Noncontact anterior cruciate ligament injuries: An analysis of program interventions for female soccer players

Amber Louise Jacobsen
NONCONTACT ANTERIOR CRUCIATE LIGAMENT INJURIES
AN ANALYSIS OF PROGRAM INTERVENTIONS
FOR FEMALE SOCCER PLAYERS

A Project
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By
Amber Louise Jacobsen
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Approved by:

Dr. Stephen Kinzey, First Reader

Dr. Hosung So, Second Reader

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Date
ABSTRACT

With the rapid increase in women’s sports competition, the rate of Anterior Cruciate Ligament (ACL) injury has also increased. The rate of injury is substantially higher in female athletes compared to the rate of injury in males. High risk sports for women are predominately soccer, volleyball, and basketball. Since competition levels are rising each year, an epidemic of female noncontact ACL injuries has followed. Alarming studies show that women athletes sustain two to eight times more ACL injuries in high risk sports than men. Women’s soccer has the highest injury rates of all high risk female sports. Proper identification of at risk female athletes is currently unavailable.

The purpose of this project, therefore, is to review ACL injury literature and develop a performance evaluation and injury risk assessment (PEIR) for soccer players. In addition, a strategy guide for decreasing injury risk is included.

High risk sports require vast amounts of cutting, jumping, turning, and landing. Multiple risk factors are associated with noncontact ACL injuries in high risk female athletes. They are environmental, anatomical, hormonal, and
neuromuscular. Research indicates that neuromuscular differences in women appear to be the single factor that contributes the most to the incidence of noncontact ACL injury.

In examining literature of ACL injuries in high risk female soccer athletes, four injury prevention programs were found. Three out of four programs significantly reduced knee injury incidents and increased performance. These programs decreased biomechanical risk factors by targeting neuromuscular training. Successful program interventions include: proper strength, balance and movement training.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>SECTION</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>iii</td>
</tr>
<tr>
<td>CHAPTER ONE: INTRODUCTION</td>
<td></td>
</tr>
<tr>
<td>Introduction to the Project</td>
<td>1</td>
</tr>
<tr>
<td>Purpose of the Project</td>
<td>4</td>
</tr>
<tr>
<td>Scope of the Project</td>
<td>5</td>
</tr>
<tr>
<td>Research Questions</td>
<td>6</td>
</tr>
<tr>
<td>Significance of the Project</td>
<td>6</td>
</tr>
<tr>
<td>Limitations of the Project</td>
<td>9</td>
</tr>
<tr>
<td>Definitions of Terms</td>
<td>10</td>
</tr>
<tr>
<td>CHAPTER TWO: REVIEW OF RELATED LITERATURE</td>
<td></td>
</tr>
<tr>
<td>Mechanism of Injury</td>
<td>14</td>
</tr>
<tr>
<td>Reasons for Female Anterior Cruciate Ligament Injuries</td>
<td>16</td>
</tr>
<tr>
<td>Identification of Anterior Cruciate Ligament Injury Risk</td>
<td>21</td>
</tr>
<tr>
<td>CHAPTER THREE: METHODOLOGY</td>
<td></td>
</tr>
<tr>
<td>Methods</td>
<td>23</td>
</tr>
<tr>
<td>CHAPTER FOUR: RESULTS</td>
<td></td>
</tr>
<tr>
<td>Comparison of Anterior Cruciate Ligament Injury Prevention Programs</td>
<td>25</td>
</tr>
<tr>
<td>Similar Components of the Successful Programs</td>
<td>31</td>
</tr>
</tbody>
</table>
CHAPTER FIVE: SUMMARY, CONCLUSIONS,
AND RECOMMENDATIONS

Summary ..................................................... 38
Conclusions ................................................... 40
Recommendations ............................................. 43

APPENDIX A: JACOBSEN PERFORMANCE EVALUATION AND INJURY
RISK ASSESSMENT PERCENTAGE (PEIR) .................. 45

APPENDIX B: JACOBSEN ANTERIOR CRUCIATE LIGAMENT INJURY
PREVENTION EVALUATION GUIDELINES
AND STRATEGIES FOR PEIR ............................... 53

APPENDIC C: FIGURE 1. AND FIGURE 2. DEFINITIONS OF
AN ANTERIOR CRUCIATE LIGAMENT ..................... 58

APPENDIX D: FIGURE 3. MAGNETIC RESONANCE IMAGING (MRI)
OF AN ANTERIOR CRUCIATE LIGAMENT AND
A POSTERIOR CRUCIATE LIGAMENT .................... 62

APPENDIX E: TABLE 1. ANTERIOR CRUCIATE LIGAMENT INJURY
PREVENTION PROGRAMS FOR
FEMALE SOCCER PLAYERS ............................... 64

REFERENCES .................................................... 66
CHAPTER ONE
INTRODUCTION

Introduction to the Project

Soccer is considered the most popular sport in the world, and female interest has grown extremely fast within the past decade. In 1991 the first women’s soccer world championship took place in China, consisting of 12 teams. By 2003, 104 nations played the qualification round for the World Cup in the United States (Faude, Junge, Kindermann, & Dvorak, 2005).

With the increase of female sports popularity, starting with the passing of Title IX in 1972, and highlighted by the success of the United States Women’s world cup soccer team and the Women’s National Basketball Association, more female athletes are participating nationally than ever before. This rapid increase has resulted in a higher skill level requiring peak performance in speed, aggressiveness and fitness while raising the standard of competition. This new level of competition creates an increased potential for injury. Most notably has been the seemingly epidemic of knee injuries mostly from noncontact Anterior Cruciate Ligament (ACL) tears (Pettineo, Jeste, & Leht, 2005).
This epidemic has lead to recent research that reveals why ACL injuries in female athletes creates so many career ending injuries, and what can be done to prevent them.

Worldwide, high risk sports injure the lower extremity more often in both male and female athletes versus other sports. This is primarily because competitive team sports including soccer, basketball, and volleyball demand lower extremity dynamic stability to withstand the demands of cutting, decelerating, and jumping (Mandelbaum et al., 2005). The injury rate, however, is significantly higher in females compared to the rate in males. Researchers show that female basketball and soccer players sustain three to four times more knee injuries than men who participate in the same sport. They also found that from 1980 to 1990, the rate of injuries doubled to a total of 1.4 million women (Oliver, & Healy, 2005, p.59).

Many researchers state that women are two to eight times more likely to have a noncontact ACL injury. Alarmingly, there are an estimated 38,000 ACL injuries in women every year, and 2,200 of these occur in collegiate athletics (Hewett, Lindenfeld, Riccobene, & Noyes, 1999; Irmischer, Harris, Pfeiffer, DeBeliso, & Shea, 2004).
The severity of the situation is the fact that ACL injuries require surgery more often in women than in men (Irmischer et al., 2004).

Currently, two-thirds of ACL injuries are noncontact related; of these injuries, the season ended for 91% of the female athletes surveyed (Pettineo et al., 2005).

High school, club, and collegiate sports have become very competitive as female athletes have become stronger, faster, and more powerful. The opportunity to earn college scholarships has increased the level of play and has expanded the athlete pool, which inevitably has increased the physical demands (Oliver & Healy, 2005).

During its 2001 to 2003 seasons, within the Women's United States Soccer Association (WUSA), injury data on 202 players from eight teams were collected and analyzed. A total of 173 injuries in 110 players were recorded; 60% of all injuries were located in the lower extremities, and the most common location, (31.8%) was in the knee (Giza, Mithofer, Farrell, Zarins, & Gill, 2005).

Understanding female soccer players' risk factors, mechanisms for injury, and the correct training components create a successful ACL injury prevention program. This is
vital to the longevity of a female athlete participating in high risk sports and her quality of life in general.

Unfortunately, prescreening for high risk female athletes for injury prediction is still understudied. Until then, elimination of controllable risk factors has proven to reduce the risk of injury (Hewett et al., 2005).

Purpose of the Project

Numerous studies indicate that ACL injury rates are significantly higher in women versus men in high risk sports. This directly relates to the importance of needing an ACL injury prevention program for high risk female sports. Several intrinsic and extrinsic factors contribute to the problem of female ACL injury. Sport and gender specific injury prevention programs need to be implemented to target all risk factors. Also, screening athletes for injury risk needs to be researched and developed to help decrease risks. Little research has been conducted specifically on ACL injury prevention and screening for female soccer players.

Therefore, the purpose of this project is to analyze literature and bring awareness to the athletic community of the risk factors for female soccer players of ACL injury.
Also, to develop a performance evaluation and injury risk assessment (PEIR) for soccer players. Jacobsen’s PEIR is designed to prescreen athletes for performance levels and injury risk. Each injury risk factor is recognized as being high, medium and low for ACL injury risk. This assessment will display an athlete’s area of improvement and score an injury risk percentage. The evaluation is designed to give trainers and coaches information on their athletes to correct abnormalities and to enhance overall performance. Percentage rates can be reassessed after training to check for a decrease in injury rates (APPENDIX A). Also, included is the Jacobsen Evaluation Guidelines and Strategies for PEIR to help correct risk factors (APPENDIX B).

Scope of the Project

This qualitative, informative study uses a review of literature taken from sports medicine journals and human kinetics textbooks. The primary goal is to educate the athletic community including coaches, athletes and physical education teachers about the significance of a noncontact ACL injury for high risk female sports participants.

Furthermore, information reviewed in this project will promote an understanding of the mechanisms of injury, the
risk factors, and identification of ACL risk for females playing in high risk sports. In addition, it compares the current ACL injury prevention programs targeting female soccer players.

Research Questions

My research questions for this project are: (1) what ACL injury programs exist for female soccer players; (2) what are the successful training components of them; and (3) which program has the best reduction in ACL injury rates.

Significance of the Project

The knee is the most frequently injured joint in athletics and most injuries are caused by the extreme stresses of twisting and turning activities such as those found in skiing, soccer, and American football (Peterson & Renstrom, 2001).

The significance of this injury is based on the statistics of injuries sustained by this devastating injury. There are an estimated 38,000 ACL injuries in women every year and 2,200 of these occur in collegiate athletics (Irmischer et al., 2004).
In a review from 1990-2002, ACL injuries in the National Collegiate Athletic Association basketball and soccer totaled 1268 and represented approximately 15.8% of the Nation’s schools. Of the injuries, 67% were noncontact ACL injuries in female soccer players. Males averaged 58% (Agel, Arendt, & Bershadsky, 2005). The injury rates were exceptionally higher in females, specifically soccer. Noncontact injury is defined in this study as having no apparent contact, contact with the ball, or contact with the floor. Unfortunately, the training regimens in the schools in this study were not recorded. The mechanisms of injury might be better understood and injury rates could have been decreased if this longitude study included training regimens (Agel et al., 2005).

The severity of the situation is that ACL injuries require surgery more often in women than in men. It is estimated that the total cost for ACL reconstruction and rehabilitation for these female athletes is 37 million dollars annually. An astounding 17,000 dollars is estimated per injury for treatment and rehabilitation and does not take into account the loss of long-term participation, loss of scholarship funding, and future disability from arthritic changes in a reconstructed knee (Fagenbaum & Darling, 2003).
Data, collected in 2004 by the American Board of Orthopaedic Surgeons, revealed that ACL reconstruction ranked sixth among the most common surgical procedures performed by all sports medicine fellows and third among those surgeons identified as generalists. Furthermore, the Center for Disease Control and Prevention has reported that approximately 100,000 ACL reconstructions are performed annually (Griffin et al., 2006).

Injuries to the ACL pose a major threat to women of all ages and athletic levels. The high incidence rate of injury has serious physical, mental, and economic implications. This injury is considered one of the most devastating and can potentially end an athlete's career. Rupture of the ACL of the knee is a serious, common, and costly injury. The consequences of an ACL injury include both temporary and permanent disability. In addition to these costs, the athlete may experience absence from work, school, and sports which greatly influences his or her quality of life (Griffin et al., 2006; Irmischer et al., 2004).

The significance and statistics justify the need for more sport and age specific ACL prevention programs and prescreening methods to predict injury risk for high risk athletes. If these programs are developed, the athletic
community will be prepared to help reduce female ACL injury risks by effectively training and screening their athletes (Boyle, 2004, p. 156; Irmischer et al., 2004).

Limitations of the Project

This project contains several limitations which include the following: (1) there were few prevention programs available to analyze and the research was repetitive regarding the topic in general; (2) few studies are being done on sport specific ACL injuries in high risk female athletes; (3) most of the research combined all high risk sports in general and were not sport or gender specific; (4) the same researchers are doing the follow-up studies; (5) more risk factors other than neuromuscular control need to be tested; (6) there is also a need to examine sport, age, and gender specific research covering numerous locations and backgrounds; and (7) the lack of research on identification of at risk athletes. Prescreening methods need to be studied.

On a positive note, this research was conducted in time to witness a very successful nationwide female soccer injury program called the Prevent Injury and Enhance Performance (PEP) program, conclude its three year study. This study
targeted knee injury prevention and performance enhancement for teenage female soccer players in the California Coast soccer league (Mandelbaum et al., 2005).

Definitions of Terms

(1) ACL: Anterior crucial ligament: The ligament of the knee that originates on the anteromedial portion of the tibia’s intercondylar eminence, passes laterally to the posterior cruciate ligament, and attaches on the medial portion of the posterior aspect of the lateral femoral condyle. The ACL prevents anterior displacement of the tibia relative to the femur, internal and external rotation of the tibia on the femur, and hyperextension of the tibiofemoral joint (APPENDIX C)

(2) BMI: An index for estimating obesity, obtained by dividing weight in kilograms by height in meters squared. In adults, a BMI greater than 30 kg/m² indicates obesity; a BMI greater than 40 kg/m² indicates morbid obesity, and a BMI less than 18.5 kg/m² indicates a person is underweight.

(3) Functional Training: sport specific, purposeful training
(4) Lumbar: Referring to the five lumbar vertebrae which are situated below the thoracic vertebrae and above the sacral vertebrae in the spinal column. The five lumbar vertebrae are represented by the symbols L1 through L5. There are five lumbar nerves.

(5) MRI: magnetic resonance imaging scan is radiology technique that uses magnetism, radio waves, and a computer to produce images of body structures (APPENDIX D)

(6) Neuromuscular: Referring to the relationship between nerve and muscle, in particular to the motor innervations of skeletal muscles and its pathology.

(7) Noncontact: No contact with another person.


(9) PCL: Posterior cruciate ligament.

(10) Plyometrics: A form of training that attempts to combine speed of movement and neuromuscular coordination with strength; Any exercise in which muscles are repeatedly and rapidly stretched ("loaded") and then contracted (as in jumping high off the ground or in push-ups with a clap between them). The aim of plyometrics is to improve muscle power.
(11) Proprioceptive: the acquisition of stimuli by peripheral receptors in addition to the conversion of mechanical stimuli to a neural signal that is transmitted along afferent pathways of the sensorimotor system.

(12) Q-Angle: The acute angle formed by a line from the anterior superior iliac spine of the pelvis through the center of the patella and a line from the tibial tubercle through the patella. The angle describes the tracking of the patella in the trochlear groove of the femur. The normal angle is around 15 degrees. It is usually greater in females.

(13) Valgus: (vål'gəs) [L., bowlegged] Bent or turned outward, used especially of deformities in which the most distal anatomical part is bent outward and away from the midline of the body.

(14) Varus: (vā'rūs) [L.] Bent or turned inward, used especially of deformities in which the most distal part of the anatomy is turned toward the body's midline. There are many varus conditions. In coxa varus, the shaft of the femur turns inward with respect to the neck of the femur. In genu varus, either the femur or tibia turns inward at the knee, causing a bowlegged deformity. Talipes varus is a clubfooted
condition in which the foot turns inward and the person walks on the outer border of the foot.

(15) WUSA: Women's United States Soccer Association


Mechanism of Injury

Injury mechanisms of the ACL can result from a twisting impact, when the knee is in internal rotation and hyperextension, or in external rotation and valgus (Peterson & Renstrom, 2001, p. 273). The mechanism of injury is when the ACL virtually gets itself into a position of no return. This position is when the spine is forwardly flexed and rotated to the opposite side, the knee is slightly flexed, and the hips are in adduction and internal rotation (Irmischer et al., 2004)

Upon landing, one foot is out of control, and the body weight is forward on the balls of the feet. The hips then abduct and extend in a shut down mode causing the pelvis and hip to become uncontrolled. This creates a position of mechanical or neuromuscular lack of control. Neuromuscular control is demonstrated by the body being in a ready position. This is when the hips, knees and ankles are in alignment and flexed while the weight is forward. This enables the athlete to land, change direction, and use speed
appropriately (Fagenbaum & Darling, 2003; Griffin et al., 2006; Mandelbaum et al., 2005; Pfeiffer et al., 2004; Oliver & Healy, 2005).

A controlled landing is where the athlete comes down on both feet with the weight of the body in a center-balanced position in mid-foot stance (Fagenbaum & Darling, 2003). When landing is performed with the knees in a valgus or varus position, elevated impact forces are observed (Bahr & Krosshaug, 2005; Irmischer et al., 2004).

An analysis of athlete interviews and videotapes shows that the majority of ACL noncontact injuries occur at the time of landing or deceleration, and side step cutting. Furthermore, the position of the leg at the time of injury displays tibial rotation, apparent knee valgus, foot pronation, and a relatively extended knee and hip (Griffin et al., 2006).

At the time of injury, 35% of patients were decelerating, 31% were landing, 13% were accelerating, and 4% were falling backward (Boden, Dean, & Feagin, 2000).
Reasons for Female Anterior Cruciate Ligament Injuries

There are multiple reasons for female ACL injuries. Research continues to try and identify the causes, and programs are being developed to test and address these risk factors. Griffin et al. (2005) explains the multiple risk factors in four categories: environmental, anatomical, hormonal, and neuromuscular.

First, environmental or external factors include meteorological conditions, the type of surface (grass, hard floor, etc.), the type of footwear and its interaction with the playing surface, and protective equipment. These risks are considered limited for ACL injuries.

Second, anatomical factors pertain to the mechanical alignment of the lower extremity, the quadriceps femoris angle (Q-angle), the degree of static and dynamic knee valgus, foot pronation, body mass index (BMI), the width of the femoral notch, and ACL geometry (Ahmad et al., 2006; Arendt, 2001; Boyle, 2004; Oliver & Healy, 2005; Chandrashekar, Slauterbeck, & Hashemi, 2005; Shelbourne, Davis, & Klootwyk, 1998).

Third, hormonal factors consist of sex hormones, knee laxity, and menstrual cycle (Ahmad et al., 2006; Rozzi,
Lephart, Gear, & Fu, 1999; Wojtys, Huston, Lindenfeld, Hewett, & Greenfield, 1998). Much remains unknown and is being researched regarding these factors.

Fourth, neuromuscular factors such as: movement patterns, altered activation patterns, and inadequate muscle stiffness are the most used in prevention programs because they are correctable (Chappell et al., 2005; DeMorat, Weinhold, Blackburn, Chudik, & Garrett, 2004; Myer, Ford, & Hewett, 2004).

Currently, there is conflicting data in a variety of studies which explore the relationship of these factors to ACL injuries. It is difficult to modify anatomical risk factors in female athletes versus environmental, hormonal, or neuromuscular factors; therefore, most prevention programs target these areas.

Neuromuscular control of the knee can be defined as the unconscious response to an afferent signal concerning dynamic knee joint stability (Hewett, Myer, & Ford, 2004). Research indicates that neuromuscular differences in women appear to be the single factor that contributes most to the incidence of ACL injury (Irmischer et al., 2006; Pettineo et al., 2005). One reason is that many women join organized sports that involve jumping without possessing adequate
levels of muscular strength and power. Without the proper base level of fitness, the ability of those individuals to safely participate in those sports is questionable (Boyle, 2004, p.157).

Most ACL injuries occur when landing from a jumping activity, running, turning, or cutting, or from running and stopping abruptly. Motions of this nature can cause the ACL to tear by rotational stresses, extreme valgus stress, or by hyperextension of the knee (Faude, Junge, Kindermann, & Dvorak, 2005; Ford, Myer, & Hewett, 2003; Hewett et al., 2005). Women tend to land more flat-footed and with straighter legs than men do. In reaction to this, ground forces are increased therefore increasing force on the joints (Oliver & Healy, 2005, p. 60). Meira & Brummitt (2005) categorize neuromuscular control limitations of the female athlete as delayed hamstring reaction and faulty knee mechanics during jumping and landing. Their research also shows that female athletes rely on their quadriceps during deceleration, and that their hamstrings are slower and weaker allowing poor control.

Noncontact ACL mechanisms have been identified as the leading causes of ACL injuries in female athletes. These mechanisms include poor landing strategies combined with
elevated impact forces and rapid decelerations that occur when landing from a jump or performing a cut-and-turn maneuver (Giza et al., 2005; Irmischer et al., 2004). Consequently, the highest numbers of ACL injuries in women are found in sports that include rapid deceleration, pivot turns, and jumping, such as soccer, volleyball, and basketball (Boyle, 2004; Colby, Francisco, Yu, Kirkendall, Finch, & Garrett, 2000).

Another high risk factor is maturation after the age of 12 years. Knee injury rates increase for females versus males due to the lack of neuromuscular adaptations to growth spurts (Hewett et al., 1999; Myer et al., 2004).

Most definitely, the reasons for ACL injury consist of many factors. What they have in common is the need for proper injury prevention methods targeting female athletes in high risk sports. Eliminating risk factors that can be modified such as neuromuscular control and deficiencies in sport specific strength, balance, movement, and conditioning levels will reduce the rate of ACL injuries for female soccer players (Hewett et al., 2004). The movement training includes acceleration, deceleration, and change of direction. In recent studies the areas of conditioning that
now need to be developed are muscular and movement specificity (Boyle, 2004, p. 168; Sell et al., 2006).

In summary, noncontact ACL injuries frequently occur from a complex interaction of environmental, anatomical, hormonal, and neuromuscular risk factors. The most correctable risk factor is neuromuscular control. Studies show that athletes who increased their performance in drills that tested balance and neuromuscular control were less likely to become injured (Oliver & Healy, 2005, p. 60).

The central nervous system involves learned behaviors with an emphasis on patterns of movements and their reactions to at risk positions. Since training can modify these neuromuscular components such as knee stiffness, improving balance, and minimizing at risk positions, it will potentially decrease ACL strain (Griffin et al., 2005).
Identification of an Anterior Cruciate Ligament Injury Risk

Currently, a successful method for identifying and prescreening athletes at risk of ACL injury is not available. However, ideas for prescreening athletes include testing biomechanical measures such as dynamic neuromuscular control parameters. Dynamic parameters are rarely studied, usually only static. Parameters consist of jump-landing risk assessments, specifically knee motion and loading (Hewett et al., 2005). Other screening techniques include preseason screening for neuromuscular control. Three basic screening tests include:

(1) Leg dominance; (2) Jump-landing techniques; and (3) High risk sports movement assessments (Myer, Ford, McLean, & Hewett, 2006).

Neuromuscular control is demonstrated by the athlete landing and holding an aligned position for up to five seconds (Hewett et al., 2004). Common landing errors include landing with a straight or hyper extended knee, landing with a varus or valgus knee position, and landing solely on the heels. Athletes who land from a jump with hyper extended or straight knees must be taught bent knee landings. Heel landing must be corrected to the appropriate forefoot.
landing. Manual and verbal feedback or cues will help the athlete avoid unsafe landing positions.

High risk sports assessments should include sport specific movements such as jumping, landing, cutting, pivoting, and acceleration and deceleration. Maintaining a ready position during all movements is vital to injury prevention. The ready position is where the hips, knees, and ankles are straight and aligned, and with a slight bend in the knees. The athlete’s body weight should be forward and on the balls of the feet, and the back is flat. All movements must be planned and controlled.
CHAPTER THREE

METHODOLOGY

Methods

For this project, a literature review of research articles was conducted discussing the following ACL injury related topics: (1) the significance; (2) mechanisms of injury; (3) reasons for female injuries; (4) risk identification; and (5) prevention programs and their successful components.

Research consisted of searching peer reviewed medical journals and through textbook readings. Most of the studies and data reviewed for this study were published in the American Journal of Sports Medicine, the Journal of Athletic Training, the Physical Therapy Journal, and Human Kinetic textbooks. All research articles are dated within the past decade.

Terms used for my search were ACL injury prevention programs, and female soccer players and ACL injuries. Articles in the analysis study were limited to only female soccer ACL injury prevention programs. Four ACL injury programs targeting female soccer players were found.
The development of the Jacobsen Performance Evaluation and Injury Risk Assessment Percentage (PEIR) for soccer players was based on all research findings. It was developed to give the athletic community a prescreening method to help reduce injury risk. Currently, no other prescreening assessment has been developed. In addition, the Jacobsen Anterior Cruciate Ligament Injury Prevention Guidelines and Strategies for PEIR will give recommendations for improvement areas.
CHAPTER FOUR
RESULTS

Comparison of Anterior Cruciate Ligament Injury Prevention Programs for Female Soccer Players

Four ACL prevention programs were found targeting female soccer players. They include the following: (1) Hewett et al. (1999) "The Effect of Neuromuscular Training on the Incidence of Knee Injury in Female Athletes: a Prospective Study." This study researched high school aged female soccer, basketball, and volleyball players. Fifteen female teams (n=366) were included in the neuromuscular training intervention, and an additional 15 female teams (n=463) were used as a control group. Males were also used in the study, but my research focuses specifically on the female population. The program consisted of a six week neuromuscular training intervention. Nineteen participants performed three times a week (60 to 90 minute sessions) before their competition. Noncontact ACL injuries were decreased by 72% in the training intervention compared to the untrained control group. Two soccer players sustained a noncontact ACL injury versus zero in the trained group. Three phases were implemented throughout the jump training
program. Phase I included proper jump technique; phase II concentrated on building a base of strength, power, agility, and the final phase III targeted achieving maximum vertical jump height. Nine of the 14 injuries were noncontact knee injuries. Study limitations included groups that were non-randomized and not equal in numbers. Recommendations and future directions are for female athletes participating in sports that entail jumping, pivoting, and cutting (such as playing soccer) be trained before they play with a proven effective jump training program. The program should include progressive resistance weight training for the lower extremity.

(2) Heidt, Sweeterman, Carlonas, Traub, & Tekulve (2000) “Avoidance of Soccer Injuries with Preseason Conditioning.” For this program, a neuromuscular training intervention on high school female soccer players was conducted. The control group had (n=258) and an intervention group (n=42) trained preseason. The intervention consisted of sport-specific cardiovascular conditioning (13 treadmill speed training sessions two times a week), plyometric work, sport cord drills (Seven agility sessions over a seven week period), strength training, and flexibility. It is customized for each athlete’s sport, position, and
individual strengths and weaknesses. This form of acceleration training promotes proper technique, and avoidance of injury movements. Gains in strength and speed before season are noted to enhance muscular efficiency during season. Progression of neuromuscular control went from unidirectional, bidirectional, and then multidirectional. Foam obstacles were used to create sport-specific maneuvering. The results showed that the trained group had a significant decrease, (14%) in overall injuries, than the control group, (33.7%) The occurrence of ACL injuries was near even, displaying 2.4% ACL injuries in the trained group versus 3.1% in the control. The discrepancy may be due to the low-intensity plyometrics used in the trained group and smaller number of participants. This study demonstrated a significantly lower incidence of injury in female soccer players who underwent preseason conditioning.

(3) Pfeiffer, Shea, Roberts, Grandstrand, & Bond (2004) "Effects of a Knee Ligament Injury Prevention (KLIP) Program on the Incidence of Noncontact ACL Injury: A Two-Year Prospective Study of Exercise Intervention in High School Female Athletes." This cohort study assesses the effects of a knee ligament injury prevention exercise program on the incidence of noncontact ACL injuries in high school (soccer,
basketball, and volleyball) female athletes. One-hundred and twelve teams from 15 schools were divided into treatment and control groups. Treatment participants engaged in a plyometric-based exercise program twice a week throughout the season. Practice, game exposures and compliance were recorded on a weekly basis. A total of 1,439 athletes (n=862 control) and (n=577 treatment group) were observed. Six noncontact ACL injuries were reported, three from each group. The incidence of ACL injuries per 1,000 exposures was 0.167 in the treatment group and 0.078 in the control group. Results suggest that a 20 minute plyometric exercise program that focuses on the mechanics of landing from a jump and deceleration when running, performed twice a week during season, will not reduce the rate of noncontact ACL injuries in high school female athletes. This was the only study that showed a lack of injury rate decrease of all the studies. The study was too broad and only focused on combining high risk sports instead of just one element. Female soccer players were the fewest participants, and no injuries occurred in this group. The Control group of soccer players reported one injury. Therefore, the rate of decrease was accomplished in the female soccer category. Even so, programs should be sport specific. An earlier study done by
Pfeiffer et al. (2004) tested the effects of a Knee Ligament Injury Prevention (KLIP) program on collegiate women. KLIP showed a decrease in injury rates in active women following a low-intensity plyometric training session (Pfeiffer, Shea, Roberts, Grandstrand, & Bond, 2006):

(4) Mandelbaum et al. (2005) "Effectiveness of a Neuromuscular and Proprioceptive Training Program in Preventing Anterior Cruciate Ligament Injuries in Female Athletes: A two-year Follow Up." This cohort design studied age and skill levels matched for fourteen to eighteen year old enrolled female soccer players over a two year period. Control teams participated in their traditional warm-up, and only the coaches knew of the study. The trained teams replaced their traditional warm-up with a sports-specific training intervention consisting of education, three warm-up activities, five stretching techniques for the trunk and lower extremity, three strengthening exercises, five plyometric activities, and three soccer-specific agility drills. A video tape was used to demonstrate the exercises performed by female members of the United States Olympic Development Program. Proper technique is emphasized in the video tape for its viewers or the trained group. The three step-stop-deceleration pattern developed by Henning and
Griffis (1990) was used in this training. In its first year, 52 teams (n= 1041) were in the intervention group, and 95 untrained control teams (n=1905). Year two consisted of 45 intervention teams (n=844), and 112 teams (n =1913) control groups. The decrease in team numbers was due to some athletes turning 19 years of age who were therefore excluded from the year two study. In season one, after 37,476 athlete exposures there were two reported ACL injuries in the intervention group versus 32 in the control group after 68,580 athlete exposures. The results showed an 88% decrease in injuries for the trained group in year one, and a 74% reduction in ACL injuries during year two. Overall, six ACL ruptures were reported in the trained teams and an alarming 67 in the control group. Neuromuscular training in this study demonstrated a substantial benefit in decreasing female soccer ACL noncontact injuries. The emphasis for the PEP program has turned to biomechanical risk factors and the use of neuromuscular and proprioceptive intervention to address potential biomechanical deficits. A nonrandomized design limited this study (APPENDIX E).
Similar Components of the Successful Programs

Three out of the four female soccer player ACL injury prevention programs demonstrated a decrease in rates. Rationale behind those successes is that they combined strength, balance and movement training to their program to enhance performance as well as reduce injury factors. These components pertain to the neuromuscular components of sports. They were all sport-specific minded and used a combination of plyometric, quality technique practice, and balance. The study that did not show a large benefit lacked the plyometrics component, and the athletes were of combined sports.

More similarities in the successful programs included awareness of proper technique, functional balance or stabilization, strength gains and muscle balance. Hewett et al. (1999) and Mandelbaum et al. (2005) incorporated flexibility and strength components. Other research shows that female soccer players may have hamstring-to-quadriceps muscle strength imbalances which have a correlation to ACL injuries. Overcompensation of quadriceps muscles demonstrates a need for hamstring strength to decrease female risk factors for ACL injury.
Compliance rates of programs are as follows: Hewett et al. (1999) reported 70%, Heidt et al. (2000) reported 100%, Mandelbaum et al. (2005) 98%, and Pfeiffer et al. (2004) did not report. Compliance rates were higher in the programs that targeted injury prevention with performance enhancement. Enhancement occurs through a combination of strength and plyometrics to increase overall power. This combination, along with neuromuscular training, will create an optimal female athlete. Performance enhancement programs will attract more players to participate as well.

Research shows that although the age of starting prevention programs is still not clear, many injuries begin with female athletes during the middle to late teenage years (Hewett et al., 2004). According to Griffin et al. (2000), an estimated 80,000 ACL tears occur annually in the United States, and the highest occurrence is in individuals 15 to 25 years old who participate in pivoting sports. Therefore, early adolescence should be a good time to start an injury intervention to decrease the neuromuscular risk factors (Griffin et al., 2006, p.20) Creating basic training at an earlier age (eight to 12 years) such as form running, fast feet drills, stopping, starting, jumping, and strength
training will prepare young athletes for the demands of athletics (Oliver & Healy, 2005).

Prevention methods include a variety of components that work together to create a balanced athlete. Most knee injury prevention programs are based on altering dynamic loading through neuromuscular training (Griffin et al., 2005; Myer et al., 2004).

The successful programs included stretching, strengthening, aerobic conditioning, agilities and plyometrics (movement training), and risk awareness. Adding performance enhancement also contributed to the success rates (Boyle, 2004; Griffin et al., 2001; Griffin et al., 2006; Heidt et al., 2000; Hewett, Ford, & Myer, 2006; Hewett et al., 1999; Mandelbaum et al., 2005; Myer et al., 2004; Oliver & Healy, 2005; Peterson & Renstrom, 2001; Pettineo et al., 2005).

Rationale for the successful components includes the following: Plyometric exercises, which are based on evidence that the stretch-shortening cycle activates neural, muscular, and elastic components and, therefore, should enhance joint stability or dynamic stiffening. Plyometric exercises have also been found to decrease landing forces and varus or valgus moments and increase effective muscle
activation. This activation enhances balance and postural exercises by stimulating joint stiffness.

Movement and awareness training, including cognitive training, visualization, verbalization, and feedback, should provide more biomechanical positioning for protective mechanisms, reducing joint moments and ACL loading (Hewett et al., 1999; Hewett et al., 2006; Mandelbaum et al., 2005). In addition, movement training helps the athlete cope with unanticipated movements.

The muscle strengthening objective is to improve the quality of muscle function. Core strength as well as hamstring and quadricep strength should be emphasized, a higher ratio of hamstring-to-quadriceps strength should reduce shear (Ahmad et al., 2006; Mandelbaum et al., 2005).

In order to prevent tears, strengthening the surrounding muscles is crucial. An increase of strength provides stability and less stress on the ligaments as well. Maintaining a strong musculature may provide protection during situations that produce at risk positions. Strength training and plyometrics have been found to not only reduce injury but to enhance performance as well (Griffin et al., 2006; Oliver & Healy, 2005).
Dynamic neuromuscular training may also facilitate muscle adaptation that protects the athletes’ ACL from increased loading (Griffin et al., 2006).

Knowing that a program improves performance will also attract more players to participate as opposed to just injury prevention. Various studies show that athletes who had increased their performance in drills that tested balance and neuromuscular control were less likely to become injured (Oliver & Healy, 2005, p. 60).

Training programs for women that focus on neuromuscular control and balance of the lower extremities may be effective in modifying landing mechanics. Neuromuscular control adaptations are shown to help prevent noncontact ACL injuries. A balance training program focuses on developing neuromuscular control of the lower extremity through strengthening exercises, plyometrics, and sport specific agilities. Addressing the proprioceptive and biomechanical problems that are demonstrated in the high risk female athletic population will help reduce ACL injuries (Griffin et al., 2006; Hewett et al., 2000; Irmischer et al., 2004; Mandelbaum et al., 2005; Myer et al., 2004; Pfeiffer et al., 2004).
Evidence shows that hamstring reaction and landing strategies can be improved through training programs. Supervised plyometrics and strength training programs have demonstrated improved hamstring-quadriceps strength ratios, decreased landing forces, and decreased varus and valgus torques (Hewett et al., 2004). Jump-landing techniques should include a change in direction versus just straight landing tasks (Sell et al., 2006).

Research by Peterson and Renstrom (2001) discusses the necessary lower extremity training which is similar to that of the PEP program. (pps. 520-526). The PEP program includes warm-ups, proprioceptive balance and agility exercises, sport-specific drills, power and speed drills, and cool down techniques (Mandelbaum et al., 2005).

Evidence shows that females need to recognize the importance of neuromuscular control and learn how to enhance it in order to prevent ankle, knee, and hip injuries.

Strength and conditioning coaches should evaluate an athlete’s general strengths and weaknesses, injury history, and any information specific to the sport. After the athlete is evaluated, specific goals should be set. After completion of goal setting, an age and gender sport specific program must be designed. The specific program should target the
development of health components including: fitness and strength. Whereas the skill components must include: power, speed, balance, and movement skills. All components should be developed over the needed periodized time frame. The combination of these health and skill components will enable the athlete for competition and decrease their injury risks.
CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this project was to review ACL injury literature and develop a performance evaluation and injury risk assessment percentage (PEIR) for soccer players. In addition, a strategy guide for decreasing injury risk and enhancing performance was also developed. Lastly, bringing awareness to the athletic community about female ACL injury risk and making recommendations for its prevention is vital to impacting the future of high risk female athletes.

Multiple risk factors are associated with noncontact ACL injuries in high risk female athletes. They are environmental, anatomical, hormonal, and neuromuscular. Research indicates that neuromuscular differences in women appear to be the single factor that contributes the most to the incidence of noncontact ACL injury.

Proper identification of at risk female athletes is currently unavailable. Included in this project is the Jacobsen Performance Evaluation and Injury Risk Assessment Percentage (PEIR) designed to identify athletes prone to ACL injury. This assessment gives each athlete an injury risk
percentage and recommendations for improvement areas. A supplemental injury prevention guidelines and strategies hand out is also included for athletic trainers, coaches, and athletes upon completion of the PEIR assessment (APPENDICES A AND B).

In examining literature of ACL injuries in high risk female soccer athletes, four injury prevention programs were found. Three out of four programs significantly reduced knee injury incidents and increased performance. These programs decreased biomechanical risk factors by targeting neuromuscular training. Successful program interventions include: proper strength, balance and movement training.

Many factors must be taken into consideration when dealing with female athletes, especially when looking at their susceptibility to an ACL injury. Injuries can be rapidly reduced if the trainers and athletes understand the mechanisms of potential injury and risk factors. Thorough evaluations, correction of postural deformities and deficiencies, and undertaking a quality sport specific training program can prevent female ACL injuries.

From the review of literature, the injury prevention components that aid in the reduction and prevention of ACL injuries include increased strength, balance, and movement.
training. I also found that these components are found to enhance performance as well.

In hopes of preventing thousands of female athletes from a noncontact ACL injury, this research was done to show the potential of injury and to give recommendations for proper training and evaluation to reduce or prevent such a devastating injury.

Conclusions

Numerous authors have described risk factors for soccer injuries and discussed prevention methods such as: (1) warm-up routines with more emphasis on stretching, regular cool down, (2) adequate rehabilitation with sufficient recovery time, (3) proprioceptive training, (4) protective equipment, (5) good playing field conditions, and (6) playing by the rules. However, only few have reported the results of prevention intervention in female soccer players.

Recent studies show that there is evidence that neuromuscular training including plyometrics, balance, and technique training, along with a heightened awareness of injury biomechanics, reduces the risk of serious knee injuries in female athletes. What specific exercises or sequence of exercises or what intensity and duration of
exercise are most important is still unknown (Griffin et al., 2006). Furthermore, identification of at risk athletes is still understudied.

Neuromuscular control targeting jump training programs incorporating stretching, plyometrics, and weight training have been encouraged to increase performance while decreasing injury risk in competitive athletes in jumping sports (Hewett et al., 1999). For this reason numerous Olympic, collegiate, and high school teams have developed such programs. All reported prevention programs for ACL noncontact injuries center on alteration of neuromuscular risk factors, but each is unique. Some are sport, gender, and age specific.

Currently, the underlying mechanism which makes intervention programs effective is not clearly understood; however, existing evidence points to changes in balance, strength, and neuromuscular coordination as being possible contributors (Griffin et al., 2006).

Conclusions indicate that using a neuromuscular training program that is sport specific may have a direct benefit in decreasing the number of ACL injuries in female soccer players. The key to any conditioning program should
be to prepare the athlete to play the sport (Boyle, 2004, p. 169).

Through this research, the most current program that prepares female soccer players to play their sport is the Santa Monica ACL Prevention Program called Prevent Injuries and Enhance Performance (PEP). The PEP program is a highly specific 15 minute training session that replaces the traditional warm-up. It was developed by a team of physicians, physical therapists, athletic trainers and coaches.

The program's goal is to teach players strategies to avoid injury by avoiding vulnerable positions, increasing flexibility, increasing strength including plyometrics training, and increasing proprioception. These components are also shown to increase performance.

Optimally, the program is designed to be performed two to three times per week during the season. Training emphasizes a proper warm up, stretching, strengthening, plyometrics, and sport specific agility training. It is important to use proper technique during jumping, maneuvering (not excessive side to side movement), and aim for soft landings (Mandelbaum et al., 2005).
Recommendations

First, although several research studies have been conducted targeting ACL injury prevention, but more sport-specific programs and screening methods need to be tested.

Coaches should also evaluate an athlete’s general strength and weaknesses, injury history, and set personal goals. After the athlete is evaluated, an age and gender sport specific program should be designed to develop fitness, strength, power, speed, balance, and movement skills.

I recommend the PEP program (Santa Monica ACL Prevention Project) because it is specifically designed for female soccer player’s 14 to 18 years of age. Currently, the highest ACL injury incidence is in individuals 15 to 25 years old, who participate in pivoting sports (Griffin et al., 2000). This program is proven to reduce injury risks for female high risk athletes.

The program is a sports-specific warm up training intervention before activity over a two year period. The intervention consists of education, stretching, strengthening, plyometrics, and sport-specific agility drills designed to replace the traditional warm-up exercises. The results showed that there was an 88% decrease
in ACL injuries the first year and in year two, a 74% reduction rate followed.

In summary, my recommendations include: an awareness of the risk, screening for performance levels and injury risk, and implementing a successful prevention program. The Jacobsen Performance Evaluation and Injury Risk Assessment Percentage (PEIR) will help coaches, trainers, and athletes screen for injury risks and overall performance levels. Also, the Jacobsen ACL Injury Evaluation Guidelines and Strategies for PEIR will help with correcting risk factors (APPENDIX A AND B). My recommended female soccer player ACL injury prevention and performance enhancement program is the PEP program.
APPENDIX A

JACOBSEN PERFORMANCE EVALUATION AND INJURY RISK ASSESSMENT PERCENTAGE (PEIR)
Jacobsen Performance Evaluation and Injury Risk Assessment Percentage (PEIR)

This assessment uses all the related literature reviewed in this project to create a screening method for injury risk in soccer. Both male and female athletes can be measured by the PEIR assessment. This enables coaches and athletic trainers to individually evaluate performance and risk factors associated with noncontact ACL injuries. Each player now has an injury risk percentage that can be reduced if their performance abnormalities are properly corrected through training. Continuing to assess athletes after a training period will show if a decrease in their PEIR percentage has occurred.

Risk assessments include general and neuromuscular control factors. Categories are grouped into general, sport-specific, and movement mechanics. Athletic trainers and coaches should use this assessment to prescreen female soccer players for knee injury risk as well as an overall performance indicator. Each category checked means an abnormality has been found. Add all risk factors up to obtain a percentage of overall knee injury risk and performance discrepancies. Once the evaluation is complete, athletic trainers and coaches now have the information
necessary to properly train each individual player’s abnormalities as well as enhance their performance.

Circle all that apply to the athlete being evaluated. Each category is scored as a low risk worth (1) point, a medium risk worth (2) points, and a high risk worth (3) points. At the end of the Evaluation add up all points and divide by the amount possible. You now have your PEIR percentage.
Jacobsen Performance Evaluation and Injury Risk Assessment Percentage (PEIR)

Risk Levels
High = 3 points
Medium = 2 points
Low = 1 point

General Risk Factors

(1) Over 12 years of age?
   (High) _______

(2) Female?
   (High) _______

(3) Health problems inhibiting performance?
   (a) Severe (High)
   (B) Moderate (Medium)
   (c) Mild (Low)
   (Total Points) _______

(4) Previous injuries?
   (a) Hip (High)
   (b) Knee (High)
   (c) Ankle (High)
   (Total Points) _______
Sport-Specific Risk Factors

(5) Skill level?
   (a) Untrained (High)  
   (b) Moderately Trained (Medium)  
   (c) Elite Trained (Low)  

(Choose One) _______

(6) Signs of single-leg dominance?
   (a) Right foot dominant (Low)  
   (b) Left foot dominant (Low)  
   (c) Ambidextrous (No risk in this category)  

(Medium) _______

(7) Cardiovascular endurance is below age level?  

(High) _______

(8) Muscular strength and endurance is below age level?  

(Fitness gram or State Fitness Tests Failed)  
   (a) Mile run. (High)  
   (b) Push-up. (Low)  
   (c) Curl-up. (Low)  
   (d) Flexibility (Hamstring Sit and Reach). (Medium)  
   (e) Trunk Lift. (Low)  
   (f) Body Mass Index (BMI) above the norm? (High)  
   (G) Above average height (High)  

Total Points_______

49
(9) Lower body strength abnormalities?

   (Body weight squat)
   (a) Thighs not parallel to the floor (Low)
   (b) Knee movement (Low)
   (c) Knees are over the toes (Low)
   (d) Heels are up (Low)
   (e) Weak hamstring muscles (Low)

   (Total Points) _____

(10) Balance abnormalities?

   (Performed and held controlled for five seconds)
   (a) Single-leg stance uncontrolled for right leg (Low)
   (b) Single-leg stance uncontrolled for left leg (Low)
   (c) Box jump up and back down is not center balanced and controlled (Low)
   (d) Swaying observed (Low)

   (Total Points) _____

Movement Mechanics Risk Factors

(Pace is at three-quarter game speed)

(11) Gait or form running abnormalities?

   (Jog to cone)
   (a) Weight is back instead of forward (Medium)
   (b) Flat foot contact (Medium)
(c) Arms not in opposition to legs (Medium)
(d) Foot contact is not below the knee (Medium)

(Total Points) _______

(12) Jump-landing abnormalities?

(Standing broad Jump-land test, bound in place, 180 degree jump)

(a) Cannot hold an aligned controlled position for five seconds (Medium)
(b) Flat footed or on heels (Medium)
(c) Foot pronation (Medium)
(d) Knees turned inward or outward (Medium)
(e) Hyper extended knee (Medium)
(f) Hip rotation (Medium)
(g) Limited knee flexion (quad. dominance) (Medium)
(h) Hard landing (Medium)

(Total Points) _______

(13) Cutting and pivoting abnormalities?

(Zigzag run, figure eights, shuttle run tests)

(a) Limited knee and hip flexion (Medium)
(b) Chest is not slightly forward (Medium)
(c) Back is not flat (Medium)
(d) Flat footed (Medium)
(e) Hip, knee, and ankle are not in alignment (Medium)
(14) Acceleration or deceleration abnormalities?
(Start and stop to a cone 10 feet in distance)
(a) Weight not on front of feet
during acceleration (Medium)
(b) Accelerates or decelerates
without rapid steps (Medium)
(c) Sudden stop (Medium)

(Total Points) ______

(15) Fatigue mechanics abnormalities?
(Jump rope, vertical jumps or jog until the athlete is
fatigued and then test the following for proper mechanics)
(a) During jumping-landing (Medium)
(b) During acceleration (Medium)
(c) During deceleration (Medium)
(d) During Pivoting or cutting (Medium)

SCORE:

Point Total = ______

Total Possible Points = 100

PEIR percentage = ______
APPENDIX B

JACOBSEN ANTERIOR CRUCIATE LIGAMENT INJURY
PREVENTION EVALUATION GUIDELINES AND
STRATEGIES FOR PEIR
General History Risk Factors:

(1) Age is over 12 years (Every year of maturation over 12 years of age increases ACL injury risk)

(2) Health problems inhibiting performance

(3) Previous injury to the hip, knee, or ankle

(4) Skill level:
   (a) Untrained = high risk
   (b) Moderately trained = medium risk
   (c) Elite trained = low risk

(5) Single leg dominance (medium risk)

(6) Cardiovascular conditioning level:
   (a) Above average = low risk
   (b) Average = medium risk
   (c) Below average = high risk

(7) Muscular strength and endurance:
   (a) Above average = low risk
   (b) Average = medium risk
   (c) Below average = high risk

(8) Body mass index level (BMI):
(a) Above Average = high risk  
(b) Average = medium risk  
(c) Below average = low risk

(9) Height:  
(a) Above average = high risk  
(b) Average = medium risk  
(c) Below average = low risk

Movement Risk Factors

High risk movements include unanticipated movements, lack of balance, abnormal running, jump-landing, cutting, pivoting, and acceleration and deceleration. All movements should be started from a ready position. Unanticipated movements are when the athlete does not prepare the body for sudden changes in direction. The ready position prepares the athlete for movement.

(1) Ready position:

(a) Mentally prepared for changes in direction  
(b) Hips, knees, and ankles are in alignment  
(c) Weight is forward and on the balls of the feet  
(d) Bend in the knees and hips  
(e) Arms out and bent slightly
(2) Form running techniques:
   (a) Hips, knees, and ankle alignment
   (b) Weight forward
   (c) On balls of feet
   (d) Arms in opposition to legs
   (e) Feet contact the ground under the toes

(3) Jump-Landing techniques:
   (a) Hips, knees, and ankle alignment
   (b) Soft ground contact
   (c) Land on the balls of the feet
   (d) Knee flexion
   (e) Land with toes under the knees
   (f) Athletes should be able to jump and hold a controlled and center balanced position for five seconds

(4) Cutting, Pivoting techniques:
   (a) Anticipate your movements
   (b) Hips, knees, and ankle alignment
   (c) Chest slightly forward and the back is flat
   (d) Bend knees and hips
   (e) Weight forward and on the balls of the feet
(5) Acceleration and deceleration techniques:

(a) Take rapid steps
(b) Weight forward during acceleration
(c) On balls of the feet
(d) Planned stops that are not abrupt
APPENDIX C

FIGURE 1. AND FIGURE 2. DEFINITION OF
AN ANTERIOR CRUCIATE LIGAMENT
A ligament in the knee that crosses from the underside of the femur (the thigh bone) to the top of the tibia (the bigger bone in the lower leg). Abbreviated ACL. Injuries to the ACL can occur in a number of situations, including sports, and can be quite serious, requiring surgery.

The Anterior Cruciate Ligaments, one on either side of the knee, are so called because they cross each other in front of the knee. "Cruciate" taken from the Latin "crux" for "cross" means "in the form of a cross."
A knee injury involving the Anterior Cruciate Ligament (ACL). The ACL runs diagonally across the front of the knee from the underside of the femur (the thigh bone) to the top of the tibia (the bigger bone in the lower leg).
Females are seven times more likely to suffer an ACL injury than their males. The reasons are complex. In females the Q-angle (for quadriceps) is greater and tends to pull the kneecap (patella) out to the side. Women have looser knee joints. Their hamstring muscles are generally weaker than their quadriceps, which adds stress to the joint. When men jump they land on both legs with their knees bent, while women land with their knees in a straighter position, putting more stress on the knee joint.

Initial treatment includes ice and anti-inflammatory drugs. The next phase is usually stretching, exercise and physical therapy to rebuild strength and regain motion. The ACL does not heal on its own, but the surrounding knee muscles can be built up through exercise and physical therapy, a process that can take up to a year. Severe ACL injuries, especially in younger patients, may be surgically repaired.

Webster’s New World Medical Dictionary (2nd ed.) (2003).


APPENDIX D

FIGURE 3. MAGNETIC RESONANCE IMAGING (MRI)

OF AN ANTERIOR CRUCIATE LIGAMENT AND

A POSTERIOR CRUCIATE LIGAMENT
Figure 3. (Left) MRI of normal ACL (1) and PCL (2); (Middle) ACL in extension; and (Right) ACL in flexion (p.274).

APPENDIX E

TABLE 1. ANTERIOR CRUCIATE LIGAMENT INJURY PREVENTION PROGRAMS FOR FEMALE SOCCER PLAYERS
<table>
<thead>
<tr>
<th>No.</th>
<th>Author</th>
<th>Sport</th>
<th>N</th>
<th>Duration</th>
<th>Sex</th>
<th>Random</th>
<th>Equipment</th>
<th>Components</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Heidt et al. (2000)</td>
<td>Soccer</td>
<td>300</td>
<td>1 Year</td>
<td>Female</td>
<td>No</td>
<td>Sports cord; Box Jump</td>
<td>Strength, Agility, Polymetrics, Proprioception</td>
<td>2.4% Injury trained versus 3.1% control</td>
</tr>
<tr>
<td>2</td>
<td>Hewett et al. (1999)</td>
<td>Soccer, Basketball, Volleyball</td>
<td>1263</td>
<td>1 Year</td>
<td>Male and Female</td>
<td>Yes</td>
<td>Jump Box; Balance</td>
<td>Strength, Polymetrics, Proprioception</td>
<td>0.43 Injury control group versus 0.12 trained group</td>
</tr>
<tr>
<td>3</td>
<td>Mandelbaum et al. (2005)</td>
<td>Soccer</td>
<td>1885</td>
<td>2 Years</td>
<td>Female</td>
<td>No</td>
<td>Cones, Soccer balls</td>
<td>Flexibility, Agility, Technique, Strength</td>
<td>88% ACL injury decrease Year 1; 74% decrease Year 2</td>
</tr>
<tr>
<td>4</td>
<td>Pfeiffer et al. (2004)</td>
<td>Soccer, Basketball, Volleyball</td>
<td>1439</td>
<td>9 Weeks</td>
<td>Female</td>
<td>No</td>
<td>None</td>
<td>Agility, Technique</td>
<td>1 Soccer control; 0 Soccer trained</td>
</tr>
</tbody>
</table>
REFERENCES


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