

What are the factors contributing to the differences in  
ACL injuries in male and female athletes?

Submitted by  
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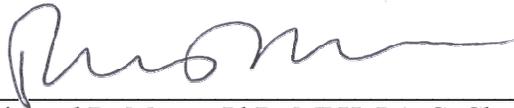
A project presented to the Department of  
Physician Assistant of Wichita State University  
in partial fulfillment of the  
requirements for the degree  
of Master of Physician Assistant

May 2006

Wichita State University  
College of Health Professions  
Department of Physician Assistant

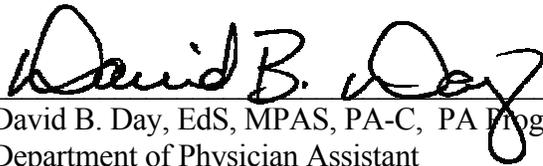
We hereby recommend that the research project prepared under our supervision by Justin Pool entitled What are the factors contributing to the differences in ACL injuries in male and female athletes will be accepted as partial fulfillment for the degree of Master of Physician Assistant.

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May 8, 2006  
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*Abstract*

Introduction: ACL injuries, particularly of the female gender have become an ever increasing problem for young athletes. This rise in injury rate has been noted since the growth of the female playing sports. In 1972 Title IX of the Educational Assistance Act was enacted which requires that institutions receiving federal funding provide equal access for women in sporting activities. Since that time to the present a two to eight fold increase in female ACL injury has been noted as compared to their male counterpart. Methodology: The purpose of this paper was to perform a systematic review of the literature and examine the cumulative data addressing the issue. This paper will provide a systematic review of the literature addressing ACL injury. Articles used included male and female athletes ranging from 12-28 years old. The articles also ranged between different sports such as basketball, soccer, volleyball, and skiing. Results: Twenty-one articles were reviewed and matched the criteria using evidence based methods. It was very apparent that a majority of the articles supported the idea that females are at increased risk of ACL injury and it seems to be due to multiple factors. None of the articles mentioned any one factor being a definitive cause to female injury. Some of the articles were unclear on their outcomes. Conclusion: The female athlete is at increased risk and many factors play a significant role in contributing to ACL injury. Much of the research points to neuromuscular factors as one of the greatest causes, but final conclusions were never made.

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## Acknowledgements

I would like to thank my family, especially my wife for all the support and patience over the last couple of years. I know that I have given my wife many headaches. There has been many times when she needed a break and I was unable to be home to give her one because of a test or work on this paper. I also want to thank my son Jordan, he was born the first week of school, and has always been there to play, when I needed a break. Thanks again to all for your love, patience, and support.

## *Introduction*

The anterior cruciate ligament (ACL) is one of the most common, severe, and debilitating knee injuries in men and women in both contact and non contact sports. Within the past 20-30 years the prevalence of ACL tears has been noted more significantly in the female athlete. Title IX of the Educational Assistance Act was enacted in 1972 and requires that institutions receiving federal funding provide equal access for women to funding of extracurricular activities. This federal law has contributed to a geometric increase in the number of female athletes participating at the high school, collegiate, and professional levels.<sup>1-3</sup> With this dramatic increase of females participating in sports like their male counterparts, many more injuries have been documented associated with the female, particularly the knee. According to Arendt et al., females were two times as likely to have ACL injuries as a result of player contact and three times more likely to obtain such an injury through noncontact mechanisms as their male counterparts.<sup>4</sup> The latest research indicates that female athletes are two to eight times more likely to experience anterior cruciate ligament rupture than male athletes.<sup>5-10</sup>

Research on this topic in the past has looked at many knee related injuries as a sports-specific problem. For females the activities that top the list are military training, rugby, soccer, basketball, gymnastics, and volleyball. It was thought that the injury obtained in the male and female athlete was directly related to the particular sport played. Due to the title IX act passed in the 70's and a closer following of female athletes, a new question has now been proposed in the medical world. The question most researchers are looking at now, addresses the actual factors or

mechanics of a woman's body that are leading to more ACL injuries. Numerous theories have been suggested to explain this problem. Many of these theories include both extrinsic and intrinsic factors. Intrinsic factors would be considered uncontrollable, and would include greater physiological rotatory laxity, smaller size of ACL associated with smaller intercondylar notch, valgus malalignment, hyperextension, diminished proprioception, leg dominance, quadriceps dominance, hormonal influence, postural alignment, etc. Extrinsic factors would be considered potentially controllable. These include decreased strength and conditioning, inappropriate shoes, motivation, deceleration forces during injury, neuromuscular control, and body movement. These extrinsic factors are the focus of prevention of ACL tears in the female athlete.

Due to these factors, many questions have arisen regarding the increasing rate of ACL tears in the female athlete. The ACL is made of two bundles, the anteromedial and posterolateral. Both of these bundles originate from the posterior medial femoral condyle and insert into the anterior medial aspect of the tibial plateau. In addition to the ligament itself, other soft tissues provide secondary support to the knee. These secondary support structures are the tendons and muscles, namely the quadriceps, hamstrings, and the gastrocnemius. Both the hamstrings and gastrocnemius are important in that they provide a posterior force on the tibia that helps to counteract anterior translation.<sup>7</sup> The ACL is the primary restraint to anterior tibial translation, and it also provides secondary restraint to internal rotation, as well as varus/valgus angulation with the knee in full extension. The quadriceps and hamstring muscles further stabilize the joint.<sup>11</sup> It's known that ACL injuries occur in

a variety of ways. In a 5 year study conducted by Medvecky et al., 84 women basketball players were followed and an alarming 93% of all the ACL injuries diagnosed were from non-contact mechanisms. Non-contact mechanisms must involve anterior shear of the tibia in relation to the femur. The quadriceps can produce significant anteriorly directed forces on the tibia, especially in the area of 0° to 40° of knee flexion. The magnitude of the quadriceps' force can be influenced by the muscle size, the degree of central nervous system activation, and the velocity of movement. In addition, eccentrically loaded muscle can develop much more force than muscle that is shortening. These factors can theoretically produce enough force to tear the ACL. The most likely mechanism causing this isolated tear is extension and internal rotation of the tibia on the femur.<sup>12</sup> This isolated mechanism has also been found in cadaver studies.

#### *The purpose of this study*

The factors contributing to the differences in ACL injuries in male and female athletes will be evaluated. Female athletes are of particular interest, due to their significant increase in ACL injuries. An ACL injury is a serious, devastating injury and understanding why it is more prone to tear, especially in females, would greatly advance the prevention of such injuries. The current research available has been unable to determine an exact cause of this increase in ACL injuries. Many factors are likely contributing to the problem, but which factors seem to be the most common or controllable have yet to be clearly identified. Anatomical, hormonal, or neuromuscular in nature, this study will identify factors that are the most important in determining causes of ACL injury in athletes, particularly the female athlete. This

study is not intended to focus on one particular study, but rather to provide a systematic review of current theories into one paper, looking at possibilities of one particular factor being most prevalent.

### *Methodology*

This paper is an evidence based research study in which articles were identified using databases such as Medline (First Search), Medline (PubMed), and CINAHL databases from 1995 to the present date. The key terms used in finding articles related to factors and differences in ACL tears in male and female athletes included: anterior cruciate ligament (ACL), gender, risk factors, injuries, and mechanics. Upon retrieval of all articles, data analysis was performed focusing on factors contributing to differences in ACL tears in male and female athletes. All the literature was from peer reviewed sources.

### *Results*

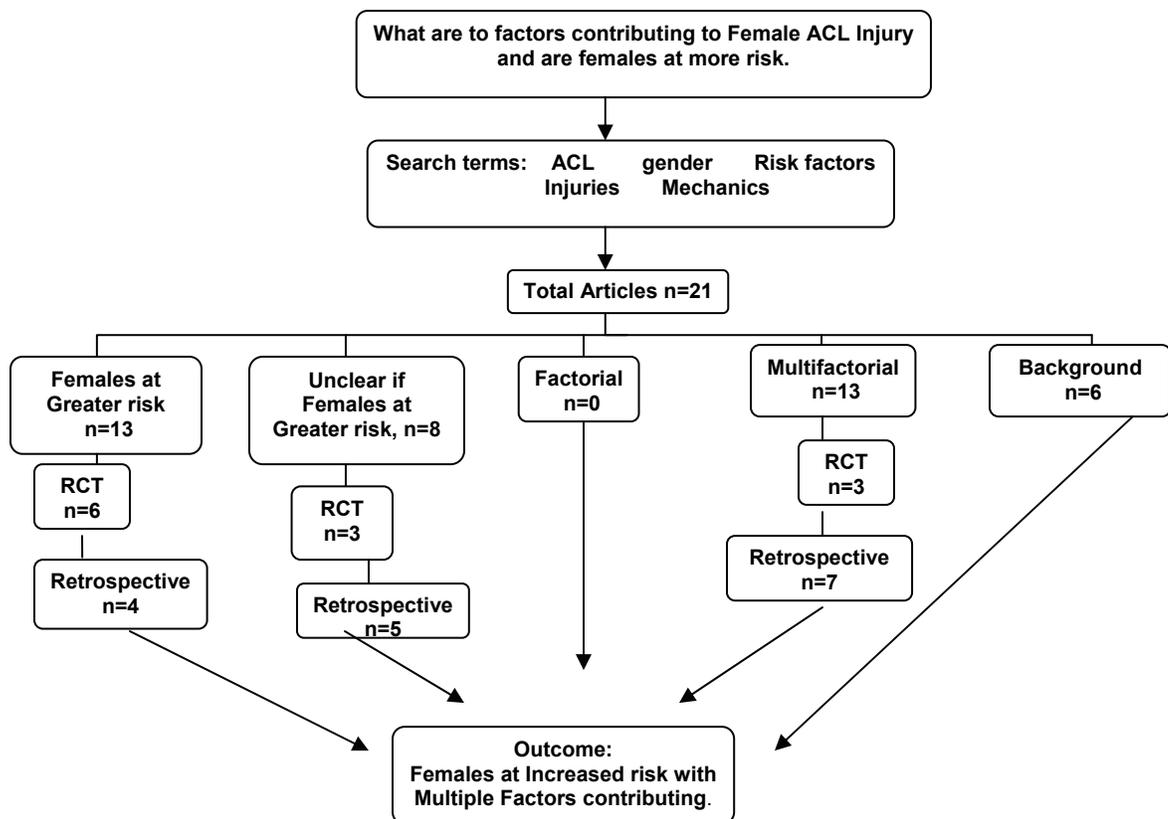
Twenty-one articles dated from 1995 to 2004 were used in this paper and all met the inclusion criteria (Figure 1). As noted in Figure 1, some of the articles addressed more than one topic resulting in an overlap in the result section. Six of the articles related background information about females and ACL injury.<sup>2,13-17</sup> This included information regarding what factors are already identified, mode of injury, and statistics showing the prevalence of ACL injury in female athletes.

Thirteen articles addressed the topics of either multifactorial causes, factorial causes and that females are at increase risk to ACL injury. Multifactorial causes would include neuromuscular imbalances, hormonal influences, biomechanics,

anatomical, extrinsic and intrinsic factors. Of the Thirteen articles, eight agreed that females are at increase risk and that the cause is multifactorial.<sup>1,4,7,8,10-12,14</sup> Five supported the idea of multiple factors, but were uncertain if this predisposed females to more ACL injuries.<sup>2,3,14,16,17</sup>

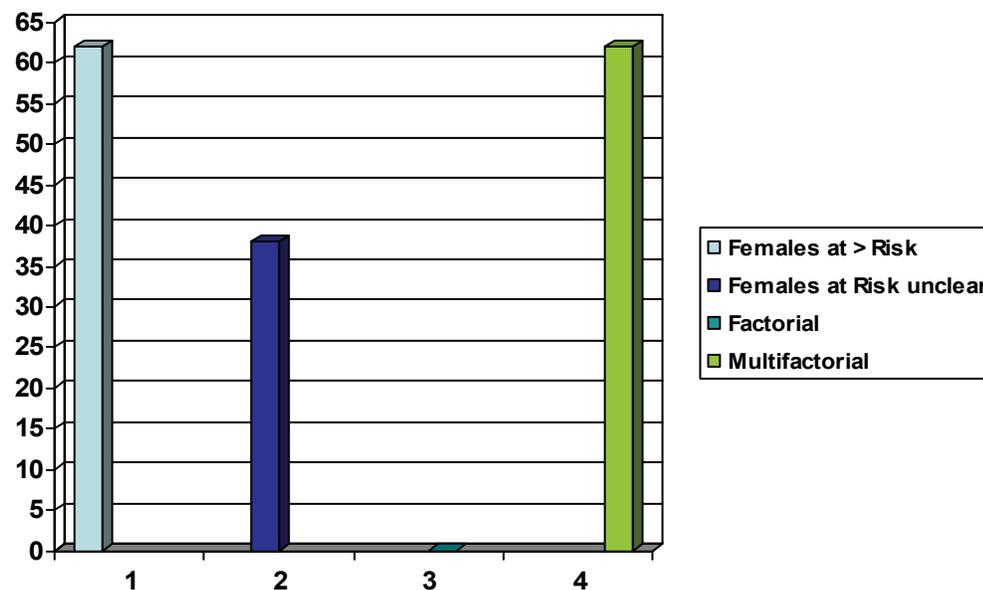
Three articles concluded that it was unclear whether or not females are at increased risk or if multiple factors contribute to female ACL injury.<sup>5,6,15</sup> Five other articles stated that females are at increased risk, but more research is needed to clarify factorial vs. multifactorial causes.<sup>9,13,15,16,18</sup>

Figure 1: Literature Review Flow Sheet



In a statistical sense, 62% of the articles found that it is multiple factors that lead to ACL injury in females. Within that 62% it was also noted that females are at increased risk. Thirty-eight percent of the articles were unclear if females were at greater risk and did not mention whether it was multifactorial. None of the articles suggested that ACL injuries are due to any one factor. All of the articles represented levels one and two in terms of “Levels of Evidence” which can be further graded as A or B recommendations (Figure 2, Appendix A).

Figure 2: **Results** (percent)



### *Discussion*

ACL injury in female athletes can be categorized by a number of factors. Ford et al., identified numerous studies that found a much higher incidence of knee injuries in females compared with males participating in jumping and cutting sports.<sup>13</sup>

Each of these studies evaluated the factors that maybe responsible for the significant increase in ACL injuries in female athletes. More than 95% of the studies reviewed all looked at ACL injury occurring as a result of a non-contact episode, such as landing after jumping or sidestepping. Hence, many of the studies in this review dealt with non-contact ACL injuries. McLean et al. looked specifically at the biomechanics of males and females during a side-step cutting motion. The purpose of their study was to look at females during cutting maneuvers evading a defensive player. They looked at the gender differences in knee kinematics (a branch of mechanics that studies the motion of a body or a system of bodies without consideration given to its mass or the forces acting on it) and to what extent these are linked to abnormal neuromuscular control. This study found that females had less hip and knee flexion, hip and knee internal rotation, and hip abduction. Females also had increased knee valgus and foot pronation angles, and increased variability in knee valgus and internal rotation. The final conclusion of the study was that gender differences in the joint kinematics suggest that increased knee valgus may contribute to ACL injury risk in women, and that the hip and ankle may play an important role in controlling knee valgus during sidestepping.<sup>19</sup> Another study with a similar finding was conducted by Roger et al., and concluded that female athletes also performed cutting maneuvers with less knee flexion, more knee valgus, and less hip flexion than male athletes.<sup>20</sup> Due to these factors the authors suggest that female athletes experience greater load to their lower extremities during landing and cutting, putting them at risk of increasing the force or strain put on the ACL.

One study looked specifically at postural alignment. This study evaluated for any correlation between ACL injury and foot pronation. The authors stated that navicular drop values, a commonly used clinical measure of foot pronation, are significantly higher in individuals who have sustained ACL injuries.<sup>6</sup> This is an important biomechanical aspect because this extra pronation increases the tibiofemoral torque and the internal tibial rotation during active states and thus puts high stress on the ACL. This specific finding still needs more study, but the evidence does suggest a link between foot pronation and a higher load to the ACL.

This is an important aspect of ACL injuries because of the force and stress that is applied to the knee joint when jumping, cutting, and particularly landing. Most non-contact injuries have occurred during any type of deceleration action such as stopping quickly or landing from jumping. The theory that females land with the leg in a more extended position is a concern because it has been reported that this particular pattern consisted of an internal rotation tibial torque and valgus movement placed on the knee flexed between  $0^{\circ}$  and  $40^{\circ}$ , as this is when the most stress is placed on the ACL.<sup>19</sup> Lephart et al., reported the average angle of knee flexion at the time of injury to be  $22^{\circ}$ . Another study by Decker et al. looked at ACL injuries during movements that involved quick deceleration, such as landing from a jump or making a cut. They found that most ACL injuries were a result of this type of movement (landing from a jump was reported in 30 of the 72 injuries or 41%). The reason ACL injury occurs more frequently during landing is that females tend to land in a more extended position at ground contact thus predisposing the ACL to greater

loads and that the neuromuscular function, particularly of the hamstring musculature, is inadequate in females compared to males.<sup>21</sup>

In a normal landing, the lower extremity joints function to reduce and control the downward momentum acquired during the flight phase through joint flexion.<sup>21</sup> Anatomically it has been found that the hamstring muscles work synergistically with the anterior cruciate ligament. When activated the hamstring muscles can resist anterior tibial translation relative to the femur and in turn lessen the probability of a giving way episode.<sup>5</sup> This is especially important while landing. Cowling et al. looked at whether or not gender altered lower limb muscle synchrony during abrupt landing. They hypothesized that females would have a delay in hamstring activation, making them more vulnerable to ACL injury. The study identified that males and females displayed similar quadriceps muscle activation patterns when landing. However, significant differences were noted in the hamstring muscle activation pattern. Improved synchrony between peak hamstring activity and peak tibiofemoral shear forces enables the hamstring muscles to act as a synergist to the ACL. Due to this fact, females would be more vulnerable to injury. Males show a better synchrony suggesting that they may be more protected from ACL injuries.

Many studies have looked at other factors that have association with ACL injury. One of these factors looks at the anatomical differences in males and females. Quadriceps angle (Q-angle) is one possibility of why females are more prone to ACL injury. Due to a wider pelvis, females have an increased angle between the long axis of the femur and the tibia, which may account for increased female injury rates.<sup>1</sup> Q-angle (tibiofemoral angles), continues to be a debated topic in relationship to females

and the prevalence of ACL tears. It does however make sense that the angle created by wider hips in the female puts the lower extremities in a valgus position, which has been hypothesized to put the ACL at risk of tearing. Current evidence is not sufficient to prove this hypothesis. The studies that have been published reported no correlation between ACL injuries and Q-angles.

Femoral notch size is also a possible factor contributing to ACL injury. The ACL size and orientation determine width and shape of the femoral notch. Ireland suggests that, regardless of gender, smaller notches have been associated with increased rate of ACL injuries.<sup>14</sup> Arendt found that the cross-sectional area of the ACL in the female was significantly smaller than that of the male.<sup>2</sup> These studies however, indicated that there is not sufficient evidence to make a consensus on the role of the size of the notch and size of the ACL.<sup>2</sup> Femoral notch size is an intrinsic factor considered by many to be a factor of increased ACL injury. A small notch width index (NWI) has been found to predispose the ACL rupture.<sup>10</sup> The NWI ratio is the width of the intercondylar notch to the width of the distal femur at the level of the popliteal groove on a tunnel view radiograph.

It is believed that the smaller notch size generally associated in females correlates to smaller weaker ACL's. Interesting is that the NWI in the acute, unilateral tears was not different from the control group and no gender difference was noted.<sup>12</sup> Patients that had bilateral ACL injuries had significantly decreased NWI versus controls, as well as those with acute, unilateral injuries. They also reported and defined a critical notch width stenosis as less than 0.18mm in females and 0.20mm in males. This continues to be a debated topic. Many athletes with smaller

notch size are still playing in high level sports with no reported injuries. Also it's questionable as to how the width of the notch is measured. Some measure using general AP views of the knee, while others think MRI is the best way to get an exact measurement. In one cadaveric study, it was determined that there was no difference in ACL area between knees with NWI less than or equal to 0.2 or greater than 0.2.

Other studies have also looked at the effects that hormones have on females. Hewett et al., observed a trend toward an increase in non-contact ACL injuries during the ovulatory phase of the menstrual cycle, and a decrease in these injuries in the follicular phase of the cycle.<sup>1</sup> Arendt identified three hypotheses relating to sex-specific hormones and ACL injuries. She suggested that sex-specific hormones increase tissue laxity and this increased laxity leads to increased injury.<sup>2</sup> Sex-specific hormones change the composition and cellular structure of ligaments leading to a weaker ligament and that there might be a hormonal influence on the neuromuscular control of extremity function.<sup>2</sup> These studies have shown that there is a possibility that hormones have an effect on ligament injury but were unable to make a consensus that hormones were a significant factor. Further study of hormonal contribution to ACL injuries is needed.

Ligament Laxity is defined as the combination of joint hypermobility and musculotendinous flexibility.<sup>11</sup> It has been reported that this laxity is more common in females than males. This may be due in large part to hormonal influences found in women. A significant increase in laxity in the third trimester, as well as greater laxity in multigravidae versus primigravidae was reported by Toth et al.<sup>11</sup> This hormonal influence is still heavily debated and will be discussed in further detail later in this

paper. Medvecky et al. identified that two issues of debate include whether the increased ACL injury rate can be attributed to ACL laxity and whether ACL laxity is different between men and women.<sup>12</sup>

Many studies are pointing towards females inherently having more lax joints than males, however, no significant evidence has been documented to support this. One very interesting study between joint looseness and tightness in football players suggests that players with increased joint laxity are predisposed to ACL injury. The study rated players on the ability to perform five maneuvers (palms to floor, knee recurvatum, knee-ankle rotation, lotus position, and upper extremity laxity). Seventy-two percent of the players with three or more indices sustained grade three knee ligament rupture versus only 4% in the tight category.<sup>12</sup>

Exercise and fatigue of joints has raised many questions with regards to ligament laxity. Chu et al., describe ligament creep as a stretching of the ligament. Current thought is that ligaments contribute to the overall sensorimotor control of the joint, with its neural input integrated with that of other sensory structures to control joint coordination during normal daily motion.<sup>18</sup> Ligamentous creep is associated with desensitization of the reflex arcs initiated by the mechanoreceptors in the ligament, which diminish the reflexive muscle activity and expose the joint to further instability and potential injury. This stretching seems to occur when the joint/ligament has been fatigued. Chu et al., found just that in their study, reporting that after static anterior load on the proximal tibia the ACL developed creep. The increased force and activity was more prominent in females. They concluded that athletes or workers should allow at least a 24 hour period of rest between intense

activities that expose the ligaments to creep. Medvecky et al., reported similar findings as they found that an anterior posterior laxity increase of 20% in collegiate basketball players after 90 minutes of practice and in recreational runners after a 10-kilometer race.<sup>12</sup>

Estrogen and progesterone receptors have been found on the ACL in both men and women.<sup>10-12,15,16</sup> These receptors were found in the nuclei of synoviocytes, stromal fibroblasts, and cells in the walls of the blood vessels in the ACL. This might suggest that estrogen and progesterone play a role in the structure of the ACL. Collagen production by fibroblasts located in the ACL can be affected by the physiologic levels of estrogen, fueling speculation that injury may occur more readily in women because of their hormones.<sup>10</sup> Medvecky et al. noted that at physiologic levels of estradiol, a 60% decrease in both fibroblast proliferation, collagen synthesis, and a decrease in the tensile strength of the ACL was seen. Although this was seen on ACL studies on rabbits, it still gives us some very interesting information.

Another important hormone is relaxin. It is largely responsible for changes at the pubic symphysis that accommodate passage of the fetus during birth. Relaxin like estrogen in that it also causes increased collagen turnover and decreased density, order, and integrity of collagen bundles.<sup>11</sup>

These types of hormones according to many studies are key in the development of ligament structural changes and laxity. The consensus is that this structural change that puts females at increase risk of ACL injury generally occurs during the ovulatory phase (days 10-14, when estrogen levels surge).

The most significant factors to date are the neuromuscular factors in ACL injuries. It is believed that women in general have quadriceps dominance, ligament dominance and leg dominance.<sup>2</sup> Quadriceps dominance means that women tend to use their quadriceps muscle first, which possibly leads to anterior tibial translation causing ACL injury. Males tend to rely initially on their hamstrings which give further knee stabilization.<sup>2</sup> Ligament dominance is when an athlete allows the knee ligaments, rather than the lower extremity musculature, to absorb a significant portion of the ground-reaction force during sports maneuvers. This results in high valgus knee movements and high ground-reaction forces.<sup>1</sup> Leg dominance is described as an imbalance between muscular strength and coordination on opposite limbs with the dominant limb often demonstrating greater strength and coordination. Females tend to generate lower hamstring torque on the nondominant than in the dominant leg. This might be a factor in ACL injury as it has been demonstrated that side-to-side balance in strength and flexibility is important for the prevention of injuries and when imbalances are present, the athlete is more prone to injury. Neuromuscular factors are one of the leading factors in females with ACL injuries.<sup>2</sup> Evidence of this was shown in quadriceps dominance, ligament dominance, and leg dominance. Each study dealing with these three factors showed a significant decrease in injury when implementing a neuromuscular training program pinpointing strengthening these three areas.

Limb dominance or the ability to be more dominant with one or the other lower limb has also been considered a factor in ACL injuries. This is an interesting phenomenon as it puts the less dominant limb at a possible increased risk of ACL

tears. It also is very applicable for those that have a significantly more dominant leg to make strength and conditioning changes in the off-season to balance out the differences. According to Matava et al., this particular area of ACL injury has not been evaluated in great detail. They specifically evaluated lower limb dominance related to ACL injury.<sup>17</sup> They conducted a survey and studied 80 patients between the years 1992 and 1998. Upper extremity preferences for writing and throwing and the lower extremity preference for kicking were used to define upper and lower limb dominance. They found that there was no significant difference in the side-to-side distribution of non-contact ACL tears; there was no significant relationship between lower limb dominance and the likelihood of sustaining a tear; and there was no significant gender effect on either the side-to-side distribution of ACL tears or the risk of a tear as a function of the dominant limb. Because of the limited research that related specifically to this topic they concluded that although nothing significant was found, more research on this topic is needed.<sup>17</sup>

Many studies are definitely indicating that neuromuscular factors play a major role in the significant increase in female ACL injury, however, no direct cause has yet been identified. Hormonal and anatomical factors in many studies have shown significance, but more studies are needed to confirm a relationship.

### *Summary*

The female athlete is of particular interest due to significant increase in ACL injury since the 1980's. Neuromuscular factors, anatomical differences, hormonal influence, extrinsic factors, and intrinsic factors all seem to play an important role in association with female athletes and ACL injury. Neuromuscular factors include

quadriceps dominance, leg dominance, and ligament dominance. Anatomical differences include increased Q-angle (quadriceps angle), ligament size, narrower femoral notch, and increased hypermobility or laxity and valgus knee motion.<sup>13</sup> Hormonal influence include estrogen, relaxin, progesterone, and others. Extrinsic factors include muscle strength, shoe-surface interaction, skill level, experience, and conditioning, while intrinsic factors include anatomic factors.<sup>4</sup> The possibility of more factors involving ACL tears is not limited to what has been stated previously. This study addressed the most significant causes and noted any other contributing factors. Hewett et al., stated that the neuromuscular theory offers the greatest potential for intervention and possible prevention of knee injuries in female athletes.<sup>1</sup>

Some foreseeable limitations of this project could be that it is difficult to obtain or read an important article that has some of the most recent findings in this area. Another limitation is that there currently are many theories about which factors are the cause of more ACL tears in female athletes. It was difficult to find enough evidence to say that one factor was more prevalent than another. Many hypotheses have already indicated that multiple factors play a role. With this, the chance to know which factors are the major leaders is difficult to determine.

### *Conclusion*

This study was very interesting considering the many factors and theories currently present with regards to ACL injury in male and female athletes. Research at the present indicates that increased risk of ACL injuries among women is likely multifactorial, with no single structural, anatomic, or biomechanical feature solely responsible.<sup>4</sup> As such, many opportunities are out there to help in finding causes of

ACL injuries, particularly in the female. Finding an answer could prevent a significant number of injuries and help to preserve the careers of many male and female athletes. This paper focused on finding that answer. Whether it is neuromuscular, anatomical, hormonal, an extrinsic factor, or an intrinsic factor, an answer could help many sports related programs implement muscle strength programs to help in reducing this debilitating knee injury. It's very evident that the ACL is very complex and that injury to it is multifactorial. Most of the studies that were evaluated pointed to neuromuscular factors such as ligament laxity, quadriceps dominance, ligament dominance, and leg dominance. Anatomical differences such as a widened pelvis (Q-angle) and smaller femoral notch sizes in females are also some factors that were addressed. Going into this evidence based research I would also consider hormonal influences. Increases in ACL tears during females monthly menstrual cycle was very interesting, however, I was disappointed that most of the studies had weakness or limitations, such as a lot of the participants were on oral contraceptives. This field of research is important as many of these devastating injuries can be prevented through proper strength and conditioning directed specifically toward quadriceps/hamstring balance, proper landing technique, cutting maneuvers, and lower limb balance.

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## Appendix A

<b>Study Year</b>	<b>Research Addresses</b> 1. Mode of Injury 2. Risk factors Involved 3. Prevention 4. Background	<b>Level of Evidence</b> 1. Random control 2. Retrospective 3. Background	<b>Demographics</b> Main data  M = Males F = Females	<b>Findings</b>	<b>Supportive of Research</b> 1. Females at Greater Risk 2. Unclear if females at greater risk 3. Factorial 4. Multifactorial 5. Background
<b>Hewett et al</b> 2001	2,3	2	n/a	*Female Athletes demonstrate 3 Neuromuscular Imbalances	1,4
<b>Arendt</b> 2001	2,3,4	2	n/a	*Neuromuscular Control and Balance, favor Injury Reduction	2,4
<b>White et al</b> 2003	2	1	51 Collegiate Basketball and Soccer Players 25 M, 25 F	*Found weakness between Ham/Quads in females * No conclusive evidence that females at > risk than males	2,4
<b>Arendt et al</b> 1995	2	2	5 yr eval of ACL injuries in Collegiate M/F soccer and Basketball	*Females had 2.4% increase of ACL injuries than males	1,4
<b>Cowling et al</b> 2000	1	1	7 M, 11 F Landing on single limb	*Gender did not alter landing Kinematics	2
<b>Trimble et al</b> 2002	1	1	43 uninjured College aged Subjects	*Link between foot pronation and stress to ACL *Relationship between Genu recurvatum and Torsion is less clear	2

<b>Lephart et al</b> 2002	2,3	2	n/a	*Females activate Quads near full ext. with little hamstring involvement. Inc. Risk ACL injury	1,4
<b>Hollman et al</b> 2003	1	1	11 unimpaired Adults 6 M, 5 F	*Knee Kinematics differ between men and women	1,4
<b>Fayad et al</b> 2003	1,2	1	42 M, 42 F, ages 16-39	*Notch size larger in males than females	1
<b>Harmon et al</b> 2000	1,2	2	n/a	*Females have inc. Incidence of ACL tears	1,4
<b>Toth et al</b> 2001	2,3	3	n/a	*Inc female Participation in sports *Inc ACL injury in Females	1,4
<b>Medvecky et al</b> 2000	all	3	n/a	*Numerous Factors have been implicated *Neuromuscular Factors appear most contributory to Female ACL injury	1,4
<b>Ford et al</b> 2003	1,4	1	81 High school basketball players 47 M, 34 F	*Females Display more Valgus knee motion. This can lead to inc in ACL injury	1
<b>Ireland</b> 2002	2,4	3	n/a	*Multiple factors responsible	1,4
<b>Carcia et al</b> 2004	2,4	1	20 active young Females	*Displacement and stiffness of ACL were not affected by day of menses	2
<b>Arendt et al</b> 2002	2,4	2	n/a	*No significant relationship between ACL injury and menstrual cycle	2
<b>Matava et al</b> 2002	2,4	2	44 M, 36 F presented with acute ACL tears	*No significant correlation between side of injury and dominant limb	2,4

<b>Chu et al</b> 2003	1	1	10 M, 10 F young and healthy	*Creep(stretch) developed in the ACL *Static Anterior load inc risk in females	1
<b>McClean et al</b> 2004	1	1	8 M, 8 F	*No statistically significant data	2,4
<b>Roger et al</b> 2004	1	1	High School and Collegiate Basketball 19 M, 19 F	*Females exhibit 5.8 degrees less knee flexion at contact	1
<b>Decker et al</b> 2003	1	1,3	12 M, 9 F during landing	*Females land in more erect posture	1

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