and external rotation (Prentice, 2006).

National Collegiate Athletic Association (NCAA) – Membership organization and governing body of collegiate level sports that collectively initiates laws and regulations that protect the student athlete's welfare and academic success.

Noncontact ACL Injury- Occurs when the athlete engages in great forces or movements that apply an excessive load on the knee and results in ACL injury (Yu, 2007).

Pes Anserine Complex – Made up of the sartorius, gracilis, and semimembranosus.

Plyometrics - Exercise that maximizes the myotatic, or stretch, reflex (Prentice, 2006).

Screw Home Mechanism – When the knee extends, the tibia will externally rotate because of the medial condyle being larger than the lateral condyle (Prentice, 2006).

Sport Specific Education of Proper Techniques- Instruction, usually by someone who has undergone education by attending a symposium, conference, etc., of the safest body mechanics and movements to reduce the likelihood of injury.

Valgus – Body part that bends outward (Prentice, 2006)

Varus – Body part that bends inward (Prentice, 2006).

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction

There are approximately 80,000 ACL injuries that occur annually within the United States (Shimokochi, 2008). It is estimated that over 1.7 billion dollars in the United States alone is spent on ACL surgery and rehabilitation services (Quatman, 2009). A growing body of evidence suggests that ACL injuries occur from a combination of anatomical, biomechanical, neuromuscular, and proprioceptive mechanisms. There is an increasing interest and amount of research dedicated to ACL injuries which is the origin of potential major biological consequences, financial expenses, psychological stress, and difficulties in performing the smallest everyday tasks (Bien, 2011).

With the increasing awareness and ability to properly diagnosis an injury to the ACL and the increased understanding of body mechanics, the formation and utilization of ACL injury prevention programs have begun to develop. Due to the nature of sports and their variances in the demands placed upon the body, there is not one optimal ACL injury prevention program. The purpose of this chapter is to review the anatomy, epidemiology and mechanisms of ACL injury. It will further review how an ACL injury is evaluated, the factors that influence ACL injury, and discuss why women are more prone to injuring their ACL. An assessment of the prevention programs that have already been effective in the sport arena will also be presented. The main purpose of this study is to examine the absence or utilization of an ACL injury prevention program at NCAA colleges and universities (Division I, II, and III levels), NAIA universities, junior colleges, as well as at the high school level. It will assess what their ACL injury prevention program exercises and protocol consist of and determine if the training program in

use reduces the rate of ACL injuries by considering their ACL injury rate (non-contact vs. contact).

2.2 Anatomy

The knee is the largest capsule and joint in the body; it is formed by four bones, muscles, menisci, and ligaments. It is one of the most commonly injured structures during sporting activities due to the intense actions and loads that are placed upon the knee. The knee is primarily a hinge joint that allows movements consisting of flexion and extension, however since some rotation, gliding, and rolling is also involved within the knee joint; the knee is not a true hinge joint (Frind, 2008). The bones of the knee consist of the femur, tibia, fibula and patella. The distal portion of the femur extends inferiorly forming two condyles; the medial and the lateral. The femoral condyles articulate with the patella which rests within the intercondylar groove. The medial femoral condyle's articular surface is larger and longer than the lateral femoral condyle (Prentice, 2006). This creates a rotational component within the knee that will be discussed in more detail later. The proximal portion of the tibia allows for the femur to rest upon the tibial plateau in the concavities medially and laterally respectively. Between the two cavities is an area known as the tibial spine, this is where the anterior and posterior cruciate ligaments are located. The patella covers and protects the knee joint and is located at the distal end of the femur resting within the intercondylar groove between the medial and lateral femoral condyles. The patella moves in conjunction with the articulations of the knee, primarily with the quadriceps musculature. The patella is pulled superiorly, inferiorly, laterally and medially depending on the knee and muscle movements within the knee and hip, the depth of the femoral condyles, and the patellar shape. The patellar tendon originates at the apex of the patella and inserts at the tibial tuberosity. All major movements created in the knee are involved with

articulations between these three bones. Each bone has a covering on its ends called articular cartilage, which decreases the friction and forces created with movement between the bones. The fibula is the fourth bone in the knee joint that lies on the lateral distal leg adjacent to the tibia. The knee is surrounded by a nourishing capsule called the synovial membrane. There are bursas and fat pads located superiorly, inferiorly, laterally, and medially to the knee joint that act as cushions to the joint. These fat pads and bursas can become irritated and inflamed due to acute or chronic trauma to the knee, which can cause pain and discomfort within the joint (Prentice, 2006).

The knee's stability is maintained by the four main ligaments within the joint. The medial collateral ligament or MCL inserts superiorly to the medial femoral condyle and inserts on the tibia a little inferiorly to the pes anserine complex. Some of the fibers of the MCL are attached to the deep posterior capsular ligament and the semimembranous that attaches to the posterior portion of the medial meniscus. This attachment allows for the MCL to pull posterior during knee flexion. Its main function is to prevent the knee from valgus loads and external rotational stresses (Prentice, 2006). The MCL is surrounded by connective tissue and has a healthy blood supply, thus, making it the only ligament in the knee capable of scarring over and healing by itself; if the tear is not too severe (Frind, 2008). On the opposite side of the knee, is the lateral collateral ligament or LCL which prevents excessive outward forces or varus stresses. The LCL becomes loose with knee flexion and taut in extension. The LCL originates at the lateral femoral epicondyle and inserts at the head of the fibula. Originating at the posterior tibia and extending anteriorly, superiorly, and medially inserting on the medial femoral condyle is the posterior cruciate ligament (PCL). The PCL prevents against posterior forces and excessive rotation to the tibia on the femur (Prentice, 2006). It is stronger, meaning it is less injured than

the anterior cruciate ligament (ACL) and is also a multifascicular structure as is the ACL. The ACL originates anterior and inferiorly to the tibia and extends posterior, inserting at the lateral femoral condyle. The ACL is a multifascicular structure meaning that it is comprised of three bands, the anteromedial, intermediate, and the posteriolateral (Frind, 2008). It mainly prevents against the tibia sliding forward on the femur, knee hyperextension, and excessive internal rotation of the knee (Prentice, 2006). When the knee is in a flexed position the anteromedial fibers of the ACL tighten and the posteriolateral fibers loosen. The ACL provides an estimated 85% of the total knee restraint during anterior tibial translation when the knee is flexed at approximately 20-30 degrees of flexion (Quatman, 2009). The hamstrings work in accordance with the ACL to provide the utmost stabilization within the knee (Prentice, 2006).

There are two menisci, the medial and the lateral which are thinner on the inside of the knee and thicker at the edges, creating a cup that the femur can fit snugly into. The medial meniscus is in the shape of a “c” and the lateral meniscus forms an “o” shape. The menisci of the knee primarily act as shock absorbers that limit and dissipate the forces generated between the tibial plateau and the femur (Prentice, 2006). The knee has the capability to absorb eight times an individual’s bodyweight when landing from a vertical jump, but typically the body can only endure up to four times its bodyweight before an injury occurs (Ramsey, 2003). The menisci also provide lubrication and joint stability within the knee joint. The medial genicular artery supplies blood to both the medial and the lateral menisci (Prentice, 2006). When injury to the ACL occurs, the medial meniscus is usually torn in conjunction due to the mechanism of internal rotation and hyperextension. The internal rotational forces pinch the medial meniscus and the hyperextension of the joint increases those forces. Further, an injury to the meniscus and the ACL predisposes the patient to developing osteoarthritis within the knee (Frind, 2008).

Figure 2.1
(Frind, 2008)

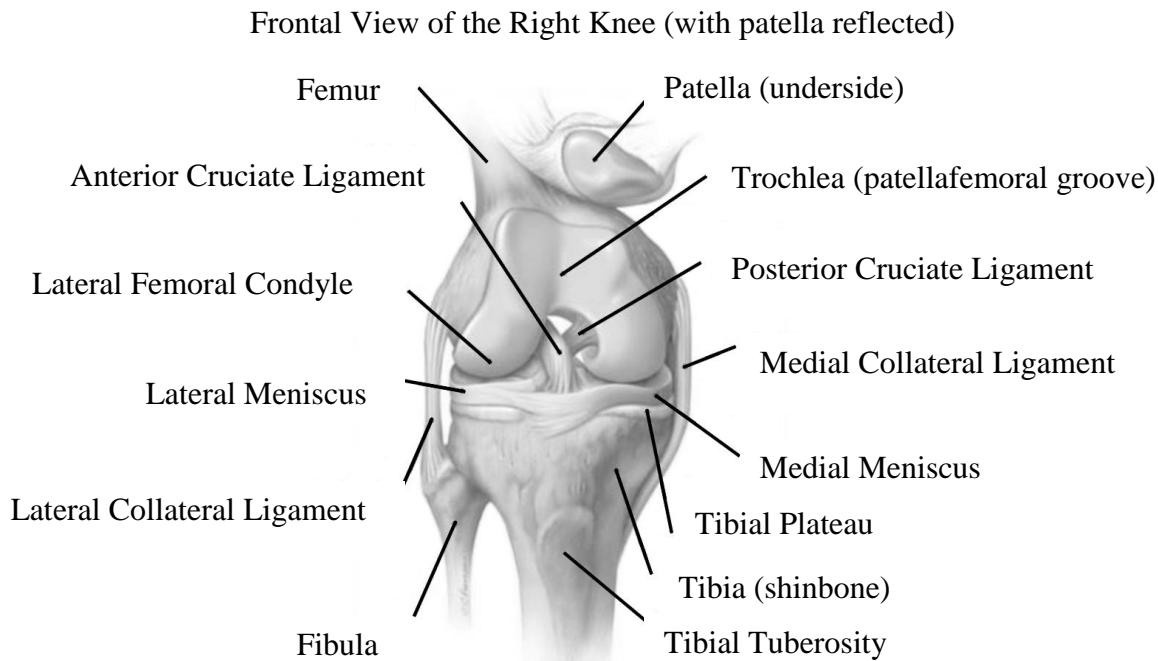


Figure 2.1 Anatomy of the Knee
(Frind, 2008)

The musculature surrounding the knee is made up of the hamstrings and quadriceps groups in conjunction with the gastrocnemius. The hamstrings are made up of three muscles which include on the medial side, the semiteninosus and semimembranosus and on the lateral side the biceps femoris. The hamstrings are located posteriorly and are responsible for knee flexion and limiting knee hyperextension; thus making it important in protecting the ACL. The popliteus muscle also aids in stabilization of the knee in flexion, by pulling the lateral meniscus posteriorly during knee contraction (Prentice, 2006). The quadriceps musculature group consists of the vastus medialis, vastus lateralis, vastus intermedialis, and rectus femoris which all play a role in extending the knee (Frind, 2008). The vastus medialis is most important muscle within the quadriceps musculature for proper patellar tracking. The tendon of the tensor fascia latae known as the iliotibial band, aids in knee stabilization by becoming taunt in both knee flexion

and extension. Finally, the gastrocnemius aids in knee flexion, it originates on the medial and lateral femoral condyles and inserts on the calcaneus (Prentice, 2006).

The knee joint enables movement in both the transverse and frontal anatomical planes. The knee's anatomical makeup allows for flexion, extension, rotation, and minimal rolling and gliding. For example, the tibia will glide anteriorly and minimally rotate posteriorly on the femur when the knee extends. One of the most important anatomical mechanical properties in the knee is known as the “screw home” mechanism. This mechanism displays how the anatomical makeup of the knee joint causes the tibia to externally rotate as the knee extends (Prentice, 2006). As discussed earlier, the lateral femoral condyle is larger than the medial condyle; this anatomical asymmetry causes the tibia to externally rotate with full knee extension. The popliteus muscle counteracts this imbalance and unlocks the knee so that knee flexion can be achieved. It does this by contracting the knee which then causes the femur to externally rotate (Frind, 2008).

2.3 Epidemiology of ACL Injuries

Injury to the ACL has become a highly researched area of interest within the past few decades. ACL injuries are one of the most common injuries in sports that has the potential to severely impact an athlete's career. ACL injuries have become a more prevalent topic due to the recent findings that female athletes seem to be more susceptible to tearing or injuring their ACL (Hewett, 1999). According to Hewett (1999), female athletes (greater than 12 years old) participating in sports that involve cutting or jumping actions have a 4 to 6 times greater incidence rate of general knee injury than their male counterparts. Similarly, Bien (2011) found that high school and collegiate women athletes have a 3 to 4 times higher likelihood of sustaining

an injury than men. Sports that demand actions such as cutting and/or pivoting make up an estimated 70% of all acute ACL injuries (Micheo, 2010).

It is estimated that 1 out of every 3,000 athletes in the United States will suffer from an ACL tear. In a National Collegiate Athletic Association (NCAA) survey that was conducted over a 16 year period, ACL ruptures were the found to be the second most common injury to the lower extremity (Micheo, 2010). According to Hootman (2007) over a 15 year span, more than 50% of all the NCAA reported injuries were to the lower extremity. The knee was the second most frequently injured lower extremity injured. In an injury survey that was conducted between the 1990-1993 seasons by the NCAA, 15% of the institutions participating in the study reported that on average the incidence rate of knee injuries was 1 for every 1,000 athlete-exposures. This means that approximately 10,000 knee injuries are expected yearly to occur among the female collegiate athlete population (Hewett, 1999). Within the past 16 years the rate of ACL injury has increased annually by 1.3%, but only account for an estimated 3% of all bodily injuries. Although 88% of ACL injuries were reported to result in a severe loss of playing time (NCAA category for documentation) before the athlete was able to return fully to their previous activity without restrictions. The steady increase of ACL reported injuries could be attributed to the increased awareness of ACL injuries and the long term negative anatomical effects of this injury. The increase may also be attributed to having access to more technologically sound diagnostic equipment such as MRIs and arthrograms and an overall increase in participants engaging in sporting activities (Hootman, 2007).

Every year over a 15 year period, Hootman (2007) found that there were approximately 2,000 ACL injuries that occurred within the 15 sports at the NCAA level that participated in the observational study. Football had the most reported incidence of ACL injuries, but women's

gymnastics had the highest injury rate per athletic exposure (*See Table 2.1*). Hootman's finding are in agreement with the International Olympic Committee's concept statement on non-contact ACL injuries in female athletes released in 2008, it reported that the rate of ACL injury per every 1,000 athlete exposures was highest in women's gymnastics (4.9 injury rate per 1,000 exposures), men's spring American football (0.33 injury rate per 1,000 exposures), and female soccer (0.28 injury rate per 1,000 exposures) (Renstrom, 2008) (*See Table 2.2, 2.3*). The NCAA data stated that women's gymnastics had an injury rate of 0.33 per every 1,000 athlete-exposures, followed by women's basketball (0.23), and women's soccer (0.28). These female sports were 3 of the top 4 sports that exhibited the highest injury rates, the other being men's spring football (Hootman, 2007).

Table 2.1
(Hootman, 2007)

Frequency, Distribution and Rates of Select Sports (ACL) for Games and Practices Combined for
15 Sports, 1988-1989 to 2003-2004

Sport	Frequency	Percentage of All Injuries	Injury Rate per 1,000 Athlete-Exposures	95% Confidence Interval
Men's Baseball	56	0.7	0.02	0.01,0.02
Men's Basketball	167	1.4	0.07	0.06,0.08
Women's Basketball	498	4.9	0.23	0.21,0.25
Women's Field Hockey	53	1.6	0.07	0.05,0.09
Men's Football	2159	3.0	0.18	0.17,0.19
Women's Gymnastics	134	4.9	0.33	0.28,0.39
Men's Ice Hockey	78	1.2	0.06	0.05,0.07
Women's Ice Hockey*	3	0.7	0.03	0.00,0.07
Men's Lacrosse	131	2.7	0.12	0.10,0.15
Women's Lacrosse	145	4.3	0.17	0.14,0.20
Men's Soccer	168	1.3	0.09	0.08,0.11
Women's Soccer	411	3.7	0.28	0.26,0.31
Women's Softball	129	2.4	0.08	0.06,0.09
Women's Volleyball	142	2.0	0.09	0.07,0.10
Men's Wrestling	147	1.5	0.11	0.10,0.13
Men's Spring Football	379	3.5	0.33	0.30,0.37
Total ACL Injuries	4800	2.6	0.15	0.14,0.15

*Data Collection for Women's Ice Hockey began in 2000-2001

Table 2.1 Frequency, Distribution and Rates of Select Sports (ACL) for Games and Practices Combined for 15 Sports, 1988-1989 to 2003-2004 Displays the frequency, distribution, and ACL injury rate for Hootman's study conducted using 15 different sports at the NCAA level over a 16 year period (2007).

Figure 2.2
(Renstrom 2008)

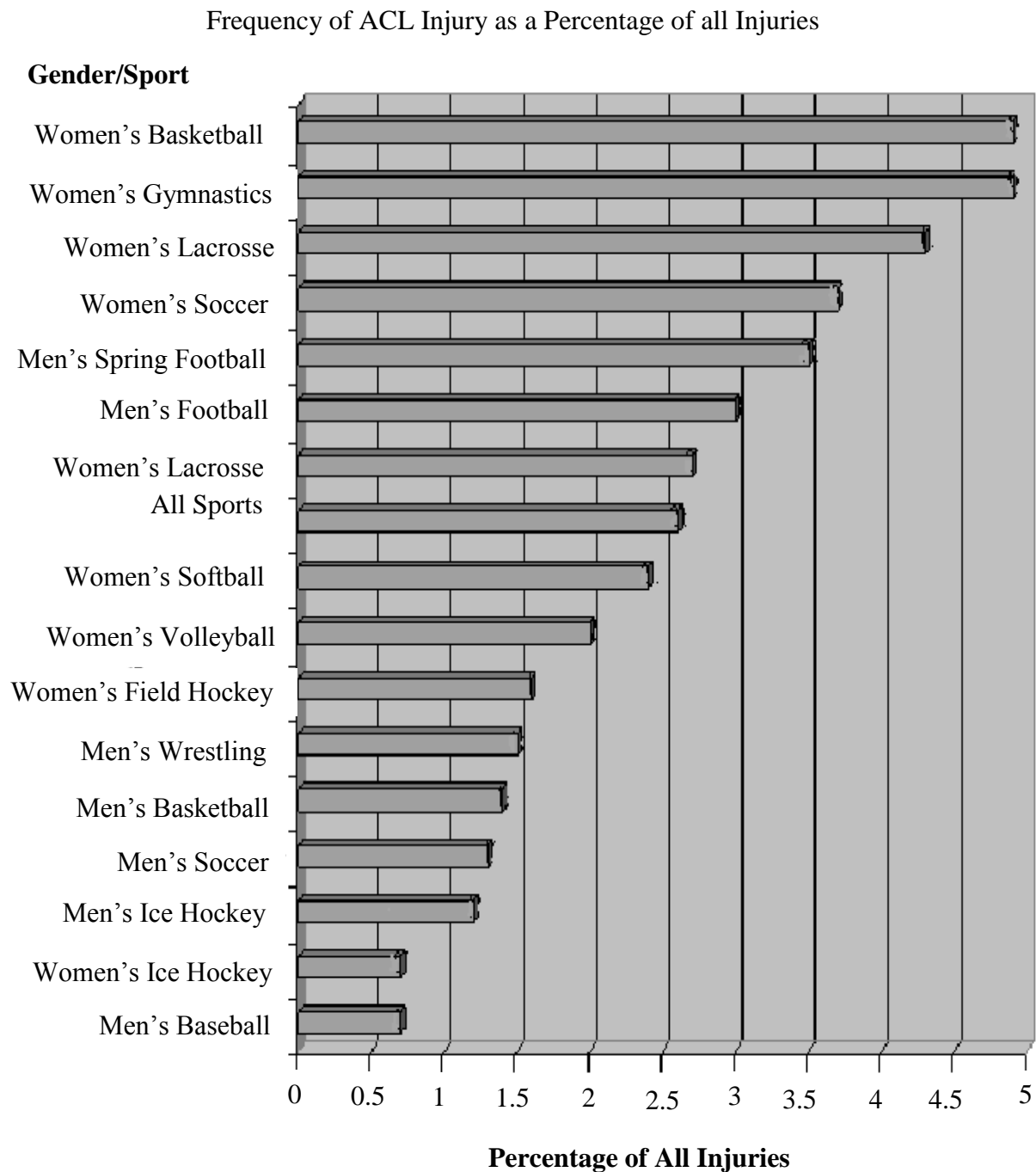


Figure 2.2 Frequency of ACL Injury as a Percentage of all Injuries

Figure expresses the frequency of injury to the ACL, refers to the percentage of ACL injuries.

Figure 2.3
(Renstrom 2008)

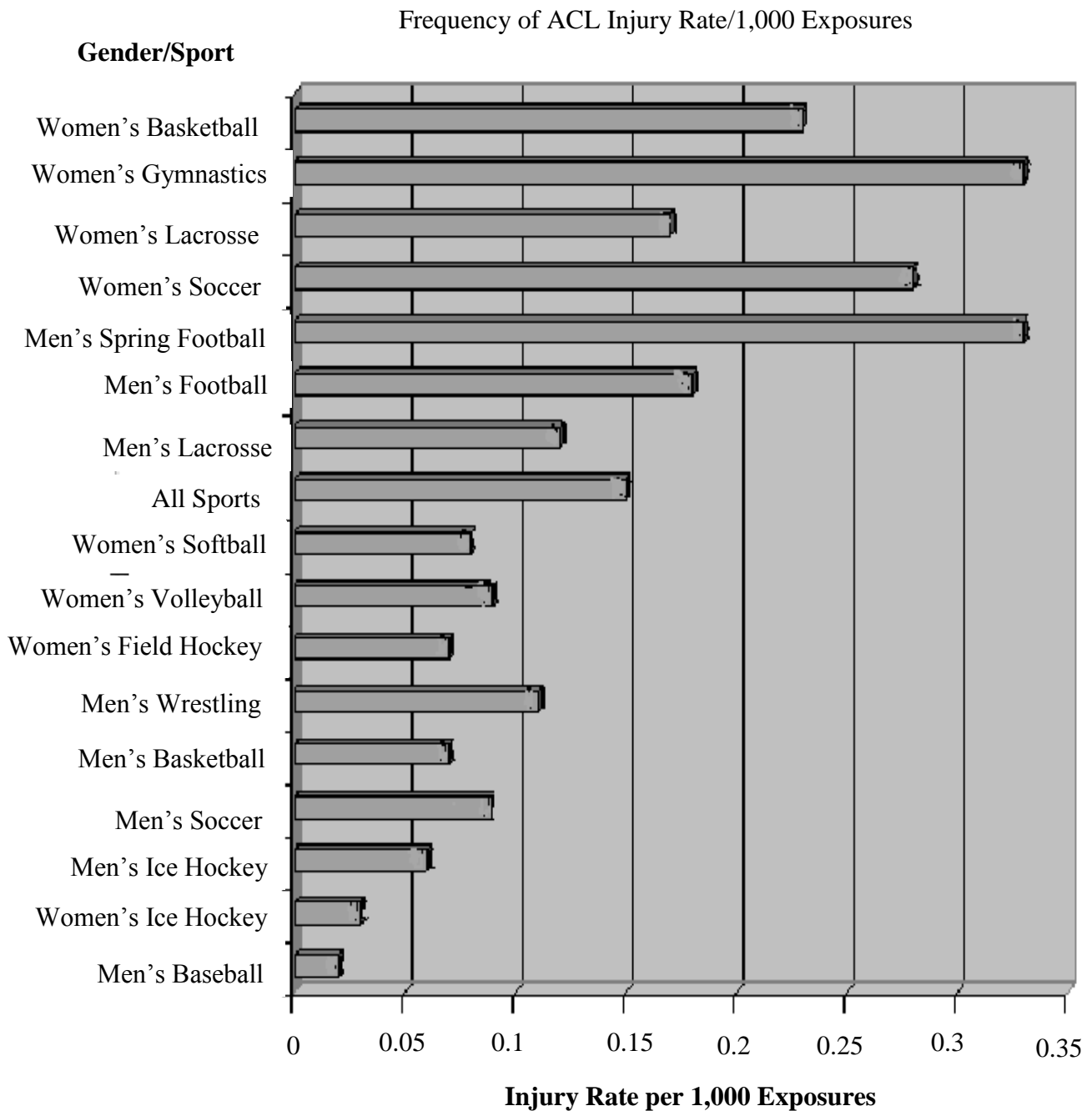


Figure 2.3 Frequency of ACL Injury Rate/1,000 Exposures Figure expresses the frequency of injury to the ACL, illustrates the rate of injury to the ACL per every 1,000 exposures.

The lowest incidence rates per 1,000 athlete-exposures were men's baseball (0.02), women's ice hockey (0.03) and men's ice hockey (0.06) (Renstrom, 2008). Similar to these findings Hootman (2007) found that the lowest injury rates reported by the NCAA were women's ice hockey and baseball (0.7 percent of all injuries reported), men's ice hockey (1.2 percent of all injuries reported), men's soccer (1.3 percent of all injuries reported), and men's basketball (1.4 percent of all injuries reported). The International Olympic Committee's statement also expressed that the percentage of ACL injuries on a team when compared with all the injuries reported for that team, ACL injuries were the highest in female sports such as soccer, lacrosse, gymnastics, and basketball (Renstrom 2008). These conclusions are similar to that of Ireland's (1999) analysis of ACL epidemiology, which stated female non-contact ACL injuries in basketball and soccer were 2 to 4 times greater than their male counterparts participating in the same sports, but this study was performed among the high school population and not at the collegiate level. At the high school level, women's basketball had 3.75 more ACL injuries per hour of athlete-exposure compared to men's basketball. Similarly, a study was conducted among New Jersey high schools that showed women's basketball ACL injuries were 3.52 greater than men's basketball; with season ending injury also being greater in women. These differences shown between the injury rates of women and male sports may be contributed to level of competition and skill, playing style, conditioning, and the intrinsic and/or extrinsic factors that will be addressed in further detail later in this article (Ireland, 1999).

2.4 Mechanisms of ACL Injuries

The ACL becomes susceptible to injury when an excessive strain is loaded upon it, which typically occurs with an anterior tibial force when the knee is in a flexed position. Further, when the knee is extended or is hyperextended and is combined with internal tibial rotation and an

anterior tibial force the ACL is at risk for injury (Markolf, 1995). ACL loading forces that occur in the last 30 degrees of knee extension and hyperextension put the ACL at a greater risk of injury (Micheo, 2010). The most dangerous load put onto the ACL occurs with a valgus stress when the knee is at more than 10 degrees of flexion in combination with an anterior tibial force. It has been found that external rotational forces combined with anterior tibial forces actually decrease the chances of ACL rupture due to a decrease in the load induced upon the ACL and its surrounding structures (Markolf, 1995). These findings correlate with Berns (1992), who studied cadaver knees to determine the effects of different strains on the ACL. His findings exhibited that forces to the proximal tibia in conjunction with valgus stress produced a greater strain on the anterior medial bundle of the ACL. However, this was only compared to putting anterior shearing forces on the anterior tibia in a direct manner without rotational stress.

ACL injuries can be a result of either contact or non-contact mechanisms. Contact ACL injuries are defined as an “ACL injury sustained as a result of direct contact to the knee or another body part by another player or object during the course of play” (Gilchrist, 2008). The definition of a non-contact ACL injury would then be classified as “sustained by an athlete without extrinsic contact by another player or object on the field” (Gilchrist, 2008). These definitions will be the classifications that are used throughout this paper. Griffin (2000), states that 30% of ACL injuries are the direct result of contact with another player or object, therefore that the remaining 70% of ACL injuries are non-contact injuries. Non-contact injuries were found to be primarily the result of improperly landing from a jump, cutting, or sudden deceleration (Arendt, 1993).

A valgus collapse occurs when the knee collapses inward (Prentice, 2006). The primary actions that take place in a valgus collapse are knee valgus forces with hip internal rotation and

tibial rotation. Valgus collapse primarily occurs within the frontal plane of motion and not under multi-planar conditions; it is usually associated with ACL injury in conjunction with the MCL in women. This is one of two of the most frequently observed biomechanical actions that occur with non-contact ACL injuries; the other being an anterior tibial shearing mechanism. When an athlete has a torn ACL they are usually able to function normally within a sagittal plane, but when rotational movements are demanded in multi-planar dimensions the instability and feelings of a valgus collapse or “giving away” occur. According to Quatman (2009), most valgus knee collapses occur when the knee is between 0-30 degrees of flexion; the tibia is placed in an internally rotated position with the foot planted usually during some sort of deceleration phase or maneuver. Krosshaug (2007) found that female basketball players have a 5.3 times greater risk of suffering a valgus knee collapse with an ACL injury when compared to their male counterparts. Anatomically, women have a greater valgus angle in their knees predisposing them to experience a valgus knee collapse (Quatman, 2009). Valgus collapse may also result from women having the tendency to be more quadriceps dominant than men (Hewett, 2000). Weak gluteal muscles can contribute to the valgus collapse mechanism (Bien, 2011). When the gluteus medius is weak, it hinders the ability of the hip musculature to maintain hip abduction; this further presents a problem with single leg landings, cutting, and pivoting motions when changing directions (Bien, 2011). Quatman (2009) stated that women have a higher rate of valgus collapse injuries than men, but men experience ACL injury more frequently within the sagittal plane. This statement correlates with Fayad (2003) who found that posteriolateral bone bruises are more frequently observed in women, men exhibited more injuries to their medial meniscus, LCL, and PCL; which is more common with ACL injuries that occurred within the sagittal plane. In Quatman’s (2009) study, it was found that the participants who injured their ACLs at a later date had

displayed more than 8 degrees of knee valgus forces when landing from a drop jump in comparison to those who did not sustain an ACL injury.

In a video analysis study performed by Krosshaug (2007), the mechanisms of ACL injury in basketball were identified and observed. This study not only observed the actual mechanism, but also the athlete's position, behavior, and reaction to the athlete's playing situation and stance. The results of the study showed that the knee usually collapsed inward or in a medial manner due to extreme valgus loads placed on the knee joint or internal rotation of the tibia on the femur. Krosshaug's (2007) study found that 72% of the ACL injuries were from non-contact mechanisms, this is similar to Boden's (2010) findings who found that approximately 75% of ACL injuries were non-contact. With all of the ACL injuries, other competitors were in close proximity, which may have influenced the movements that lead to injury. In almost half of the female injuries, the player was pushed or involved in a collision prior to experiencing the injury. This observation suggests that the impact or contact could have influenced the proceeding movement patterns that resulted in the occurrence of the injury. Krosshaug observed that valgus knee collapse occurred more in female players compared to male players. Females were found to have a 5.3 times higher risk of sustaining an ACL injury than the males within the study. When landing from a jump, the females involved in the observational study landed in a position that exemplified greater hip and knee flexion (Krosshaug, 2007). Earlier studies found that in the majority of non-contact ACL injuries the injury occurred immediately after landing while the knee was in an extended position. Knee hyperextension can put the knee into the position of the "point of no return". The "point of no return" occurs most frequently when landing in an upright position with the hips in a semi-flexed position and the knees in a straight or locked position. This position causes an excessive anterior or forward movement in the knee (Micheo, 2010).

When landing from a jump there are two landing techniques, a soft and a stiff landing, that are identified by Laughlin (2011). A stiff landing was defined as the participant landing with minimal bending of their trunk and hips and their legs at almost full extension. A soft landing was when the participant would land with their leg bent with maximal flexion in their trunk and hips. In this study the participants drop landed in a soft manner or had to perform a stiff landing, in both cases the participants were told to land with their foot in a fore-foot to rear-foot contact pattern; which has been proven to decrease the impact of the landing. Laughlin's study found that landing softly, landing with the knee and hip in flexion, resulted in a decrease in the peak ACL forces. This could be explained as the knee flexion angle placing the hamstring in tension resulting in an increased posterior shearing force. Landing with a stiff knee, meaning minimal to no knee or hip flexion, the landing forces were higher (0.70) compared to the soft landing (0.58). The forces acting on the ACL was lower in with a soft landing technique at 0.71 body weight (BW) when compared to the stiff landing position which was 0.80BW (Laughlin, 2011). This study supports Krosshaug's (2007) study that the forces acting upon the ACL are minimized when there is knee and hip flexion present, although Laughlin (2011) does not address valgus loading.

2.5 Evaluation of ACL Injuries

When an ACL injury occurs, most of the time a pop or a cracking sound can be heard and/or felt and swelling will become prevalent within the knee joint. On evaluation there will be a positive finding with a Lachman's test, anterior drawer, and pivot shift test. If these tests are positive a physician will typically order a magnetic resonance imaging (MRI) test to confirm the diagnosis. Depending upon the severity of the injury to the ACL, the athlete may be able to continue to be athletically functional and/or in their normal daily living while only exhibiting

minor signs of instability. An athlete could may not cope as well with the ACL injury and have difficulty performing normal everyday activities; this is typically the case when the ACL is not an isolated injury (Maxey 2007).

Most ACL injuries result in the athlete having to undergo surgery to repair the torn ligament. If surgery is not performed, the athlete will be at risk for developing osteoarthritis within the joint and having instability within the knee (Frind, 2008), which could lead to meniscal tears (Maxey, 2008). Another complication with ACL rupture is that the articular cartilage is damaged approximately 85% of the time. This causes the articular cartilage to give way and a bone bruise to occur (Frind, 2008). Bone bruises to the lateral femoral condyle or posteriolateral tibial plateau are primarily caused by compressive lateral loads and they occur approximately 80% of the time after an ACL injury (Quatman, 2009). A bone bruise will heal in time, but instead of new articular cartilage the body generates fibrocartilage. This cartilage is not the most optimal stabilizing and cushioning structure, thus arthritis usually develops over time (Frind, 2008). It has also been found that a hematoma forms in the femoral intercondylar notch, which is the origin of the ACL after a complete rupture. Due to the increased severity of an injury to the ACL in combination with a meniscal injury osteoarthritis occurrence is 21-48%, which is significantly higher than when just the ACL is injured. An injury to only the ACL has a 0-13% occurrence of osteoarthritis. The prevalence of osteoarthritis after not having reconstructive surgery and undergoing conservative treatment (31-48%) does not differ significantly when compared to having the surgery (29-51%) (Micheo, 2010). If choosing to participate in sport without undergoing reconstructive surgery the athlete must alter some of their movements, for example eliminating or decreasing the amount of pivoting and quick lateral movements and wearing an ACL custom made brace to provide joint stability.

As technology advances, so does the surgical techniques used to repair a torn ACL. Surgeons are now able to perform arthroscopic surgery, which has many different variations, that all allow for minimal incision sizes. The grafts most widely used to reconstruct an ACL are the central third of the patellar tendon, a graft from the hamstring, or more recently the use of an ACL from a cadaver. The factors that influence graft selection are the athlete's thoughts and concerns, the biomechanical integrity of the graft selection, and how the graft will withstand the demands placed upon it as it functions as the new ACL. Research has shown that a 14 mm graft from the middle of the patellar tendon has 168% of the strength of a normal healthy ACL, but has an increased stiffness rate (Maxey 2008). These findings correlate with Micheo (2010), who stated that the patellar tendon provides a superior postoperative stability within the knee joint and has the decreased risk of re-injury. It has been found that a single strand graft of the semitendinosus only had approximately 70% of the strength of an intact ACL, but if a multiple strand graft is used they become just as strong or stronger than a healthy ACL (Maxey 2008). Sward (2008) stated, that the risk of a re-rupture or a graft failure after undergoing ACL surgery is greatest within the first 12 months after surgery; this must be considered when returning to play and when assessing the need and utilization for an ACL rehabilitation and prevention program for the athlete.

2.6 Factors That Contribute to ACL Injuries

There has been an influx of research committed to studying different factors that could potentially predispose an individual to an ACL sprain or complete rupture. The main topics of interest include both intrinsic and extrinsic factors. The most common extrinsic risk factors are the environment, the interaction between the athlete's footwear and the playing surface, protective equipment, and weather conditions. By altering or reducing the risks brought forth by

the extrinsic factors, a reduction of the injury risk to the ACL will occur; this is one of the first steps in creating an effective ACL injury prevention program. Internal risk factors refer to those factors that cannot necessarily be entirely affected by the athlete's actions or environmental awareness, but can be reduced if aware of them and how to counteract them. These include the athlete's hormone levels, muscular strength, neuromuscular awareness levels, and anatomical and genetic makeup.

Extrinsic risks are factors that can be impacted by the athlete, athletic trainer, or coach. Myklebust (2002) proposed a theory that athletes are more susceptible to getting an ACL injury during a game than in practice. This theory was also supported by Lambson's (1996) study that found that the football players injured their ACL in a game 69% of the time, with the remaining 31% being injured during a practice. Hootman (2007) found similar results when reviewing all reported injuries within the NCAA in a 16 year span. It was found that the highest ACL injury rates were during each sport's in season period and that the chances of sustaining an injury during a game are 3.5 times greater than when in practice. The overall results of Hootman's study showed that there is an estimated 1 ACL injury for every 2 games played and 1 ACL injury for every 5 practices for a team of 50 when the team is in season. An explanation may be the level of competition. In practice, the intensity of drills are usually lower than in a game, as a result the athlete's competitiveness level is also lower in practice (Hootman, 2007). Another explanation may be the fitness of the athlete at each level of play (Lambson, 1996). Athletes tend to play harder and push themselves to their maximum threshold during games when compared to practice (Hootman, 2007). A study performed by Lambson (1996) found that football players who played at the varsity level were more likely to injure their ACL compared to players that were on the junior varsity, sophomore, and freshman teams. As athletes mature they acquire a

greater skill level which is typically accompanied with them becoming stronger, faster, and more physically fit predisposing the athlete to more powerful impacts, pivoting stresses and deceleration loads (Lambson, 1996).

It has been common practice for athletes to wear ACL braces in order to increase the stabilization of their knee and prevent an ACL injury. Kocher (2003) identified 180 out of 9,410 professional skiers who were at a higher risk for an ACL injury. In this study there was a group who wore an ACL brace and one that did not. The risk for ACL injury when wearing a brace was significantly lower at 2%, when compared to those who did not wear a brace; their ACL injury rate was 13% (Kocher, 2003). In contrast to this study, Ramsey (2003) found that when wearing the DonJoy Legend knee brace participant's rectus femoris muscle activity readings on an EMG increased by 21% at foot strike with the ground. Furthermore, there were significant decreases in the activity of the biceps femoris (44%) and semitendinosus (17%). In combination with each other, these findings express that the increased quadriceps activity could potentially pull the tibia anteriorly upon foot strike (Ramsey, 2003). It may suggest that unlike what Kocher (2003) found, the brace may aid more to an athlete's proprioceptive awareness than to the actual mechanical stabilization of the knee (Ramsey, 2003). When analyzing these results, Ramsey proposed that the knee proprioceptors had an increased afferent output as did the boundaries between the brace, skin, and bone. This caused an increased sensitivity in the central nervous system prompting an adaptive motor response; thus the muscle activity was altered showing a difference in the EMG results (Ramsey, 2003). To date, there have not been many studies conducted on the functionality and preventive benefits of wearing an ACL brace, thus more research is warranted in order to determine if braces help prevent injury (Griffin, 2000).

Another extrinsic factor for ACL injury is athlete's footwear and playing surface. It is believed that by increasing the friction and traction between the surface of play and the athlete's footwear that the athlete will be able to perform at a higher level. The increased traction can actually predispose the athlete to an ACL injury, especially when the athlete is fixated and performs a pivotal motion with deceleration. In a study conducted with football cleats, it was found that athletes who wore cleats that increased the friction ratio also increased the risk of ACL injury (Lambson, 1996). Boden (2000) agrees with Lambson (1996) stating that higher rates of ACL injury are reported to have occurred to those athletes who wear cleats that have smaller pointed cleats around the interior of the shoe. This model of cleat increases the torsional resistance allowed by the cleat, increasing the ability for the cleat to fix and increase friction with the surface (Boden, 2000). A study was conducted by Gehring (2007) that found soccer players who wore cleats with 8 round studs in the forefoot and 4 in the rear foot presented with higher levels of stimulation of the medial quadriceps femoris muscle. This finding is important because it contributes to the conclusions drawn from Lambson (1996) and Boden's (2000) studies, that the higher level of stimulation of the quadriceps causes a more forceful anterior translation and thus strain on the ACL. The stud configuration increases the traction and ground force resistance experienced by the lower extremity. Gehring (2007) did find that wearing a bladed cleat with 9 blades in the forefoot and 4 in the rear foot will not enhance the risk for ACL injury as does the rounded soccer cleat.

The weather can impact the playing surface and athlete's performance which can also increase the risk of an ACL injury. Most athletes prefer a shoe with smaller cleats on the interior surface because the increased friction and traction the shoe provides is most optimal when playing surfaces are dry. Griffin (2000) stated the non-contact ACL injuries are found to be more

frequent when the playing surface is dry, this may be contributed to the type of cleat worn by the athlete. During rugby matches held in Australia, it was found that ACL injuries were more frequent when there were low levels of rain and a high evaporation rate (Renstrom, 2008). These results could be attributed to the fact that traction variables between the athlete's footwear and the playing surface decrease. More studies need to be conducted in order to further investigate the influence of weather on the frequency of ACL injuries.

Extrinsic risk factors can be altered or decreased in terms of potential for injury, and monitored by the athlete, athletic trainer, and coach. For example, all parties can make sure that the field conditions are safe and do not present an increased risk of injury. The athletic trainer can try to make sure that the athlete's choice of footwear is complimentary to the sport and field conditions so as not to increase the torsional resistance to the point of likely injury. Before choosing a new surface to install, the occurrence of injury and benefits of the type of flooring should be investigated by all parties to ensure the athlete's safety. Monitoring and attempting to reduce the extrinsic factors that could have the potential to increase the risk of ACL injury is one of the first steps to reducing the prevalence of ACL injury.

Intrinsic risk factors are those factors which can't necessary be controlled entirely by the athlete, coach, or athletic trainer's actions, but awareness of the athlete's predisposition to ACL injury can help to reduce their risk of injury. There have been numerous studies that have researched the effects of hormonal levels, in particular the female menstrual cycle, and how it influences the risk of injury to the ACL (Wojtys, 2002). There have also been numerous studies that have compared females and males on how their anatomical makeup influences the susceptibility to ACL injury (Shimokochi, 2008). These dispositions will be discussed in detail when reviewing females and ACL injuries.

A major intrinsic factor of anatomical contribution to injury would be the knee joint's laxity. Laxity within a joint is influenced by the hypermobility of the joint in conjunction with muscletendinous flexibility. Griffin (2000) stated that joint hypermobility seems to be more genetically determined, but flexibility within the muscles can be influenced and altered by participating in stretching and conditioning programs. Females have been found to have increased levels of tibio-femoral laxity, producing lower resistance to rotation and translation on the femur (Renstrom, 2008). The higher laxity could provide some answers as to why women have greater chances of exhibiting genu recurvatum or hyperextension of the knee when entering into an extended position. In a study referred to by Boden, it was found that there is an increase in joint laxity in athletes who participate in sports such as basketball and running after 30 minutes of activity. The laxity increased both anteriorly and posteriorly anywhere from 18-20% of its original state (Boden, 2000). Johanssen reported finding evidence in a study conducted on long distance runners that post-exercise, the knee joint laxity increased and as the recovery period time passed laxity decreased within the joint. The anterior-posterior displacement of the tibia when walking did not show significant laxity, but there was a statistically significant increase with internal-external tibial rotation. There have been studies that have exhibited that joint laxity increases anterior-posteriorly, torsionally, and with valgus-varus stresses. There is no one singular cause of the increased joint laxity, but it can be inferred that exercise induces joint laxity, or having decreased muscle resting tone induced by muscle fatigue can contribute to the increased laxity (Johannsen, 1989). Similarly Arendt (1995) suggests that activities that require repetitive stress with high levels of strain produce joint laxity, but activities that require large stresses at a low strain level do not produce joint laxity. In contrast to these findings, some studies did not find any significant differences in joint laxity in relation to sex or age when laxity

was measured with a K-T arthrometer (Daniel, 1983). A study using an arthrometer as cited by Arendt (1995), found that the knees of both those who had intact ACLs and ACL deficiencies exhibited anterior laxity. Myer (2008) performed a study over a four year period, on 1,558 female soccer and basketball players. Prior to the start of season, the athlete's anterior-posterior knee laxity measurements were recorded with a CompuKT knee arthrometer. Myer found from the participants who injured their ACL, that for every 1.3 mm of side-to-side measurements in total anterior to posterior tibiofemoral translation laxity the participant had a 3 times greater chance of sustaining an ACL injury. Thus, it can be deduced that joint laxity does compromise the knee's stability and increase the risk for an ACL injury to occur (Myer, 2008). Boden (2010) made the observation that if the medial compartment of the knee joint is constrained and the lateral compartment exhibits laxity then this combination could potentially allow a shift in the joint. The lateral tibial plateau could anteriorly shift rotating internally, this movement can increase the strain placed on the ACL and thus could cause injury (Boden, 2010). Joint laxity is a topic that needs more research conducted; the use of an arthrometer may not be sufficient for detecting and determining those athlete's whom are at an increased predisposition of ACL injury (Arendt, 1995)

In conjunction with these studies, Shultz (2009) conducted a study that focused on knee joint laxity in combination with poor neuromuscular biomechanics. Shultz performed a study on 96 participants to find if people with greater varus/valgus and internal/external rotational knee laxity have more complications controlling the knee motions in the frontal and transverse planes. According to Stensrud (2010), valgus movement within the knee joint can predict ACL injury with a 73-78% accuracy. The participant's in Shultz's (2009) study that had a higher grade of varus/valgus and internal/external rotational knee laxity landed from a drop jump with greater

frontal and transverse knee motions. The women in the study had a 4.3 degree greater laxity in varus/valgus values and 6.1 degree greater internal/external rotational laxity than the males in the study; although women displayed similar results to the males with anterior knee laxity (6.6 degrees compared to 6.8 degrees) (Shultz, 2009). As the study continued, it was found that women who had a higher knee laxity exhibited greater hip adduction and knee valgus movements in the early landing phase, then progressed to having greater hip adduction with internal rotation in the last period of the landing phase when compared to women who had lower levels of laxity. Men who were labeled as being highly laxative, as compared to the men who were less lax, sustained greater hip adduction and varus knee movements for long periods throughout the trials. This study displays that the valgus collapse, which is believed to put the ACL at great risk, is seen mostly in women who have greater knee laxity; the higher muscle activation levels can be attributed to the body's compensatory mechanism to improve the knee stability (Shultz, 2009). Correlating with these findings, Stensrud (2010) found that women who dropped from a 20cm height lacked the needed strength and ability to decelerate their body. This improper muscular balance increased the demands placed on the quadriceps and hamstrings along with the surrounding musculature; potentially putting the knee at risk for injury (Stensrud, 2010). Rozzi (1999) also conducted research on this topic that will be discussed later in correlation to women's predisposition to having increased joint laxity and their biomechanical coping mechanism. In conclusion, laxity was shown to be greater in women, the lack of functional knee stability due to laxity within the transverse and frontal planes will contribute to the injury of the ACL (Shultz, 2009).

Muscular imbalances and the neuromuscular interplay between the muscles have been deemed one of the main contributory causes of ACL injury. Neuromuscular control refers to the

“body’s unconscious efferent response to an afferent signal regarding dynamic joint stability” (Mandelbaum, 2005). It’s believed that the hamstrings help to decrease the stress of the tibia sliding forward on the femur, knee hyperextension, and producing posterior shearing forces that contribute to knee stability (Renstrom, 1996). It was found by Renstrom that isometric contraction of the hamstrings puts less strain on the ACL than when the knee is passively taken through its entire ROM; these results were not significant between 0-60 degrees of knee flexion. These results exhibit that the hamstrings, which act as agonists, can aid in limiting the stresses placed upon the ACL (Renstrom, 1996). It also stresses the importance of the efficiency of the muscle motor stimulation within the hamstrings, their flexibility, and strength level (Boden, 2000). It is important to remember that any interruption of the muscle activity that is compensating for a muscular imbalance will also produce or add to the already unstable and lax knee, resulting in damage to the ligaments (Rozzi, 1999). Limiting the knees ability to enter into a state of hyperextension also decreases the stress and strain on the ACL (Myer, 2008). It is believed that if the hamstring to quadriceps strength ratios are less than 60%, the athlete is more susceptible to injuring their ACL (Hewett 1999). Muscular imbalance between the quadriceps and hamstrings can cause the knee joint to become lax; anteroposterior tibiofemoral laxity has been shown to increase the risk of sustaining an ACL injury. If the hamstrings are strong then they can limit the stresses imposed upon the ACL, but at the same time the hamstrings must remain flexible so as not to increase the strain and resistance to the actual ACL function (Myer, 2008). If the hamstrings become inflexible, then they can contribute to the compressive tibio-femoral joint forces and make the knee more susceptible to ACL injury (Boden, 2010). In conjunction with the prior studies discussed, Stensrud (2010) found that having decreased knee control lead to an increased frontal knee angle; this predisposes the athlete to an ACL injury.

The quadriceps are the antagonist to the ACL, meaning that they have the potential to increase the stress and the strain induced upon the ACL if they are unable to adequately counteract the strength of an excessive hamstring contraction. Renstrom (1996) found that isometric and isotonic contractions of the quadriceps increase the strain on the anteromedial ACL when in 0-45 degrees of knee flexion. This finding is important because most non-contact ACL injuries occur when the knee is in slight flexion or near hyperextension, at both of these points the quadriceps are involved in the muscular balance with the hamstrings and the knee joint (Boden 2000). When the knee is in slight flexion (hamstrings are activated), the angle between the infrapatellar tendon and tibia is greatest, thus when in full knee extension (quadriceps activated) the shearing forces on the tibia anteriorly increase with a compressive tibiofemoral joint force; increasing the strain placed on the ACL (Shimokochi, 2008). Huston (1996) found that elite female athletes fire their quadriceps first when anterior translation on the femur occurs, whereas males and female participants in the study, who were not part of the experimental group, contracted their hamstrings first in response to the anterior tibial translation stimulation. The males in the study had decreased quadriceps recruitment (17%), but they also exhibited higher levels of stimulation of their gastrocnemius (33%) in comparison to the females who had 35%, and 17% muscle stimulation respectively (Huston, 1996). Hewett (2000) stated that women are more quadriceps dominant which may potentially explain Huston's discovery. It is more probable that due to the nature of the quadriceps and their firing patterns that they contribute more to the stresses placed on the ACL from increasing the loads placed upon the tibiofemoral joint than by adding to the anterior shearing forces that are taking place with sharp movements (Boden, 2010).

To summarize, when the quadriceps produce extreme knee extension it may contribute to increased stress and load on the ACL. This factor is of concern when an athlete performs an action that requires weight to be applied to the posterior heel, or during deceleration. It is important to note that the quadriceps to hamstring strength ratios in females are less than males (Arendt, 1995). This could offer another explanation to why females are more susceptible to ACL tears than males. If there is a muscular imbalance between the quadriceps and hamstrings, it is also known as “quadriceps dominance”. When an athlete is quadricep dominant, the athlete needs to stabilize their knee during movements, the knee extensors (quadriceps) are stimulated over their knee flexors (hamstrings) and the gluteal muscle group (Hewett, 2009). Coordination and neuromuscular awareness between the hamstrings and quadriceps must work in unison in order to reduce the risk of ACL injuries (Griffin, 2000). The quadriceps and hamstrings must be able to efficiently work together as a unit, so as to properly absorb the ground reaction forces placed on the lower extremity. Inadequate disbursement of the forces causes an increase in the compressive forces placed on the knee that can contribute to ACL injury (Boden, 2010). Hewett (2000) claimed if the hamstring to quadriceps strength ratio is lower than 60%, susceptibility to ACL injury becomes more evident. It must also be considered that muscle fatigue can alter the lower limb biomechanical and neuromuscular factors that could dispose an athlete to ACL injury (Griffin, 2000). For example, when the hamstrings start to fatigue, there is less stability in the transverse plane; thus the knee is at a greater risk for injury (Alentorn-Geli, 2009). Muscular imbalance between the two legs will predispose the athlete to ACL and lower extremity. When one leg is weaker than the opposing leg, the musculature mainly the quadriceps and hamstrings, become unbalanced and loose coordination causing inadequate absorption of forces and strain on the knee joint (Hewett, 2009). A muscular imbalance of strength of 20% or more will increase

the risk of injury (Bien, 2011). Lastly, a muscular imbalance or weakness should not be present within the trunk, also known as “trunk dominance”. Trunk dominance does not allow the body to efficiently control the momentum of the trunk of the body, causing an unstable core throughout deceleration motions; leading to increased lateral forces placed on the lower extremity predisposing it to injury (Hewett, 2009).

Improper biomechanics contribute to positions that increase the ACL’s susceptibility to injury. It is common for non-contact ACL injuries to occur when the athlete’s foot is in a flat-footed position. A flat-footed or near flat-footed position separates the lower extremity into a two part segment. This lower body segmentation does not allow for the ground force’s energy to dissipate efficiently throughout the body and it causes excessive forces to act on the joints. This can cause buckling to occur within the joints and injury to the structures that reside at the force absorption sites. Boden (2010) stated that when landing from a jump, instead of landing with the feet in a hind-foot or flat foot, a safe shock absorption landing is landing on the forefoot. This means that the ankle should land in a position that promotes ankle plantarflexion when coming into contact with the ground. Putting the ankle into plantarflexion allows the forces to travel and dissipate through the gastrocnemius and soleus, protecting the ACL and its surrounding structures from high compressive forces (Boden, 2010). According to Stensurd (2010), the majority of non-contact ACL injuries occur when most of the weight is distributed to only one leg; thus making the proper technique of landing to absorb the forces of impact even more important. The ACL’s threshold before rupture is 2,160 N of force, which is easily exceeded if the gastrocnemius and soleus do not dissipate the greater part of the ground reactive forces (Boden, 2010).

It has been found that when a ligamentous injury occurs, the risk for incurring the injury, (in this case an ACL injury) contralaterally greatly increases (2-4%) compared to the risk of sustaining a first time ACL injury. This phenomenon is believed to exist because the biomechanical and material properties to the injured ACL and knee joint are equivalent to the opposing knee. The strain placed on the contralateral ACL will be of equal or greater load due to compensation from the injured ACL (Sward, 2010). For example, if an excessive valgus knee predisposition is present in the knee with the injured ACL, then due to anatomical makeup, the contralateral knee will display the same valgus angle. Thus, if the knee valgus angle did contribute to the injured ACL, then the knee valgus angle already predisposes the contralateral knee to injury. After having a unilateral ACL injury, the risk of sustaining another ACL injury increases. According to Faude, 5 out of 19 participants who had previously injured their ACL sustained a new ACL injury. As opposed to the 6 participants of 124 who had never had an ACL injury (Faude, 2006). Sward (2008) stated that an athlete who presents with predisposing factors such as joint laxity, knee hyperextension, small and narrow intercondylar notch, muscular imbalance, or any of the other contributing factors discussed should be aware and started on a neuromuscular and biomechanical ACL injury prevention program to decrease the probability of sustaining a contralateral ACL injury. Myklebust and Holm (2003) conducted a study in which a follow up with athletes who had undergone previous ACL surgery 6-11 years prior to the study was recorded. It was found that 11 of 50, or 22% of the athletes who had chosen to continue to play after surgery had reinjured the same ACL (Myklebust & Holm, 2003). These findings are similar to Hewett (2009) who stated the risk for a second ACL injury occurs between 12-28% of the time in the young female population. In relation to contralateral ACL injuries, 6 of the 50, or 9% of the participants had injured their contralateral ACL (Myklebust & Holm, 2003). After

suffering from an ACL injury, it is important for all parties involved to consider the possibility of future injuries to the ACL (Sward, 2010).

2.7 Females and ACL Injuries

It has been found that women injure their ACL approximately 2 to 8 times more than their male counterparts (Boden 2010, Myer 2008, Hewitt 1999). This is in agreement with Knowles (2010) who states that females are twice as likely to have to undergo ACL surgery than males. Female's overall injury rate (1.37 injuries per 1,000 athletic exposures) is fairly lower compared to that of their male counterparts (2.47 injury rate per 1,000 exposures) (Knowles, 2010). Taking into account the risk factors, such as the level of play and the specific sport being played, around 30,000 serious knee injuries are expected to plague female athletes participating at the high school and collegiate level per year (Hewett, 1999). Women are 2 to 4 times more likely than males to have surgery to their lower extremity (Knowles, 2010). It is estimated that 10,000 female collegiate athletes each year will sustain some type of knee injury and that 2,200 ACL ruptures will occur with the female collegiate athlete population (Hewett, 1999). Women have a higher rate of injury to the knee compared to males; 46% higher in soccer (resulting in a 3 times rate of ACL surgery compared to males), 44% higher in basketball, and 30% higher in softball/baseball (Knowles, 2010). The difference in the amount of ACL injuries between male and female athletes are thought to be due to differences in their anatomy, neuromuscular efficiency, physiology, conditioning levels, training exercises, and hormones (Wojtys, 2002).

Females have wider hip angles and a wider pelvis, thus they have a larger Q-angle than males. The Q-angle is the measurement from the anterior superior iliac spine to the tibial tuberosity. It represents the angle at which the patella tendon and rectus femoris are in relation to one another. Male's Q-angles are approximately 15 degrees in comparison to female's that are

approximately 20 degrees. It is thought that the larger Q-angle may contribute to increased stress placed on the ACL (Prentice, 2006). A wider pelvis or Q-angle will cause the knee to be positioned in a more valgus or knock-kneed position. This position predisposes the female athlete to a greater risk of placing increased lateral loads or stresses on the ACL (Boden, 2000). Females have also been found to have smaller ACLs which cause lower levels of stress and stiffness within the joint; producing lower elongation levels at the failure point, decreased energy absorption, and an increased likelihood of tearing or rupturing the ACL (Boden 2000, Griffin 2000, LaParde 1994).

Figure 2.4
(Renstrom, 2008)

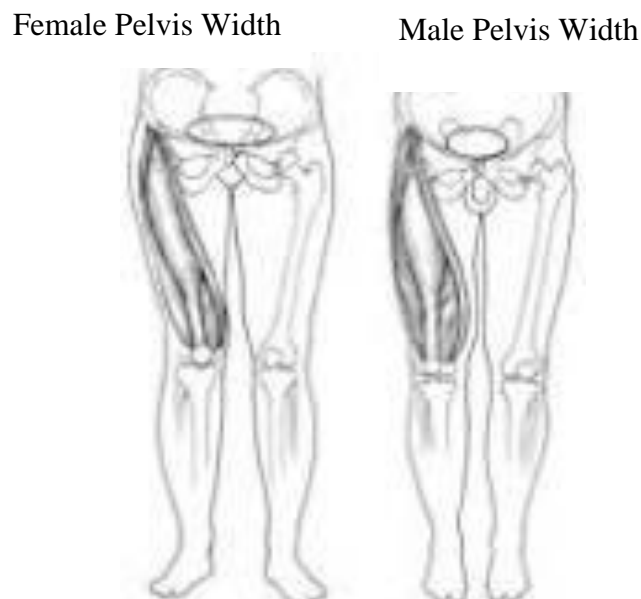


Figure 2.4 Comparison of the Width of the Female and Male Pelvis “In general, when compared with men or equal ages, women have wider pelvises as well as greater hip varus, knee valgus, and foot pronation” (Griffin 2000).

An increased hip flexion angle when landing from a jump can increase the strain put onto the ACL. Boden (2009) stated that higher hip flexion angles push the torso more posteriorly to the knee causing knee extension and hip flexion torques to be excessively high in order to try and stabilize the torso with impacts to the ground. Females have also been found to have greater levels of tibial torsion and foot pronation; although there is not sufficient research on these differences and their potential contribution to ACL injuries (Renstrom, 2008).

Another possible explanation for females being predisposed to ACL injuries are female's inclination to having anteverted hips. Anteverted hips cause the hamstrings to be placed into a shortened position. A shortened position can lead to decreased stability within the knee. The hips undergo an anteversion motion when experiencing deceleration forces. During deceleration the upper body compensates by leaning backward and having one leg anteriorly extend further than the rest of the body. This position will cause high anterior tibial force to be placed on the knee, increasing the tensile force placed on the ACL and injury rate (Shimokochi, 2008).

The dimensions of the intercondylar notch have been speculated and studied in correlation with ACL injuries. It has been found that females have a smaller notch width index than males (Griffin, 2000). Intercondylar notch stenosis is present when the average notch width index is set at less than 0.20. It has been assumed that if the intercondylar notch is smaller than the actual size of the ACL or the ACL is small, the ACL is more susceptible to injury. Research has shown that those who have intercondylar notch stenosis are at an increased risk to suffer from an ACL injury specifically non-contact injury. Athlete's who have intercondylar notch stenosis are more susceptible to ACL tears when participating in sports that involve pivoting and cutting maneuvers. The normal notch in which the ACL lies is in the shape of an upside down U. A knee with intercondylar notch stenosis is more in the form of a narrow A (LaParde, 1994). An

ACL that lies in a narrow A is more susceptible to shearing forces against bone. The ACL may impinge on the lateral femoral condyle when valgus stress is applied or with full extension when the ACL is in contact with the anterior portion of the intercondylar notch (Boden, 2000).

Although, LaParde found that no difference existed between males and females for the average notch width index, the study did find a trend that women were more predisposed to ACL tears. If the notch and ACL are smaller in size, when sudden external tibial torsion occurs, there could be an increased concentration of impingement and tension put onto the ACL (LaPrade, 1994).

However, in more recent literature by Boden (2010), it has been proposed that since most ACL injuries occur with the knee with some flexion present, the likelihood of the notch width being the sole contributor to injury is highly unlikely. If this were the case, the impingement caused by a small groove would cause injury more to the mid-body of the ligament as opposed to the common tear at the ligament's origin (Boden, 2010).

Women, as discussed earlier do have a greater laxity within their knee. In a study conducted by Rozzi (1999), women were shown to possess greater knee laxity when referring to anterior tibial translation on the femur. Women's anterior tibial translation was 6.06mm (± 1.46 mm), which is significantly higher than the males who were 4.8mm (± 1.53 mm). It is Rozzi's belief that the actual cause of this may be a deficit with the proprioceptive mechanisms, secondary to actual knee joint laxity. Joint stability is determined by a combination of factors working in unison; proprioception, kinesthetic, visual, and vestibular (equilibrium) systems and the commands sent by way of the cortical, and spinal nerve motor systems. These systems work in conjunction with one another to provide sensory information to the brain that then carries out a stimulus response. An athlete is also believed to have a "programmed" response; meaning that the body is already programmed to respond with certain muscle tensions with expected loads. If

this pre-programming is faulty or causes a muscular imbalance, it could potentially result in a reflex deficiency predisposing the athlete to an injury. In addition to the findings that women have a higher knee joint laxity or more anterior tibial torsion than do men, women were also recorded as having a longer reactionary period to detect joint motion with knee extension. Rozzi (1999) also found as did Ramsey (2002), that there was an increased stimulation of the lateral hamstring complex when the participants landed from their first jump. The increased stimulation that was found in women may mean that women exhibit a “pre-programmed” response in order to compensate for any proprioceptive or joint laxity. An increased stimulus by the lateral hamstrings would protect the knee from any excessive anteriolateral strains or from a potential subluxation; the increased firing could be a bodily protective mechanism carried out by the surrounding musculature of the knee (Rozzi, 1999). In conclusion, women may try and compensate for their knee laxity and proprioceptive deficiencies as was outlined by Shultz (2009), Rozzi (1999), Daniel (1983), Arendt (1993), Myer (2010), and Boden (2010) through pre-activated neuromuscular stimuli also known as a “programmed” response.

One of the most intriguing topics of discussion in the difference between females and males is the female menstrual cycle and its effect on hormone levels in relation to ACL susceptibility to injury. Females have higher estrogen levels in their bodies when compared to men; this fact is significant because estrogen has the ability and effect to relax soft tissue. Estrogen’s function in the body is to reduce the synthesis of collagen and the production of fibroblasts. The ACL fibroblasts produce collagen, which functions as the primary load bearing mechanism of the ACL, thus making the fibroblastic activities important to fully understand (Boden, 2000). In a clinical study performed on rabbit ACLs, it was found that as estradiol concentrations increased the proliferation of fibroblasts decreased. This finding, although found

in rabbit ACLs rather than in human, is important because it demonstrates that if there are fluctuations in estrogen levels in the body during menstruation, then the cycle may have an impact in the type, amount, and metabolism of collagen within the body's ligaments, in this case the ACL (Liu, 1997). If soft tissue becomes weaker due to collagen synthesis levels and is unable to perform at its intended strength then female athletes could potentially, in theory become more susceptible to ACL injuries (Boden, 2000). Shultz (2005) agreed with Boden, in that due to the high levels of fluctuation in hormone levels, the higher vs. lower levels could cause the collagen to weaken after a few days. It has been found that the fibroblasts of the ACL have the receptor sites for the hormone estrogen and progesterone. During the menstrual period different levels of estrogen are circulating within the body, thus a possible correlation exists between the fluctuation of the levels of estrogen in the body and the collagen strength levels (Griffin, 2000). During menses, hormone levels fluctuate and can change as much as 400 fold every 4 hours when near the time of ovulation. These massive fluctuations in hormone levels can cause a disturbance in the body's equilibrium. The most studied in relation to the effects on the ACL effect are progesterone, estrogen, and testosterone levels (Shultz, 2005). Early in the menstrual cycle, sex-hormones are lower in elevation. Estrogen and progesterone output increases after the first couple days of the start of menses, which is also known as the last half of the follicular phase (Slautebeck, 2002). Shultz (2005) found that estrogen levels were elevated on days 1 to 5 of the initial estrogen surge period, which is just prior to ovulation, days 1 to 5 of the early luteal phase, and days 1 to 4 of the late luteal phase. Estrogen, as was priory believed, was not elevated in any nature on the days of actual menses or the fifth day of the late luteal phase. According to Shultz, greater knee laxity was shown on day 5 of the menses, days 3 to 5 of the estrogen surge prior to ovulation, and in the luteal phase (days 1-4 in the early luteal phase, 1,2,4, and 5 of the

late luteal phase). Knee laxity was reportedly increasing significantly throughout the phases (46N to 89N to 133N) respectfully (Shultz, 2005). In conclusion, as was also found by Boden (2000), Shultz (2005) showed that knee laxity increased on the days of the menses when estrogen and progesterone were elevated. It is good to note that when examining Shultz's (2005) findings, knee laxity does decrease as soon as progesterone levels rise despite the values of the estrogen level.

Wojtys (2002) found that there is a higher rate of ACL injury in females when they are in the ovulatory phase of menstruation, which lasts around 5 days, when compared to the follicular and luteal phases. This is why it may be speculated that ACL injury is more prevalent during the ovulatory phase, due to the recent increase in estrogen concentrations. Myklebust (1998) found that ACL injury was more likely to occur one week before or just after the initial start of menstruation when studying a Norwegian handball team. The increased risk of ACL injury during this time period is attributed to possible tissue laxity due to fluctuations in hormone levels prior, during, and post menses (Myklebust, 1998). Slauterbeck's (2002) study correlates with Myklebust's (1996), in that Slauterbeck's study it was found that 26 of the 37 participants tore their ACLs during the follicular phase of their menstrual cycle; meaning the majority of ACL injuries occurred in the early phases of menstruation.

Estrogen has also been found to decrease motor skills because of its effect on the central and peripheral nervous system; if these systems are at a lower functioning level it could dispose the knee to injury (Boden, 2000). In a study conducted by Zimmerman, Parlee, Stocker, and Posthuma (1973) showed that neuromuscular control in females varies during the menstrual cycle. During the ovulation phase, Sarwar (1996) found that the functional efficiency of skeletal muscle was altered. The muscle relaxation time decreased during menses accompanied by an

increase in muscle fatigue. Sarwar's results are attributed to the fluctuations in the myosin ATPase or calcium absorption rate during menses. An increase in ATPase can decrease the relaxation ability of human muscles (Sarwar, 1996).

The use of oral contraceptives was also studied by Wojtys (2002) who found that females who weren't using oral contraceptives as opposed to those who were taking oral contraceptives were 2.5 times more likely to suffer from an ACL injury during the ovulatory phase. This finding suggests that oral contraceptives may release synthetic hormones that could potentially alter ACL injury susceptibility. Wojtys had 69 female participants who had sustained an ACL injury report their mechanism of injury, previous history of injury, and if they were taking an oral contraceptive. In addition, a urine sample was taken to determine what phase of the menstrual cycle the participant was in by taking measurement levels of the estrogen, creatinine, progesterone, and luteinizing hormone (Wojtys, 2002). These synthetic hormones could affect the balance of the fibroblastic collagen production and affect the type, quantity, and strength of the collagen being produced. In a small self reported study conducted by Slauterbeck (2002), 10 of the 26 participants who sustained an ACL injury reported that they were using oral contraceptives at the time of their injury; the ACL injuries also occurred a couple days prior to the start or 2 days after the start of the menses. These findings are similar to Nielsen and Hammar (1989) who found that female soccer players who took oral contraceptives had fewer injuries during the soccer season than those who were not taking oral contraceptives. Hewitt (2000) found that higher impact forces and valgus movements of the knee were exhibited when landing from a jump by female athletes who were not using oral contraceptives. It was also concluded from his study that, females who were taking oral contraceptives displayed "higher

levels of hamstring to quadriceps strength ratios, an increase in unilateral stability, and decreased knee laxity” (Hewitt, 2000).

Although all of these findings are not conclusive and more research needs to be conducted, it is likely that the menstrual cycle does alter the functionality of the skeletal muscle and collagen synthesis. A major limitation in studying the menstrual cycle and its effect on susceptibility to injury is that self reported data can be inaccurate. It is difficult to determine what phase the female in question is in is difficult and the use of oral contraceptives can alter the results as discussed earlier.

2.8 Prevention Programs

The most important treatment for an ACL injury is to implement a prevention program to reduce the chances of sustaining an ACL injury. The prevention of ACL injuries should include many different aspects including; The most common elements that are utilized within most ACL injury prevention programs are increasing flexibility, education to the athlete and coach of higher risk positions and movements, strengthening, alterations in techniques, increasing conditioning and fitness levels, making gains in skill, agilities within the sport, balance awareness, neuromuscular training, and plyometric drills all performed within multi-plane scenarios (Shultz 2010, Renstrom 2008, Zazulak 2007, Hewitt 1999). It is important to know how to identify the athlete who is at a higher risk of injury to their ACL and to initiate a preventative program to avoid a traumatic injury. It is important to take into consideration when developing a program and when to engage in the program, that muscular fatigue will have an impact on athletic and skill performance (Bien, 2011). Prevention programs have been shown to be more effective if done in the pre-season with an in-season maintenance program (Alentorn-Geli, 2009). They should be performed at least 8 or more weeks at a time, this will allow for the proper

neuromuscular and performance changing effects to effectively be learned and retained (Bien, 2011). Although there is no key ACL injury prevention program, utilizing all of the factors above and continuing education about the causes and conditions of excess strain on the ACL can reduce injury (Shultz, 2010).

Since tibiofemoral joint loading in combination with pivoting and cutting maneuvers are the leading causes of ACL injury, most prevention programs focus on increasing an athlete's neuromuscular and proprioceptive training. The athlete's proprioception must be at a high awareness level because a poorly trained system will impair the core stability within the body, which can affect the control of the knee; and may contribute to injury (Zazulak, 2007).

Identification of those at a high risk to injure their ACL should be conducted. One way in which to do this is by identifying those who display a high knee abduction movement when landing from a drop. This is one of the major non-contact mechanisms that is seen more often in women than in males, due to the inclination for women to present with increased valgus collapse, as discussed earlier. Myer's (2010) study took the measurements of body mass, length of the tibia, isokinetic knee flexion/extension strength on a Biodex System II, and hamstring to quadriceps strength ratio. A three dimensional hip, knee, and ankle kinematic data were collected for each of the 3 contact phases of the vertical jump. Lastly, the landing stance and biomechanics were recorded by videotape and analyzed. The female participants in the study were found to have high knee valgus movement when landing from a drop jump and performing pivoting movements, making them predisposed to ACL injury and potential candidates for an ACL preventive program. By identifying an athlete who has a higher inclination to injure his or her ACL a higher rate of commitment to an ACL injury prevention program should occur. To identify through measurements the predisposing factors, a preventative program could be

instituted for certain individuals instead of taking time from the team's practice (Myer, 2010). Although this study would not be cost effective, the outcomes may prove to be much greater. A cheaper screening process would be to have medical personnel (e.g., athletic trainer) who is knowledgeable in ACL injury prevention and the proper techniques to record and review drop landings looking for proper technique, identify weak musculature that were discussed previously, perform balancing tests for core and lower extremity stability on uneven surfaces, and measure strength ratios of the hamstrings versus the quadriceps (Bien, 2011).

Prevention programs should focus on neuromuscular awareness to try and educate and reduce forces that put unwanted strain on the ACL and the surrounding musculature. The focus should include decreasing the forces created by improper landing through proper education, decrease valgus and varus loads, improve the valgus angle, single legged stability, and proprioception with an emphasis on balance. Barendrecht (2011) performed a study with a team of handball players, in which the effects of neuromuscular training versus a regular training program had on the lower extremities kinematic and single leg stability. The neuromuscular training program was given twice a week for 20 minutes in combination with the regular training program that the control group was performing for a 10 week period (*See Table 2.4*). Barendrecht (2011) found that there were improvements in the knee valgus angle, an increase in contact time to dissipate forces from a jump landing, and an increase in knee flexion angles, leading to changes that have been confirmed to decrease the risk of ACL injury.

Table 2.2
Barendrecht (2011)

<i>Warm-Up Exercises (6 minutes)</i>	
Without Ball:	Jogging, running forward with knee lifts, running forward with heel strikes, running backward with side steps, side shuffle, carioca, running forward with upper body rotations, running with increasing speed, shuttle run.
With Ball:	Run with sidesteps and bouncing, stop jumps with knees bent 90 degrees, small 1 leg jumps with landing on alternative legs, side to side jumps.
Alternate Exercises:	Running with side steps, 1 leg hop twice left, twice right, and stop jump. Running and cutting, jump shot pass, landing with bent knees, cutting and jump shot.

Table 2.2 (cont'd)

<i>Mat Exercises (4 minutes)</i>	
Couples standing on 1 leg and throwing a ball (both legs).	
Jump shot from a step box and landing on 2 legs.	
Step down from a box on 1 leg while catching a ball (both legs).	
Balance fight on 2 legs and 1 leg	
Stop jump on 2 legs while catching a ball and immediately jump 180 degrees (both sides).	
<i>Balance Board Exercises (4 minutes)</i>	
Standing on 2 legs with knees bent and throwing a ball.	
Squat exercise (on 2 legs and 1 leg) while throwing ball	
Standing on 1 leg with bent knee while throwing ball	
Standing on 1 leg with bent knee and bouncing (as progress eyes shut).	
Balance fight on 2 legs	
<i>Plyometric Exercises (2 Exercises 15-20 sec. with 30 sec. rest per session) on a mat</i>	
Wall jumps	Skate jumps
Forward Lunges	Side to Side Jumps on 2 legs (later 1 leg)
Broad Jumps	Bounding
Tuck Jumps	Scissor Jumps
180 degree Jumps	One-leg hop and stick (3 sec. both legs)
Squat Jumps	Up, Down and 180 degree vertical
Two legged jump forward and backward (later 1 leg)	Two legged cross jumps (later on 1 leg)
Triple broad jump and vertical	

Table 2.2 (cont'd)

<i>Strength Exercises in Couples</i>	
Squat 2-3 series, 8-10 reps, weight up to max 10% body weight	
Nordic hamstring 2-3 series, 3-10 reps.	

Table 2.2 Barendrecht's (2011) Neuromuscular Training Program protocol used in the study. Was performed twice a week for 20 minutes by the experimental group in the study.

A similar study was conducted by Noyes (2011), where it was suggested that in order to further prevent ACL injury, neuromuscular training should also include education of the athletes to control not only their lower extremities with proper landing techniques and cutting maneuvers, but also to incorporate the upper body and trunk into the program. In this study, the participants were high school aged volleyball players who underwent a 90-120 minute training session including neuromuscular training, 3 days a week for a 6 week period. A significant improvement was found in the absolute knee separation distance, which signifies an improvement in the alignment of the lower extremity when drop landing (Noyes, 2011).

In correlation with Noyes' (2011) study, Barber-Westin (2011) conducted a study examining proper techniques at 3 months and 1 year after experiencing an educational training program. This study utilized similar exercises and training protocol as was used by Noyes (2011) who took parts of a prevention program provided by Sportsmetrics (Cincinnati Sports Medicine Research and Education Foundation, Cincinnati, OH). If knee separation values are low then the athlete is predisposed to incurring valgus collapse, so the aim of the study was to improve the

ankle alignment and knee separation values. After completion of the first educational training program there was a 69% improvement in 11 of the athlete's knee separation distance, these distance improvements were still retained at the one year follow up. Barber-Westin (2011) found that before any training started, 75% of the participants exhibited less than 60% of knee separation. Following the first training period three months later, 31% of the participants had less than 60% knee separation. The last measurement taken one year after the preliminary preventative training session, the percentage decreased again to only 19% who had the poor lower limb separation distance. Prior to the educational preventative program, the abnormal lower limb position was displayed by 77% of the participants this number decreased to only 34% of the participants who had poor lower limb position (this included the knee and ankle separation distances) after undergoing an educational session on prior landing technique (Barber-Westin, 2011). This study shows that with proper educational training, the participants can and will increase their neuromuscular and kinematic awareness which will further decrease the risk of ACL injury.

The most important aspect of prevention is education. The athletes, coaches, and support medical and conditioning staff should be aware of the elements that predispose an athlete to injury. Knee joint laxity has been shown to predispose the knee to ACL injury. For example, the awareness of those who are at a greater risk of an ACL injury due to joint hypermobility and flexibility could limit the risk of injury. These athletes can perform a muscular strength and education training program prior to the start of the season to decrease their knee joint laxity predisposition (Myer, 2008). It has been found that athletes are more susceptible to ACL injury when landing with the knee in a valgus or varus position (Hewett, 1999). Landing in this position does not allow for the knee to be at its utmost stability or provide adequate force disbursement

from ground resistance forces. Increasing the knee flexion angle (knees should be slightly over the toes) and landing with the impact being with the toes first will significantly reduce the tibial shearing forces placed on the knee. It was shown that by increasing the knee flexion angle and landing toes first on impact with the ground, on average there is a 7.8% reduction in the impact forces and a 22 to 87.9% decrease in the tibial shearing forces experienced within the knee (Myers, 2010). Thus athletes should undergo neuromuscular awareness and training programs to learn to avoid excessive abduction and adduction forces to the knee and how to properly land and cut with the knee in a stable protective position (Hewett, 1999). The proper knee and hip flexion angles in conjunction with lateral movements in the frontal, transverse, and coronal plans need to also be part of an ACL prevention program (Myer, 2008). Having the knee in slight flexion instead of at an extended or hyperextended position may limit ACL injury (Hewett, 1999). When the knee and trunk are in slight flexion during landing, it will direct the ground resistance forces to the posterior knee; instead of the anterior portion of the knee which causes a shearing force on the ACL. Although by having the forces favor the posterior knee, it can cause some knee extension movement. If the quadriceps are properly strengthened and conditioned they can dissipate these posterior shearing forces adequately (Myers, 2010). This correct form of landing will also correct any quadriceps imbalances that were present prior to the training (Hewett, 2009). It was also found that the ankles should also exhibit some plantarflexion upon impact of a landing (Boden, 2010, Myer 2008). High axial loading from improper dissipation of forces causes a buckling of the knee, anterior shearing on the tibia, and strain on the ACL (Boden, 2010). In a video-based analysis study conducted by Boden, it was found that the participant's who landed with their feet in less plantarflexion, with more of a flat-footed position, had a significantly higher injury rate than those who landed with their ankles in plantarflexion. Those

participants who landed initially with a flat-footed position or minimal ankle plantarflexion and had experienced an ACL rupture had come into a complete flat-footed position 50% sooner than those who had landed with their ankles plantarflexed (Boden, 2009).

Henning (1990) introduced the concept of a 3 step stop deceleration to break down from a run. The 3 step breakdown acts to dissipate some of the impact forces and excess loads on the knee joint, by limiting the rotational forces and ground reaction impacts (Mandelbaum, 2005). The breakdown of a run in 3 steps as compared to 1 direct forceful impact with the ground may reduce the excessive loads and rotational forces acting upon the ACL, which may decrease the injury rate. Movements such as cutting and pivoting are actions that require reactionary movements that can be achieved with similar plyometric exercises such as the 3 step breakdown because they demand high levels of interpretation of visual cues and pre-planning proper reactionary movements (Alentorn-Geli, 2009). Athletes should make sure to strengthen not only their core strength, but also their hamstrings, gluteals and their quadriceps. Ettlinger put together a prevention program for staff members at 20 ski areas. The study educated the skiers on how to avoid high risk behavior, to recognize dangerous situations, and how to effectively and safely react to these stimuli if necessary. The skiers were educated on what are high risk behaviors and movements that put excessive stress on the ACL and knee joint. The participants of the study were told and showed how not to extend their legs fully when falling (instead keep them slightly flexed, to stay down until they have completely come to a halt when sliding, when jumping know where they will land, and landing with knees and feet in a flexed position. Over a 2 year span there were 31 ACL sprains on average before the preventive program and 16 ACL sprains after the program was implemented. This represents a 61% reduction in ACL sprains in the staff after utilization of the program; there were no differences in the control group (Ettlinger, 1995).

Ettlenger's study provides evidence that through educational prevention programs, ACL sprains can be reduced.

Myklebust administered a prevention program to the female Norwegian Handball Federation teams during three seasons. The program focused on improving the athlete's consciousness of the quality of their movements while controlling their knee balance when standing, cutting, jumping and landing (*See table 2.5*). Myklebust educated athletes on proper mechanics and correct utilization of their core muscles for stabilization and keeping the knee over the toe position to avoid stressful conditions on the ACL. After three seasons, Myklebust's (2003) prevention program decreased ACL injuries, but the findings were not statistically significant. Micheo suggests that neuromuscular patterns should be the primary concentration in a preventative program to improve joint stability under different static and dynamic forces. The main focus would be on educating the co-contraction of the quadriceps and hamstrings with a correction to any muscular imbalances. These exercises included, joint repositioning, shifting and balancing on stable and unstable surfaces, closed kinetic chain exercises, plyometrics, perturbation training, and proper form with drop landings (Micheo, 2010).

Table 2.3
(Myklebust, 2003)

Final Anterior Cruciate Ligament Injury Prevention Program

Floor Exercises

Week 1: Running and planting, partner running backwards and giving feedback on the quality of the movement, change position after 20 s

Week 2: Jumping exercise—right leg—right leg over to left leg—left leg and finishing with a two-foot landing with flexion in both hips and knees

Week 3: Running and planting (as in week 1), now doing a full plant and cut movement with the ball, focusing on knee position

Week 4: Two and two players together two-leg jump forward and backwards, 180° turn and the same movement backwards; partner tries to push the player out of control but still focusing on landing technique

Week 5: Expanding the movement from week 3 to a full plant and cut, then a jump shot with two-legged landing

Mat Exercises

Week 1: Two players standing on one leg on the mat throwing to each other

Week 2: Jump shot from a box (30–40 cm high) with a two-foot landing with flexion in hip and knees

Week 3: “Step” down from box with one-leg landing with flexion in hip and knee

Week 4: Two players both standing on balance mats trying to push partner out of balance, first on two-legs, then on one leg

Week 5: The players jump on a mat catching the ball, then take a 180° turn on the mat

Wobble Board Exercises

Week 1: Two players standing two legged on the board throwing to each other

Week 2: Squats on two legs, then on one leg

Week 3: Two players throwing to each other, one foot on the board

Week 4: One foot on the board, bounding the ball with their eyes shut

Week 5: Two players, both standing on balance boards trying to push partner out of balance, first on two legs, then on one leg

Table 2.3 Myklebust’s (2003) ACL Injury Prevention Program performed on teams in the Norwegian Handball Federation.

Zazulak used core proprioception awareness as a guide to investigate the theory that if the proprioception of the core is weak it will predispose and predict if an athlete will sustain a knee or an ACL injury. Results found that athletes who exhibited poor core proprioception were at an increased risk of sustaining a knee injury. It also found that female athletes whose bodies were more imbalanced suffered more ACL injuries than those males who had injured their ACL's. The females who had higher levels of trunk proprioception and control of their movements than males, did not sustain an ACL injury throughout the three year period. Thus, Zazulak (2007) suggests that females who had a poor ability to control their core proprioception were more susceptible and it could be predicted that they would have a knee injury at some point in time.

Hewett demonstrated that a decrease in peak landing forces can be achieved by limiting the amount of valgus and varus stresses placed on the knee through a preventative program that included plyometrics, stretching, and strengthening. The preventative program was also successful in increasing the muscular strength and power of the hamstrings, decreasing side to side hamstring muscle strength imbalance, and hamstring to quadriceps torque ratios. This study focused on the muscle imbalances that predispose athletes to injury as was discussed earlier. By increasing the strength ratio between the hamstrings and quadriceps, the load and stress placed on the ACL diminishes, thus making it less likely to be injured. This neuromuscular program was implemented in another study performed by Hewett, this time in high school female athletes. The study consisted of 43 sports teams from 12 high schools. The coaches and sports trainers at the schools were given instructional videos and a manual for the 6 week neuromuscular training program that was to be done during preseason. The training program was 60-90 minutes in duration and was performed 3 days a week every other day. The prevention program consisted of 3 phases (*See Table 2.6*) Exercises were increased in duration in the first 2 phases and

participants were encouraged to perform as many jumps as possible. See table 2.7 for list of exercises and table 2.8 for the protocol for the weight training and stretching. Hewett's findings were that the injury rate for a serious knee injury was 2.4 to 3.6 times greater in the group that did not participate in the neuromuscular program. The high school females who did not use the program were at a 4.8 to 5.8 times higher risk of enduring a knee injury than males who were not involved in a prevention program. The female athletes who did partake in the program were found to be 1.3 to 2.4 times more likely to suffer from a knee injury than males who were not in the program. Although the females who did undergo the neuromuscular program still sustained knee injuries, the risk factor for sustaining these injuries did decrease, this could be attributed to the increased stability of the knee joint from the preventive exercises and the education on how to limit excessive adduction and abduction stress on the knee (Hewett, 1999).

Table 2.4
(Hewitt, 1999)

Exercise Phases		
Phase I: Technique	Week 1	Week 2
Wall Jumps	20 sec	25 sec
Tuck Jumps (use mat)	20 sec	25 sec
Broad Jumps Stick (hold) Landing	5 reps	10 reps
Squat Jumps (use mat)	10 sec	15 sec
Double-Legged Cone Jumps (use mat)	30 sec/30 sec	30 sec/30sec (side to side and back to front)
180 Degree Jumps	20 sec	25 sec
Bounding in Place	20 sec	25 sec
Phase II: Technique	Week 3	Week 4
Wall Jumps	30 sec	30 sec
Tuck Jumps (use mat)	30 sec	30 sec
Jump, Jump, Jump, Vertical Jump	5 reps	8 reps
Squat Jumps (use mat)	20 sec	20 sec
Bounding for Distance	1 run	2 runs
Double-Legged cone Jumps (use mat)	30sec/30sec	30sec/30sec (side to side and back to front)
Scissors Jump	30 sec	30 sec
Hop, Hop, Stick Landing (use mat)	5 reps/leg	5 reps/leg

Table 2.4 (cont'd)

Phase III: Technique	Week 5	Week 6
Wall Jumps	30 sec	30 sec
Step, Jump Up, Down, Vertical	5 reps	10 reps
Mattress Jumps	30 sec/30sec	30sec/30sec (side to side and front to back)
Single-Legged Jumps Distance (use mat)	5reps/leg	5reps/leg
Squat Jumps (use mat)	25sec	25sec
Jump into Bounding (use mat)	3 runs	4 runs
Hop, Hop, Stick Landing	5reps/leg	5reps/leg

Table 2.4 Jump training program phases as used in Hewett (1999) study.

Table 2.5
(Hewitt, 1999)

Jump Training Exercises	
180 Degree Jumps	Two-footed jump. Rotate in mid-air. Hold landing for 2 sec. and then repeat in reverse direction
Bounding for Distance	Start bounding in place and slowly increase distance with each step. Keep knees high.
Bounding in Place	Jump from one leg to the other straight up and down, progressively increasing rhythm and height.
Broad Jumps-Stick (hold) Landing	Two-footed jump as far as possible. Hold landing for 5 sec.
Cone Jumps	Double-Legged jump with feet together. Jump side-to-side over cones quickly. Repeat forward and backward.
Hop, Hop Stick	Single leg hop. Stick second landing for 5 seconds. Increase distance of hop as technique improves.
Jump into Bounding	Two-footed broad jump. Land on single leg, then progress into bounding for distance.
Mattress Jumps	Two-footed jump on mattress, tramp, or other easily compressed device. Perform side-to-side and back-to-front.
Scissors Jump	Start in stride position with one foot well in front of other. Jump up, alternating foot positions in mid-air.
Single-Legged Jumps, Distance	Single-legged hop for distance. Hold landing (knees bent) for 5 sec.
Squat Jumps	Standing jump raising both arms overhead, land in squatting position touching both hands to floor.
Step, Jump Up, Down, Vertical	Two-footed jump onto 6-to-8 inch step. Jump off step with two feet, then vertical jump.
Tuck Jumps	From standing position jump and bring both knees up to chest as high as possible. Repeat quickly.
Wall Jumps (Ankle Bounces)	With knees slightly bent and arms raised overhead, bounce up and down off toes.
Before jumping exercises: Stretching (15-20 minutes), skipping (2 laps), side shuffle (2 laps). Post-training: Cool-down walk (2 minutes), stretching (5 minutes). *Each jump exercise is followed by a 30-second rest period.	

Before Jumping Exercises: Stretching 15-20min, skip 2 laps, side shuffle 2 laps

Table 2.5 Jump Training Exercises: Depicts the list of exercises with a description of how to perform them that was used in Hewett's ACL injury prevention program study.

Table 2.6
(Hewitt, 1999)

Stretching and Weight Training Program	
<i>Stretches</i>	<i>Weight Training Exercises</i>
Calf Stretch 1	Abdominal Curl
Calf Stretch 2: Soleus	Back Hyperextension
Quadriceps	Leg Press
Hamstring	Calf Raises
Hip Flexors	Pullover
Iliotibial Band/Lower Back	Bench Press
Posterior Deltoids	Latissimus Dorsi Pull down
Latissimus Dorsi	Forearm Curl
Pectoralis/Biceps	Warm-Down/Short Stretch

Stretching: 3 sets of 30 sec. each

Weight Training: 1 set of each exercise, generally 12 reps for upper body exercises and 15 reps for the trunk and lower body exercises.

Table 2.6 Stretching and Weight Training Programs: Depicts the list of stretches and weight training exercises that was used in Hewett's ACL injury prevention program study.

The Santa Monica Orthopedic and Sports Medicine Research Foundation developed a prevention program in 1999 called the Prevent Injury and Enhance Performance Program (PEP). The PEP incorporated a warm up, stretching, plyometrics, strengthening, and agilities that were sport specific with the goal of improving neuromuscular and strength coordination to the musculature of the knee. Gilchrist utilized the program on NCAA DI women's soccer teams that chose to participate. The outcome of the program showed that those who were in the prevention program only sustained 7 ACL injures as compared to the 18 ACL injuries from the group that did not participate in the prevention program (Gilchrist, 2008). These results are similar to Hewett's (1999) study, neuromuscular and proprioceptive training can help prevent ACL injuries as long as the program is used on a repetitive base to adequately improve strength,

proprioception, and balance within each individual athlete. Mandelbaum's study expressed similar results of ACL incidence rate decreasing with the PEP program. Results revealed an 88% decrease in ACL injuries when compared to those athletes who had not participated in the program. There were many limitations to this study that could have allowed for the major decrease in ACL injury (Mandelbaum, 2005).

It is important to keep in mind that practicing the proper techniques during an ACL prevention program is different to performing them on a competitive level in an athletic setting. The athlete is going from a conscious awareness of their movements with proper instruction to performing unanticipated complicated movements that require higher levels of motor control in a game setting. Benjaminse studies the relationship between the motor learning in an athlete in relation to undergoing an ACL injury prevention program. One of the problems with the transition as identified by Benjaminse is that when performing a training program, the participant is consciously aware of their movements which may potentially hinder the automatic motor control system leading to a potential collapse in the natural coordination of movement. Under stress and pressure to perform with swift movements, explicit learning from the prevention training program could be decreased or lost because of implicit learning and the player's intelligence overriding the system (Benjaminse, 2011). This idea is not in agreement with Barber-Westin's study that was discussed earlier. Barber-Westin (2010) stated that with neuromuscular training the participants will retain the proper techniques and kinematic awareness even with the passage of time and different sport settings. Benjaminse asserts that children between the ages of 6 to 12 should undergo an ACL injury prevention program that would teach the proper biomechanics and neuromuscular adaptations. Learning at a young age would allow the young athletes to adapt to the proper playing techniques and make the proper

movements and reactions to become automated. Benjaminse (2011) also strongly urges that participants need to perform the movements properly without making mistakes and responding to their corrections instead of viewing an expert perform the task. Prevention programs with the proper biomechanics need to be stressed through instruction, video, and training at a regular interval; this will ensure that the athlete is still performing with the proper safe techniques.

ACL injury prevention programs have produced, in and out of the laboratory, results that support that they do help reduce the incidence of ACL injury. Learning the proper techniques and movements that will decrease the strain on the knee will not only ensure the health of the ACL, but it will also aid in the stabilization in the body's lower extremity and core. Developing a program that consists of stretching, strengthening, aerobic conditioning, education of certain "high risk" movements and stances, proprioception, and plyometric training seem to be the most efficient and beneficial (Alentorn-Geli, 2009). There is no one specific recommendation or research to this date that expresses the benefit of one specific program. Each sport has different demands, thus each type of athlete needs to be catered to with specific drills and training that will address those demands and needs of their sport.

The main purpose of this study is to examine the absence or utilization of an ACL injury prevention program at NCAA colleges and universities (Division I, II, and III levels), NAIA universities, junior colleges, as well as at the high school level. It will assess what their ACL injury prevention program exercises and protocol consist of and determine if the training program in use reduces the rate of ACL injuries by considering their ACL injury rate (non-contact vs. contact).

2.9 Summary

An ACL injury can be the result of anatomical makeup, biomechanical or a neuromuscular imbalance or poor form and technique. As discussed, one of these predispositional factors does not mean that an ACL injury will occur, but the risk of ACL injury does increase with the combination of one or more of these factors. Females do have a greater relative risk for sustaining an ACL injury than do men for many reasons, thus it may be even more important for female sports to actively participate in an ACL injury prevention program. Most ACL injury prevention programs incorporate a warm-up, strength training in the lower extremity and core in equality and feedback, education about proper techniques in landing, cutting, and pivoting, proprioception and neuromuscular exercises including the use of plyometrics, speedy decision making, and stretching. Compliance with these programs can sometimes be challenging, but the most effective way to increase the follow through is with education and identification of those who are at risk. Due to the nature of there being so many prevention programs in circulation the purpose of this study is to determine if there is one optimal ACL injury prevention program that could be utilized at all levels of play.

CHAPTER 3

RESEARCH METHODS

3.1 Purpose

This section will discuss the methodology that will be used to investigate the efficiency and effectiveness of ACL injury prevention programs that are being utilized at the NCAA, NAIA, junior college, and high school levels.

3.2 Research Design

This study was a one trial non-experimental survey study conducted at the NCAA collegiate, NAIA, junior college, and high school levels across the United States. The demographic variables will include the number of years certified as an athletic trainer, sex, race, and sports supervised. The institutional demographics will be NCAA Division I, II and III colleges and universities, NAIA universities, junior colleges, and high schools. Other survey variables in this study will include if an ACL injury prevention program was in place, exercises, frequency and duration of the ACL injury prevention program, education of the director of the injury prevention program, and the number of ACL injuries within the past 2 years within each sport at each institution.

3.3 Participant Selection Criteria

The study population was comprised of NCAA Division I, II, III colleges and universities, NAIA universities, junior colleges, and high schools across the United States. Within all 3 divisions, the NCAA consists of more than 400,000 student-athletes who are enrolled and academically studying in over 1,000 colleges and universities throughout the United States (NCAA, 2011). In the years 2009-2010 there were approximately 7,628,377 student athletes participating in high school athletics (NFHS, 2011). There were, 1,000 participants that

were asked to volunteer for the study. Only certified athletic trainers who hold a staff or intern position at the time of the administration of the study will be asked to participate in the study.

3.4 Instrumentation

The survey was composed on 38 questions consisting of two different sections: Demographics and ACL prevention program.

3. 4. 1 Demographic Information

The demographic section was created to assess various aspects of the ATC and institution where the ACT was employed. The survey asked about sex, age, race, and years experience of the ATC. In addition, data was collected on what year the participant graduated from their undergraduate program, whether the undergraduate program was an internship or accredited athletic training education program, and what year they graduated from their graduate school. Participants were asked questions pertaining to their education and if their school has implemented an ACL preventative program. Along with the above mentioned survey questions, participants were asked about employment (NCAA Division I, II, III, NAIA universities, junior colleges, or high school), sport responsibility, and total number of athletes they are responsible for providing coverage.

3. 4. 2 ACL Prevention Program

Participants were asked if they use an ACL injury prevention program at their institution. Survey questions will also ask about the frequency (e.g., how many times a week) and duration of the ACL prevention program per session. Questions will inquire about when the program was carried out in relation to when within the practice session: beginning, middle, and/or end. Questions will also be asked about the warm up and cool down routine, stretching, strength training, educational routines, and exercises. For educational purposes it will also record who

provided instruction to the athlete through the ACL prevention program and if the person doing so had received any educational background within the ACL or injury prevention field.

Finally, the survey asked for the number of ACL injuries that were diagnosed by diagnostic tests (e.g., MRI, arthrogram, etc), or by a physician's diagnosis. Respondents will also be asked to include the sex, sport, mechanism of injury (e.g., non-contact/contact), and if the athlete had a history of prior injury to that knee.

3.5 Procedure

This study was conducted after getting approval from Michigan State University's Institutional Review Board. SurveyMonkey.com, a website that allows researchers to post and distribute surveys via the internet, will be utilized to collect responses. This website allows researchers to create and distribute surveys and questionnaires by way of the internet. It then collects the data and allows for the researcher to analyze their results.

The survey was a one-time, self administered survey to approximately 1,000 randomly selected certified athletic trainers. The NATA provided the researcher with 1,000 randomly selected electronic mail (e-mail) addresses from the "certified" category from the NATA membership database. The e-mail correspondence sent to participants included an explanation of the study (Appendix C) and a link to the survey. Implied consent was determined by those who complete and returned the survey. The survey will take approximately 15-20 minutes to complete.

The data collection website, SurveyMonkey.com, allowed for the researcher to access it at any time with 24 hour admittance. SurveyMonkey.com access was limited to only the primary researcher and the three members of the research board committee. All survey responses were anonymous, the institutions name and names of who filled out the survey were not asked. The IP

addresses would not be documented by those who had access to the data or by SurveyMonkey.com. If data was printed, the data was kept in a locked cabinet.

3.6 Data Analysis

Demographic information and ACL injury prevention program questions were summarized using descriptive data. All data collected were nominal data. The statistical significance level was set at $p < .05$. Data was analyzed using the Statistical Package for the Social Sciences (SPSS) 19.0 software.

H1: ACL injury prevention programs will be effective in reducing the incidence of ACL injury.

Descriptive statistics were performed/1 way between subjects ANOVA

H2: The number of noncontact ACL injuries will be higher compared to contact ACL injuries.

A dependent t-test was performed to determine the difference between noncontact and contact ACL injuries.

H3: There will be an inverse relationship between the number of hours dedicated to the ACL injury prevention program and the incidence of ACL injury.

Pearson r correlation was used to determine the relationship between the number of hours dedicated to ACL injury prevention program and the incidence of ACL injury.

H4: ACL injury prevention programs that are conducted by ACL educated instructors will have a decreased number of ACL injuries compared to an ACL prevention program not conducted by an ACL educated instructors.

An independent t-test was performed to determine if there are differences between an ACL prevention program conducted by an ACL educated instructor or a non-educated instructor.

H5: Athletes who participate in an ACL injury prevention program prior to practice will have a lower incidence of ACL injury then those who participate in a program during practice.

An independent t-test was performed to determine if there is a difference in when (i.e., prior to practice) an athlete participates in an ACL injury prevention program.

H6: The most utilized screening tool used to determine if an athlete is at risk of ACL injury will be sex and the athlete's sport.

Descriptive statistics were performed on all screening tools.

3.7 Research Question

R1: Will there be certain activities of an ACL injury prevention program (i.e., agility training, plyometrics, and education of proper techniques) that could decrease the incidence of an ACL injury?

Descriptive statistics were performed on all activities utilized on an ACL injury prevention program.

CHAPTER 4

RESULTS

4.1 Overview

This research was conducted to investigate the absence or utilization of an ACL injury prevention program at NCAA colleges and universities (Division I, II, and III levels), NAIA universities, junior colleges, as well as at the high school level. It assessed what their ACL injury prevention program exercises and protocol consist of and determine if the training program in use reduces the rate of ACL injuries by considering their ACL injury rate (non-contact vs. contact).

4.2 Demographic Data

One hundred and fifty-two participants began and completed the survey. The survey was sent out to 1,000 athletic trainers who were registered with the National Athletic Trainer's Association. Therefore, there was a 15.2 % response rate. The average age for the participants in the survey was 36.09 (± 9.46) years old with the minimum age being 22 and the eldest being 57 year old. On average, the participants were active athletic trainers for 12.23 (± 9.05) years, with the minimum number of years being 1 and the longest being 36 years. Participants were found to have graduated from their undergraduate institution on average 13.89 (± 9.48) years ago with the minimum being 1 year and the maximum being 37 years ago. The majority of the participants were Caucasian (125/142 [82.2%]), followed by those who were two or more race (5/142 [3.3%]), and Asian and Hispanic (each 2/142 [1.3%]). There were 5 participants who preferred not to report their racial ethnicity and 10 that chose to not answer the question. The sex of the participants was close to being equal as 70 of the participants were females (70/141 [46.1%]) and

71 of the participants were male (71/141 [46.7%]), 11 participants chose not to answer the question.

The majority (60/137 [43.8%]) of the participants were employed and working at the high school level, followed by the NCAA Division IA (22/137 [16.1%]), and NCAA Division III (21/137 [15.3%]). There were 15 participants who chose not to answer the question of their associated level of employment (*See Table 4.1*).

Table 4.1

Percentage of Level of Employment Represented by Athletic Trainers

Division of Employment	Number of Participants	Percent
High School	60	43.8
NCAA IA	22	16.1
NCAA DIII	21	15.3
NCAA DII	11	8.0
NAIA	8	5.8
Private School	5	3.6
NCAA IAA	4	2.9
Junior College	4	2.9
NCAA IAAA	2	1.5
Total	137	100

**15 participants chose not to answer*

Twenty-nine of the participants were employed within the National Athletic Trainer's Association District 4 (29/143 [20.3%]), followed by District 2 (24/143 [16.8%]), and District 3 (16/143 [11.2%]) (*See Table 4.2*).

Tablet 4.2

Percentage of NATA Districts Represented by Athletic Trainers

District	Number of Participants	Percent
District 4	29	20.3
District 2	24	15.8
District 3	16	10.5
District 6	15	10.5
District 1	14	9.8
District 7	12	8.4
District 5	11	7.7
District 9	9	6.3
District 10	7	4.9
District 8	6	4.2
Total	143	100

**9 participants chose not to answer*

The majority of the participants graduated from an undergraduate institution within the NATA District 4 (31/143 [21.7%]), District 2 (24/143 [16.8%]), and District 5 (17/143 [11.9%]). (See Table 4.3).

Table 4.3

Percentage of NATA Districts Represented by Athletic Trainers When Attending Undergraduate School

District	Number of Participants	Percent
District 4	31	21.7
District 2	24	16.8
District 5	17	11.9
District 7	13	9.1
District 1	13	9.1
District 3	11	7.7
District 6	11	7.7
District 8	11	7.7
District 9	8	5.6
District 10	4	2.8
Total	143	100

**9 participants chose not to answer*

The average number of athletes that the participants were in charge of overseeing, working with and/or supervising ranged from 15 to 1,600 athletes; with the mean at 306.82 \pm 261.348. There were 10 participants who chose not to answer.

The athletic trainers were asked to list the sports that they directly supervised. The majority of the participants worked with or supervised men's basketball, men's and women's track and field/cross country, men's football, baseball, women's basketball, and women's soccer. (See Table 4.4).

Table 4.4

Sports Athletic Trainers Supervised

Sport	Sport Coverage
Men's Basketball	70
Track/XC	64
Football	63
Baseball	62
Women's Basketball	61
Women's Soccer	60
Softball	56
Men's Soccer	55
Women's Volleyball	50
Women's Tennis	37
Men's Wrestling	34
Men's Tennis	34
Swim/Dive	32
H.S. (General Sports)	27
Men's Golf	23

Table 4.4 (cont'd)

Table 4.4 (cont'd)

Cheerleading	18
Women's Lacrosse	18
Men's Lacrosse	17
Field Hockey	16
Hockey	15
Men's Volleyball	10
Gymnastics	6
Women's Rowing	4
Rodeo	2
Women's Water Polo	2
Women's Badminton	2
Men's Badminton	2
Ski	1
Frisbee	1
Flag Football	1
Bowling	1
Equestrian	1
Men's Rowing	1
Women's Wrestling	1
Women's Football	1
Women's Weight Lifting	1

Table 4.4 (cont'd)

Men's Weight Lifting	1
Men's Water Polo	1
Total	152

4.3 ACL Injury Prevention Programs

The ACL injury prevention program portion of the survey instrument was constructed to determine the participant's awareness, education, and usage of ACL injury prevention programs within their place of employment. A majority of the participants were aware of ACL injury prevention programs (142/152 [93.4%]). There were 137 participants who stated that they were aware of the increasing research that has been dedicated to finding the common mechanism of ACL injuries (137/152 [90.1%]). Participants were asked if they had ever attended a convention, seminar, or symposium that had discussed ACL injury prevention programs, a majority had stated that they had (101/152 [66.4%]).

Overall, there was a mean of 4.24 ± 3.73 ACL injuries that occurred within the past 2 years that were diagnosed with MRI imaging or by a physician (*See table 4.5*). There were 644 ACL injuries reported by the participants of the study. It was reported that 118 of the athletes were not participating in an ACL injury prevention program at the time of injury (118/152 [77.6%]), 21 reported that some of the athletes were involved in a program (21/152 [13.8%]), and 12 were involved in an ACL injury prevention program (12/152 [7.89%]); one participant chose not to reply. Of the athletes who injured their ACL, 5 (5/32 [15.625%]) were reported to have been participating in an ACL injury prevention program with low effort, 14 exhibited moderate effort (14/32 [43.75%]), and 13 (13/32 [40.625%]) were said to have displayed high

levels of effort during the program. There were 30 responses to the question of if the athletes who injured their ACL were wearing an ACL brace at the time of injury, the majority of the athletes were not (29/30 [96.6%]).

Table 4.5

Number of ACL Injuries Diagnosed Within the Past 2 Years

Number of ACL Injuries	Frequency	Percent
0	14	9.2
1	19	12.5
2	21	13.8
3	19	12.5
4	22	14.5
5	21	13.8
6	12	7.9
7	5	3.3
8	3	2.0
9	2	1.3
10	7	4.6
14	2	1.3
15	3	2.0
16	1	0.7
25	1	0.7
Total	152	100

Of the ACL injuries listed above, those that occurred due to a non-contact mechanism had a mean of 2.59 ± 2.31 . (See Table 4.6). Of all the ACL injuries reported by the participants, 394 were described as being non-contact ACL injuries (394/644 [61.2%]). Non-contact

mechanisms were defined as those injuries that were “sustained by an athlete without extrinsic contact by another player or object on the field” (Gilchrist, 2008).

Table 4.6

Number of Non-Contact ACL Injuries

Number of Non-Contact ACL Injuries	Frequency	Percent
0	29	19.1
1	26	17.1
2	35	23.0
3	17	11.2
4	18	11.8
5	12	7.9
6	6	3.9
8	5	3.3
9	1	0.7
10	3	2.0
Total	152	100

The majority of the ACL injuries that were reported did not occur to those athletes who had previously injured their knee or ACL (24/32 [75%]). There were 8 (8/32 [25.0%]) ACL injuries that occurred in athletes that had a previous history of injuring the same knee or that ACL.

There were 149 responses in regards to whether or not the participant's institution or place of employment utilizes a program specifically designed as an ACL injury prevention program. Participates were reminded that the program or exercises could have been included in certain lower extremity strength and conditioning exercises; such as lunges, hip and knee manual resistance, plyometrics, and agility drills. The responses were almost equal, with 72 participates (72/149 [48.3%]) stating that they had a program in place and the remaining 77 (77/149 [51.7%]) did not have an ACL program in place.

It was found that the majority of ACL injury prevention programs have been utilized for longer than the past 2 years (38/71 [53.5%]). The minority of participants reported that their ACL injury prevention program was currently in its second year of utilization (6/71 [8.5%]) (*See Table 4.7*).

Table 4.7

Years an ACL Injury Prevention Program Has Been Utilized

How Many Years Program Has Been in Place	Frequency	Percent
Longer than past 2 years	38	53.5
Only in its 1 st year	10	14.1
Only in its 2 nd year	9	12.7
Past 2 years	6	8.5
None	8	5.3
Total	71	100.0

**81 participants chose not to answer*

The most frequent reasons participants were committed to an ACL injury prevention program was to prevent and/or decrease the number of ACL injuries occurring within their sports program (45/71 [63.4%]). Another reason to participate in a program was that the strength and conditioning staff required and/or already had the athlete's perform exercises that could be described as being a prevention program (31/71 [43.7%]) (*See Table 4.8*). Participants in the survey expressed that, "The school does not use a specific ACL injury prevention program. However, the exercises they [the athletes] perform could be considered ACL injury prevention exercises". This was also expressed by another participant who stated, "We do not have a specific ACL injury prevention program but our strength and conditioning coach advises the athletes to participate in a strength circuit which contains exercises that pertain to ACL prevention". These responses were common among the participant's additional comments concerning their sports teams' participation in an ACL injury prevention program.

Table 4.8

Reasons for Being Committed to an ACL Injury Prevention Program

Why Committed to ACL Injury Prevention Program	Frequency	Percent
Prevent/Decrease ACL Injuries	45	63.4
Strength & Conditioning Staff Require Program	31	43.7
Literature Suggests Utilizing a Program	21	29.6
Program in Place Upon Taking Staff Position	17	23.9
Coaches Require a program	13	18.3
Total	71	

**Participants could select all choices that applied*

***Only those participants who stated they had a prevention program answered this question.*

For those participants who took the survey and their place of employment did not have an ACL injury prevention program in place or a program that would assist indirectly in reducing ACL injuries, the most common reason for not utilizing a prevention program was that their sports teams do not have a significant number of ACL injuries to justify the implication of a program (28/76 [36.8%]). Not having enough time to put forth to develop a program was also a common reason given by the participants (27/76 [35.5%]) (See table 4.9). One participant stated that there was no ACL prevention program in place because, “Their coaching and athletic training staff is new, thus there has not been time to utilize one”. Another participant said that as

of January 2012 an ACL injury prevention program will begin at their institution with the sports they cover and/or supervise.

Table 4.9

Reasons for Not Participating in an ACL Injury Prevention Program

Why Not Committed to ACL Injury Prevention Program	Frequency	Percent
Not Significant Amount of ACL Injuries for Justification for a Program	28	36.8
Do Not Have Time to Assemble a Program	27	35.5
Time Does Not Allow it	22	28.9
Coaches Do Not Want a Program	16	21.1
Athlete's Non-Compliance	15	19.7
Never Heard of a ACL Prevention Program	6	7.9
All of the Athletes Wear ACL Braces	0	0
Total	76	

**Participants could select all choices that applied*

***Only those participants who stated they did not have a prevention program answered this question.*

For the institutions that currently participate in an ACL injury prevention program, the majority of the athlete's engaged in the program during the teams weight lifting sessions (46/70

[65.7%]). If a prevention program was in place and was utilized during a practice session, the majority of the participants stated that the program took part just prior to the team's practice time (18/70 [25.7%]). The least common time for athlete's to partake in an ACL program was at the end of their team's practice (2/70 [2.9%]) (*See Table 4.10*).

Table 4.10

Times to Participate in an ACL Injury Prevention Program

Time Allotted for Program	Frequency	Percent
During Weight Lifting	46	65.7
Prior to Practice	18	25.7
Beginning of Practice	12	17.1
Only During Pre-Season/Off-Season	8	11.4
Middle of Practice	3	4.3
End of Practice	2	2.9
Total	70	

**Participants could select all choices that applied*

***Only those participants who stated they had a prevention program answered this question.*

The majority of participants responded that their strength and conditioning coach is the director of their ACL injury prevention program (34/70 [48.6%]). Athletic trainers were only reported to take the athletes through the program 21.4% of the time (29/152) (*See Table 4.11*).

Table 4.11

Director of the ACL Injury Prevention Program

Director of Program	Frequency	Percent
Strength and Conditioning	34	48.6
Coach	29	41.4
Athletic Trainer	15	21.4
Athlete	2	2.8
Other	1	1.4
Total	70	

**Only those participants who stated they had a prevention program answered this question.*

Of the staff athletic trainers who answered that their institution currently did participate in an ACL prevention program, 50% (35/70) of the programs directors had undergone some sort of training in the area of ACL injuries and preventive exercises that could be used to reduce the rate of ACL injury. The most frequently reported educational training the program director received was by obtaining information from a sports medicine clinic, hospital, athletic trainer, or strength and conditioning staff member that specialized in ACL injury prevention (21/35 [60.0%]). It was found that watching a video concerning ACL injury prevention programs in order to obtain the proper educational information was the least used method of training (6/35 [17.1%]) (See table 4.12).

Table 4.12

Educational Training Received by the Director of the ACL Injury Prevention Program

Educational Training	Frequency	Percent
Sport Clinic/Hospital, ATC, Strength and Conditioning Staff Educated in ACL Injury Prevention	21	60.0
Attended a Seminar, Symposium, Convention Presentation	18	51.4
Read Current Research Articles	17	48.6
Watched a Video	6	17.1
Total	35	

**Only those participants who stated they had a prevention program answered this question.*

Of the respondents to the survey, 92.9% of them expressed that their sports teams did participate in a strength and conditioning program (65/70). Of those who stated that they engaged in a strength and conditioning program, the average time spent with a strength and conditioning coach while participating in activity was 33.79 minutes \pm 26.04 minutes; with the maximum time being 90 minutes. Athletes were said to take part in a strength and conditioning program 2.94 \pm .99 16/152 [1.2 %] times per week on average. The maximum time spent per week in a strength and conditioning program was 5 times per week (12.5%) and the minimum was 2 times per week (43.8%). The off-season was when the majority of the staff athletic trainer's reported that their teams engaged in an ACL prevention program (56/63 [88.9%]). Teams involved in ACL injury prevention programs occurred the least often when in-season, but there was not a significant difference (50/63 [79.4%]) (See table 4.13).

Table 4.13

Time of Year Team's Participate in an ACL Injury Prevention Program

Time of Year	Frequency	Percent
Off-Season	56	88.9
Pre-Season	53	84.1
In-Season	50	79.4
Other	1	0.15
Total	63	

**Participants could select all choices that applied*

***Only those participants who stated they had a prevention program answered this question.*

It was found that most ACL injury prevention programs incorporate many of the same exercises and activities. The most frequently used exercises were having the athlete's perform lower extremity and strengthening exercises, plyometrics, and engaging in agility drills (15/17 [88.2]). (See Table 4.14).

Table 4.14

ACL Injury Prevention Programs Areas of Concentration

Exercise/Activity	Frequency	Percent
Agility Drills	15	88.2
Plyometrics	15	88.2
Lower Extremity Strengthening Exercises	15	88.2
Stretching	14	82.4
Weight Lifting	14	82.4
Core Stability and Strengthening Exercises	12	70.6
Sport Specific Education of Proper Techniques	11	64.7
Total	17	

**Participants could select all choices that applied*

***Only those participants who stated they had a prevention program answered this question.*

It was reported by the staff athletic trainers that 88.2% (15/17) of their athletes take part in an ACL prevention program as a team; whereas only 11.8% (2/17) reported that the athlete's participated as an individual.

Having athletes go through a set of exercises and drills for screening purposes during pre-participation physicals in order to find any potential health risks and areas of concern is common, especially among the collegiate setting. This study found that 76.5% (52/68) of the athletic trainers reported that their institution does not do any form of screening to find those athletes who are at a higher risk of sustaining an ACL injury. Of those athletic trainers who expressed

that their place of employment does screen for at risk individuals the most common form of screening was by clinical assessment which was defined as assessing strength ratios, testing joint laxity, etc (12/16 [75%]). No one reported that they did diagnostic screening with the KT-2000 (See table 4.15).

Table 4.15

Screening Methods to Determine Athlete's who are at a Higher Risk of Sustaining an ACL Injury

Diagnostic Tool	Frequency	Percent
Clinical Assessment*	12	75.0
Athlete Has Prior History of Knee/ACL Injury	10	62.5
Sport Specific (women's basketball, women's soccer, football)	8	50.0
Video Analysis	2	12.5
KT-2000	0	0
Total	16	

**Assessing strength ratios, joint laxity, etc.*

***Participants could select all choices that applied*

There were no responses to the question why an institution that had an ACL injury prevention program in place had ceased using it. Since there were no responses the question was discarded.

4.4 Assessment of Hypotheses

H1: *ACL injury prevention programs will be effective in reducing the incidence of ACL injury.*

This hypothesis was partially supported ($F_{(2, 148)}=10.52, p=.000$). Participants were asked if they participated in an ACL prevention program. They had the option of selecting ‘yes’, ‘no’, or ‘some of their athletes participated’. Between group differences found significant findings for participants who said ‘yes’ ($M=3.72$ injuries) compared to ‘some of their athletes’ (7.52 injuries) ($p=.006$) and ‘no’ ($M=3.52$) compared to ‘some of their athletes’ ($p=.000$). However, when pairwise comparisons were made between ‘yes’ and ‘no’ there were no significant differences ($p=.986$).

H2: *The number of noncontact ACL injuries will be higher compared to contact ACL injuries.*

This hypothesis was supported as results revealed that noncontact ACL injuries were significantly higher than the number of contact ACL injuries ($t = 3.749, p=.000$). Non-contact ACL injuries accounted for 61.2% (394/644) of the ACL injuries reported.

H3: *There will be an inverse relationship between the number of hours dedicated to the ACL injury prevention program and the incidence of ACL injury.*

This hypothesis was not supported as results revealed that there is no relationship between the number of hours dedicated to an ACL injury prevention program and the reduction of ACL injuries ($r = -0.265, p = 0.360$).

H4: ACL injury prevention programs that are conducted by ACL educated instructors will have a decreased number of ACL injuries compared to an ACL prevention program not conducted by an ACL educated instructors.

This hypothesis was not supported as the instructors who were educated in ACL injury prevention programs did not significantly differ in the number of ACL injuries reported when compared to those individuals who did not receive any type of education in ACL injury prevention ($t=-0.686, p=0.495$)

H5: Athletes that participant in an ACL injury prevention program prior to practice will have a lower incidence of ACL injury then those who participate in a program during practice.

This hypothesis was not supported as those athletes who participated in an ACL injury prevention program prior to practice did not have a lower rate of ACL injury then those athletes who participated in one during practice ($F_{(2, 61)}=.15, p=.862$).

H6: The most utilized screening tool used to determine if an athlete is at risk of ACL injury will be sex and the sport they participate.

This hypothesis was not supported by respondents of this survey. The most utilized screening tool for those at risk for ACL injury was clinical assessment; such as measuring strength ratios, finding joint laxity within the knee, poor kinesthetics, etc (7.9%). It was shown that only 5.3% of the athletic trainers stated that they based screening off of the sport and the sex of that sport.

4.5 Research Question

***RI:** Will there be certain activities of an ACL injury prevention program (i.e., agility training, plyometrics, and education of proper techniques) that could decrease the incidence of an ACL injury?*

The study revealed that there are not certain activities that were shown to decrease the incidence of ACL injury. Only 17 participants in the study answered this question, for reasons unknown to the surveyor. The responses expressed that for the most part all of the athletic trainers utilized the same activities within the ACL prevention program their team was using (See Table 4.16). Even though taking athlete's through sport specific drills and exercises with proper mechanics was only chosen by 11 of the 17 participants, none of the other activities were shown to have any impact on the number of ACL injuries reported within the study. From this study it cannot be concluded that certain exercises or activities would reduce the rate of ACL injury. Further testing needs to be conducted to determine this conclusion, especially since the response rate and sample size for this survey was extremely low.

Table 4.16

ACL Injury Prevention Programs Areas of Concentration

Exercise/Activity	Frequency	Percent
Lower Extremity Strengthening Exercises	15	88.2
Plyometrics	15	88.2
Agility Drills	15	88.2
Weight Lifting	14	82.4
Stretching	14	82.4
Core Stability and Strengthening Exercises	12	70.6
Sport Specific Education of Proper Techniques	11	64.7
Total	17	

**Participants could select all choices that applied*

***Only those participants who stated they had a prevention program answered this question.*

CHAPTER 5

DISCUSSION

5.1 Overview

This study was inconclusive in determining if ACL injury prevention programs can reduce the prevalence of ACL injuries. It was also inconclusive as to what particular exercises and activities could reduce the prevalence of ACL injuries within the high school and collegiate athlete. This study did find that non-contact ACL injuries are significantly higher in number than those sustained by contact mechanisms. Participants who stated that their athletes participated in an ACL injury prevention program had significant reductions in ACL injuries compared to those who stated only some of their athletes were committed to a program, however, when compared to individuals who did not participate in an ACL injury prevention program there were no significant findings. This section will therefore discuss the relevant findings and relationships between this study and similar studies and how further research should be conducted to determine if ACL injury prevention programs can reduce the prevalence of ACL injuries.

5.2 Relation to the Research

Results of this research indicated that non-contact ACL injuries occur more frequently in the collegiate and high school athlete compared to contact ACL injuries (non-contact ACL injuries 61.2%). This finding is in agreement with Gilchrist (2008), who stated that non-contact ACL injuries make up approximately 70% of all ACL injuries. Similarly, Boden (2011) and Krosshaug (2007) reported that approximately 75% and 72% of ACL injuries were from non-contact mechanisms, respectively.

It was hypothesized that ACL injury prevention programs will be effective in reducing the incidence of ACL injuries. Athletic trainers who had all their athletes participate in an ACL

prevention program reported 3.72 ACL injuries compared to 7.52 for those who reported that only some of their athletes participated in an ACL injury prevention program. There were 3.52 injuries reported for the participants who reported that none of their athletes participated in a program. Although this hypothesis was partially supported, other studies have found some validation for having athletes participate in an ACL injury prevention program. In Hewitt's (1999) prevention program study on high school athletes, it was determined that those female participants who had not partaken in the program were 4.8 to 5.8 times at a greater risk of sustaining a serious knee injury compared to men. When Gilchrist (2008) conducted an ACL prevention program, only 7 athletes sustained an ACL injury which was considerably less than the group that had not participated in the program (18 ACL injuries). Finally, in a study by Mandelbaum (2005), those athletes who participated in a prevention program were found to have an 88% decrease in ACL injuries compared to those athletes who were not fully committed to the program. These studies suggest that ACL injury prevention programs could decrease the frequency of ACL injury.

Results of this study revealed no significant difference in reducing ACL injuries if the instructor had received or had attended any form of ACL injury prevention training. To date, no in depth research has been committed to exploring the educational background of individuals who instruct ACL injury prevention programs. This study also revealed that there is no effective time (i.e., before, after practice) to have athletes perform the ACL prevention program. Researchers have also indicated that prevention programs are most effective when they are utilized throughout the pre-season and in-season (Alentorn-Geli, 2009; Hewitt, 1999). This discrepancy may be due to the lower response rate of the current study; therefore, further research should be committed to the frequency of the program during the seasons (i.e., pre-

season, in-season) and week to determine the most effective time allotment needed in order to reduce the rate of ACL injury.

The most utilized tool for screening athletes who are at risk for sustaining an ACL injury was found to be athlete's undergoing a clinical assessment. A clinical assessment was defined as screening for genu recurvatum, valgus or varus angles within the knees, having wide pelvis angles, checking for proper body mechanics, and foot positioning. Numerous researchers agree that this type of assessment is useful in screening for ACL injuries (Barendrecht, 2011; Myer, 2010; Huston, 1996). Specifically, Barendrecht (2011) had the participants in his study perform a drop test and tested single leg stability with a one leg hop test. In both of these tests, the participants knee separation distances, valgus and varus angles, soft landing techniques, and leg stability were all measured to determine landing contact time, knee flexion angles, and knee valgus angles. All of these tests required the participant to exhibit balancing, control of their body mechanics, awareness in space, and muscle activity levels in order to correctly and safely land from the drop test without displaying signs of increasing the load on the ACL. In another study by Myer (2010), participants performed a drop vertical jump with a video analysis measuring the distance between 2 marked knee alignments. This calculation from the lab-based assessment was then used in a predicted algorithm to determine the amount of knee valgus movements. The more the knee valgus movement, the higher the risk became for the participant to have an ACL injury (Myer, 2010). Finally, Huston's (1996) study found that the female participants muscle activation patterns fire their quadriceps first over the hamstrings, and gluteal musculature. This means that there is increased anterior translation on the femur by the tibia. It could be deducted from Huston's (1996) study that increased stress and strain is placed upon the tibiofemoral joint with the increased anterior shearing forces with sharp movements or landing

from a jump. Athletic trainers should be aware of and be able to identify those athletes who are at a greater risk for sustaining an ACL injury. This can be performed in the athletic training room and should become a customary practice.

This study found that agility drills, plyometrics, lower extremity strength exercises, stretching, and weight lifting were the most frequently utilized exercise and activities among the participant's ACL prevention programs. However, this study did not find one particular exercise or activity that is more effective in reducing ACL injuries. Numerous researchers suggest that one or more of these exercises are vital to include in an ACL injury prevention program (Hewitt, 1999; Myer, 2010; Mykelbust, 2003; Boden, 2000). In all of these studies, there was an entity of the program that was more strongly tested, but all utilized a stretching and a strengthening program. A couple examples would be, Hewitt (1999) focused on the body mechanics of landing from a jump and how landing softer and with more knee flexion will decrease the loads placed on the knee and ACL. Myers (2010), study also correlated with Hewitt's (1999) study and focused on landing techniques, but he stressed neuromuscular training to decrease the strains put on the ACL. Myklebust's (2003) study addressed core strength and neuromuscular control and concluded that there is a need for athlete's to have adequate proprioceptive control as well as a good solid core in order to reduce strain on the ACL. These studies did not find any conclusive evidence in determining what an ACL injury prevention program should specifically consist of, but further studies are being conducted.

5.3 Relation to the Athletic Training Setting

The majority of the prior research concerning ACL's has been committed to ACL mechanisms of injury, ways in which to determine those athletes who are at a higher risk for ACL injury, and if ACL prevention programs were effective. These programs were mainly

conducted in relation to females and those sports in which a perceived higher risk of ACL injury occurs (usually found to be football, men's and women's basketball, and men's and women's soccer). It is important to continue researching within the field of ACL injury prevention programs because the best treatment is always prevention of the injury itself. On average, 88% of ACL injuries result in a severe loss of time (NCAA category of time loss) before the athlete is able to return fully to their previous activity without restrictions, thus finding and utilizing an effective ACL injury prevention program would greatly benefit collegiate and high school athletes (Hootman, 2007). By determining what exercises, plyometrics, agility drills, strength and conditioning programs, and stretches are most beneficial to the athlete the most efficient ACL injury prevention program could be developed. An effective and efficient program would increase the athlete's lower extremity strength, proprioception, and further decrease the likelihood of sustaining an injury.

If an effective ACL injury prevention program can be developed, the rate of ACL injury could decrease, which would decrease the amount of playing time missed by athlete's each year due to ACL injury. One of the most important aspects of an athletic trainer's job is injury prevention, thus, this concept would be exemplified by teams and intuitions at the high school and collegiate level to begin or continue to participate in an ACL prevention program. It is important to take into consideration that each sport has different demands and requires different angles, cuts, and levels of play. Due to these factors, every sport would require different aspects of an ACL prevention program to cater to their specific sports demands. For this reason, it is vital that the individual leading the ACL injury prevention program should have a thorough knowledge of the sport and also the most up to date research concerning the most effective ACL injury prevention programs.

Athletic trainers should be aware of athletes who are at the highest risk for ACL injuries, especially if they are responsible for supervising those particular sports. The most effective way to determine those athlete who are at a higher risk for injury, would be to conduct a screening assessment. According to Micheo (2010), those sports that are at the highest risk are those that demand actions such as cutting and/or pivoting; these types of sports make up an estimated 70% of all acute ACL injuries. It is also important for athletic trainers who work with female athletes to stay educated in ACL injury mechanisms and prevention. As stated by Hewitt (1999), female athletes have a 4 to 6 times greater incidence rate of general knee injury than their male counterparts. Determining and identifying those athletes who are at a higher risk for ACL injury can be the most important aspects to injury prevention and decreasing the rate of ACL injury among the sport setting.

It is important for athletic trainers to educate their athletes, coaches, strength and conditioning staff, and anyone else who may be affiliated with the team's training so that the proper body mechanics, landing and pivoting techniques can be practiced on a consistent basis. The consistency will help the athlete transition from poor mechanics to more controlled movements that may decrease the rate of injury; specifically in this case ACL injury.

5.4 Limitations

There were many limitations to this study. The sampling procedure is perhaps the largest limitation in this study. The sample size was very small; this was because the survey was only sent out to 1,000 certified athletic trainers who were registered with the NATA via email. When asked about sending the survey out to additional addresses, the National NATA commented that this was not possible due to the researcher's status as a student. This limited the surveys sampling because it eliminated those athletic trainers who are not registered with the NATA and

those who elected not to receive surveys from the NATA when they paid their membership dues. The sample is not representative of the collegiate level because the majority of the participants who participated in the survey were from the high school level (60/137 [43.8%]).

Another limitation of the study was the participant's non-response to some of the survey questions. Only 17 responses were recorded when asking what the participant's institution's ACL injury prevention program consisted of, the duration of the program when it was performed, and how many times per week the program was run. This low response rate does not give a representative sample nor does it give solid evidence on what if any, certain activities in an ACL injury prevention program are most relevant to reducing the rate of ACL injury. The survey also does not specify between the ACL injuries sustained by males and females. Therefore, it is impossible to determine if more of the ACL injuries occurred in female or male sports. It was also not recorded what injuries occurred in each sport, sex of the sport, or how many occurred within that sport. Therefore, the study is unable to determine if ACL injuries are more frequent in a particular sport or gender.

Self-reporting bias limited the results of the study. The survey required the participants to determine if their team participates in anything that could be classified as an ACL injury prevention program. A statement was made in regards to what classified a prevention program, for example, if the team was involved in lower extremity strengthening and conditioning program such as lunges, hip/knee manual resistance, plyometrics, or agility drills that could be determined as helping to reduce ACL injuries. Thus the participants had to determine if their team's activities could be interpreted as such, which could present self-serving bias. The participants were asked to state what types of activities (i.e., agility drills, plyometrics, strengthening exercises, core stability, sport specific drills, or weightlifting) their teams

participated in when performing the ACL injury prevention program. This led the participants to determine what categories their specific program would classify as they could choose as many as was relevant to them. Another question led the participants to determine what level of effort their athlete who sustained an ACL injury was exerting towards the ACL program they were participating in, their options included low, moderate, and a high level of effort. This question requires the responder to give their opinion, in which case the definition of the level of effort can vary from one individual to another, the athlete's effort could alter on a daily basis, and/or the athletic trainer may not directly view the program.

5.5 Future Research Considerations

It can be determined from this study that the relationship between ACL injury prevention programs and the reduction of ACL injury warrants further investigation. Researchers should continue to explore the frequency of ACL injuries within specific sports while considering the sex of the sport. Further research should also focus on how different exercises that are performed by the athletes influence the strength and prevalence of ACL injury within the team in relation to their exposure time. Since a majority of the ACL prevention programs that were in place were reported being directed by the strength and conditioning staff, future research may want to focus on the strength and conditioning staff and their feedback about their programs.

Education is an important factor in decreasing the prevalence of ACL injury. More research should be committed to determining how those teams that currently participate in an ACL injury prevention program educate their athletes in relation to performing tasks with the proper form and or techniques throughout the athlete's career at the institution. Consideration should be taken in the re-screening process, if the athletes undergo re-educational technique sessions, and if they are monitored and corrected on a daily basis on their form or techniques

with movements. Education of the athlete, coaches, and support staff should focus on those exercises that are utilized within the strength and conditioning program in addition to those activities performed in conjunction with practice sessions.

It was found that non-contact ACL injuries are more prevalent than contact injuries. Although there has been numerous research dedicated to finding the causes of non-contact ACL injuries, it is still unclear why these injuries occur and what factors can classify an athlete who is at a higher risk for injury. Thus, future research should be committed to determining the common mechanisms that cause non-contact ACL injuries.

More studies are also warranted to clarify if having a previous injury to the same knee, whether it be to the ACL or any of the surrounding structures increases the risk of sustaining an ACL injury. Future research should also focus on other such risk factors that could increase and identify those athletes who are at a higher risk for ACL injury, such as wearing ACL braces, having a wider pelvis angle, landing with an uneven toe strike, etc. By being able to better identify those factors that put athlete's at a higher risk for ACL injury, further steps can be taken to try to decrease these factors and thus hopefully reduce the prevalence of ACL injury.

5.6 Conclusions

The results of this study reinforced previous studies in that non-contact ACL injuries are more prevalent than contact ACL injuries. Although, ACL injury prevention programs showed no direct effect on decreasing the frequency of ACL injuries in those institutions that participate in an ACL injury prevention program, further research should be conducted before a conclusion can be drawn. Even though the study could not deduce from the results what exercises offer the most benefit to the athlete in trying to decrease the frequency of ACL injuries, it can be inferred that all of the factors studied are perceived as being necessary. The results of this study revealed

the warrant for further investigation into the utilization of ACL injury prevention programs as a means to decrease the prevalence of ACL injury, in relation to the sport, sex of that sport, duration and timing of the program, effective screening tools, and most beneficial exercises and/or activities performed within the ACL injury prevention program.

APPENDICES

Appendix A

Demographic Questionnaire

INSTRUCTIONS: Please completely read each question below. When answering the questions please think about your athletic training career for the past 2 years. Please fill the survey out based off of the team or athletes you supervise and those that you yourself are responsible for. Please answer honestly and to the best of your ability.

- 1) How old are you?
- 2) How many years have you been an active certified athletic trainer?
- 3) What year did you graduate from your undergraduate institution?
- 4) Please select the racial ethnicity that best describes you:
 - a. Caucasian/White
 - b. African/African-American/Black
 - c. Hispanic/Latin-American
 - d. American Indian/Eskimo
 - e. Asian (including Hawaiian and Pacific Islander)
 - f. 2 or more races
 - g. Prefer not to report
- 5) Sex
 - a. Female
 - b. Male

6) Of which NCAA Division are you affiliated with or are you employed through an outreach program or high school?

- a. NCAA I-A
- b. NCAA I-AA
- c. NCAA I-AAA
- d. NCAA II
- e. NCAA III
- f. NAIA
- g. High School
- h. Private School (K-12)
- i. Junior or Community College
- j. Clinic
- k. Hospital
- l. Other (Please specify)

- 7) What NATA district are you currently employed and practice in?
- a. 1 (CT, ME, NH, RI, VT, New Brunswick, Nova Scotia)
 - b. 2 (DE, NJ, NY, PA)
 - c. 3 (DC, MD, NC, SC, VA, WV)
 - d. 4 (IL, IN, MI, MN, OH, WI, Manitoba, Ontario)
 - e. 5 (IA, KS, MO, NE, ND, OK, SD)
 - f. 6 (AR, TX)
 - g. 7 (AZ, CO, NM, UT, WY)
 - h. 8 (CA, NV, HI, Guam)
 - i. 9 (AL, FL, GA, KY, LA, MS, TN, Puerto Rico, Virgin Islands)
 - j. 10 (AK, ID, MT, OR, WA, Alberta, British Columbia, Saskatchewan)
- 8) What NATA district was your undergraduate institution affiliated?
- a. 1 (CT, ME, NH, RI, VT, New Brunswick, Nova Scotia)
 - b. 2 (DE, NJ, NY, PA)
 - c. 3 (DC, MD, NC, SC, VA, WV)
 - d. 4 (IL, IN, MI, MN, OH, WI, Manitoba, Ontario)
 - e. 5 (IA, KS, MO, NE, ND, OK, SD)
 - f. 6 (AR, TX)
 - g. 7 (AZ, CO, NM, UT, WY)
 - h. 8 (CA, NV, HI, Guam)
 - i. 9 (AL, FL, GA, KY, LA, MS, TN, Puerto Rico, Virgin Islands)
 - j. 10 (AK, ID, MT, OR, WA, Alberta, British Columbia, Saskatchewan)

9) What specific sport(s) do you supervise and/or work with? Please be specific to the sex of the sport.

10) How many athletes/patients are directly under your care throughout an academic year?

Appendix B

ACL Injury Prevention Program Survey

INSTRUCTIONS: Please completely read each question below. When answering the questions please think about your athletic training career for the past 2 years. Please fill the survey out based off of the team or athletes you supervise and those that you yourself are responsible for. Please answer honestly and to the best of your ability.

- 1) Are you aware of anterior cruciate ligament (ACL) injury prevention programs?
 - a. Yes
 - b. No
- 2) Are you aware of the increasing research dedicated to ACL mechanisms of injury?
 - a. Yes
 - b. No
- 3) Have you attended a convention, seminar, or symposium that discussed ACL injury prevention?
 - a. Yes
 - b. No
- 4) How many ACL injuries (that were diagnosed with MRI imaging or by a physician) has the team you are responsible for had within the past 2 years?
- 5) How many of the ACL injuries listed above (question 4) were non-contact ACL injuries?
- 6) Were the athletes who sustained an ACL injury participating in an ACL injury prevention program at the time of injury?
 - a. Yes all of the athletes
 - b. Some of the athletes
 - c. None of the athletes

- 7) In your opinion, what level of effort were the athletes exerting when performing in the ACL injury prevention program?
- a. Low level of effort
 - b. Moderate level of effort
 - c. High level of effort
 - d. If athletes gave different levels of effort please specify
- 8) Were the athletes that sustained an ACL injury using ACL or knee braces at the time of injury?
- a. Yes
 - b. No
 - c. Other (if some did and some did not please specify)
- 9) Had the athletes that sustained an ACL injury had a previous history of knee or ACL injury to the same knee?
- a. Yes
 - b. No
 - c. Other (if some did and some did not please specify)
- 10) Does your team/athletes utilize an injury prevention program specifically designed for ACL injury prevention? (Please remember that certain lower extremity strength and conditioning exercises do serve to decrease ACL injuries, ex: lunges, hip/knee manual resistance, plyometrics, agility drills)
- a. Yes
 - b. No

11) For how long, if any, was there an ACL injury prevention program in place?

- a. Only 1st year
- b. Only 2nd year
- c. 1st and 2nd year
- d. Neither 1st or 2nd year
- e. Longer than the past 2 years

12) Please explain why your team is currently committed to an ACL injury prevention program. Please check all that apply.

- a. Prevent or decrease ACL injuries
- b. Literature suggest implementing an ACL injury prevention program
- c. Coaches require athletes to do an ACL injury prevention program
- d. It was in place when you took your position
- e. Other (please specify)

13) Please explain why your institution/or team DOES NOT participate in an ACL injury prevention program. Please check all that apply.

- a. Never heard of an ACL injury prevention program
- b. Do not have time to put a program together
- c. Coaches do not want us to do an ACL injury prevention program
- d. All our athletes wear ACL braces
- e. Athletes non-compliance to participate in an ACL injury prevention program
- f. No time for athletes to participate in an ACL injury prevention program
- g. Do not have a significant number of ACL injuries in order to justify the implication of an ACL injury prevention program
- h. Other

14) At what time does the team/individual engage in the ACL injury prevention program?

- a. Prior to practice
- b. Beginning of practice
- c. Middle of practice
- d. End of practice
- e. During weight lifting
- f. Other

15) Who runs or directs the program each time it is utilized?

- a. Coach
- b. Athletic trainer
- c. Strength and Conditioning Coach
- d. Athlete
- e. Other (please specify)

16) Did the person who runs your ACL injury prevention program receive any type of training in the area of ACL injury prevention?

- a. Yes
- b. No

17) What type of training did the program director receive?

- a. Went to a seminar, symposium, or convention presentation
- b. Received information from a Sport Clinic/Hospital, Athletic Trainer, or Strength and Conditioning staff specializing in ACL injury
- c. Watched a video concerning ACL injury prevention programs
- d. Read current research articles dedicated to ACL injury prevention programs
- e. Other (please specify)

18) Does your sport engage in a strength and conditioning program?

- a. Yes
- b. No

19) What is the duration of the program when it is performed?

20) How many times per week does the team participate in the program?

21) What does your ACL injury prevention program consist of? Please select all that apply.

- a. Stretching
- b. Weight Lifting
- c. Lower extremity strengthening exercises
- d. Core stability and strengthening exercises
- e. Plyometrics
- f. Sport specific education of proper techniques
- g. Agility drills
- h. Other (please specify)

22) Is the ACL injury prevention program conducted as a team or is it on certain individuals?

- a. Team
- b. Individuals
- c. Other (please specify)

23) During what time does your team engage in the strength and conditioning program?

- a. Pre-season
- b. In-season
- c. Off-season
- d. Other (please specify)

24) Does your institution screen for individuals who are at a higher risk of ACL injury?

- a. Yes
- b. No

25) What diagnostic tool does your institution use to determine if an individual is at a higher risk of ACL injury?

- a. KT-2000
- b. Clinical assessment (assessing strength ratios, joint laxity, et. within the clinical setting)
- c. Previous ACL injury (athlete has a history of prior knee or ACL injury)
- d. Sport specific (i.e. women's soccer, women's basketball, football)
- e. Video analysis
- f. Other (please specify)

26) Did your team have an ACL injury prevention program and then ceased using it? If so, please explain why. Check all that apply.

- a. Athletes were non-compliant with the ACL injury prevention program
- b. Program took too much time out of practice
- c. ACL injuries were not decreasing incidence of ACL injury
- d. Coach didn't want the program to take time out of practice
- e. Athletes began to wear ACL braces
- f. Other (please specify)

Appendix C

Letter to Survey Participants

Dear Fellow Athletic Trainer,

My name is Tara Bailey and I am a graduate assistant athletic trainer at Michigan State University. I am writing to ask for your participation in research for my Master's thesis, entitled "ACL Prevention Programs and It's Effectiveness in Reducing the Rate of Injury in the College and High School Athlete." **This student survey is not approved or endorsed by the NATA. It is being sent to you because of NATA's commitment to athletic training education and research.**

The survey in the link below is designed to determine if ACL injury prevention programs are effective in reducing the incidence rate of ACL injury at the high school and collegiate levels. The survey will examine if there is a greater incidence rate of ACL injury when considering the gender and sport. It will also examine what ACL injury prevention programs consist of across the country. The survey will take approximately 25 minutes to complete. Participation is voluntary and you must be 18 years or older to participate in this research study. Your participation may contribute to a better understanding of what the most effective ACL injury prevention program should consist of and what athletes are at the greatest risk of ACL injury.

Your confidentiality will be protected to the maximum extent allowable by law. Information gathered from this research will not be used to identify you in any way. SurveyMonkey.com assigns a number to your response, so no identity information will be linked to your questionnaire. Data will only be accessed by the primary researcher (myself), three advisors, and the Michigan State University Institutional Review Board and will be kept under double lock and key for three years. You may decline participation or withdraw at any time and you may also skip questions, all without penalty. There are no known risks inherent in participation.

If you have any concerns or questions about this research study, such as scientific issues, how to do any part of it, or to report an injury, please contact me, Tara Bailey, at 105 IM Sports Circle, East Lansing, MI 48823, at (517) 355-1627, or at baile202@msu.edu. If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at 207 Olds Hall, MSU, East Lansing, MI 48824.

I thank you in advance for your contribution to this research and for your willingness to share your experiences in hopes to better the lives of others that will follow you in this profession. Please click on the link below to proceed to the survey. Doing so will indicate your voluntary agreement to participate in this research. Please complete your survey no later than **December 30, 2011.**

Sincerely,
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Participants for this survey were selected at random from the NATA membership database according to the selection criteria provided by the student doing the survey. The student survey is not approved or endorsed by NATA. It is being sent to you because of NATA's commitment to athletic training education and research.

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