DYNAMIC WARM-UP AND INJURY PREVENTION FOR FEMALE SOCCER PLAYERS – A RESEARCH STUDY

By

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ABSTRACT

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This study was conducted to determine whether or not the inclusion of a specific exercise regimen would significantly decrease the incidence and severity of injury incurred by female soccer players by increasing the range of motion in the joints of the knees, hips, and low back. Subjects for the study were girls on the soccer teams at Farmington High School during the 2010 fall soccer season. The control group was made up of Junior Varsity players and the experimental group was made up of Varsity players.

Format for the study was a 6 week period, which included four weeks in September and two weeks in October of 2010. Control was established through having both groups participate in the same pre-practice and pre-match warm-up regimen: the Core Performance Movement Prep. After training was completed, the experimental group participated in a specific exercise regimen (Postural Restoration Institute's Soccer Program or PRI) designed specifically for soccer players to increase the range of motion (ROM) thus reducing the incidence and severity of injuries.

Both groups were pre-tested and post tested to determine the difference in range of motion in the joints of the knees, hips, and low back. Injuries incurred by both groups were logged and categorized in order to determine whether or not the PRI Soccer Program had a significant impact on incidence and severity of injuries. A single factor analysis of variance (ANOVA) was used to ascertain the degree of statistical significance resulting between the control and experimental groups in ROM. A goniometer was used to evaluate ROM for hips and knees, while an inclinometer was used to evaluate ROM in the lower back.

No statistical significance was achieved between the experimental and control groups at the measurement sites. The incidence and severity of injuries both appeared to decline in athletes performing the PRI soccer program based on observation of data obtained during the intervention study although this was not found to be statistically significant. When observing frequency distributions, the experimental group appeared to have fewer injuries and less severe injuries compared to the control group. Therefore, for this 6 week intervention with female soccer players, the PRI program did not appear to improve joints' ROM, but tended to reduce the frequency and severity of soccer injuries.

Key Words: range of motion, Postural Restoration program, soccer training, and injury prevention

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Chapter 1
Introduction

According to the National Strength and Conditioning Association (NSCA) Fly Solo Manual (2007), the majority of the population, including athletes, experience and suffer from postural asymmetry that is created by anterior pelvic tilt. Symptoms can be found in both the upper extremity and the lower extremity. In the upper extremity, symptoms occur at the back, between the shoulder blades, top of the shoulder blades, the neck, and the face. In the lower extremity, symptoms occur at the hip, groin, knee, and the sacral-iliac joint. Symptoms can result in the inability to fully adduct, extend or flex the legs on one or both sides of the body (NSCA Fly Solo Manual, 2007). The manual also stated that athletes suffering from postural asymmetry may have difficulty rotating the trunk, abducting horizontally, and may experience limited internal rotation on one or both sides of their body (NSCA Fly Solo Manual, 2007). A simple observation of athletes who have one shoulder raised higher than the other and who shift their weight from one leg to the other are signs that the athlete may suffer from postural asymmetry (NSCA Fly Solo Manual, 2007).

The Postural Restoration Institute's Soccer Program (PRISP) was designed to improve the warm-up of soccer players before training or competition to help prevent injuries. The soccer program was similar to the Hruska Activators developed by Ron Hruska, MPA, and PT at his Postural Restoration Institute in Lincoln, Nebraska. The soccer program was based on the study of myokinematics, which was the study of motion, or lack of motion, produced by specific forces (NSCA Fly Solo Manual, 2007). "The Hruska Activators are designed to create symmetrical muscle flexibility, strength, and length by facilitating, turn on, specific muscle groups and inhibiting, turn off, others. The goals of these exercises are to warm-up the internal temperature of the muscles and establish proper muscle recruitment patterns aligning the body to be in a mechanical advantage to express power and strength." (NSCA Fly Solo Manual, Module 4, 2007, p. 12)

The soccer program exercises were designed to help postural restoration through recruitment patterns, which generated a neutral or level pelvis. "A neutral pelvis, or level pelvis, is described as the angle and rotation the pelvis creates in relation to the entire body." (NSCA Fly Solo Manual, Module 4, 2007, p. 12) In order for restoration to occur, the muscles responsible for moving the pelvis were taught what position was needed.

Through participation in the Postural Restoration exercises, the objective was for the joints at the knees, the hips, and the lower back to become capable of full range of motion (ROM). Repetition of the exercises established a muscle activation pattern required to move the joint through its full range of motion. The exercises also influenced and improved the soccer player's breathing patterns and breathing ability by allowing the player to expand her chest wall upon deep inhalation (NSCA Fly Solo Manual, 2007).

Due to postural asymmetry, many soccer athletes suffer from injury during both training and competition. It was the goal of this research study to prevent or reduce the incidence of injury for female soccer players by the implementation of the Postural Restoration Institute's Soccer Program into the warm-up.

Statement of the Problem

The game of soccer continues to increase in popularity around the world. Some may argue that it is the most popular sport in the world. With the passing of Title IX of the Education Amendments in 1972 the number of females participating in organized sports rose exponentially. With the increase in popularity of organized sports and soccer being no exception, there was an increase in injuries. That was brought to the attention of the medical world (Junge, Rosch, Peterson, Graf-Baumann, and Dvorak, 2002; Keller, Noyer, and Buncher, 1987; Schmidt-Olsen, Buneman, Lade, and Brassoe, 1985; Steffen, Myklebuse, Olsen, Holme, and Bahr, 2008; Sullivan, Gross, Grana, Garcia-Moral, 1980; and Zazulak, Hewett, Reeves, Goldberg, and Cholewicki, 2007) "The goal of the soccer athlete is to train and compete at optimal levels of performance while avoiding injury." (Thomsen, 2008, para. 1) As a former collegiate female soccer player and current girls' soccer coach, the researcher was very concerned with reducing the incidence and severity of injury to players. The problem faced by participants and coaches continues to be the degree to which strength and flexibility affect injuries.

Purpose of the Study

The purpose of this study was to determine the effect that a specialized exercise regimen would have on the incidence and severity of injuries incurred by female soccer players at Farmington High School during the 2010 soccer season. An exercise program developed specifically for soccer players was chosen for inclusion into the regular practice plan. Because the Postural Restoration Institute's Soccer Program was developed to train the muscle groups required to increase range of motion (ROM) at the hips, the lower back, and the knees, it was included into the exercise regimen of an experimental group of soccer players. The effect that increased ROM had on the incidence and severity of injuries was compared between the control group and the experimental group.

Research Hypotheses

Hypothesis 1: Participation in the Postural Restoration Institute's Soccer Program would increase the range of motion (ROM) in the joints of the knees, hips, and lower back.
Hypothesis 2: Participation in the Postural Restoration Institute's Soccer Program would reduce the overall incidence of mild, moderate, and severe injuries in the lower extremities at the hip, hamstring, groin, knee, and ankle in the Farmington High School girls' soccer team.
Hypothesis 3: Participation in the Postural Restoration Institute's Soccer Program would reduce the number of severe injuries sustained to the hip, hamstring, groin, knee, and ankle in the Farmington High School girls' soccer team.

Delimitations

This research study was delimited to the addition of one specific exercise regimen to the regular practice schedule for the Farmington High School girls' soccer team.

Data for this study was collected during a 6 week period during September and October of 2010. Age range for the participants was 13 to 18 years old.

Limitations

Data for this study was collected over a short 6 week intervention period during September and October of 2010. Age range for the participants was limited to 13 to 18 years old.

The participants were divided into a control and an experimental group. The researcher was not able to control absences caused by participants' job requirements, family vacations, and student participation in other school-sponsored activities.

Assumptions

It was assumed that the inclusion of the Postural Restoration Institute's Soccer Program at the conclusion of practice would reduce the incidence of injury in all categories of mild, moderate, and severe injuries when compared to non-experimental subjects.

Definitions of Terms

An injury was defined as any trauma sustained by a soccer player regardless of contact or non-contact which resulted in the player missing at least one day of training or match play or a combination of both. Injuries were categorized as mild, moderate, or severe.

Mild Injury- Injury requiring minor first-aid, ice, and inactivity for one day.

Moderate Injury-Injury requiring treatment from an athletic trainer and inactivity for more than one day.

Severe Injury-Injury requiring medical treatment from medical personnel other than an athletic trainer for physical therapy or surgery or a combination of both and inactivity for the duration of rehabilitation.

Moderate and severe injuries may have also resulted in the player's inability to perform daily activities successfully. (M. Brenton, personal communication, January 10, 2009)

Postural Restoration Institute Soccer Program Exercises: See Appendix A

Twelve specific exercises designed to increase the range of motion (ROM) in the knees, the hips, and the lower back.

Core Performance Movement Prep: See Appendix B

Ten specific exercises designed to increase the internal temperature of the muscles before activity.

Chapter 2

Review of Literature

It was estimated by the National Center for Education Statistics that there are nearly 20,000 public and private high schools in the United States (Powell and Barber-Foss, 2000). Because of the number of high schools across the United States, the opportunity for females to participate in organized sports at the high school level was increased by nearly 40% between 1988 and 1998 according to the National Federation of State High School Associations (Powell and Barber-Foss, 2000). Kontos and Brown (2000) reported soccer was the second most popular sport in the United States with more than 1.5 million registered soccer players under the age of 18. The NCAA reported that women's collegiate soccer was the most popular female sport with 6,787 women playing (Kontos and Brown, 2000). The increase in female participation in organized sports was attributed to the passing of Title IX of the Educational Assistance Act in 1972. Title IX allowed females equal opportunity to participate in sport, which caused the number of participants in organized sports to increase exponentially (Silvers, 2009). The increase in female soccer participation in particular can be attributed to several recent events. The U. S. Women's National soccer team was very successful in recent years, and in 1994 the United States hosted the Women's World Cup (Kontos and Brown, 2000). The increase of female participation has heightened the concern for player safety in all organized sports, including soccer.

The increased numbers of participants in organized sports has also led to an increase in injuries among all athletes. Numerous studies were conducted in hopes of finding an answer to injury occurrence and developing injury prevention programs (Croisier, Ganteaume, Binet, Genty, and Ferret, 2008; Fisher, 2006; Hewett, Stroupe, and Noyes, 1996; Hewett, Myer, Ford, Heidt, Colosimo, McLean, van den Bogert, Paterno, and Succop, 2005; Hewett, Ford, and Myer, 2006; Hudy, 2004; Junge and Dvorak, 2004; Junge et al., 2002; Keller et al., 1987; Kontos and Brown, 2000; Meyer, Brent, Ford, and Hewett, 2011; Pafis, Ispirlidis, and Godolias, 2007; Powell and Barber-Foss, 2000; Rumpf and Cronin, 2012; Schmidt-Olsen et al., 1985; Silvers, 2009; Steffen et al., 2008; Sullivan et al., 1980; Zazulak et al., 2007). Research findings have shown that female injury rates were much higher in sports that incorporate jumping, cutting, pivoting, change of direction, and deceleration as opposed to activities with lower impact (Crosiser et al., 2008; Fisher, 2006; Hewett et al., 1996; Hewett et al., 2005; Hewett et al., 2006; Hudy, 2004; Junge and Dvorak, 2004; Junge et al., 2002; Kellet et al., 1987; Kontos and Brown, 2000; Meyer et al., 2011;Pafis et al., 2007; Powell and Barber-Foss, 2000; Rumpf and Cronin, 2012; Schmidt-Olsen et al., 1985; Silvers, 2009; Steffen et al., 2008; Sullivan et al., 1980; and Zazulak et al., 2007). Researchers examined all aspects of probable injury causes, including: biological and anatomical differences between genders, player position on the field, indoor versus outdoor, environment, weather, playing surface, practice versus games, footwear, artificial bracing, and player factors. Of particular concern was the injury rate between male and female athletes. It was found that female athletes participating in sports such as soccer, basketball, and volleyball experienced higher rates of injuries and severity of injuries than did their male counterparts. Several studies analyzed anatomical and physiological differences between male and female athletes (Crosiser et al., 2008; Fisher, 2006; Hewett et al., 1996; Hewett et al., 2005; Hewett et al., 2006; Hudy, 2004; Junge and Dvorak, 2004; Junge et al., 2002; Kellet et al., 1987; Kontos and Brown, 2000; Meyer et al., 2011;Pafis et al., 2007; Powell and Barber-Foss, 2000; Rumpf and Cronin, 2012; Schmidt-Olsen et al., 1985; Silvers, 2009; Steffen et al., 2008; Sullivan et al., 1980; and Zazulak et al., 2007). Areas researched were the difference in pelvic structure and lower extremity alignment (Q-angle), differences in the diameter of male and female anterior cruciate ligaments, the effects of the gender hormones testosterone and estrogen, and the effects of the female menstrual cycle. The focus of the research was to determine why female athletes incur more injuries than their male counterparts.

Not only has the game of soccer increased in popularity in the United States but also around the world. It can be argued that the game of soccer is the most popular sport in the world. It was estimated that 200,000 professional and 240 million amateur players, male and female, play the game of soccer around the world (Junge and Dvorak, 2004). Because of increased participation, soccer injuries have increased around the world. That came to the attention of the medical world as stated by Junge et al. (2002); Keller et al. (1987); Schmidt-Olsen et al. (1985); Steffen et al.(2008); Sullivan et al. (1980); and Zazulak et al. (2007). According to Thomsen (2008, para. 1) "The goal of the soccer athlete is to train and compete at optimal levels of performance while avoiding injury." Several studies analyzed injury prevention programs for both male and female soccer athletes, but few studies analyzed the incidence of injuries in female soccer players (Junge and Dvorak, 2004). Research on injury prevention varied in duration, number of participants, as well as prevention programs. Keller et al.'s (1987) research reviewed several studies. The studies varied among professional and amateur athletes, gender, duration, and prevention programs.

Preventing injury implied the identification and understanding of the factors leading to that injury. Such an approach allowed for the development of the most appropriate strategies for reducing the risk of injury. Injury prevention programs first identified and understood the factors that lead to an injury. To help prevent musculoskeletal injuries, "...specialists propose specific exercise programs like strengthening exercise programs to restore muscle imbalances, stretching exercise programs to decrease muscle stiffness, and balance exercise programs to improve proprioception." (Pafis et al., 2007, para. 1)

Injuries are caused by intrinsic or extrinsic factors. Intrinsic factors are those that are related to the individual. Those factors include "...joint instability, muscle strength, tightness, and asymmetry; body mechanics; psychological; and injury history." (Rumpf and Cronin, 2012, p. 21) Extrinsic factors are those that pertain to the environment such as "...level of play and position on the field; amount and standard of training and competition; warm-up and stretching; pitch (indoor/outdoor); quality of pitch; rules of play; and equipment." (Rumpf and Cronin, 2012, p. 21)

Injury Definition

In the current literature, there was not a consistent definition of an injury but rather a variety of definitions. It was critical to know the differences in definitions when comparing the results from the numerous studies. The differences in injury definition caused the injury rates in some studies to be inflated due to the reporting of minor injuries such as blisters and abrasions. Rumpf and Cronin (2012) found the most common injury definition throughout research was based on the duration of a player's absence from training or games for a period longer than 48 hours but not including the day the injury occurred. Other studies used an injury definition that required the injuries sustained by athletes to be serious enough to result in the athlete missing either training sessions or games or both (Keller et al., 1987). Sullivan et al. (1980, p. 325) defined an injury "...as any medical problem that occurred during regularly scheduled games or practices and prevented the child from continuing to participate as the other players did." Injury definitions such as these help determine to what extent the injury will affect the athlete's performance and health. Another advantage for these types of injury definitions was to help determine the severity of the injury in terms of the amount of inactivity required for rehabilitation.

Steffen et al.'s (2008, p. 3) definition of injury was "...if it caused the player to be unable to fully take part in the next match or training session." Injuries were also categorized as either acute injuries, overuse injuries, or recurrent injuries. "Acute injuries were defined as injuries with a sudden onset associated with a known trauma, whereas overuse injuries were those with a gradual onset without any known trauma. Recurrent injuries were defined as an injury of the same type and the same site and that occurred after a player's return to full participation." (Steffen et al., 2008, p.3) Injury circumstances (contact vs. non-contact), the type of injury, and the location of the injury were also recorded.

The study of "Soccer Injuries of Youth" used three definitions for injuries based on severity. The first of the three was a slight injury. A slight injury required minor first-aid and no reduction in activity. The second injury based on severity was classified as a moderate injury. A moderate injury required medical care without hospitalization and reduced activity. The third type of injury was labeled as a severe injury. A severe injury required hospital treatment and reduced activity (Schmidt-Olsen et al., 1985).

An injury in the Junge et al.'s (2002, p. 654) study was defined "...as any physical complaint caused by soccer that lasted for more than 2 weeks or resulted in absence from a subsequent match or training session." The severity of the injuries for this study were placed into three categories based on time of inactivity from training sessions and matches as well as duration of athlete complaints. Injuries were classified as mild if a player complained for more than two weeks or was inactive for up to one week.

Injuries were classified as moderate if the inactivity from soccer was more than one week and less than four weeks. Injuries were classified as severe if the inactivity was at least four weeks or there was a fracture or dislocation or other severe tissue damage. Injuries were classified as overuse injuries it they were caused by repetitive microtrauma without an identifiable traumatic event (Junge et al., 2002).

Injury Rates

Youth soccer athletes sustained fewer injuries (two to five times fewer) during participation than did American youth football athletes. The incidence of soccer related injury increased with the age of the athlete from youth leagues to professional leagues (Keller et al., 1987). Sullivan et al. (1980) documented similar injury rates in the 12-19 year old athletes with a higher incidence of soccer related injury among the 14-16 year old athletes in an Oklahoma youth study. Keller et al. (1987) also found similar results in a study of youth players in the Norway Cup. The studies documented reduced injury rates (5-fold lower reduction) within the 7-12 year old athletes compared with the older athletes. Playing time differed among the age group of the athletes. The injury rates recorded in those previous studies reflected not only the risk of injury from playing soccer, but also the amount of exposure to soccer. Injury rate comparison was more meaningful when injuries were expressed in injury incidence per unit of time, e.g. per 1,000 hours of training and or matches. Comparisons of injuries in that manner showed that older (professional) athletes sustained injuries 15-30% more than younger (youth) athletes because older players were more willing to take risks than younger players (Keller et al., 1987).

Technical skills were a factor in injury rates. As the age of the athlete increased, so did the athlete's technical skills. The increase in technical skills affected the injury rate sustained by athletes. With the increase in age, increase in technical skills, and the increased intensity of competition, there was an increase in injury rates sustained among older and professional athletes. The increase in injury rates in older athletes was attributed to the athletes' willingness to perform more high-risk technical skills than younger, less skilled athletes. Older athletes were found to perform with more intensity in both training sessions and during competition. Due to increased levels of intensity, injuries caused through collision produced greater large joint reactions to speed and momentum, than was found in younger athletes (Keller et al., 1987). Keller et al. (1987) referenced the Sullivan et al. (1980) study of Oklahoma youth soccer league injuries to reinforce the fact that the Oklahoma players sustained fewer than half the number of injuries incurred by the Norway Cup competitors of the same age range. Keller et al. (1987) also found that the younger Norway players sustained fewer than half the number of injuries sustained by the older and more skilled athletes. Both Keller et al. (1987) and Sullivan et al. (1980) determined that as age, sport specific skills, and competition levels increased, injury rates also increased.

The incidence of injury reported in the "Soccer Injuries of Youth" (Schmidt-Olsen et al., 1985) was based on 1000 hours of training and match play. The participants ranged in age from 9-19 years of age. The researchers used a four-tier scale of injury interpretation to classify injuries as mild, moderate, severe, or serious. The rate of injuries for the study was 19.1 per 1000 hours of activity, which represented 5.2% of the participants. Of those injuries, 2.2% were classified as mild, 2.6% were classified as moderate to severe and 0.4% were classified as serious. The greatest rate of injuries were sustained by the older girls who registered 47.2 injuries per 1000 hours of activity, while boys of the same age group sustained 20.6 injuries per 1000 hours of activity. The lowest incidence of injury was in the youngest group of girls. Overall, the girls sustained twice the number of injuries as did the boys. As the age of the athlete increased, both boys and girls sustained greater incidence of injury (Schmidt-Olsen et al., 1985).

According to Keller et al. (1987), female youth athletes sustained up to twice the number of injuries as did male youth athletes. It was unknown if older female athletes also had a higher injury rate than did the older male athletes. The higher injury rate among female youth athletes was attributed to their lack of skill. The difference between injury rates among male and female athletes was unclear (Keller et al., 1987).

Injury characteristics in the Steffen et al. (2008) study were reported after an eight-month season, which included a two-month preseason and a summer break. The intervention program used in the Steffen et al. (2008) study was the "11" program that was developed as a structured warm-up to target ankle and knee sprains and groin and hamstrings strains. Out of a total of 2020 female soccer players in the Steffen et al. (2008) study, 20% of players (396) sustained at least one injury during the time frame of the study. Of the 396 players, 3% (57) sustained two injuries while 1% (15) sustained three injuries, for a total of 483 injuries. Re-injuries accounted for 20% (98) of the total 483 injuries. Of the re-injuries, 1.9% (9) were re-injuries of previous injuries sustained during the same season. "The proportion of re-injured players in the intervention and control groups was 16% (n=32 out of 204) vs. 22% (n=43 out of 192), respectively (P=0.22)." (Steffen et al., 2008, p. 4)

Player skill level and experience was also a factor in injury during the game of soccer. Rumpf and Cronin (2012) found in their study that players who had lower skill levels experienced more injuries than the more skilled players. Less experienced players also experienced more severe injuries. Experienced players were able to recognize and avoid injury-causing situations. Less experienced players were unable to recognize injury causing situations and may not have had the skills to avoid these situations, causing them to experience a higher incidence of injury (Rumpf and Cronin, 2012).

Injury Severity

Injury severity was evaluated in terms of amount of inactivity from training, matches, or both. Rumpf and Cronin (2012) found four general categories in which injury severity were classified throughout research: 1) minor (2-3) days, 2) mild (4-7 days), 3) moderate (1-4 weeks), and major (>4 weeks). Keller et al. (1987) noted that other studies used a definition of injury as loss of playing time in training, matches, or both. The use of that definition resulted in only the more serious injuries being reported. It was reported that approximately half of the injuries resulted in athletes missing more than one week of training. Also the incidence of more severe injuries, which resulted in more than one month of missed training was low (0.03%-11%). In older athletes, the reported severe injuries were four times greater than the younger athletes (Keller et al., 1987). Other measures that could be used to determine severity of injury were time lost from school or work, disability when performing daily activities, or the financial cost of medical care. Measures of the preceding were not reported in the studies even though the information was required for evaluation of the significance of the injuries observed. "Future studies must include these measures of injury severity if the impact of the injury on the life of the athlete is to be fully appreciated." (Keller et al., 1987, p. 233)

Injuries recorded in the Steffen et al. (2008) study were classified into three categories based on severity. Severity of the injury was based on the length of absence from training sessions and match play until the player was fully recovered to participate in all aspects of organized soccer. Severity categories were as follows: minor (1-7 days), moderate (8-21 days), and major (> 21 days). Players who suffered from moderate or major injuries were examined and treated by medical personnel. Minor injuries were examined by the team coach or physical therapist assigned to the team.

Soccer Injury Sites

Due to the increase in popularity of soccer among children and youths, the medical field became interested in soccer related injuries and the types of injuries being reported. According to the available research literature, the vast majority of soccer related injuries occurred in the lower extremity, mainly affecting the ankle, knee joints and the muscles of the thigh and calf (Junge and Dvorak, 2004). "The most common types of injuries are sprains, strains and contusions." (Junge and Dvorak, 2004, p. 930) Lower extremity injuries generally occur from either overuse or from impacts. When these results were reported as a percentage of the total injuries sustained, the injuries to the lower extremity represent 88% for the older athletes, 72.5% for professional athletes, and 68% for youth athletes (Keller et al., 1987). The study of "Soccer Injuries of Youth," (Schmidt-Olsen et al., 1985) stated that the severe injuries located in the upper extremity were mainly fractures. That was due to younger players not being as coordinated and skilled as older players, resulting in more falls with the arms extended to break the fall.

Soccer injuries were also categorized by type of injury: contact or impact injuries and non-contact injuries. Contact injuries were caused by a variety of instances, but the majority result from player-to-player contact, legal or illegal, or from ball contact, legal or illegal. Non-contact injuries generally occur during running, turning, change of direction, pivoting, deceleration, or landing from a jump. Kontos and Brown (2000) found that the primary injury reported in their study was in the form of contusions. The contusions were a result of an impact with either another player, the ground, or the ball.

Upper extremity injuries

Youth athletes had a higher incidence of upper extremity injuries due to illegal ball contact with the upper extremity, more frequent falls with outstretched hands to catch themselves, or the increased fragility of growing upper extremity epiphyses. Insufficient technical skills such as heading the ball properly, mechanical weakness of immature dental tissues, and an increase in head to ball weight could explain the increased incidence of head and facial injuries among youth athletes (Keller, et al. 1987). The use of lighter soccer balls at younger ages was common but not universal and was used as an effort to decrease the chance of injuries. In areas where synthetic balls were not used, leather soccer balls were sometimes used. When leather balls became wet they increased in weight, producing increased body-ball impact forces, which caused more severe head injuries. As a result, manufacturers worked toward improving synthetic soccer balls, which do not absorb moisture (Keller et al., 1987).

Lower extremity injuries

Lower extremity injuries to the pelvis, hip, knee, and ankle were more common in sports that involve jumping, landing from a jump, pivoting, deceleration, and changing direction. Keller et al. (1987) found injuries occurring at the knee represent 12%-20% of total injuries sustained by professional soccer players. Professional soccer players suffering from leg injuries rarely experience loss of playing time while 12% of leg injuries suffered by younger athletes results in loss of playing time. The Oklahoma youth study reported a higher incidence (twice the rate) of ankle injuries than did other studies, which reported that20% of all injuries were ankle injuries. Other factors not reported that may cause ankle injuries are the condition of the playing surface, types of shoes worn by the athlete, and the use of preventative measures such as ankle taping, wrapping, or bracing (Keller et al., 1987).

One-third of lower extremity injuries, regardless of competition, intensity and age, were ligament sprains. Professional players and older players sustained two to four times the number of muscle strains than did younger players. Youth athletes sustained proportionately more contusions than did older athletes. The younger athletes and their parents did not tolerate such injuries as well as older athletes, thus causing more loss of playing time in both training and competition. "Although these differences may reflect dissimilarities in the intensity of play, they suggest that greater attention to warm-up and flexibility training might reduce injury among older players." (Keller et al., 1987, p. 233) Among youth athletes, injury to the lower extremities predominated, with the majority of injuries occurring to the ankles and feet (Schmidt-Olsen et al., 1985).

"Soccer requires the athlete to perform kicking, twisting and cutting maneuvers throughout the pelvis and hips, thus exposing these areas to mechanical and soft tissue stress." (Masek, 2007a, para. 1) Injuries to the pelvis and hip accounted for a small number of injuries, but they were significant (Masek, 2007a). Hip impingement or femoral-acetabular impingement is a combination of mechanical abnormalities of the femoral head (ball) and the acetabulum (socket). It is characterized by abnormal contact or rubbing between the femoral head and the acetabulum causing damage to the articular cartilage or labral cartilage of the femoral-acetabular joint. Continued abnormal contact or rubbing can also cause damage to the anterior aspect of the acetabular labrum and the underlying articular cartilage, which can lead to labral lesions. The game of soccer requires an athlete to perform repetitive kicking, twisting, and side-to-side movements, which can provide the greatest risk of causing hip impingement. Hip impingement injuries are common to soccer players and can often times be disabling (Masek, 2007a).

Labral injuries (tears and strains) of the hip are not common in soccer. Playing a sport that requires repetitive twisting motions along with movements to end-range hyperflexion, repetitive hyperextension and external rotation may predispose susceptible athletes to labral tears (Masek, 2007b). "When biomechanics are altered due to pelvic malalignment, undue stress may be placed on soft tissues; as a result, the individual may develop postural patterns that predispose the individual to secondary pathologies such as impingements and instabilities." (Masek, 2007b, para. 1) An athlete suffering from a labral tear will exhibit mechanical symptoms as well as pain in the anterior groin. The pain may also radiate to the knee (Shmerl, Pollard, and Hoskins, 2005).

Athletes who were predisposed to labral tears suffered from muscular imbalance in the pelvis. The muscle imbalance was caused by tightness of the hip flexors and lumbar erector spinae coupled with weak, inhibited gluteal and abdominal muscles. The resulting imbalance caused anterior pelvic tilt, increased hip flexion, and hyperlordosis of the lumbar spine (Shmerl et al., 2005). "Hip flexion contracture might lead to increased weight-bearing upon the anterior acetabulum and labrum predisposing to tearing." (Shmerl et al., 2005, p. 632.e5)

Not only was an athlete susceptible to labral injuries while playing soccer, he/she also had problems with rotation ability of the hip. An individual's ability to shift into his/her hip is called acetabular femoral internal rotation (AF IR). According to the Postural Restoration Institute, a congruently aligned hip allows pain free mechanics to occur around the spine, hips, knees, and ankles. Congruently aligned means that the ball is maximally surrounded or covered by the socket (Bartels, 2008). During running activities such as soccer, shifting into the hip describes, "…the socket rolling over the ball of the femur as the weight of the body is transferred to the supporting lower extremity (heel strike to mid stance)." (Bartels, 2008, para. 2)

When athletes were positioned in a Left Anterior Interior Chain (Left AIC) pattern, they remained in a shifted state on the right hip, never shifting into a left hip even though weight had been transferred to the left lower extremity. Without the left shift of the hip, over compensation was achieved by excessive femur (ball) rotation. Excessive femur (ball) rotation results in overuse of the hip flexors and lateral quadriceps. That leads to weakening of the left glutes and left inner thigh muscles, which are the primary hip shifting muscles. As the ability of the left hip to shift diminishes, the muscles compensating pull the ball away from the socket until it is no longer aligned congruently. Instability of the hip predisposed athletes to abnormal joint forces and they experienced pain through the back, hips, knees, and feet (Bartels, 2008).

"The most common injury locations in female soccer players are the knee, the ankle, and the thigh." (Steffen et al., 2008, p. 1) Of particular concern is the risk of serious injury of the knee, especially to the anterior cruciate ligament or ACL. It was estimated that girls and women suffered 38,000 ACL injuries yearly in the United States (Hewett et al., 2005). After an ACL injury, athletes may experience chronic knee pathology, which includes instability and secondary injuries to the menisci and articular cartilage may occur. Athletes who suffered ACL injuries experienced an early onset of osteoarthritis. Daily living activities and quality of life can also be hindered for an athlete who has suffered from an ACL injury and the secondary injuries (Silvers, 2009). It was revealed at the National Athletic Trainers of America Symposium that out of 333,149 high school girls, 18% of girls' injuries were to the knee. Of 380,783 high school boys, only 10% of the injuries sustained were to the knee. The Symposium also reported knee surgeries accounted for 89% of all surgeries performed on female basketball players (Hewett et al., 1996).

As with all injuries, ACL injuries were categorized in two groups: contact and noncontact. "Seventy percent of all reported ACL injuries are noncontact in nature, whereas the remaining 30% involve contact from an outside force such as an opposing player, goalpost, or another object on the field or court." (Silvers, 2009, p. 83) Extrinsic and intrinsic factors were also potential factors that place some individuals at a higher risk for an ACL injury. Extrinsic factors were those factors that can be controlled by an individual. Those factors included strength, neuromuscular coordination, movement technique, field conditions and the type of footwear worn by the athlete (Chaudhari et al., 2007). Intrinsic factors were those factors that cannot be changed or controlled by the individual. The factors included ligament properties, anatomical alignment and geometry, and hormonal environment (Chaudhari et al., 2007).

The contributing factors to a noncontact ACL injury occurring in the field of play "...commonly involves one step-stops, cutting tasks, sudden changes of direction, landing from a jump with inadequate knee and hip flexion (at or near full extension), or a lapse of concentration (because of an unanticipated change in the direction maneuver play)." (Silvers, 2009, p. 83) Deceleration maneuvers coupled with changes in direction with the foot in a closed chain position were usually associated with noncontact ACL injuries (Silvers, 2009). Silvers (2009) explained that when the foot was in a closed chain position and pronated, there was internal rotation of the tibia, and the knee was at or was reaching full extension, which ranges from 0-20 degrees of flexion. During that instance, if a player changed or attempted to change direction, the resulting excessive torsional force could potentially strain or completely rupture the player's ACL (Silvers, 2009). Other biomechanical studies have "...found that most of the injuries were sustained in noncontact situations at the time of foot strike with the knee near full extension, during activities characterized by a sudden deceleration before a change in direction or from a landing motion." (Chaudhari et al., 2007, p. 794)

Silvers' research of ACL injuries examined the role of the dominant leg of soccer players and the risk of injury to the ACL (Silvers, 2009). The study examined both male and female soccer players (52 females and 41 males). Results found that almost half of the ACL noncontact injuries occurred in the preferred kicking leg (30) and the contralateral leg (28). When results were compared between genders, significant difference was found in the distribution of noncontact injuries: 74.07% (20/27) of the injuries to males were found in the dominant kicking leg; whereas injuries found in the dominate kicking leg of females was 32.26% (10/31) ($p<0.002$) (Silvers, 2009). The results from that study also found that female soccer players were more likely to injure the ACL in the supporting leg. "This research suggests that limb dominance does serve as an etiologic factor with regard to ACL injuries sustained while playing soccer." (Silvers, 2009, p. 84)

Female athletes were more susceptible to knee injuries than their male counterparts. It was hypothesized the reason for higher knee injuries in female athletes was due to females having neuromuscular control deficits when compared to male athletes. Those deficits increased joint loads in the lower extremity during sports activities (Meyer et al., 2011). "Neuromuscular control deficits are defined as muscle strength, power, or activation patterns that lead to increased knee joint and ACL loads." (Meyer et al, 2011, p. 22) There were four neuromuscular deficits female athletes demonstrated: "ligament dominance", "quadriceps dominance", "leg dominance", and "trunk dominance 'core' dysfunction" (Meyer et al., 2011). Ligament dominance was "...defined as an imbalance between the neuromuscular and ligamentous control of dynamic knee joint stability." (Meyer et al., 2011, p. 22) Quadriceps dominance was "...defined as an imbalance between knee extensor and flexor strength, recruitment, and coordination." (Meyer et al., 2011, p. 22) Leg dominance was "...defined as an imbalance between the 2 lower extremities in strength, coordination, and control." (Meyer et al., 2011, p. 22) Trunk dominance 'core' dysfunction was "...defined as an imbalance between the inertial demands of the trunk and control and coordination to resist it." (Meyer et al., 2011, p. 22) In order to maintain knee stability during landing from jumps and pivoting or cutting, neuromuscular control of high-load movements was required. Deficits in neuromuscular control may have increased the risk of injury to the ACL because the deficits affected dynamic knee stability.

There was a two- to ten-fold higher incidence rate of ACL injuries between female and male athletes (Silvers, 2009). With the increase in popularity of soccer after Title IX, the number of knee injuries to female soccer athletes drastically increased. Within the United States alone, there were more than 30,000 Anterior Cruciate Ligament (ACL) injuries to females, both women and girls, per year (Zazulak et al., 2007). ACL injuries resulted from combinations of components. The components included the center of the mass of the body displaced away from the plantar surface of the foot that was flat on the ground, valgus positioning of the lower extremity, and relative extension with unbalanced weight distribution. Valgus angulation and increased strain on the ligaments of the knee could have been caused by proprioceptive deficits in the body's core. Previous research suggested that the ACL in females might experience impingement along the medial border of the lateral femoral condyle when combined with a valgus load due to the narrow geometry of the female intercondylar notch (Silvers, 2009). These deficits may have helped contribute to decreased activity in neuromuscular control of the lower extremity (Zazulak et al., 2007).

Anatomical differences between males and females could have been a contributing factor to more ACL injuries in females. "The typical female demonstrates increased femoral anteversion, an increased Q angle, excessive tibial torsion, and excessive subtalar pronation compared with her male counter part." (Silvers, 2009, p.84) Males have a smaller Q angle than do females. Because of the greater Q angle in females, more stress was placed on the knee in certain athletic circumstances (Hudy, 2004). The Q angle is "...formed by the width of the pelvis from the head to the femur (thigh bone) to the knee." (Hudy, 2004, p.8) Females also have a smaller intercondylar notch than do males, as well as a smaller diameter of the ACL (Silvers, 2009). The intercondylar notch is formed at the insertion of the ligament attachment to the bone. It was suggested that due to the smaller intercondylar notch, less surface area was available to disperse the forces causing a decrease in the amount of force that the ACL could withstand before succumbing to injury (Hudy, 2004). Another potential anatomic cause for ACL injury was the impingement of the ACL against the lateral portion of the medial intercondylar notch (Silvers, 2009, p. 84)

"The core of the body includes the passive structures of the thoracolumbar spine and pelvis and the active contributions of the trunk musculature. The stability of the body's core is contingent on neuromuscular control of the trunk in response to internal and external forces, including the forces generated from distal body parts and from expected or unexpected perturbations." (Zazulak et al., 2007, p. 369) Unstable behavior resulting in injury throughout all segments of the kinetic chain could be due to deficits in core neuromuscular control. For example, hamstring injuries occurred due to the contribution of abdominal muscle fatigue. "Many athletic maneuvers, such as running, jumping, and cutting, are inherently unstable and require neuromuscular control to maintain stability and improve performance." (Zazulak et al., 2007, p. 369)

The findings in "The Effects of Core Proprioception on Knee Injury" showed that increased knee injury risk was associated with increased error in core proprioception. Decreased core proprioception may have altered dynamic knee stability, which would explain the increased risk of knee injury during sports activity in the high-risk population such as female athletes (Zazulak et al., 2007).

Regardless of age, the proportion of dislocations and fractures was relatively low. Younger soccer athletes did not sustain greater proportions of fractures even though there was decreased strength in the growing epiphyseal plates of long bones to external loading (Keller et al., 1987).

A study related to core strength development was conducted by Steffen et al. (2008) in Norway, which utilized female soccer players who participated in an Under-17 soccer league. Through the process of block-randomization, with four teams per block, the 113 teams were divided into an intervention group and a control group. Players in the control group did nothing different during their pre-event warm-ups. A core strength development program, the "11" (see Appendix C) was injected into the warm-up regimen of the intervention group.

Most of the injuries recorded in the Steffen et al. (2008) study were acute in nature (n=421, 87%). Those injuries were located in the lower extremity in the anterior lower leg, knee, and ankle. The anterior lower leg was the site for the most common overuse injuries (n=62, 13%) with anterior lower leg pain (29% of all overuse injuries) and knee pain accounted for 19%. Ankle sprains were the most common acute injury suffered by 28% of the players.

Of the 421 acute injuries, 42% were non-contact injuries, while 58% of the injuries occurred as a result of player-to-player contact. Contact injuries were higher during match play (86%, n=209), than contact injuries during training sessions (14%, n=33) (Steffen et al., 2008).

There was no significant difference in injury severity, type of injury, or location of injury between the control group and the intervention group. Over the time of the study by Steffen et al. (2008), nine ACL injuries occurred with five occurring in the control group and four occurring in the intervention group. Ankle sprains were the most common type of re-injury in both groups. There was no significant difference between the control group and the intervention group in the number of re-injuries.

It was suggested that females lack or tend to lack the strength needed in the hamstrings and or suffer delays in hamstring activation to help prevent ACL injuries (Hudy, 2004). Knee stabilization depended on the strength of the hamstrings. When the hamstrings were activated, they helped compress the joint, which helped restrain anterior motion of the tibia (Hewett et al., 1996). The combination of those two "...functions decrease anterior shear forces and greatly reduce load on the primary restraint to anterior tibial motion, the ACL." (Hewett et al., 1996, p. 772) There were several studies that looked at hamstring imbalances and the injuries that result from those imbalances. "The Prospective Study: Strength Imbalances and Prevention of Hamstring Injury in Professional Soccer Players" examined the relationship between muscle injury and strength disorders among professional soccer players. The study required professional soccer players to perform a pre-season isokinetic test designed to determine two factors. The first factor was whether or not strength variables would predict subsequent hamstring strain. The second factor being studied was whether or not normalization of balanced hamstring strength would reduce the incidence of hamstring injury (Croisier et al., 2008).

When hamstring strains were examined, the most predictive indicators were related to individual features (intrinsic factors) rather than environmental factors (extrinsic factors). "Injury is a common occurrence through rapid, active extension of the knee, which solicits eccentric action to the hamstrings decelerating the lower leg in the late swing phase." (Croisier et al., 2008, p. 1469) Hamstring muscles were also vulnerable to injury when they became active hip extensors during the rapid change from eccentric to concentric contractions. Further justification of the analysis of strength imbalance, as a factor for hamstring strains, was that at some exercise intensities, players exceeded the mechanical limits tolerated by the hamstring muscle unit. For the Croisier et al. (2008) study, professional soccer players from France, Belgium, and Brazil were recruited. In order to be considered eligible for the study, the following criteria had to be met by the players: (1) must be considered fit for competitive soccer activity by the team medical staff; (2) must have been involved in training sessions through the start of the new season; and (3) must have successfully completed the previous season as a healthy player. A total of 462 players who ranged in age from 20-32 years participated in this study (Croisier et al., 2008, p. 1470).

Players who were without deficits during preseason training did not perform subsequent isolated hamstring strengthening. The teams' physical therapists or athletic trainers supervised the hamstring conditioning program, which consisted of manual, isotonic, or isokinetic strengthening (Croisier et al. 2008).

Criteria for hamstring injury in that study included: (1) a physical examination, which showed pain on palpation, passive stretch, and active contraction of the involved muscle; (2) a diagnosis supported by ultrasonography or magnetic resonance imaging; (3) a player who missed four weeks of training and match time. The medical staff from each team documented hamstring injury data on standardized forms from the start of preseason to the end of the playing season (Croisier et al., 2008).

According to the hamstring study by Croisier et al. (2008), a significant difference was noted in hamstring injury frequency for one season and the preseason isokinetic status and the strengthening prevention program that was designed to correct the isokinetic parameters studied, or lack of participation in the strength prevention program. Players who did not have any preseason strength imbalance had an injury rate of 4.1%. Players with untreated imbalances had an injury rate of 16.5%. Untreated strength imbalances during soccer participation increased the risk of hamstring injury by more than four times when compared to a normal strength profile (Croisier et al., 2008).

A common injury to the hip involved the adductor muscles. The adductor group consists of five muscles: Adductor Longus, Adductor Brevis, Adductor Magnus, Pectineus, and the Gracilis. Those five muscles form the inner thigh or the area more commonly known as the groin (Brumitt, 2005). The pubic bone is the origin of the adductor muscles, which attach to the femur and tibia (Gracilis) (Brumitt, 2005). When the adductor muscles contract, they pull the leg across the midline of the body or adduct. The adduction of that muscle group stabilizes the leg during dynamic movements such as cutting or pivoting. They also help with deceleration (Brumitt, 2005).

Groin injuries were somewhat common among soccer players. Groin pains or injuries may be caused by a single injury, or gradually by multiple microtraumas caused by overuse due to sudden, powerful overstretching of the leg and thigh in external rotation and abduction (Smodlaka, 1980). Strains to the adductor muscles occurred when excessive eccentric forces were applied during movements of deceleration and the adductors were unable to handle the forces (Brumitt, 2005).

Indoor versus Outdoor

Rumpf and Cronin (2012) found that players 16 years of age and younger were found to have a 2-fold greater chance of sustaining an injury playing outdoor soccer than were older (>16) players. They also found a 4.5-fold greater chance of sustaining an injury playing indoor soccer when compared to outdoor play. The severity of injuries in indoor soccer was also greater than outdoor soccer for youth players (Rumpf and Cronin, 2012).

Keller and colleagues (1987) reported that a study of professional soccer players revealed the incidence of injury to be much greater during outdoor soccer, 1.45 injuries per player outdoor vs. 0.8 injuries per player indoor. Soccer athletes sustained more fractures, cuts, infections, and hamstring strains during outdoor soccer play compared to more tendinitis, dental injury, and upper extremity injuries during indoor soccer. During their study of Oklahoma youth soccer players, Sullivan et al. (1980) determined that the condition of the playing surface was a contributing factor in the number of injuries suffered by players. Their primary conclusion was that heavy use of outdoor fields prevented proper maintenance of the playing surface. In 1987, Keller et al. recommended further study and research be conducted in several areas regarding player safety and injury prevention. Areas for consideration were the effects of the pace of the game, presence of perimeter boards to the field of play, shock absorbing qualities of the playing surface, surface traction on the playing field, and the cleanliness of the playing environment (Keller et al., 1987).

Player Position

When considering the incidence of injury among players, player positioning was taken into account. Player positioning during soccer was unevenly distributed. For example, there was only one goalkeeper throughout a match, but depending on the flow of the game and the playing formation, as many as eight players were acting as defenders or strikers. Common formations are 4-4-2 (four defenders, four midfielders, and two strikers) plus a goalkeeper, 4-3-3 (four defenders, three midfielders, and three strikers) plus a goalkeeper, 3-5-2 (three defenders, five midfielders, and two strikers) plus a goalkeeper. During the Swedish senior men's study reported by Ekstrand, the formation of 4-3-3-1 (four strikers, three midfielders, three defenders, and one goalkeeper) was used to compare incidence of injury among player positions; no significant differences among players were reported. The formation of 3-3-4-1 (three strikers, three midfielders, four defenders, and one goalkeeper) was studied in the McMaster and Walter study of professional soccer athletes; no significant difference in the incidence of injury among players was reported. In a youth study of soccer athletes, midfielders sustained far fewer injuries than expected, whereas goalkeepers sustained a disproportionately higher number of injuries than expected. Better officiating in and around the goalkeeper might reduce the incidence of injury to goalkeepers (Sullivan et al., 1980, p. 326).

Kontos and Brown (2000) reported in their study that injury risk was similar across all positions with the exception being midfield players, who had the highest number of injuries on average. Forwards, defenders, and goalkeepers followed (Kontos and Brown, 2000). However, midfielders were found to have a low mean of injury severity. According to Kontos and Brown (2000), goalkeepers had the highest incidence of ankle injuries, compared to other positions. It was found that defenders had the most ankle sprains per player, while midfielders suffered the most contusions to the lower leg per player (Kontos and Brown, 2000).

Midfielders in the Kontos and Brown (2000) study experienced a higher number of injuries, minor in nature and low in severity. The results suggested that midfielders, who generally cover more of the field and run more than other positions, experience more contusions, sprains, strains, and overuse injuries because of the requirements of the position (Kontos Brown, 2000).

Rumpf and Cronin (2012) found similar findings to Kontos and Brown (2000) in that midfielders were injured more frequently. Defenders were injured more often than strikers and goalkeepers. The goalkeepers younger than 14 years of age were found to have similar injury as field players (Rumpf and Cronin, 2012). As with previous research, the incidence of injury was found to increase with age in all positions with the exception being goalkeepers (Rumpf and Cronin, 2012).

Practice versus Games

Players performed at a higher level of intensity during games. Because of the increased demands on players during games, the incidence of injury is likewise increased (Rumpf and Cronin, 2012).

According to research results, a higher incidence of injury occurred during games among youth players than during training sessions (62% compared to 38%). Among senior and older players, the incidence of injury occurred almost equally between games and training sessions (Keller et al., 1987). According to the incidence of injury results reported in the Ekstrand and Gillquist's study conducted in 1983, 84% of the overuse injuries occurred during training sessions, while two-thirds of the traumatic injuries occurred during matches. Amount of time spent in training sessions and match play differed among youth, older, and senior professional soccer athletes (Keller et al., 1987).

The quality of training along with the amount of training also affected injuries sustained by players. Rumpf and Cronin (2012) found that increased amounts of training sessions coupled with longer preseason training reduced the number of injuries players experienced during the regular season. The quality of training was also a factor in injury incidence. Injuries and muscle strains were reduced when training sessions incorporated proper warm-up and stretching (Rumpf and Cronin, 2012). Rumpf and Cronin (2012) found an increased risk of hamstring injuries when training sessions did not include special flexibility programs for hamstrings.

Player Factors in Soccer Injury

The predisposition of an injury can be due to characteristics of the player such as previous injuries, incomplete rehabilitation from previous injuries, poor flexibility, weakness, and pathologic joint laxity. A player's injury history contributes to the incidence of injury experienced by that athlete. Rumpf and Cronin (2012) found that youth players who suffered previous injuries or multiple injuries had a higher incidence of re-injury. Re-injuries to players were attributed to incomplete or insufficient rehabilitation (Rumpf and Cronin, 2012). Predisposition to injury was related to the athlete's gender. Rumpf and Cronin (2012) found that female soccer players experienced a higher rate of injuries than male soccer players. The higher rate of injuries for female soccer players was attributed to less experience and substandard technical skills (Rumpf and Cronin, 2012).

Numerous studies researched the disparity between sexes and injury, especially ACL injuries. When researching ACL injuries between male and female athletes, research was focused on three areas: anatomical, hormonal, and neuromuscular (Meyer et al., 2011).

The incidence of injury for female players, both non-elite and elite, was similar to that of male players. For every 1000 training hours, the range was from 1.2 to 7 injuries and for every 1000 match hours, the range was 12.6 to 24 injuries. The incidence of injury somewhat decreased in female adolescent players: 8.9-9.1 and 1.5-2.6 per 1000 match and training hours (Steffen et al., 2008).

Poor flexibility was not only an injury factor for soccer athletes but also for athletes participating in other sports. Keller et al. (1987) found in a study conducted by Ekstrand and Gillquist of the senior Swedish soccer players, that the flexibility of the soccer players was significantly less in hip abduction and extension, ankle dorsiflexion, and knee flexion when compared to age-matched controls who were not soccer players. The study did not find the reason behind the decreased flexibility. It may have been a result of the type of training program implemented within the teams as well as a reflection of old injuries. Senior soccer players with decreased flexibility were found to have more incidence of tendinitis and muscle strain than soccer players with normal flexibility. The study also found that 11% of all sustained injuries were related to muscle tightness. The findings from the senior Swedish soccer players' study suggested that soccer players could benefit from conditioning programs designed to increase flexibility even though it does not prove causality (Keller et al., 1987).

Soccer injuries to both the ankle and the knee were predisposed by pathologic ligamentous laxity. Research in Ekstrand's senior Swedish soccer players cites that 71% of noncontact knee injuries occur due to pathologic ligamentous laxity from previous injuries. The most common example of a noncontact knee injury was that of recurrent giving-way episodes in the knee with chronic deficiency in the anterior cruciate ligament. Reoccurring ankle sprains were attributed to previous injury to the lateral ligaments of the ankle. Senior soccer players with a history of previous ankle sprains sustained new ankle sprains twice as often as soccer players without a history of ankle sprains. Evidence does not suggest normal physiologic laxity was associated with an increase in injury rates (Keller et al., 1987).

It has been suggested that knee injuries in other sports are predisposed by strength asymmetry. The Swedish senior soccer study by Ekstrand examined this possibility as well. The study compared H/Q ratios, hamstring strength in relation to quadriceps strength, in injured and non-injured athletes. The study found that knees, which subsequently sustained noncontact injuries, also had preexisting quadriceps weakness. It was also found in that study that noncontact knee injuries sustained were due to previous injury, which caused pathologic ligamentous. The cause of re-injury cannot be distinguished between abnormal knee laxity or muscle weakness (Keller et al., 1987).

The findings from the Swedish senior soccer players' study by Ekstrand suggested that athletes had received incomplete rehabilitation since there was a correlation between new knee and ankle injuries with previous injury to the same joint. During that study, 20% of the minor injuries were followed by moderate or major injuries within two months, which supported the evidence of incomplete rehabilitation by the athletes. The second injury sustained by athletes was more severe in nature than the initial injury. Those findings could lead to speculation that athletes are predisposed to recurrent injuries and or new injuries because of inadequate rehabilitation and healing due to altered coordination, balance, skill, self-confidence, flexibility, muscle strength, and cardiovascular endurance (Keller et al., 1987).

In their study, Croisier et al. (2008) clarified that hamstring injury was influenced by strength imbalances. When compared to the normal group, players with untreated strength imbalances were four to five times more likely to sustain an injury.

Other Injury Factors

Bracing

Prophylactic and functional knee bracing has generally been studied in football players and not specifically in soccer players. Silvers reported in her 2009 study that there was no conclusive evidence that showed the use of functional knee braces prevented ACL injuries. Silvers reviewed the study by Deppen and Landfried conducted in 1994, in which they examined high school football players over a four-year period. The results showed no significant difference between football players who wore prophylactic knee braces and football players who did not wear prophylactic knee braces in preventing ACL injuries (Silvers, 2009).

Footwear

Soccer cleats or boots come in many different varieties depending on playing surface, artificial turf or natural grass, and player preference. Smaller cleats are usually worn on artificial surfaces, while longer cleats are worn on natural surfaces. Molded cleats and sometimes screw-in metal stud cleats are worn when playing on natural grass. Longer grass conditions warrant the metal stud cleats. Whatever type of soccer cleat is worn, " ...it is important to remember that although an increased friction coefficient may enhance performance, it may also inadvertently increase ligamentous injury." (Silvers, 2009, p. 85) Silvers' research noted in previous research by Ekstand and Nigg in 1989 that "...there is an optimal range to be incorporated in shoe design-one that will minimize rotational friction to avoid injury yet optimize transitional friction to allow peak performance when performing activities such as cutting and decelerating." (Silvers, 2009, p. 85)

Independent factors that may have increased noncontact ACL injuries in females were that of playing surface and shoe type. Silvers (2009) reported on a study that compared incidence of ACL injury between male and female European handball teams who played on either a wooden floor or artificial floor. The study found that the risk of noncontact ACL injury to women was higher than was the risk to men when both played on artificial floors (Silvers, 2009).

Weather

Weather contributes to the risk of injury when playing on natural surfaces in outdoor venues. When playing on natural grass, wet weather compromises the integrity of the field. One-fourth of the total injuries reported in both the Swedish senior soccer players' study by Ekstrand and the Oklahoma youth study by Sullivan et al. (1980) were attributed to poor field conditions. Criteria for determining injuries due to field conditions were not specific. Poor field conditions were attributed to weather and irregularities in playing surfaces of the field. Weather cannot be controlled. Players can choose appropriate shoes for playing surfaces and weather conditions. Athletes can choose from a wide variety of playing shoes that are made for every type of field. There was insufficient data to be able to compare cleat design with safety of shoe type. Current belief is that screw-in type cleats present a higher risk for ankle and knee injuries. The molded or ribbed sole cleats may be a safer option for athletes (Keller et al., 1987).

A study conducted by Orchard and Powell in 2003 and cited by Silvers (2009), researched weather and its correlation to knee and ankle sprains during 5,910 NFL team games (Silvers, 2009). Teams playing on grass fields suffered fewer incidences of significant knee sprains than teams that played on artificial turf. The study also found that cold weather in open/outdoor stadiums was associated with a lower risk of ACL injuries when compared to the same stadiums during hot weather. The incidence of ACL injuries was lower during the cooler months of the season in both open natural grass and artificial turf stadiums. The results did not show the same results for closed domes. The researchers concluded that there was a lower risk of knee and ankle sprains in cold weather in outdoor stadiums with either natural grass or artificial turf. "This reduction is most directly related to lower shoe-surface coefficients." (Silvers, 2009, p. 86)

Maturation and hormones

Numerous studies have been conducted over the years examining the biological, anatomical, and maturational differences between boys and girls and the relationship those differences played in injury severity and rates of injury in organized sports. The most important item was how those relationships affected growth and maturation of young female athletes.

There are three different processes that children progress through as they age: growth, maturation, and development (Baxter-Jones, Thompson, and Malina, 2002). The three processes occur simultaneously and vary among individuals. Growth refers to the specific size of a child's body as a whole and its parts. Maturation refers to the progression of the child's body towards the biologically mature state. Children mature at different rates as they grew to maturity. Maturation consists of two components: timing and tempo. Timing refers to the specific age related events that occur during the maturational process, such as the age when a female reaches menarche, the age breast development begins in females, the age that pubic hair first appears for both males and females, or the age in which maximal growth is achieved during growth spurts in adolescents (Baxter-Jones et al., 2002). Tempo refers to the speed of progression an individual reaches a mature state (Baxter-Jones et al., 2002). Development refers to the time in which children attain and demonstrate appropriate behavioral skills. Behavioral skills are culture specific, determined by the child's experiences at school, home, while playing sports (both organized and unorganized), during recreation, and life itself. Through those experiences, children learn and develop socially, emotionally, and cognitively (Baxter-Jones et al., 2002).

Skill level and performance often determine the status of young female athletes. The elite athlete possesses the best skills and performs at the highest level, which can be affected by the athlete's stature, body type, and any other environmental factors the athlete may have experienced (Baxter-Jones et al., 2002). Baxter-Jones et al. (2002) reported that females participating in basketball, volleyball, tennis, and swimming had mean statures above the 50^{th} percentile of the reference populations from the age of 10 and onwards. Elite figure skaters, gymnasts, and ballet dancers tended to be shorter in stature during early adolescence, then catch up to their peers in late adolescence (Baxter-Jones et al., 2002). Body mass was found to have similar findings (equal to or exceeding reference medians) with female athletes participating in sports other than gymnastics, ballet, and figure skating, who had lighter body masses (Baxter-Jones et al., 2002). Female distance runners also had lighter body masses.

An athlete's physique or somatotype may also be a determining factor in the sport in which the athlete participates. There are three contributing and different components to an athlete's physique: endomorphy referred to roundness of contours, fatness; mesomorphy referred to the dominance of muscular and skeletal development; and ectomorphy referred to the linearity development (Baxter-Jones et al., 2002). According to Baxter-Jones et al. (2002), athletes participating in the same sport generally had similar somatotypes and when compared to the general population they exhibited limited range of variability. Successful adolescent athletes have been shown to have similar body types as adult athletes in the same sports, which is usually less endomorphic and mesomorphic and more ectomorphic (Baxter-Jones et al., 2002).

Knee injury rates were of particular interest when comparing injury rates between boys and girls. It was hypothesized that girls were more prone to knee injuries, especially ACL injuries than boys due to the biological and anatomical differences. When comparing boys to girls, given the anatomical variations between the two, the nature of the sport was an important factor for risk of knee injury or knee surgery (Powell et al., 2000).

The study by Powell and Barber-Foss (2000) examined the risk of injury between male and female high school athletes participating in similar sports such as baseball and softball. Their search sought to determine if boys and girls playing different sports, which utilized similar skills, suffered similar injuries as boys and girls who played basketball. The study was three years in duration from 1995-1998 (Powell and Barber-Foss, 2000).

In the games of baseball and softball, the rules of the game differ but the skills required to play are similar for both sports. It was found that girls who played softball suffered a 27% higher injury rate than boys who played baseball. When injuries were combined for both sports, the majority of injuries were strains. The most common injury site for both sports was the forearm/wrist/hand (Powell and Barber-Foss, 2000).

Boys and girls who played basketball utilized similar skills, played by the same rules, practiced similarly, played similar game schedules, and played on teams of equal size. When injury results were compared between the two sports, the girls' teams suffered a slightly higher injury rate than did the boys' teams. The most common injury site for both groups was the ankle/foot. Boys' teams had fewer injuries in the hip/thigh/ leg than did girls' teams as well as knee injuries. Sprains were the most common types of injuries for both groups. Girls' teams had a higher percentage of severe or major injuries than did the boys' teams (Powell and Barber-Foss, 2000)

High school soccer is similar for both boys and girls. Powell and Barber-Foss (2000) found the injury patterns to be different when comparing injuries between the boys' and girls' soccer teams. The girls' teams had a slightly higher percentage of injuries in the ankle/foot. Boys' teams had a higher percentage of injuries to the hip/thigh/leg. Sprains were the most common type of injury for both groups. Knee injury percentages were higher in girls' teams than boys' teams (Powell and Barber-Foss, 2000).

Powell and Barber-Foss (2000) found that 76% of all knee injuries reported among the six sports were to connective tissue. The injury rates for baseball and softball were small but the knee injury rate was higher in softball than in baseball. Baseball injuries required more knee surgeries and more ACL surgeries than softball injuries. In basketball, girls' teams had higher rates for knee injuries, knee surgeries, and ACL surgeries when compared to the boys' teams. Results were similar for knee injuries, knee surgeries, and ACL surgeries in soccer with girls' teams having higher rates in all three categories (Powell and Barber-Foss, 2000).

Powell and Barber-Foss (2000) studied comparison of injury data between boys and girls in soccer, baseball and softball in the same context as boys' and girls' basketball. Data showed that knee injury and knee surgery rates were higher in girls' basketball and soccer than in boys' basketball and soccer. Girls' soccer showed an overall higher injury rate than any of the other sports in the study. The study supported the hypothesis that girls playing basketball and soccer have a greater risk of knee injury and knee surgery than boys playing basketball and soccer (Powell and Barber-Foss, 2000). From the results of the study "Sex Related Injury Patterns" by Powell and Barber-Foss (2000, p. 390) "It also appears that knee stresses during basketball and soccer have a greater potential to cause knee injury and possibly knee surgery in girls than in boys."

When looking at sports related injuries in female athletes, ACL injuries, contact or noncontact, occurred more frequently than did other injuries in a sport like soccer that requires players to land from jumps, decelerate quickly, and change directions rapidly. "High risk maneuvers such as these require balance, coordination, and strength, and they result in higher loads on the joints than those experienced during straight-ahead running." (Chaudhari et al., 2007, p. 794) ACL injuries tend to happen more in contact sports like soccer but are usually noncontact in nature (Chaudhari et al., 2007). The fact that female athletes suffered more ACL injuries than do male athletes had resulted in researchers studying intrinsic factors like hormones and the correlation between a female's menstrual cycle and the hormonal changes that occurred during that time and the possible increase of ligamentous injury, such as ACL injuries. Numerous studies comparing ACL injury rates between male and female athletes have used participants who were post pubescent or high school age or older (Chaudhari et al., 2007). Before puberty, males and females are similar in strength and endurance. Puberty causes hormone changes, increases in estrogen in females and increased testosterone in males. The increased levels of estrogen in females cause increased fat deposition and broadening of the pelvis; however, increased levels of estrogen do not cause an increase in muscle strength or muscle mass. The increased levels of testosterone in males cause an increase in muscular strength and mass (Chaudhari et al., 2007). Males may have a decreased risk of ACL injury due to the increased strength and increased muscle strength balance between antagonistic muscle groups, which may be used to protect the knee during jumping and landing activities (Chaudhari et al., 2007). As males' chronological age increases, power, strength, and coordination is demonstrated. Females demonstrate a lack of increased strength at the onset of maturation stages (Meyer et al., 2011). There is also a correlation between height, weight, and neuromuscular performances seen in males during puberty (Meyer et al., 2011). Females during that time do not demonstrate the same correlation between height, weight, and neuromuscular performance (Meyer et al., 2011). Females are more prone to the development of intrinsic risk factors for ACL injuries during puberty because of the musculoskeletal growth without the corresponding neuromuscular adaptations (Meyer et al., 2011).

Early investigators noticed during the menstrual cycle, differences occurred that increased susceptibility to injury beyond that of hormone changes during puberty (Chaudhari et al., 2007). The menstrual cycle was based on a mean of 28 days. It was broken into three phases. Days 1-9 were considered to be the follicular phase. During that phase, there were low levels of both progesterone and estrogen. During the later stages of the follicular phase there was an increase in estrogen levels that continued into the ovulation phase which was days 10-14. Days 15-28 make up the luteal phase. During that phase, the progesterone levels increased, as did relaxin levels during the second half of that phase. Research was conducted to determine if the fluctuation of progesterone, estrogen, and relaxin during the menstrual cycle caused the integrity of the ACL to become compromised allowing the ACL to be more susceptible to injury. Receptor sites for progesterone, estrogen, and relaxin were found within the ACL. Research has not provided any conclusive evidence linking increased ACL injury to any of the three phases that occurred during the menstrual cycle (Silvers, 2009).

Chaudhari et al. (2007) investigated hormone cycling in women and what effect(s) it had on the knee during the loading environment when performing high risk maneuvers. Twenty-five women and 12 men participated in the study "Knee and Hip Loading Patterns at Different Phases in the Menstrual Cycle." The women were divided into two groups: no oral contraceptive (12) and oral contraceptive (13). It was hypothesized that during the different phases of the menstrual cycle, jumping and landing activities varied in a way that caused differences in foot strike knee flexion and peak knee and hip loads in women not taking an oral contraceptive but not in women who took an oral contraceptive (Chaudhari et al., 2007). A second hypothesis for the Chaudhari et al. (2007, p. 795) study "...was that the peak joint loads would be higher in women than in men." Results of the study showed that during the performance of jumping and landing activities, there were no kinematic or loading differences that could be related to the menstrual cycle (Chaudhari et al., 2007). There were no significant differences in either foot strike knee flexion or the moments acting at the hip and knee in any of the three phases of the menstrual cycle for the two groups of women. There were no significant differences found when comparing the two females groups and the male group, the exception being the peak internal rotation moment at the hip during the landing from a vertical jump ($p<0.01$). Men averaged significantly higher peak values (Chaudhari et al., 2007). The Chaudhari et al. study found "...that neither hormonal cycling nor the use of an oral contraceptive in women appears to influence the loading at the knee or hip joint during the 3 types of jumping activities that were examined." (Chaudhari et al., 2007, p. 798) When comparing the men to the two female groups, there was statistical significance in higher peak hip internal rotation moment in the men during the vertical jump activity (Chaudhari et al., 2007)

Foul play

Thirty percent of traumatic injuries in a Swedish senior soccer players' study by Ekstrand were attributed to foul play. Injuries due to foul play usually occurred to the players who committed the foul. In order to decrease injuries associated with foul play, it was necessary for coaches and referees to teach proper play and sportsmanship (Keller et al., 1987).

During the one-year study by Ekstrand with the Swedish senior soccer players', 184 out of 256 injuries (72%) were associated with foul play. A chance event was considered to be the cause for the remainder of the injuries. It was difficult to quantify what association player skill level, personality, and psychological factors had on injuries (Keller et al., 1987).

Soccer Injury Prevention

Soccer injury prevention has been attracting more interest with more research being conducted. When deciding what type of program was warranted, consideration was given to "...whether the teams' or athletes' primary goal is injury prevention, performance enhancement, or both." (Hewett et al, 2006, p. 494) Research has placed an emphasis on "...biomechanical risk factors and the utilization of neuromuscular and proprioceptive intervention programs to address potential biomechanical deficits." (Silvers, 2009, p. 87) New knowledge and new ways to prevent injuries in both the professional athlete and the recreational athlete have become available. Junge and Dvorak (2004, p. 933) found common components of injury prevention in soccer in their research that included: "... warm-up with more emphasis on stretching; regular cool-down; adequate rehabilitation with sufficient recovery time; proprioceptive training; protective equipment; good playing field conditions; and adherence to the existing rules." Before implementing an injury prevention program into a sport, it must be understood how the program will "fit" into the general physical, mental, technical, and tactical aspects of that sport (Hudy, 2004). "Preventing injury implies the identification and understanding of the factors leading to that injury. Such an approach could allow the development of the most appropriate strategy for reducing the risk." (Croisier et al., 2008, p. 1469) Ken Kontor (2010) for Performance Soccer Conditioning has outlined four basic concepts to consider when training female athletes with ACL injury prevention as the goal. He suggested that the four concepts be incorporated into a strength and conditioning program. The first concept is to start young. All athletes are different but beginning preventative conditioning that builds strength in muscles, bones, tendons, and ligaments should begin in late elementary or early middle school. Concept two is learning proper mechanics. Coaches or strength and conditioning personnel need to teach proper mechanics of jumping, landing and changing direction. This helps "...to reduce the number of uncompromised positions the female athlete may find themselves in during practice and competition." (Kontor, 2010, p. 2) Proper mechanics are also improved with increased balance. The third concept is to train in a quality environment. Kontor (2010) suggested that an injury prevention program should be implemented during the warm-up period so as to avoid fatigue that occurs during training and competitions. Muscle fatigue causes reactions to become slower, which could cause the athlete to perform exercises with improper technique. The fourth concept of Kontor's (2010) injury prevention suggestions is that of building strength. Reduction of injuries and severity of injuries could be accomplished with stronger joints, tendons, ligaments, and muscles in the lower extremity and the core. Stronger lower extremity and core would improve balance and mechanics. Kontor (2010) felt that the strength goal of any female athlete is to effectively control her own body weight.

Injury prevention programs should be incorporated into the warm-up both during season and during preseason. Longer pre-season training has been shown to reduce the occurrence of injuries (Rumpf and Cronin, 2012). Soccer specific injury prevention programs should include exercises that "...take different forms of muscle contractions, including speed and joint position related to game actions." (Rumpf and Cronin, 2012, p. 30) Screening programs incorporated into the injury prevention program would help identify those players who are more prone to injury. The screening programs identified the player's injury history, joint stability, any muscle tightness, and any asymmetries that might exist (Rumpf and Cronin, 2012).

Injury prevention programs developed for youth players should include exercises that account for the following outcomes found by previous research: "...(a) injury incidence increased with age and especially after the age of 14 regardless of maturity and experience, (b) the lower extremities, mainly the ankle and knee joints and accompanied muscles and ligaments of the thigh and calf, were the most injured body site (80%), (c) severe injuries were more likely to be experienced by low-skilled players, (d) indoor soccer had a greater risk of injury compared with outdoor soccer, (e) poor field conditions were a significant external factor affecting injury occurrence, and (f) higher incidence of injury occurred in female players." (Rumpf and Cronin, 2012)

It should be noted that sexual maturation of young female athletes was considered when developing prevention programs that involved weight training for muscular strength increases. The onset of puberty would be an appropriate time to begin intervention programs like neuromuscular training to help overcome the deficits female athletes demonstrate in neuromuscular adaptations during musculoskeletal growth (Meyer et al., 2011). The study by Bohme et al. (1998) found that sexual maturation had a significant influence both alone and as a moderator effect on other variables in muscle groups like legs, arms, and trunk flexors. In another study by Bohme, Kiss, Mattos, and Bojikian (2000), it was found that sexual maturation significantly affected arm strength and agility in both test groups (group 1=11-12 years old and group 2=13-15 years old). Sexual maturation did not significantly affect other performance variables found in the testing of horizontal jump, sit-ups, 9 minute run, sit and reach, and 30m dash (Bohme et al., 2000).

Injuries sustained in soccer were predominantly in the ankle and knee as well as the muscles of the thigh and calf (Junge et al., 2002). "Injury prevention is the key for any athlete during their season." (Thomsen, 2008, para. 1) Junge and Dvorak (2004) found one such research study conducted on 300 female high school players ranging in age from 14-19 years. Forty-two players were randomly selected to participate in the Frappier Acceleration Training Program during the pre-season for seven weeks. The Frappier Acceleration Training Program consisted of sport-specific exercises that included: cardiovascular conditioning, plyometric work, sport-cord drills, strength training, and flexibility exercises designed to improve speed and agility (Junge and Dvorak, 2004). The results of the study showed "...the untrained group had a significantly higher incidence of injury (34%) compared with the trained group (14%)." (Junge and Dvorak, 2004, p. 935)

Studies from different sports have shown promising reductions in injury rates using training protocols which incorporate one or more exercise components focused on balance, strength, and or agility training (Steffen et al., 2008). Strength training exercises that were eccentric in nature reduced injuries (Edwards, 2006). "One factor that has been identified as a factor in knee injuries in female athletes is the variations in the types of conditioning programs for female athletes." (Powell and Barber-Foss, 2000, p. 390) In regards to ACL injury prevention, knee stability was vital in order to prevent injury to the ACL and other ligaments and menisci of the knee. Knee stability was achieved through exercises that improved muscular strength and recruitment patterns. The ratio between quadricep and hamstring strength was examined to determine what role each played in ACL injury prevention or injury. Because of the attachment site of the quadriceps, the antagonists of the ACL, the anterior shear force on the tibia increases. The hamstrings are the agonists for the ACL. They "...reinforce the ligament by preventing the excessive anterior translation of the tibia." (Silvers, 2009, p. 88) If there is a delay in contraction time of the hamstrings compared to the quadriceps, or if the hamstrings show weakness, then the ACL may be at an increased risk of injury, resulting in tensile failure (Silvers, 2009).

Silvers (2009) cited several studies that varied both in participant size and duration of study. One such study was conducted in Italy with 600 participants who were either semiprofessional or amateur soccer players. A 5-phase proprioceptive balance training program was implemented. Results showed an overall 87% decrease of ACL injuries in the experimental group when compared to the control group (Silvers, 2009). Another injury prevention study cited by Silvers (2009) was neuromuscular training over a 6-week period. The 1,263 male and female athletes from various sports participated in stretching, plyometrics, and weight training exercises. After the 6 week intervention, the untrained group consisting of female athletes suffered a 2.4-3.6 times higher incidence for serious knee injury compared to the trained group of athletes. The results also showed that trained female athletes did not suffer a noncontact ACL injury, whereas five untrained female athletes suffered noncontact ACL injuries (Silvers, 2009). A one-year study of 14-18 year old female soccer players was conducted using the Frappier Acceleration Training Program consisting of strength training, flexibility, sports-specific cardiovascular exercise, plyometrics, and sports-cord drills for seven weeks during the pre-season. The untrained group suffered an incidence of 3.1% of ACL injuries compared to the trained group who suffered 2.4% of ACL injuries.

Silvers (2009) was involved, along with several other researchers, in the development of the Santa Monica PEP ACL Prevention Program. The program was used with female soccer athletes in two different age groups: 14-18 year olds and 18-22 year olds. Both intervention groups were compared to control groups of the same age and skill level. The program was a 20-minute warm-up prior to regular training sessions over a two-year period. Following the 2000 soccer season, the intervention group suffered two ACL tears confirmed by MRI with an incidence rate of 0.05 ACL injuries/athlete/100 exposures; where as, the control group suffered 32 ACL tears with an incidence rate of 0.47 ACL injuries/athlete/100 exposures. An 88% overall reduction in ACL injury was reported. The second year of the two-year study (2001) showed four ACL tears in the intervention group with an incidence rate of 0.13 injuries/athletes/1,000 exposures. The control group resulted in 35 ACL tears with an incidence rate of 0.51 injuries/athletes/1,000 exposures. Overall reduction of ACL injuries was 74% (Silvers, 2009).

Silvers (2009) was also involved in the follow-up study of the PEP Program used in Division I Women's Soccer Teams during the 2002 Fall season. That particular study used a randomized controlled trial. The study consisted of 1,429 athletes from 61 different teams. The control group had 854 athletes from 35 teams. The intervention group had 575 athletes from 26 teams. The study was one fall soccer season in duration during 2002. With regards to all athletes participating (intervention and control), there were no significant differences between age, height, weight, or previous ACL injuries. The intervention group suffered seven ACL injuries compared to 18 ACL injuries in the control group. When comparing noncontact ACL injuries between the two groups, the control group suffered a rate three times that of the intervention group. Control group athletes, who had a prior history of ACL injuries, suffered an ACL injury 5 times more frequently than athletes in the intervention group with a history of prior ACL injury. The difference reached significance when limited to noncontact ACL injuries during that season. Significant difference was also reached in the rate of ACL injuries that occurred during the second half of the season, week 6-11 (Silvers, 2009) "This would support the concept that it takes approximately 6 to 8 weeks for a biomechanical intervention program to impart a neuromuscular effect." (Silvers, 2009, p. 91)

Hewett et al. (2005) conducted a study on ACL injuries in female athletes. The study was designed to investigate the biomechanical measures of neuromuscular control and valgus loading of the knee to predict anterior cruciate ligament injury and to what extent female athletes were at risk. Previous research has suggested that one of the primary contributing factors of ACL injuries of female athletes is that of poor or abnormal neuromuscular control of lower limb biomechanics (Hewett et al., 2005). Of particular interest was the knee joint during the execution of potentially dangerous maneuvers such as jumping, landing from a jump, pivoting, cutting, or decelerating (Hewett et al., 2005). Hewett et al. (2005) explained that stabilization of the knee joint while performing a dynamic movement occurred as a result of active muscle force combined with passive ligament restraints. Potential 3-dimensional forces may be experienced by the ACL during such sports that involve dynamic movements "…if the musculature that controls the knee joint does not sufficiently dissipate the associated torques and forces." (Hewett et al., 2005, p. 493) Prior research, which investigated neuromuscular training, has proved that such training does decrease ACL injury rates in female athletes.

Hewett et al. (2005) investigated 205 female adolescent players from volleyball, basketball, and soccer. The study was conducted during the summer of 2002 and 2003, as well as the fall of 2002. It consisted of two fall soccer seasons and one winter basketball season. All athletes were screened via 3-dimensional biomechanical analyses before their seasons began. All participants performed a drop vertical jump immediately followed by a maximal vertical jump with arms raised as in rebounding a basketball to quantify knee joint flexion-extension and adduction-abduction.

Upon completion of the Hewett et al. (2005) study, nine total ACL injuries occurred, seven in soccer and two in basketball. The study found knee abduction angles to be significantly different between the ACL injured group and the uninjured group at initial contact and at maximum displacement. The females who suffered ACL injuries were found to have greater knee abduction angles at initial contact and at maximum contact. Between the two groups, injured and uninjured, there was no difference at initial contact for knee flexion angle. The uninjured group had a greater knee flexion angle at landing than the injured group. Hewett et al. (2005) found a significant correlation between maximum knee flexion angle and peak force which was present in the uninjured group but was not present in the injured group. It was found that those athletes who suffered an ACL injury during the study had a greater stance phase peak external knee abduction moment when compared to those who did not suffer an ACL injury. The injured group also increased its vertical ground reaction force (GRF). The injured group was found to have significant correlations between knee abduction moment and angle and peak GRF. The injured group did not have a greater hip adduction moment than the control group, but there was a correlation to knee abduction moments. The uninjured group had a greater stance time (16%) than the injured group. It was found that the injured group had a 6.4 times greater side-to-side knee abduction moment than the uninjured group (Hewett et al., 2005).

The females in the Hewett et al. (2005) study who suffered an ACL injury during their respective seasons demonstrated altered neuromuscular control characteristics greater than those who did not suffer an ACL injury. The differences were noted in the lower limb biomechanics during the jump-landing movement tasks. More specifically, the females who suffered an ACL injury "...demonstrated significant increases in dynamic lower extremity valgus and knee abduction loading before sustaining their injuries compared to uninjured controls." (Hewett et al., 2005, p. 497) The increases in valgus measurements found in the injured group and not the uninjured group was likely a contributing factor for ACL injury. The primary predicators of ACL injury risk found by Hewett et al. (2005) were that of knee valgus angles and moments during the impact phase of jump-landing maneuvers. Increases in ACL force was due to valgus loading. "Physiologic valgus torques on the knee can increase anterior tibial translation and loads on the ACL by several fold. Sagittal plane variables, however, specifically knee flexion and hip and knee flexion-extension moments, were not observed to be significant predictors of ACL injury potential." (Hewett et al., 2005, p. 497) During such maneuvers that require landing, pivoting, cutting, deceleration, female athletes should be encouraged to avoid extreme valgus alignment (Hewett et al., 2005).

Hewett et al. (2005) suggested that instructing and teaching female athletes safer movement patters through neuromuscular training may help reduce high knee abduction loads that increase risk for ACL injuries during sports that require the athlete to jump, pivot, cut, and decelerate. Prevention strategies that improve muscular strength in the hamstrings and quadriceps, which promotes stability of the knee, particularly in the coronal plane, would help in reducing the risk of ACL injury in female athletes (Hewett et al., 2005). Neuromuscular training could possibly alter biomechanical movements, increase lower extremity muscle strength and recruitment positively in female athletes (Hewett et al., 2005).

Meyer et al. (2011) created a simple assessment that helped identify lower extremity technical deficits during plyometric training. Properly trained coaches and strength training coaches could evaluate athletes for technical deficits using the tuck jump because it requires athletes to perform the exercise with a high level of effort. The tuck jump could also be used for continuous assessment of an athlete's lower extremity biomechanics and performance as training progresses (Meyer et al., 2011). When assessing an athlete's performance using the tuck jump, there were four risk factor categories to assess. The four risk factor categories were: ligament dominance, quadriceps dominance, leg dominance or residual injury deficits, and trunk dominance or "core" dysfunction (Meyer et al., 2011). When assessing those four risk factor categories the evaluator should look for the following characteristics: 1) ligament dominance- lower extremity valgus at landing and foot placement less than shoulder width apart, 2) quadriceps dominance-excessive landing contact noise, 3) leg dominance or residual injury deficits-thighs not equal side to side during flight, foot placement not parallel (front-to-back), foot contact timing not equal, 4) trunk dominance or "core" dysfunction-thighs do not reach parallel (peak of jump), pause between jumps, and do not land in the same footprint (Meyer et al., 2011).

With neuromuscular training, the athlete who demonstrated one or several of the above risk factors during the tuck jump assessment could improve the neuromuscular control and biomechanics throughout the complete jump-landing sequence with practice and instruction from the coach or strength coach. Upon perfection of the tuck jump the athlete will have gained dynamic neuromuscular control of his/her lower extremity (Meyer et al., 2011). The athlete could take the newly learned skills and transfer them to competition performance (Meyer et al., 2011).

Meyer et al. (2011) showed that neuromuscular training completed during the pre-season was more beneficial than during in-season training. Pre-season neuromuscular training in the perfection of the tuck jump was highly promoted by Meyer et al. (2011) and they suggested it should be of importance in the strength and conditioning program of female athletes to help minimize and prevent ACL injuries.

According to a study completed by Edwards (2006) conducted in the United Kingdom, the incidence of injury to the hamstring among professional rugby players was 0.27 per 1000 player training hours and 5.6 per 1000 player match hours. In the U.K. study reported by Edwards (2006), Dr. John H.M. Brooks found that professional rugby players who included the Nordic hamstring protocol in their training had a lower incidence of injury as well as lower severity of injury. In another study conducted in Norway, researchers found that soccer players who included the Nordic hamstring protocol in training increased hamstring torque and strength when compared to soccer players who only performed hamstring curls (Edwards, 2006). "The Nordic hamstring exercise calls for the athlete to kneel with his ankles held down, either by a partner or a low bar, lean slowly forward without touching the ground, then come quickly back to the starting position using the hamstrings. This loads the muscle in the eccentric phase rather than the concentric phase, as with hamstring curls." (Edwards, 2006, p. 1)

After establishing the association of potential injury factors and soccer injury, Keller et al. (1987) designed a preventative program to help prevent injuries. Before and after play in both training sessions and match play, warm-up and cool-down periods were implemented. During both periods, mandatory stretching exercises consisted of proprioceptive neuromuscular facilitation techniques. All players were required to wear shin guards, which covered the malleoli, and tibial crest. Shin guards were to be worn during both training sessions and match play. Ribbed soled, all-terrain shoes were worn during winter play. Players with a previous history of ankle sprains or instabilities (48%) had their ankles taped before training sessions and match play. In order for an injured player to return to play, a physician and physical therapist had to approve. Full range of motion and 90% of normal muscle strength was also required by a physical therapist in order for an injured player to begin play again. Players who experienced laxity in the anterior cruciate ligament of the knee were not allowed to play. Following that injury prevention program for the duration of the season, there was a 75% reduction in the incidence of injury in the Swedish senior soccer players' study by Ekstrand. That reduction resulted in an 80% decrease in the teams' medical cost for caring of injured soccer players (Keller et al., 1987).

The findings of the hamstring injury prevention study demonstrated the need for injury prevention among professional athletes. Such an injury prevention program would consist of a preseason isokinetic assessment followed by a specific strengthening program for the players. In the investigation of Australian professional soccer players by Verall, it was found that in addition to risk of injury when players competed before completing resolution of muscle strength performance, that there was also a decrease in performance (Croisier et al., 2008).

According to the study on hamstring injury prevention by Croisier et al. (2008), a preventative weight- or manual-strengthening program should be implemented for all players to help reduce incidence of hamstring injury. Implementation of classic training with specific sequences aimed at strengthening the hamstrings was suggested on the basis of field experience with professional soccer players. Specific training to address the muscle imbalance between agonist and antagonist muscle groups would significantly reduce the risk of injury for athletes (Croisier et al., 2008).

Stabilization of the pelvis is a primary function of the hamstring. The attachment site of the hamstrings helps prevent forward tilt of the pelvis. If the hamstrings are overstretched, the pelvis tilts forward, causing the hamstrings to feel tight and sore, which could increase the risk of injury (Drummer, 2008).

Overstretched hamstrings could also increase the risk of injury to different areas beginning in the low back and moving in a superior direction in the body. When the pelvis is tilted forward, the muscles in the low back are arched, causing low back pain. Arching of the back muscles, which are attached to the spine, could cause altered breathing ability through the diaphragm due to elevated ribs in the front. When breathing was altered, neck muscles are used to help with breathing which causes neck pain, jaw pain, and even headaches (Drummer, 2008, para. 4).

Steffen et al. (2008) studied the injury prevention program the "11" that was created by an expert group convened by the Federation Internationale de Football

Association or FIFA (see Appendix C). The "11" injury prevention program was designed as a structured warm-up. The warm-up targeted the most common injuries in soccer, which were hamstring and groin strains, and knee and ankle sprains. The "11" program was based on previous research on injury prevention as well as established rehabilitation principles for injuries (Steffen et al., 2008). The "11" injury prevention program consisted of 10 exercises that focused on balance, dynamic stabilization, eccentric hamstrings strength, and core stability (Steffen et al., 2008).

The main focus during the introduction of the "11" to the teams was on proper exercise performance. Encouragement was given to the players for concentration on the quality of movements. There was also an emphasis on core stability, hip control, and proper knee alignment. Emphasis was given in those three areas in order to avoid excessive genu valgus in both dynamic and static balance exercises as well as landings from jumps (Steffen et al., 2008). The main focus when performing exercises for injury prevention was to perform the exercises properly with concentration on quality of movements. The program was designed for 20 minutes, which included 5 minutes of jogging before the start of the exercises. Team coaches were asked to utilize the program for 15 consecutive training sessions regardless of the number of times per week each team trained. After the 15 consecutive sessions, the coaches were required to use the program once per week for the remainder of the season. The program was to replace any other warm-up routine that was normally used by the teams (Steffen et al., 2008).

To help record injuries for the numerous players in the Steffen et al. (2008) study, each of the 18 physical therapists was assigned to as many as seven teams each. Each coach was contacted at least once per month by telephone or email for all training and match activity, as well as injury information so it could be recorded. A standardized injury questionnaire was used to interview and assess injuries for recording (Steffen et al., 2008).

According to the research conducted by Steffen et al. (2008), an injury prevention program for soccer should consist of more dynamic exercises that resemble soccer play as well as injury risk situations. Those exercises should consist of running with rapid changes of direction, dribbling, and landing after heading the ball. Steffen et al. (2008, p. 8) stated in their research that "It therefore seems reasonable to suggest that injury prevention programs for this target group should emphasize lower extremity neuromuscular control, strength and balance training. Based on previous research, it appears that such prevention programs should include at least 15 training sessions during the first 6-8 weeks of training. However, further research is needed on how to develop and implement such programs to be as effective as possible in this age and gender group." The "11" Injury Prevention Program is outlined in Appendix C.

In a study by Pafis et al. (2007), balance exercises were used to improve proprioception in order to train the brain to recognize the player's body segment position at every moment. The proprioception pathways were trained more effectively with the use of a balance exercise program under competitive circumstances. Activation of the peripheral and central nervous system receptors, mechanoreceptors within the muscles, ligaments, and tendons helped prevent injuries within the limbs and occurred more effectively and faster with the use of balance exercises. The goal of a balance exercise program was to reduce the time between neural stimuli and muscular response. It was important that balance exercise programs were used during both the rehabilitation phase and the competition period to improve proprioception.

Proprioceptive deficits inhibited normal motor response, decreasing neuromuscular stabilization of the joint. "Thus proprioceptive retraining is important to restore these deficits and assist in re-establishing neuromotor control." (Shmerl et al., 2005, p. 632.e6)

The balance training program study (Pafis et al., 2007) consisted of three groups. Group A completed the balance exercises six times per week for three weeks. Group B completed the balance exercises three times per week for six weeks. Group C was the control group and completed no balance exercises. The groups were evaluated on an electronic stability system (Biodex stability system) and a wooden balance board with hemi-cylindrical bottom surface. The wooden balance board measured the deviation from the horizontal plane by the athletes. The athletes were to maintain balance on the board while being timed. They performed one time for anterior-posterior free motion where the cylinder was placed parallel to the frontal plane and performed another time for medial lateral free movement in which the cylinder was placed vertical to the frontal plane.

The main goal of the balance exercise program was to include skills that were important technical elements of the game of soccer. Skills for the program were designed to improve awareness and knee control during standing, cutting, jumping, and landing. The exercises were designed by using elite athlete training program principles along with principles for rehabilitation of injured athletes with functional instability of their ankles or rupture of the anterior cruciate ligament (Pafis et al., 2007).

Results from the balance exercise program showed improvement for all subjects in the experimental groups (A and B) on all tests despite differences in frequency of balance program. Both training frequencies proved effective in improving balance ability for both lower limbs. It was proposed that the balance training program could be applied to soccer players at least three times per week or on a daily basis depending on the demands of training (Pafis et al., 2007).

The "F-MARC Bricks" was used as an injury prevention program in the "Prevention of Soccer Injuries: A Prospective intervention Study in Youth Amateur Players." (Junge et al., 2002) The F-MARC Bricks consisted of 10 sets of exercises designed to improve the stability of ankle and knee joints, the flexibility and strength of the trunk, hip, and leg muscles, as well as improve coordination, reaction time, and endurance (Junge et al., 2002). The intervention program was tailored for each team being studied and the situations surrounding each team. The intervention group had 36% fewer injuries of all types (Junge et al., 2002).

Based on the results from the study "The Effects of Core Proprioception on Knee Injury" (Zazulak et al., 2007), decreases in active core proprioception predicted the risk of knee injury in female athletes. Improvement in athletes' dynamic stability of the knee joint was accomplished with dynamic neuromuscular training that enhanced control of the body's core. "Interventions that incorporate core neuromuscular training, including proprioceptive exercises, may significantly reduce knee injury risk in this high-risk athletic population." (Zazulak et al., 2007, p. 372)

Hewett et al. (1996) developed a jump training program to test the effect the program had on the mechanics of landing and on the strength of the lower extremity musculature in female athletes participating in jumping sports. "The program employed in this study was designed to decrease landing forces by teaching neuromuscular control of the lower limb during landing and to increase joint stability by increasing the strength of the knee joint musculature." (Hewett et al., 1996, p. 766) The study included 11 volleyball players from a local high school team that trained using the jump program for 6 weeks, 3 days per week, and 2 hours per session with increased duration during the first two phases. The control group for the study consisted of nine males of similar weight, height, and age as the intervention group. The jump training program consisted of jumping and landing techniques, jumping for increased vertical height, and jumping for increased strength (Hewett et al., 1996). The program consisted of three phases: 1) technique phase (first two weeks of the training) which taught four basic techniques: correct posture and body alignment throughout jump, jumping straight up without moving from side-to-side or forwards or backwards, landing softly with toe-to-heel rocking and bent knee, and instant recoil preparation for the next jump; 2) fundamental phase, which built a base of strength using proper technique; 3) performance phase, which focused on achieving maximal vertical jump height (Hewitt et al., 1996).

After completion of the six week jump training, ten of the 11 volleyball players decreased peak landing forces. Decreased landing forces resulted in decreased forces experienced at the joints in the lower extremity (Hewett et al., 1996). Previous research showed that landing technique, angular momentum, and vertical height influenced peak landing forces (Hewett et al., 1996). The females also significantly decreased the adduction and abduction moments at the knee from values similar to and significantly lower than the males' values. That suggested the program altered muscular control of the lower extremity in the coronal plane (Hewett et al., 1996). Varus and valgus knee joint laxity was shown to decrease with muscular contraction. The training did not change the peak landing flexion and extension moments at the knee. The females did not demonstrate an increase in knee flexion angle moments at landing, which was shown to decrease landing forces. The males did not have an increased knee flexion angle at landing when compared to the females. The emphasis on landing softly with a toe-to-heel landing during phase one of the training did not significantly change ankle dorsiflexion and hip flexion (Hewett et al., 1996). The only predictors of significance of peak landing forces were abduction and adduction moments at the knee.

The female athletes at the beginning of the Hewett et al. (1996) jump training program had a significant imbalance between hamstring and quadriceps muscle strength. After completion of the jump training, the females' hamstring to quadriceps muscle strength ratio was even with the males in the study. It was shown in previous research that there was an increased risk of ligamentous damage in athletes with quadriceps-to hamstring muscle strength imbalances as well as hamstring-quadriceps muscle coactivation pattern reduction (Hewett et al., 1996).

Hewett et al. (2006) reviewed the results of six injury prevention studies to determine which characteristics were common to preventing injuries and more specifically ACL injuries. The regimens that effectively reduced the injury rate for ACL injuries in female athletes combined the common components of plyometric training, biomechanical analysis, and technique training (Hewett et al., 2006). The regimens that used balance training alone were not as effective at reducing ACL injuries (Hewett et al., 2006).

The plyometric component of the regimens reviewed by Hewett et al. (2006) incorporated high-intensity plyometric jumping movements that progressed beyond agility and footwork. Hewett et al. (2006) recommended plyometric components that train not only the muscles, but also the connective tissues and the nervous system. By training those three components, proper execution of the stretch-shortening cycle was carried out, allowing focus to be placed on proper technique and body mechanics, which appeared to reduce serious ligamentous injuries, like those to the ACL (Hewett et al., 2006). Female athletes who participate in multidirectional sports were better prepared for participation when an intervention training, which incorporated plyometrics with safe levels of varus or valgus stress were included into the regular training. Inducing safe levels of varus and valgus stress promoted more muscle-dominate neuromuscular adaptations that corrected neuromuscular imbalances found in female athletes (Hewett et al., 2006).

Hewett et al. (2006) also found that the successful training programs incorporated biomechanical feedback of various movements to the athletes either with video analysis, or visualization and verbalization cues. The use of such analysis by itself did not reduce ACL injuries as effectively or even at all, as did analysis with feedback on proper body positioning and techniques. Another component of successful intervention studies were those that incorporated balance and core stability training into the protocols (Hewett et al., 2006). Balance training alone did not reduce ACL injuries in the various studies reviewed by Hewett et al., 2006. Studies that utilized functional balance, like single-leg core stability, proved to reduce ACL injuries. The single-leg core stability was used in training athletes to improve awareness of knee control when cutting or jumping and to hold positions from a decelerated landing (Hewett et al., 2006). Maximum lower extremity strength was improved with balance training (Hewett et al., 2006).

Strength training incorporated into intervention protocols was also found to help reduce the risk of ACL injuries (Hewett et al., 2006). Strength training alone did not prove to reduce ACL injuries. There was "…evidence that resistance training may reduce injury based on the beneficial adaptations that occur in bones, ligaments, and tendons after training." (Hewett et al., 2006, p. 495) With strength training and plyometrics training, there was a high-intensity neuromuscular overload that likely enhanced both muscular performance and power and the injury prevention benefits caused by the neuromuscular training (Hewett et al., 2006).

Female athletes generally have lower baseline levels of strength and power compared to those of male athletes. Neuromuscular training in female athletes increased both strength and power. Neuromuscular training was a training method in which the athlete was challenged to process and utilize sensory information to control and coordinate the force generated by muscles in order to stabilize the joints, especially the knee, to overcome increased destabilizing forces that the athlete was exposed to during movement patterns (Fischer, 2006). "Dynamic neuromuscular training has also been demonstrated to reduce gender-related differences in force absorption, active joint stabilization, muscle imbalances, and functional biomechanics while increasing strength of structural tissues (bones, ligaments, and tendons)." (Hewett et al., 200, p. 496) Female athletes were not motivated to perform neuromuscular training when presented as injury prevention alone. Incorporation into a performance enhancing program, prompted participation in the neuromuscular training (Hewett et al., 2006).

Hewett et al. (2006) stated the best injury prevention programs, especially for ACL injury reduction, were those that incorporated the three following components into the neuromuscular training: 1) plyometrics, balance, and strengthening exercises; 2) the training sessions were performed more than once per week; and 3) the training program should be a minimum of six weeks in duration.

Plyometric training included jumping and landing techniques, along with cutting and decelerating techniques (Fischer, 2006). Perfect technique should be utilized by the athlete while performing plyometric training exercises. Proper plyometric training techniques included: "…(a) correct posture with chest over knees, (b) jumping vertically with minimal forward/backward or side-to-side movement, (c) landing softly on the balls of the feet with ankle, knee, and hip flexion to absorb the force, (d) recoiling immediately in preparation for the next jump, (e) maintaining knee-over-toe position (avoiding a valgus position at the knee), (f) landing with knee flexion to at least 45 degrees, and (g) landing from a jump with feet parallel, avoiding landing with one foot placed in front of the other." (Fischer, 2006, p. 48) Plyometric training should begin with low volume and intensity and increase as the athlete becomes more proficient with the exercises and techniques allowing for progressive overload of the nervous and musculoskeletal systems. The plyometric exercises should begin with movements the athletes anticipated, from voice commands, to unanticipated movements by the athlete (Fischer, 2006).

Balance training should begin with static balance exercises progressing into dynamic balance exercises. The balance exercises should become more sport specific mimicking joint range of motion, sequencing of muscle activity, speed of movement, and muscle generated force (Fischer, 2006). Static balance training exercises should begin with the athlete holding one position progressing from a bilateral stance to unilateral stance accompanied by eyes open and then closed, and finally with the athlete performing the balance exercises on flat, stable surfaces and progressing to unstable surfaces, such as balance boards or discs (Fischer, 2006). Dynamic balance exercises caused the athlete to lose balance and recover without falling or causing injury. Dynamic balance exercises should also be sport specific and increase in volume to improve muscle endurance as well as include cutting maneuvers (Fischer, 2006). Training exercises that required an athlete to suddenly change joint positions was a form of neuromuscular training referred to as perturbation training (Fischer, 2006). That type of neuromuscular training helped with joint stability by activating compensatory muscle patterns (Fischer, 2006).

In regards to adductor muscle strains and groin strains, researchers found that athletes who participated in a preseason strength training program, which included exercises specific to the adductor muscles reduced the risk of injury to those locations (Brumitt, 2005). Lower extremity injuries to the groin were prevented with careful conditioning exercises to help athletes withstand the forces encountered in the game of soccer. Exercises to develop strength in the groin muscles helped prevent injury. Resistance exercises were performed through the full range of motion and with repetitions to develop endurance. Some strength training exercises included in the injury prevention were side-lying straight leg raise (hip adduction), cable adduction, sumo squats, lunges (both forward and to the side), and single leg shuttle jumps (Brumitt, 2005). Stretching exercises increased the range of motion in the groin muscles. Special attention was directed to the thigh muscles, especially the adductors, and the lower back and abdominal muscles. Increased flexibility of the entire body with emphasis on the groin muscles helped prevent injury (Smodlaka, 1980).

The research by Hewett et al. (2006) showed that postural control was improved with proprioceptive and balance training. It was also found "…that lack of postural control and stability was also related to increased risk of ankle injury." (Hewett et al., 2006, p. 495) Risk of ACL injuries was attributed to side-to-side imbalances in the lower extremities (Hewett et al., 2006).

The Hruska Clinic used restoration of faulty movement strategies and muscular imbalance to help prevent injuries, which was called Postural Restoration. Postural Restoration "…is about neuromotor balance between the left and right side of the body. When imbalance occurs in the body, joints, bones, and muscles are affected resulting in pain in various yet understandable places." (Thomsen, 2008, para. 1)

To begin to understand Postural Restoration, one must understand the common pattern that exists in all humans. That common pattern contributes to postural asymmetry. Every human is different in the way that compensation for postural asymmetry occurs. The dominant pattern was the tendency to stand on the right leg more than the left leg, regardless of left or right hand dominance. Humans have this underlying pattern of standing on the right leg due to anatomy (organ asymmetry), vestibular imbalances, primary reflexes, gravity, environmental factors (counterclockwise world), and right hand dominance (Thomsen, 2008).

There was a need for balance between right leg use with upper torso rotation to the left and left leg use with upper torso rotation to the right. "The inability to stand on our left leg and rotate our upper body to the right creates a strategic imbalance throughout the body. This, coupled with the frequent repetition of soccer in a poorly aligned body, results in muscles that are no longer able to function which in turn causes inefficient movement of the joints and possible injury." (Thomsen, 2008, para. 5) "Soccer requires many skills (running, multidirectional changes, kicking) that are performed entirely or predominantly from a unilateral weight-bearing stance. Thus single leg dynamic stance activities which incorporate right femoral acetabular external rotation with left acetabular femoral internal rotation are necessary." (Masek, 2007b, para. 10)

Summary

The passing of Title IX of the Education Amendments in 1972 increased the number of females in organized sport. Soccer has become a tremendously popular sport in the United States. Due to the increase in popularity, more and more children, teenagers, and adults play soccer both recreationally and competitively. With the increase in player numbers, medical personnel, athletic trainers, coaches, and parents have seen the incidence of injury increase. In order to help the athletes train and compete injury free, an injury prevention program should be designed to reduce the incidence of injury. Junge and Dvorak (2004) suggested that injury prevention programs might affect males and females differently. Prevention programs may also be more effective with groups with an increased risk of injury (Junge and Dvorak, 2004).

The Postural Restoration Institute in Lincoln, Nebraska, developed a dynamic warm-up program for soccer based on postural symmetry. The program exercises "…are designed to create symmetrical muscle flexibility, strength, and length by facilitating, turn on, specific muscle groups and inhibit, turn off, others. The goals of these exercises are to warm-up the internal temperature of the muscles and establish proper muscle recruitment patterns aligning the body to be in a mechanical advantage to express power and strength." (NSCA Fly Solo Manual, 2007, p. 12)

The Core Performance Movement Prep (Verstegen and Williams, 2004) exercises were used as the dynamic warm-up for the last two soccer seasons at Farmington High School for the girls' soccer team. With the use of those exercises, the incidence of injury as well as the severity of injury was reduced. To try to help further reduce the incidence of injury and the severity of injury, the Postural Restoration Institute's Soccer Program was implemented daily at the end of training along with the Core Performance movement prep exercises, which were performed during the daily warm-up. The first four exercises of the Postural Restoration Institute's Soccer Program were introduced during the Fly Solo class at the 2009 National Strength and Conditioning Conference. After having performed the exercises and hearing about the positive results from the use of those exercises by the instructors, it was decided to incorporate the exercises daily at the conclusion of training.

Chapter 3
Methods

Sample Population

The participants for the research study included 9^{th}-12^{th} grade female soccer players who ranged in age from 13-18 years. The number of participants for this research study was a total of 22 players. The experimental group consisted of 16 players and the control group consisted of 6 players.

It was a non-probability sample or convenience sample because participation of subjects was based on subjects' availability to the Farmington High School girls' soccer team who played for and attended Farmington High School in Farmington, New Mexico. The experimental group consisted of 16 players from the Varsity team; whereas, the control group consisted of six players from the Junior Varsity Team. The experimental group included all girls who were on the Varsity team prior to the pre-testing of ROM. The control group had six participants due to various reasons such as incomplete forms, lack of pre- or post testing scores, and or knee injuries that required surgery before pre-testing began. After the Institutional Review Board (IRB) for Adams State College approved the study, parental consent was obtained (Appendix E), and all participants signed informed consent forms (Appendix F).

Instrumentation

A universal goniometer was used in a test-retest method to measure the range of motion (ROM) for flexion and extension in the hip and knees.

A basic inclinometer was used in a test-retest method to measure the range of motion (ROM) for hyperextension of the low back.

A regulation size 5 soccer ball was used by the players when performing the Postural Restoration Institute Soccer Program exercises: Hip Shift with Right Femoral Acetabular External Rotation (FA ER), and Hip Shift with Left Femoral Acetabular Internal Rotation (FA IR).

The Setting

Participants were high school aged female soccer athletes who played soccer for and attended Farmington High School in Farmington, New Mexico during the 2010 soccer season. All conditioning and training sessions were conducted at either the Farmington Soccer Complex or at Farmington High School. Weight training and some conditioning were conducted inside on a gym floor, while all technical and tactical training sessions and speed and agility training was conducted outside on a grass surface. The training program lasted six weeks in duration between September and October during the fall high school soccer season of 2010.

Procedures

The study was quantitative by design and consisted of a 6 week period where players performed the intervention strategy hypothesized to increase ROM and thereby decrease the number and severity of injuries incurred by female soccer players. Participants in this study were to have been thirty female soccer players who comprised the 2010 Farmington High School girls' soccer team. The protocol was to divide the players equally into a control group and an experimental group of 15 participants each. However, the experimental group finished the study with 16 participants, as one participant was brought up to play on the Varsity team before pre-testing began, and the control group finished the study with six participants. The control group numbers diminished due to incomplete forms, lack of pre- or post testing, and participants suffering knee injuries requiring surgery did not allow for either pre-testing or post-testing.

Both groups followed the same basic practice schedule consisting of the Core Performance Movement Prep exercises followed by the formal practice activities. At the conclusion of the daily practice schedule, the experimental group performed an exercise regimen designed to increase the ROM: the Postural Restoration Institute's Soccer Program exercises. (See Appendices A and B for complete explanation) During the 6 week data collection period, both groups performed the Core Performance Movement

Prep exercises for ten minutes prior to the beginning of practice four times per week. In addition to the basic practice regimen, the experimental group performed the PRI soccer program exercises ten minutes after practice four times per week.

Study participants were tested and measured before and after the 6 week intervention strategy period. Range of motion was measured at the knees and hip joints with a universal goniometer and a basic single inclinometer was used to measure the lower back. The athletic trainer followed the protocol suggested by Arnheim (1989) for the positioning of the goniometer for these measurements. (See Appendix D) Active movement, movement performed solely by the participants, was used during the testing of ROM at the measurement sites. Active movement was used to indicate "…three factors: an ability and willingness to execute certain movements, muscular power, and range of active movement." (Arnheim, 1989, p. 283) Active movement could have been normal, limited, or excessive. Limitations in active movement could have been caused by pain, spasm, contracture, or compression (Arnheim, 1989).

Measurements for knee flexion were conducted while the subjects were in the supine position. The stationary arm of the of the goniometer was positioned along the lateral femur pointing toward the lateral condyle of the greater trochanter, while the moving arm was placed parallel to the lateral midline of the fibula toward the lateral malleolus (Arnheim, 1989). The ROM measurements for knee extension were conducted while the participants were seated on the athletic training table. The stationary arm of the goniometer was placed parallel to the lateral aspect of the femur (Arnheim, 1989). The center of the goniometer was placed at the lateral condyle of the femur (Arnheim, 1989). The moving arm was parallel to the fibula (Arnheim, 1989). The participants were in a supine position for hip flexion. For the testing, the stationary arm of the goniometer was placed along a line from the crest of the ilium, femur, and greater trochanter and with the moving arm positioned in line with the femur, pointing toward the lateral condyle of the femur (Arnheim, 1989). Hip hyperextension measurements were conducted while the participants were lying in a prone position. The arm positioning of the goniometer was the same as used for the hip flexion measurements. Participants were lying in a supine position with legs in a neutral position for both abduction and hyperadduction measurements of the hips. The stationary arm of the goniometer was positioned between the anterior superior iliac spine with the moving arm parallel to the anterior aspect of the femur, pointing toward the middle of the patella (Arnheim, 1989). Stabilization of the pelvis was achieved by the athletic trainer placing her forearm across the participants' abdomen and her hand on the opposite anterior superior iliac spine (Hoppenfeld, 1976). Stabilization of the pelvis and positioning of the goniometer during hip hyperadduction measurements followed the same procedures as for hip abduction measurements. Low back hyperextension was measured with the participants standing with knees straight. The inclinometer was placed in the lumbar region of the back against the spine. The participants were then told to bend backward as far as possible.

The researcher, who was the head coach for the Farmington High School girls' soccer team, administered regular practice protocol for both groups. The nationally certified athletic trainer for the Farmington High School athletic program conducted all pre- and post ROM measurements. All player injuries were reported to the coach and diagnosed by the school's athletic trainer. The athletic trainer recorded all injuries sustained by the soccer players during the study. Injury incidence was tracked and categorized as mild, moderate, or severe by definition. Refer to chapter 1 for complete definitions of injury.

According to Bobbie Rappl (B. Rappl, personal communication, March 5, 2012), PTA, Director of Clinical Development & Public Relations for the Postural Restoration Institute, the PRI's Soccer Program exercises were modified by the Postural Restoration Institute for application by a soccer player. The Postural Restoration Institute's Soccer Program performed by the Experimental Group consisted of the following exercises:

1. Paraspinal Release
    a. 1 set of 10 on the left leg
    b. 1 set of 10 on the right leg
2. Single leg RDL
    a. 10 standing on the left leg
    b. 5 standing on the right leg
3. Knee Toward Knee
    a. 1 set of 10 on the left side

b. 1 set of 10 on the right side

4. Adduction/Abduction
    a. 1 set of 10 on the left side
    b. 1 set of 10 on the right side
5. Side Lunge
    a. 1 set of 10 on the left side
    b. 1 set of 10 on the right side
6. Hip Shift with Right FA ER
    a. 1 set of 10 on the left side
    b. 1 set of 10 on the right side
7. Hip Shift with Right Hip Through
    a. 1 set of 10 on the left side
    b. 1 set of 10 on the right side
8. Hip Shift with Right FA ER
    a. 1 set of 10 on the left side
    b. 1 set of 10 on the right side
9. Hip Shift with Left FA IR
    a. 1 set of 10 on the left side
    b. 1 set of 10 on the right side
10. Hip Shift with Left FA IR
    a. 1 set of 10 on the left side
    b. 1 set of 10 on the right side

See Appendix A for illustrations and complete details.

The Core Performance Movement Prep (Verstegen and Williams, 2004) exercises performed by both the experimental and control groups consisted of the following exercises:

1. Hip Crossover
    a. 1 set of 5 on the left side
    b. 1 set of 5 on the right side
2. Scorpion

a. 1 set of 5 on the left side

b. 1 set of 5 on the right side

3. Calf Stretch

a. 1 set of 5 on the left side

b. 1 set of 5 on the right side

4. Hand Walk (A.k.a. "World's Second Greatest Stretch")

a. 1 set of 5

5. Inverted Hamstring

a. 1 set of 5 on the left side

b. 1 set of 5 on the right side

6. Lateral Lunge

a. 1 set of 5 on the left side

b. 1 set of 5 on the right side

7. Forward Lunge/Forearm-to-Instep (A.k.a. "World's Greatest Stretch")

a. 1 set of 5 on the left side

b. 1 set of 5 on the right side

8. Backward Lunge with a Twist

a. 1 set of 5 on the left side

b. 1 set of 5 on the right side

9. Drop Lunge

a. 1 set of 5 on the left side

b. 1 set of 5 on the right side

10. Sumo Squat-to-Stand

a. 1 set of 5

See Appendix B for illustrations and complete details.

The independent variables for this research study were the two groups (experimental and control) of female soccer players. The experimental group consisted of 16 players and the control group consisted of 6 players. The dependent variables were: the Range of Motion (ROM) at the knees, hips, and low back; the incidence of injury; and the severity of injuries (rated as mild, moderate, or severe).

Reliability

Farmington High School Athletic Trainer, Melynda Brenton, MS, LAT, who was a nationally licensed athletic trainer as well as licensed in the State of New Mexico, conducted all pre- and post goniometer testing of ROM at the knees, and hips as well as, a basic single inclinometer for all pre- and post testing of ROM in the low back. According to Arnheim (1989, p. 284), in order to ensure accuracy and reliability, "…the tester must use specific body positions and anatomical landmarks." Hole, Cook, and Bolton (1995) established that the single inclinometer was a reliable method of measuring ROM when operated by the same examiner. The trainer also determined the injury status as well as the severity of injuries according to previous definition.

Validity

The use of goniometry by athletic trainers and physical therapists to determine ROM has been used as a major criterion for athletes' returning to participation (Arnheim, 1989). Goniometry has been used during the early, intermediate, and late stages of injury to assess the range of motion of an affected body part (Arnheim, 1989). The universal goniometer has been used for quantifying ROM restrictions and creating treatment interventions for athletes (Brosseau et al., 2001). Research has shown that increased ROM in joints reduces injury. "In a clinical setting, limited ROM is a common impairment." (Brosseau et al., 2001, p. 396) Injuries can be a result in restrictions of joints, knee ROM being an example (Brosseau et al., 2001). "These limitations prevent normal function, and so it is imperative that physical therapists assess with valid and reliable tools to treat these restrictions adequately." (Brosseau et al., 2001, p. 396)

For this study, a basic single inclinometer was used to test the range of motion (ROM) in the low back for hyperextension. An inclinometer was used as a quick, simple, inexpensive, and minimally invasive 'Low-tech' method of measuring ROM in the low back (Littlewood and May, 2007). Hole et al. (1995) used two instruments, a CROM-cervical range of motion device and the inclinometer in an attempt to establish reliability and concurrent validity when measuring ROM in the cervical region. When data from each method was compared, results showed that the inclinometer measurements were similar or slightly less than those of the CROM. The inclinometer method of measuring ROM in the cervical region was determined to be valid (Hole et al., 1995). When comparing the inclinometer technique of measuring lumbar range of motion with radiography, an invasive technique, the results were highly correlated, which justified the use of the inclinometer technique as a valid way to measure lumbar range of motion (Saur, Ensink, Frese, Seeger, and Hildebrandt, 1996).

Through her training and certification process, the athletic trainer was determined to be competent in the proper protocol for assessing ROM measurements with both the goniometer and the inclinometer. Her measurements of ROM were considered accurate because of her training. The athletic trainer was responsible for classification of injuries as mild, moderate, and severe according to predetermined criteria established for this study. (See Chapter 1 for definitions of injuries)

The Core Performance Movement Prep program was in use two years prior to the 2010 season. It was considered to be a valid set of exercises for the purpose of initiating a state of readiness for athletic competition. The same rigid procedures of presentation were used by the researcher in conducting the PRI soccer program.

According to Bobbie Rappl (B. Rappl, personal communication, March 5, 2012), PTA, Director of Clinical Development & Public Relations at the Postural Restoration Institute, the PRI soccer program has not been validated, through research, as a program that will decrease the incidence and severity of injury. The Postural Restoration Institute did not provide written information about the PRI soccer exercises and the benefits of performing those exercises to the public. The PRI soccer program developers do teach professional continuing education courses featuring the basic protocol for application of the program. Thus, research like the current study is needed in order to support the PRI soccer program's efficacy.

Treatment of Data/Statistics

An EXCEL spreadsheet was used to document the dependent variables for the collected data. Analysis of data was performed using the SPSS statistical program. A single factor ANOVA was used to analyze the pre- to post ROM change scores at each joint. An ANOVA was also used to compare the incidence and severity of injuries between experimental and control groups. Statistical significance was established at the $p<0.05$ level.

Chapter 4

Results

The intervention research study included 22 soccer players. The athletes ranged in age from 13 years to 18 years, and were soccer players who attended Farmington High School in Farmington, New Mexico during the 2010 soccer season. The experimental group, which performed exercises from the Postural Restoration Soccer Program and the Core Performance Movement Prep Program, consisted of 16 participants (mean age 16.3 ± 0.83 years) who were older and more skilled varsity players. The control group, which performed the regular Core Performance Movement Prep exercises, consisted of six participants (mean age 15.2 ± 1.00 years) who were younger and less skilled junior varsity players. All participants signed player consent forms (Appendix F) and parents also signed consent forms (Appendix E). The training was 6 weeks in duration during the 2010 soccer season.

The means $\pm$ standard deviations displayed in Table 1 were mean scores pre to post ROM at measurements sites for both the experimental group and the control group. The measurements were conducted on the following sites: right knee flexion, left knee flexion, right knee extension, left knee extension, right hip flexion, left hip flexion, right hip hyperextension, left hip hyperextension, right hip abduction, left hip abduction, right hip hyperadduction, left hip hyperadduction, and low back hyperextension.

Table 1

Mean scores of pre/post tests of ROM at measurement sites (measured in degrees)

Measurement Sites	Experimental (N=16)			Control (N=6)		
	Mean Pre	Mean Post	Difference	Mean Pre	Mean Post	Difference
Right Knee Flexion	132	132	no change	131	135	4 increase
Left Knee Flexion	133	135	2 increase	133	139	6 increase
Right Knee Extension	6	4	-2 decrease	4	1	-3 decrease
Left Knee Extension	6	3	-3 decrease	6	2	-4 decrease
Right Hip Flexion	89	86	-3 decrease	93	91	-2 decrease
Left Hip Flexion	86	85	-1 decrease	91	87	-4 decrease
Right Hip Hyperextension	9	10	1 increase	12	12	no change
Left Hip Hyperextension	12	9	-3 decrease	11	15	4 increase
Right Hip Abduction	52	64	12 increase	48	63	15 increase
Left Hip Abduction	52	60	8 increase	49	72	23 increase
Right Hip Hyperadduction	22	17	-5 decrease	28	23	-5 decrease
Left Hip Hyperadduction	24	17	-7 decrease	26	19	-7 decrease
Low Back Hyperextension	16	16	no change	18	17	-1 decrease

Table 2 presents the means ± standard deviations results (both expressed in degrees) for the goniometer ROM measurements. The means ± standard deviations displayed in Table 2 are change scores for ROM at various joints measured in degrees for both the experimental group and the control group.

Table 2

Mean change scores for ROM at various joints (measured in degrees)

Measurement Sites	Experimental (N=16)		Control (N=6)	
	Mean	S.D.	Mean	S.D.
Right Knee Flexion	0.31	4.74	3.33	3.67
Left Knee Flexion	1.68	5.12	2.83	3.37
Right Knee Extension	-3.50	4.23	-3.83	1.72
Left Knee Extension	-3.19	4.62	-4.50	1.05
Right Hip Flexion	-0.88	12.50	-4.50	18.50
Left Hip Flexion	-2.94	12.80	-2.00	14.55
Right Hip Hyperextension	0.38	4.40	-0.17	11.74
Left Hip Hyperextension	-1.00	5.89	3.67	5.72
Right Hip Abduction	11.50	15.76	14.67	21.81
Left Hip Abduction	7.38	21.82	22.50	21.38
Right Hip Hyperadduction	-5.81	7.63	-4.17	8.57
Left Hip Hyperadduction	-6.75	7.56	6.33	6.95
Low Back Hyperextension	0.88	14.96	-1.17	14.55

The results of a single factor ANOVA showed no statistical difference ($p>0.05$) between the experimental group, Postural Restoration Institute's Soccer Program, and the control group, Core Performance Movement Prep, for ROM at any joint measured. The results of a single factor ANOVA showed no statistical difference ($p>0.05$) between the experimental group, Postural Restoration Institute's Soccer Program, and the control group, Core Performance Movement Prep for incidence of injury. The experimental group suffered seven injuries out of 16 players in the intervention study over the 6 weeks. The seven injuries resulted in a total incidence of injury of 43.95%. The control group suffered three injuries out of 6 players, which resulted in an overall slightly higher but not statistically significant incidence of injury of 50% over the 6 week study period. The incidence of mild injuries for the two groups was 12.5% (2 of 16) for the experimental group and 0% for the control group. Moderate injury incidence in the experimental group was 25% (4 of 16) and was 16.67% (1 of 6) in the control group. The control group had an incidence of severe injuries of 33.33% (2 of 6) compared to only 6.25% (1 of 16) in the experimental group.

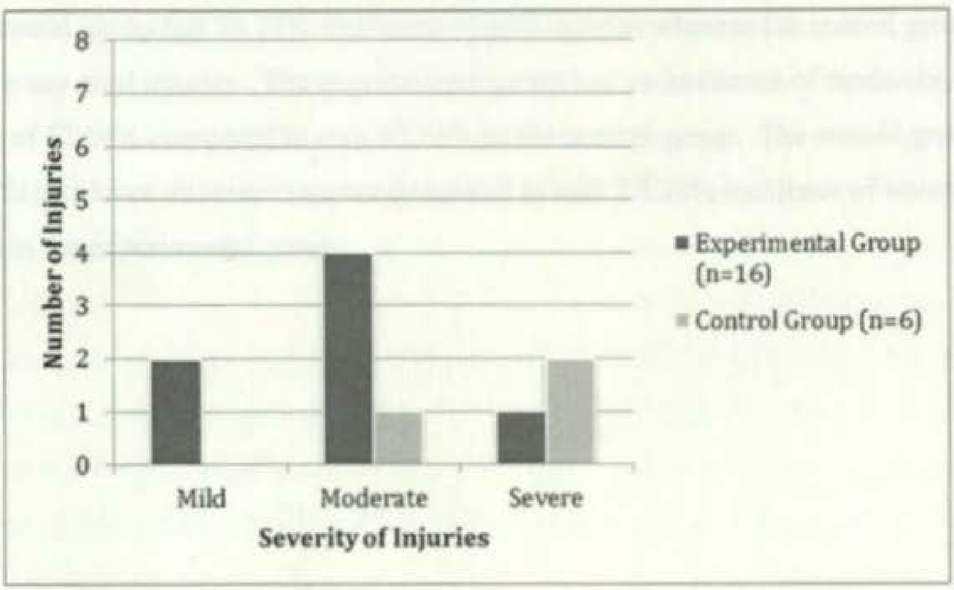
Table 3 presents the incidence and severity of injury for both the experimental and control groups.

Table 3

Injury incidence and severity

Injuries	Experimental (N=16)	Control (N=6)
Mild	2=12.5%	0=0%
Moderate	4=25%	1=17%
Severe	1=6%	2=33%
Total	7=44%	3=50%

Figure 1, below, is a bar graph representing the incidence and severity of mild, moderate, and severe injuries for both the experimental and control groups.



The results also showed no statistical differences ($p>0.05$) between the groups for mild, moderate, and severe injuries. The Postural Restoration Institute's Soccer Program group or experimental group suffered seven injuries total over the 6 week study. Of the seven injuries, two injuries were mild, four injuries were moderate, and one injury was severe. All were classified using the definitions of injuries in Chapter 1. The mild injuries consisted of a shin contusion and a foot bony abnormality. The moderate injuries in the PRI soccer program consisted of shin periostitis, lower back spasm, a cervical spasm C4/5 region, and an upper ankle sprain. The only severe injury occurring in the PRI soccer program was a lower back degenerating disc. The Core Performance

Movement Prep (control) group suffered three injuries during the 6 week study period. Two of the injuries were severe according to definition and the other injury was moderate. The severe injuries included a lower leg stress fracture to the right leg and a tear in the meniscus of the knee resulting in a sprain. The moderate injury was a knee patellafemoral syndrome.

When comparing groups for severity of injuries, the experimental group suffered a total of seven injuries compared to three total injuries in the control group. Of the seven injuries in the experimental group, two were mild injuries, four were moderate injuries, and one injury was severe. The control group injuries consisted of no mild injuries, one moderate injury, and two severe injuries totaling three injuries. The experimental group had 28.57% incidence of mild injuries whereas the control group did not have any mild injuries. The experimental group had an incidence of moderate injuries of 57.14% compared to only 33.33% in the control group. The control group had a 66.67% incidence of severe injuries compared to only 14.29% incidence of severe injuries in the experimental group.

Chapter 5

Discussion

The original research was designed for 30 participants, 15 participants in the experimental group and 15 participants in the control group. Upon study completion, the experimental group consisted of 16 participants and the control group consisted of six participants. Some participants did not complete consent forms, whether it be the participant form or the parental consent form. Two participants who signed up to participate in the study were injured and required surgery before the pre-testing of ROM began. The experimental group had one more player than proposed due to the fact that one player was brought up to participate on the Varsity team after pre-testing had occurred and before the Postural Restoration Institute's Soccer Program was implemented. The intervention study was a convenience sample of participants available from the Farmington High School girls' soccer team; therefore, the researcher was not able to recruit more participants (athletes) for the study. The groups were divided into an experimental and a control group based on original participant numbers and availability to the Varsity and Junior Varsity teams. The intervention study was designed for the experimental group, Varsity players, to perform the Postural Restoration Institute's Soccer program because the researcher, who was also the head coach, was more interested in finding a program that would reduce the incidence of injury among the Varsity players so that the team would be able to compete with all players injury free throughout the season.

The control group had the fewest participants and some of the youngest girls. The mean age of the control group was 15 ± 1.00 years. Because of the young age of the participants in the control group, they were dependent on parents for their transportation to all soccer related events. As a result of the inability to drive, not all participants completed the ROM measurement testing. Some participants in the control group who had signed up for participation were unable to complete pre- and post testing of ROM due to employment obligations.

Hypothesis 1 stated that players who participated in the Postural Restoration Institute's Soccer Program would increase the range of motion (ROM) in the knees, the hips, and low back. As stated, the hypothesis was rejected since the results did not prove to be statistically significant between the two groups.

Neither the PRI soccer program nor the Core Performance Movement Prep program significantly increased the ROM in the various test sites over the 6 week study period. That neither preventative program was successful in increasing ROM measurements significantly was most likely due to implementation problems.

Both groups of participants performed the Core Performance Movement Prep exercises as a pre-practice and pre-game warm-up. The experimental group performed the PRI soccer program as an addition at the conclusion of practice. The researcher chose not to administer the PRI soccer program after the conclusion of the Core Performance Movement Prep program due to mixed JV and Varsity players during the 7th hour soccer period. Not all students enrolled in the soccer class were participants in the study nor were they all within the experimental group. Not all members of the experimental group were enrolled in the soccer class. Athletes who needed to receive tutoring or make-up tests or missed assignments were required to seek help immediately after school concluded for the day. Due to these factors, the PRI soccer program was administered at the conclusion of practice.

During the 6 weeks period over which the experimental group performed both the Core Performance exercises and the PRI soccer program and the control group performed the Core Performance exercises, ROM increased in the following test sites in both groups: left knee flexion (2 degrees increase in experimental group and 6 degrees in control group), right hip abduction (12 degree increase in experimental group and 15 degree increase in control group), and left hip abduction (8 degree increase in experimental group and 23 degree increase in control group). The control group showed larger increases in these same joints. The control group also showed an increase in right knee flexion (4 degree increase) and left hip hyperextension (4 degree increase) while the experimental group did not improve ROM in these test sites but did show increased ROM in right hip hyperextension (1 degree increase). Of the thirteen test sites, the experimental group showed increased ROM in four test sites, while the control group demonstrated increased ROM in five test sites. All test sites that showed increased ROM in both the experimental group and control group were non-significant changes. The increases found in some of the test sites in the control group could be attributed to the players' familiarity with the exercises as they had been incorporated into the daily warm-up two seasons prior to the study along with the immediate post testing of ROM. All participants in the current study would have had at least one year of experience in performing the Core Performance exercises. According to Silvers (2009), biomechanical training must have taken place for approximately 6-8 weeks before neuromuscular effects can occur. Verstegen and Williams (2004, p. 33), the creators of the Core Performance Movement Prep exercises state, "The end result will be a significant improvement in mobility, flexibility, and stability..." The Movement Prep exercises lengthened the muscles through active elongation, stretching the muscle through a new range of motion and then contracting the muscle (Verstegen and Williams, 2004). By stretching and strengthening the muscles through the new range of motion, the tiny muscles around the joints that hold the joints together improved posture and performance while decreasing the potential for injury. This also activated the surrounding muscles of the joints making them readily available for participation throughout the training (Verstegen and Williams, 2004). The increases found in the experimental group in some of the test sites could also be attributed to the familiarity of the Core Performance Movement Prep exercises performed during warm-up prior to training. Through her research of literature, the researcher found that strengthening the musculature surrounding the knee and hip joints was the primary concern in reducing the incidence and severity of injuries; however, Keller et al. (1987) documented that ROM was the major factor in rehabilitating Norwegian professional soccer players for their return to competition. "Return to play following injury was supervised by a physician and physical therapist and required full range of motion..." (Keller et al., 1987, p. 236). It is the researcher's belief that continuation of the Core Performance Movement Prep exercises would be beneficial in reducing the incidence and severity of injuries in the Farmington High School girls' soccer team. It is also the researcher's belief that incorporating the PRI soccer exercises into the warm-up instead of at the conclusion of training may also help reduce the incidence and severity of injuries in the girls' soccer program at Farmington High School.

At the conclusion of the 6 week study, both groups had two weeks of the regular soccer season remaining. The experimental group, which consisted of varsity players, continued into state tournament competition, which did not allow for immediate post-testing of ROM. However, post-testing of ROM for control group members began at the conclusion of the 6 week intervention. The closing of the season and continuing into the state tournament interrupted the anticipated collection of data by the researcher. The primary tester, who was also the school athletic trainer, was responsible for primary duties as trainer for all fall sports, in which both the Farmington High School football team and boys soccer team also made post season play. During this time, winter sports had begun official practice, which also required the athletic trainer to provide her services. Final data was not collected until approximately four to five weeks after the conclusion of the 6 week intervention program, due to the extended seasons of both the soccer team and the football team reaching the playoffs of the state tournaments. This delay in post-testing may have resulted in smaller or no changes observed in ROM, since the intervention had been completed for several weeks and not maintained.

According to Bobbie Rappl (B. Rappl, personal communication, March 5, 2012), PTA and Director of Clinical Development and Public Relations at the Postural Restoration Institute in Lincoln, Nebraska, the PRI soccer program exercises were Postural Restoration Institute exercises that were adapted for a soccer player. Because the exercises were adapted for a soccer player, there was not any research conducted specifically on the exercises. Peer review articles of the PRI soccer exercises that were included into the current research included the articles by: Masek (2007a), Masek (2007b), Bartels (2008), Drummer (2008), and Thomsen (2008). All four authors had either worked for or currently work for the Postural Restoration Institute.

In his work at the Postural Restoration Institute, Jason Masek, MSPT, ATC, CSCS, PRC (2007a and 2007b) studied soccer hip impingement and developed exercises to strengthen the musculature of the pelvic girdle. He stated, " Asymmetry and /or pathomechanics of the pelvic structure can lead to a cascade of compensations throughout the axial spine predisposing individuals to dysfunction and potential injury." (Masek, 2007a, para. 6)

During his time at the Postural Restoration Institute, David Drummer (2008) was both a patient and a physical therapist. He attained his doctorate of physical therapy from the University of Nebraska. He has drawn upon his personal experiences with his own various injuries to develop techniques to strengthen and stretch the hamstring muscles so that they are more capable of stabilizing the pelvic girdle. According to Jennifer Gloystein (J. Gloystein, personal communication, July 31, 2012) DPT, ATC, PRC, and Director of Education and Credentialing at the Postural Restoration Institute, "Dave has not done any further research or writing on the hamstring muscles."

Bartels (2008) and Thomsen (2008) were engaged in developing exercises which promoted good body symmetry during their continued affiliation with the Postural Restoration Institute. Both stressed the need for proper body symmetry in order to promote better athletic performance. The researcher was unable to find any other research performed by the staff members Masek, Bartels, Drummer, and Thomsen at the Postural Restoration Institute that dealt with relevant issues to this current study. As stated in the introduction for the current study, the PRI soccer program exercises were developed for the express purpose of establishing pelvic symmetry, strengthening the musculature of the pelvic girdle, and to increase range of motion, which would lead to optimum athletic performance and resulting in reduced incidence of injury. The exercises were designed to take advantage of proper body mechanics in order to perform athletic skills with power and strength (NSCA Fly Solo Manual, 2007).

Hypothesis 1 may have been accepted if the intervention study had been longer in duration. It was believed that a 6 week study was not enough time for the Postural Restoration Institute's Soccer program exercises to increase ROM at the knees, hips, and low back. The researcher found that the players did not fully understand and perform the exercises with proper form and technique until week two of the intervention study. A study design that takes into account time for participants to learn exercises with proper form and technique needs to be much longer in duration. According to Silvers' (2009, p. 91) research, "...it takes approximately 6 to 8 weeks for a biomechanical intervention program to impart a neuromuscular effect"; therefore, a teaching/learning period of one to two weeks would allow for a minimum of eight weeks of proper performance.

Hypothesis 2 stated that the Postural Restoration Institute's Soccer Program would reduce the overall incidence of mild, moderate, and severe injuries to the most common injury sites in the lower extremity (hip, hamstring, groin, knee, and ankle) in the Farmington High School girls' soccer team. The experimental group suffered an overall incidence of injury of seven injuries out of the 16 participants in the group, resulting in a 43.75% overall incidence of injury. The control group consisted of six participants and suffered 3 total injuries for a 50% incidence of injury. The incidence of injury was not statistically significant; however, it suggested a trending towards significance, that the PRI soccer program exercises may reduce the incidence of injury. Perhaps with a longer application period and more participants in each group, the results would reach statistical significance. Out of the 16 participants in the experimental group, 12.5% or two out of 16 suffered mild injures and 25% (4 of 16) suffered moderate injuries. The experimental group suffered 6.25% (1 of 16) severe injuries. In the control group, 0% (0 of 6) suffered mild injuries, while 16.67% (1 of 6) suffered moderate injuries, and 33.33% (2 of 6) of the injuries were severe in nature. This hypothesis was rejected as statistical significance was not reached. When comparing incidence of injury between the groups, the PRI soccer program exercises seemed to have helped reduce the incidence of injury in the experimental group. The seven injuries included two mild injuries, four moderate injuries, and one severe injury. The mild injuries consisted of a shin contusion and a bony foot abnormality. The moderate injuries included a reoccurring high ankle sprain; a lower back spasm, treated with ice, rest, and stretching; a cervical spasm C4/5 region; and shin periostitis. The only severe injury sustained in the PRI soccer program was that of a preexisting lower back degenerating disc. The control group (Core Performance Movement Prep) suffered an overall incidence of injury of three. Of the three injuries, one injury was moderate, a patellafemoral syndrome. The other two injuries in the control group were severe in nature. One injury was a lower leg stress fracture in the right leg. The other severe injury was a knee sprain from a knee meniscus tear.

For this study, the 16 participants in the experimental group, whose mean age was 16.3 ± 0.83 years, consisted of Varsity payers with experience ranging from one year to four years of Varsity competition. Those participants were more skilled, willing to perform high-risk maneuvers, and played at higher intensity levels in training and in games. The competition of games further increased the level of intensity. Seven injuries occurred in the experimental group during the 6 week intervention program. During the 6 week program, the experimental participants logged 672 hours of training and 288 hours of competition for a total of 960 cumulative hours of participation, which resulted in one injury per 137.14 hours of participation.

The control group consisted of six Junior Varsity players with a mean age of 15.2±1.00 years, who were less skilled than the experimental group. The control group participants also played with a lower level of intensity in both training and in games. Three injuries occurred in the control group during the 6 week intervention program. The control group logged 264 hours of training and 90 hours of competition for a total of 354 cumulative hours of participation resulting in one injury per 118 hours of participation. Thus these injury rates indicate that the control group sustained injuries more often than did the experimental group. In a study of injuries among female high school varsity soccer players conducted by Kontos and Brown (2000), they found that the injury rate was higher in less skilled players when compared to female professional soccer players. "With this in mind, the discrepancy in injury rates may not be reflective of the suggestion by researchers that higher skilled players have more injuries than lower skilled athletes." (Kontos and Brown, 2000, p. 30)

With the implementation of the PRI soccer program, the results of the current study disagreed with Keller et al.'s (1987), Schmidt-Olsen et al.'s (1985), and Sullivan et al.'s (1980) conclusions that the more physically mature a player becomes and as the player's sport specific skills improve, the number of injuries that occur increases. Even though the injury data in this study resembled that of Kontos and Brown (2000), the researcher would not go so far as to disagree with the findings of Keller et al. (1987), Schmidt-Olsen et al. (1985), and Sullivan et al. (1980). The findings of the Keller et al.'s (1987), Schmidt-Olsen et al.'s (1985), and Sullivan et al.'s (1980) studies were founded upon research involving a greater number of participants than the current six members of the control group. The size of the control group was too small on which to base statements related to skill level performance. The study results indicated that the implementation of a specific exercise routine intended to strengthen and increase ROM tended to reduce the incidence of injury in the older, more skilled players.

Hypothesis 3 stated that the Postural Restoration Institute's Soccer Program would decrease the severity of injuries sustained by the players on the Farmington High School girls' soccer team, which was rejected due to statistical significance not being obtained. The severity of an injury was evaluated in terms of the amount of inactivity from training, matches, or both the athlete incurred. Upon analysis of the three different categories of injuries: mild, moderate, and severe, the Postural Restoration Institute's Soccer Program trended towards significant difference in decreasing the number of severe injuries sustained by players in the experimental group, which was one out of seven injuries compared to two out of three injuries sustained by the players in the control group.

Hypothesis 3 was rejected because statistical significance was not reached. Even though statistical significance was not reached, the experimental group sustained fewer severe injuries than the control group. Out of the seven injuries sustained by the 16 participants in the experimental group, only one was severe. The control group sustained two severe injuries out of the three total injuries. The experimental group sustained two mild injuries compared to zero in the control group. Four of the seven injuries sustained in the experimental group were moderate compared to one in the control group.

Because there was not a consistent definition of an injury, but a variety of definitions in the current literature, the definitions of injuries, mild, moderate, and severe for this study were a collaboration between the researcher, the athletic trainer and the reviewed literature. For the current study an injury was categorized as: mild-injury requiring minor first-aid, ice, and inactivity for one day; moderate-requiring medical treatment from an athletic trainer and inactivity for more than one day; and severe-requiring medical treatment from medical personnel other than an athletic trainer for physical therapy or surgery or a combination of both and inactivity for the duration of rehabilitation.

The overall incidence and severity of injury between the two groups suggests that the PRI soccer program was trending toward reduction in both the incidence and severity of injury. When comparing severity of injuries, the experimental group sustained one severe injury out of seven total injuries; whereas the control group sustained two severe injuries out of three total injuries. Both Hypotheses 2 and 3 were rejected. Even though there was no statistical significant difference between the injury rates and the severity of the two groups in this study, the literature does indicate that intervention programs can reduce the number and severity of injuries. Hewett et al. (2006, p. 497) stated that specific "…neuromuscular training may assist in the reduction of ACL injuries in female athletes…" provided the regimen contains plyometrics, are performed more than once per week, and last longer than six weeks in duration. Keller et al. (1987) found that an injury prevention program designed for senior (professional) Swedish soccer players was successful in reducing injuries by 75%. Strict adherence and commitment to following the protocol of an injury prevention program were cited by Steffen et al. (2008) as the most important factors to providing a successful injury prevention program.

The Postural Restoration Institute's soccer specific exercises were designed to increase range of motion, decrease the chance of injury, and increase performance (NSCA Fly Solo Manual, 2007). "Muscles must be taught to work through full ranges of motion." (NSCA Fly Solo Manual, 2007, p. 12)

Limitations/Practical Implications

Dedicated time in which the researcher did not have multiple responsibilities would have had a positive impact on this or future studies. With dedicated time, the researcher would be able to establish a daily protocol for the progress of the study. Ideally, the establishment of a more clinical setting, such as inside a building, would have benefited the performance and testing of participants. The establishment of equal sized experimental and control groups would enhance the validity and reliability of data.

Further limitations to the study were experienced in the time constraints placed on the athletic trainer who conducted the pre- and post testing. Farmington High School promotes an extensive athletic program whose participants rely on the services of a single trainer. During the fall sports season in 2010, both boys and girls soccer teams and the football team extended their season when those teams were included in state championship play-offs. Concurrent to the season extensions, the winter sports practices began prior to the termination of the fall sports season. All this activity impeded the timely post testing of both the PRI and Core Performance participants.

Practical implications for future studies of this type should include better control of the major aspects of the study. The time for executing the preventative exercises should be consistent each day. For consistency, the prevention program should be conducted at the same location each training session. A rigid data collection system should be adhered to for best analysis of data. A time to teach proper execution of the preventative program should occur prior to implementation of the program. For more valid and reliable results, the two groups should be equal in size and randomly selected to enhance the quality of measureable data.

Chapter 6

Summary, Recommendations, and Conclusions

Summary

The original proposal for this study called for the use of the Postural Restoration Institute's Soccer Program and the Core Performance Movement Prep in the experimental group and the Core Performance Movement Prep program in the control group during the 6 week pre-season of the 2010 fall soccer season. The experimental group performed the Core Performance Movement Prep program for 10 minutes prior to practice beginning for four days per week during the 6 week study. Then they performed the Postural Restoration Institute's Soccer program for 10 minutes at the completion of practice for four days per week during the 6 week study. The control group performed only the Core Performance Movement Prep program prior to the beginning of the daily practice for 10 minutes four days per week for six weeks. The original proposal was designed to complete a 6 week intervention program during the pre-season in the summer of 2010. Due to uncontrollable circumstances, the current study was delayed and conducted for six weeks during the regular 2010 soccer season, which consisted of both training and game competition. The experimental group logged 672 hours of training and 288 hours of competition for a total of 960 cumulative hours of participation, while the control group logged 264 hours of training and 90 hours of competition totaling 354 cumulative hours of participation. The original proposal for this study was designed to have 30 total participants with 15 players in each group. During the course of the study, several of the participants were deleted from participation in the study for failure to complete required consent forms, to complete either pre- or post ROM testing, or injuries requiring surgery during season, which resulted in uneven group size. The smaller participant number in the control group may have skewed results.

It was the researcher's belief that the PRI soccer program would have been successful under different circumstances. Had the participant size for both the experimental and control groups been equal, the study might have revealed more reliable and valid statistical evidence that the PRI soccer program would have increased the range of motion in the knees, hips, and low back. With increased range of motion in these joints, the PRI soccer program may have also resulted in a significant reduction in incidence and severity of injury.

The original proposal was designed for the program to be completed during the pre-season of 2010; however, due to circumstances out of the researcher's control, the study was completed during the fall 2010 soccer season. The researcher was hoping to establish the PRI soccer program to enhance the quality of competition at the optimal level during the season. The duration of the program was designed for six weeks, which did not appear to be a long enough time for the PRI soccer program to be beneficial. The players were not able to perform the PRI soccer program exercises with proper technique until week two. The program was performed four days per week at the conclusion of practice for 10 minutes. According to Silvers (2009, p. 91) "... it takes approximately 6 to 8 weeks for a biomechanical intervention program to impart a neuromuscular effect."

The many different delays in testing of ROM did not accurately reflect the benefits the PRI Soccer program imparted on the participants. The incidence and severity of injuries both appeared to benefit from the PRI soccer program based on observation of data obtained during the intervention study. Had the number of participants been larger and groups been equal in all aspects (age, experience, number, etc.) and the duration of the study been longer, the intervention study probably would have been a success.

The study consisted of female soccer players ranging from 13-18 years of age. A total of 22 soccer players completed the study. The experimental group consisted of 16 players (mean age of 16.3 ± 0.83 years) and the control group consisted of 6 players (mean age of 15.2 ± 1.00 years). An injury was defined as any trauma sustained by a soccer player regardless of contact or non-contact, which resulted in the player missing at least one day of training or match play or a combination of both. Injuries were categorized as mild, requiring minor first-aid, ice, and inactivity for one day; moderate, requiring medical treatment from an athletic trainer and inactivity for more than one day; and severe, requiring medical treatment from medical personnel other than an athletic trainer for physical therapy or surgery or a combination of both and inactivity for the duration of rehabilitation. The Farmington High School athletic trainer diagnosed all injuries to the soccer players during the course of the study.

There were three hypotheses for this study. Hypothesis 1: The Postural Restoration Institute's Soccer Program would increase the range of motion (ROM) in the knees, hips, and low back. Hypothesis 2: The Postural Restoration Institute's Soccer Program would reduce the overall incidence of injury (mild, moderate, and severe injuries) to the most common injury sites in the lower extremity (hip, hamstring, groin, knee, and ankle) in the Farmington High School girls' soccer team. Hypothesis 3: The Postural Restoration institute's Soccer Program would decease the severity of injuries sustained to the players on the Farmington High School girls' soccer team. All three hypotheses were rejected. Hypothesis 1 was rejected since ROM did not statistically differ at any sites tested when comparing experimental and control groups.

Hypothesis 2, reduce the incidence of injury, and hypothesis 3, reduce the severity of injury, were also rejected because statistical significance was not reached. However, when observing frequency distributions, the experimental group appeared to have fewer injuries and less severe injuries compared to the control group. The experimental group sustained a total of seven injuries out of 16 participants (mild=2=12.5%; moderate=4=25%; and severe=1=6.25%) for a total percentage of 43.75%. The control group sustained a total of three injures out of six participants (mild=0%; moderate=1=16.67%; and severe=2=33.33%) with an overall incidence of injury of 50%. Out of the seven injuries in the experimental group, two were mild equaling 28.57%, four were moderate equaling 57.14%, and one was severe equaling 14.29%. The control group sustained a total of three injuries during the intervention study. The participants sustained 0% mild injuries, 33.33% moderate injuries, and 66.67% severe injuries. This suggested that the PRI soccer program exercises were beneficial, but just needed a longer controlled and randomized intervention.

Recommendations

In the future, an injury prevention program should begin during the pre-season approximately 6-8 weeks prior to competition. Prior to that time, 1-2 weeks should be spent familiarizing the athletes with the proper technique for all exercises. According to Silvers (2009, p. 91), this would allow "… for a biomechanical intervention program to impart a neuromuscular effect." The intervention program should also be continued during the season and incorporated into the daily warm-up to ensure continued benefits for injury prevention. According to Hewett et al. (2006, p. 494) "In-season training alone is probably the most cost-effective and efficient method of achieving beneficial injury prevention effects, although the lack of high-intensity overload in these programs likely precludes measurable performance enhancement effects."

Testing for the injury prevention program should begin one season prior to implementation of intervention program to establish a baseline of incidence and severity of injury. Implementation of the intervention program should begin the following season and should continue throughout the season and possibly two consecutive seasons in order to compare injury rates and severity of injuries. Random selection of participants for each group, experimental and control, would ensure equal group size so the results would be valid and reliable. Injuries should be recorded per 1000 hours and broken into training injuries versus game competition injuries. Ideally, the tester on the designated test day for both pre- and post testing should be free from other responsibilities (other than emergencies) and conduct the testing protocol on a 20 minute interval. It was found during the current study that the testing of ROM at all measurement sites required approximately 20 minutes for completion. Prior to testing, the tester should familiarize herself with the measurement protocol. Implementation of the intervention program should be an established daily protocol, in which the researcher and participants are isolated from outside disturbances. A standardized definition of injury categories should be established.

Conclusions

The purpose of this research study was to examine the Postural Restoration Institute's Soccer Program and determine if the exercises within this program would help: (1) increase the range of motion (ROM) in the knees, the hips, and the lower back; (2) reduce the overall incidence of mild, moderate, and severe injuries to the most common injury sites in the lower extremity, which consist of the hip, the hamstring, the groin, the knee, and the ankle, in the Farmington High School girls' soccer team; and (3) decrease the severity of injuries sustained to the players on the Farmington High School girls' soccer team. The control group performed the Core Performance Movement Prep program for 10 minutes during the warm-up before training sessions and before matches. The experimental group performed the Core Performance Movement Prep program for 10 minutes prior to training sessions four days per week and performed the PRI Soccer Program for 10 minutes at the completion of training sessions four times per week. The incidence of injury, severity of injuries, and ROM at various joints was compared between the control group and the experimental group after a 6 week intervention. The results of this study did not support the three hypotheses, causing them to be rejected.

As the game of soccer continues to grow in popularity in the United States, so most likely will there be an increase in soccer related injuries. There is a need for more research on injury prevention for the soccer athlete. The intervention program, Postural Restoration Institute's Soccer Program used in this study was an attempt to help find a program that would prevent injuries so that the soccer players on the Farmington High School girls' team would perform at the optimal level. In the opinion of Thomsen (2008, p. para1) "The goal of the soccer athlete is to train and compete at optimal levels of performance while avoiding injury."

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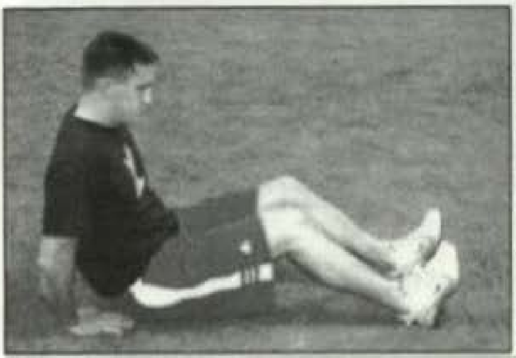
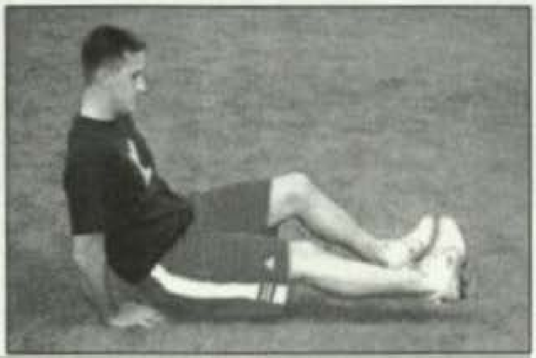
APPENDICES

APPENDIX A

Postural Restoration Institute's Soccer Program

ACTIVE FUNCTIONAL PERFORMANCE SOCCER DRILLS





PARASPINAL RELEASE

1. Sit with knees slightly bent and pull heels down into ground
2. Keep back rounded bringing belly to spine
3. Lift your right leg and bring it forward keeping your back rounded and your left heel down into ground

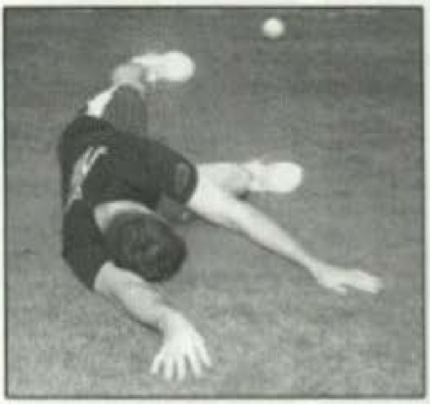
SINGLE LEG RDL

1. Stand on your left leg and shift hips to the left slightly
2. Keeping back rounded bend forward bending left knee slightly and bringing right arm across body so that your nose is over your left toes

 1

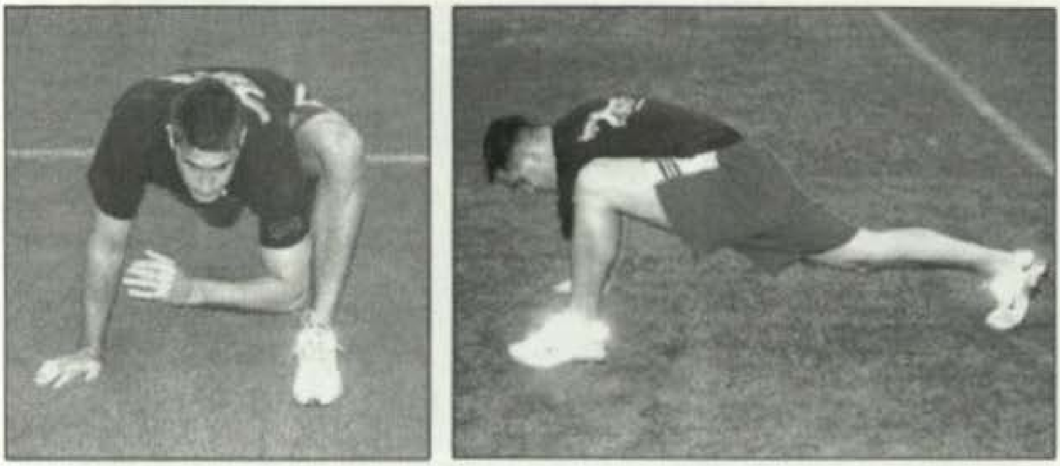
KNEE TOWARD KNEE

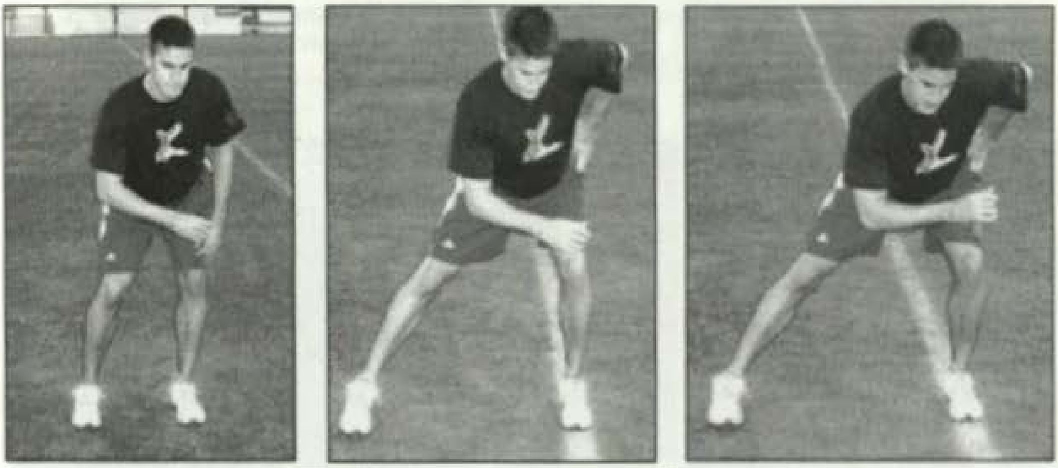
1. Lie on side with knees bent and back rounded
2. Shift top knee forward and lift up and out
3. Maintaining above position bring bottom knee up slightly until you feel inside of your thigh engage
4. Repeat on other side



ADDUCTION & ABDUCTION

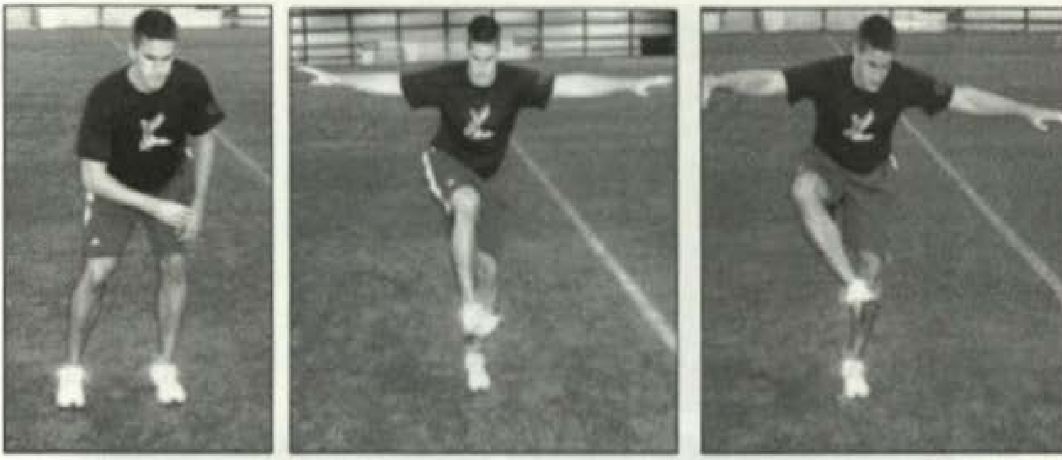
1. Lie on your side with ankle, hip, and shoulder lined up and toes of top leg pointed down
2. Lift your bent bottom knee off of the ground feeling your inner thigh
3. Maintaining this position lift the top leg keeping your toes pointed down slightly, feeling your outer hip on top





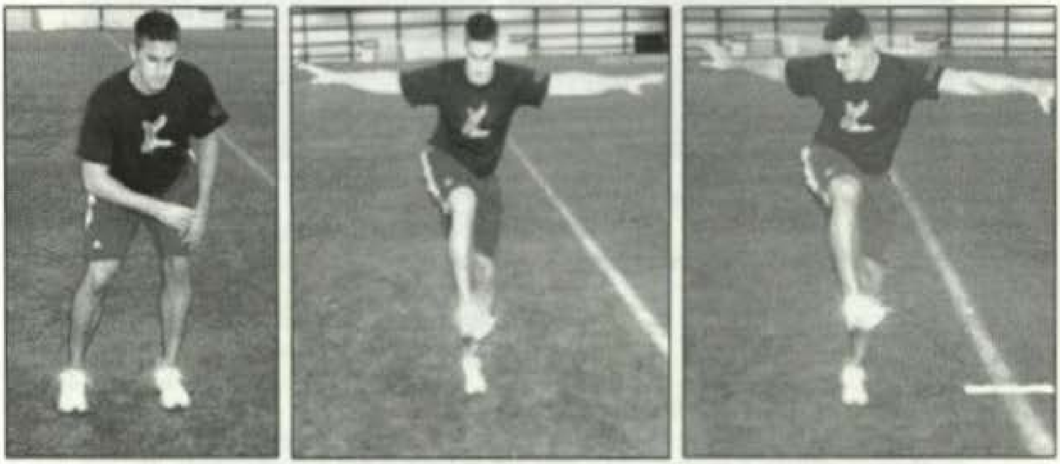
SIDE LUNGE

1. Shift your weight to the left side so that your pant seam is over your left great toe
2. Maintaining this position lift your right leg and place it out to the side
3. Shift weight further to the left feeling stretch in right inner thigh
4. Repeat on other side



HIP SHIFT WITH RIGHT FA ER

1. Shift your weight to the left side so that your pant seam is over your left great toe
2. Maintaining this position start to bring right knee up across body slightly
3. Turn foot inward while maintaining hip shift



HIP SHIFT WITH RIGHT HIP THROUGH

1. Repeat steps one and two from previous exercise
2. Concentrate more on bringing right knee across body as if volleying a soccer ball, back should follow hips to the right

HIP SHIFT WITH RIGHT FA ER

1. Shift weight to the left as stated above
2. Bring your straight right leg out to the side while turning it out slightly
3. Perform 5 small backwards circles
4. Can do with foot on top of ball

HIP SHIFT WITH LEFT FA IR

1. Shift weight to the right
2. Bring straight left leg out to the side while turning it slightly inwards
3. Perform 5 small forward circles
4. Can do with foot on top of ball as pictured

Keep stance leg slightly bent and back rounded through entire sequence

HIP CROSSOVER

UNIT:
Movement Prep.

OBJECTIVE:
To build mobility and strength in your torso by disassociating hips and shoulders.

STARTING POSITION:
Lie supine (faceup) on the floor, arms and shoulders extended out at your sides and flat, feet flat on the floor.

PROCEDURE:
Twist your bent legs to the right until they reach the floor, then twist to the left.

COACHING KEY(S):
Keep your abs drawn in and shoulders, torso, and feet in contact with the ground.

YOU SHOULD FEEL:
Stretching and contracting of your core muscles.

PROGRESSION:

Try this move with your hips and knees bent 90 degrees and your feet off the ground.

SECOND PROGRESSION:

Perform this move with your legs straight.

SCORPION

UNIT:
Movement Prep.

OBJECTIVE:
To lengthen and strengthen the muscles of your core; stretch your chest, quads, hips, and abs; and activate your glutes.

STARTING POSITION:
Lie prone (belly-down) on the floor, with your arms and shoulders pinned in the "spread 'em!" pose.

PROCEDURE:
Thrust your left heel toward your right hand by firing your left glute while keeping your right hip glued to the ground. Alternate legs.

COACHING KEY(S):
Be sure to fire (squeeze) your glute as you thrust your heel.

YOU SHOULD FEEL:
A stretch in your quads and hip flexors, along with activation of your glutes.

CALF STRETCH

UNIT:
Movement Prep.

OBJECTIVE:
To increase flexibility in this very often-neglected area.

STARTING POSITION:
From the pushup position, place your left foot over your right heel. Your weight should be on the ball of your right foot.

PROCEDURE:
Pull your right toes up toward your shin while you push your right heel down toward the ground with your left foot. Exhale as you lower your heel. Hold for a one count, raise your right heel again, and repeat.

COACHING KEY(S):
You're pulling your toes up toward the shin at the same time you're pushing the heel to the ground. Then push back through the new range of motion.

YOU SHOULD FEEL:
A stretch in your calf and ankle.

PROGRESSION:
Bend the knee of your working leg to shift the emphasis to your Achilles tendon.

HAND WALK *A.k.a. "World's Second-Greatest Stretch"*

UNIT:

Movement Prep.

OBJECTIVE:

To build stability in your shoulders and core and to lengthen your hamstrings, calves, and lower-back muscles.

STARTING POSITION:

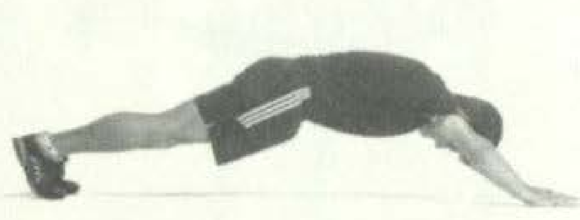
Stand with your legs straight and hands on floor.

PROCEDURE:

Keeping your legs straight and belly button drawn in, walk your hands out. Still keeping your legs straight, walk your feet back up to your hands.

COACHING KEY(S):

Use short "ankle steps" to walk back up to your hands. That is, take baby steps using only your ankles—don't use your knees, hips, or quads.



YOU SHOULD FEEL:

A stretch in your hamstrings, lower back, glutes, and calves and a burning in the fronts of your shins.

INVERTED HAMSTRING

UNIT:
Movement Prep.

OBJECTIVE:
To improve hamstring flexibility and balance, along with dynamic pillar stabilization.

STARTING POSITION:
Balance on your right foot with perfect posture (tummy tight, shoulders back and down).

PROCEDURE:
Bending at the waist, and maintaining perfect posture, grab your right foot with your left hand, extending your left leg back as you fire the left glute. (You might find it easier to extend forward with both hands out, as shown, rather than while grabbing a foot.) Your shoulder and heel should move as one, forming a straight line. Take a step back at the end of each rep as you alternate legs.

COACHING KEY(S):
Your body should be in a straight line from ear to ankle. Keep your back and pelvis flat! Someone should be able to place a broomstick snugly across your back.

YOU SHOULD FEEL:
A stretch in your hamstrings.

LATERAL LUNGE

UNIT:
Movement Prep.

OBJECTIVE:
To open up the muscles of your groin and hips. Also to hold pillar strength as you sit back and down.

STARTING POSITION:
Stand with perfect posture.

PROCEDURE:
Step out to the right, keeping your toes pointed straight ahead and feet flat. Squat by sitting back and down onto your right leg, keeping your left leg straight and the weight on the right leg's midfoot to heel. Squat as low as possible, keeping your left leg straight and holding this position for 2 seconds. Return to the standing position and repeat.

COACHING KEY(S):
Keep your feet pointed straight ahead and flat throughout.

YOU SHOULD FEEL:
A stretch in the inside of your thigh.

FORWARD LUNGE/ FOREARM-TO-INSTEP

A.k.a. "World's Greatest Stretch"

UNIT:

Movement Prep.

OBJECTIVE:

To improve flexibility in your hips, hamstrings, lower back, torso, groin, hip flexors, and quads.

STARTING POSITION:

Take a large step forward with your left leg, as if doing a lunge. Place and support weight on your right hand, even with your left foot.

PROCEDURE:

Take your left elbow and reach down to your instep (forward leg) while keeping your back knee off the ground. Then move your left hand outside your left foot and push your hips straight to the sky, pulling your toe up toward your shin. Finally, step forward into the next lunge.

COACHING KEY(S):

Keep your back knee off the ground. Exhale as you reach your elbow to the floor. At the end, make sure both hands remain in contact with the ground as you lift your hips and pull your toe toward the shin.

YOU SHOULD FEEL:

A stretch in your groin, your back leg's hip flexor, and your front leg's glute. During the second part, you should feel a stretch in your front leg's hamstring and calf.

BACKWARD LUNGE WITH A TWIST

UNIT:
Movement Prep.

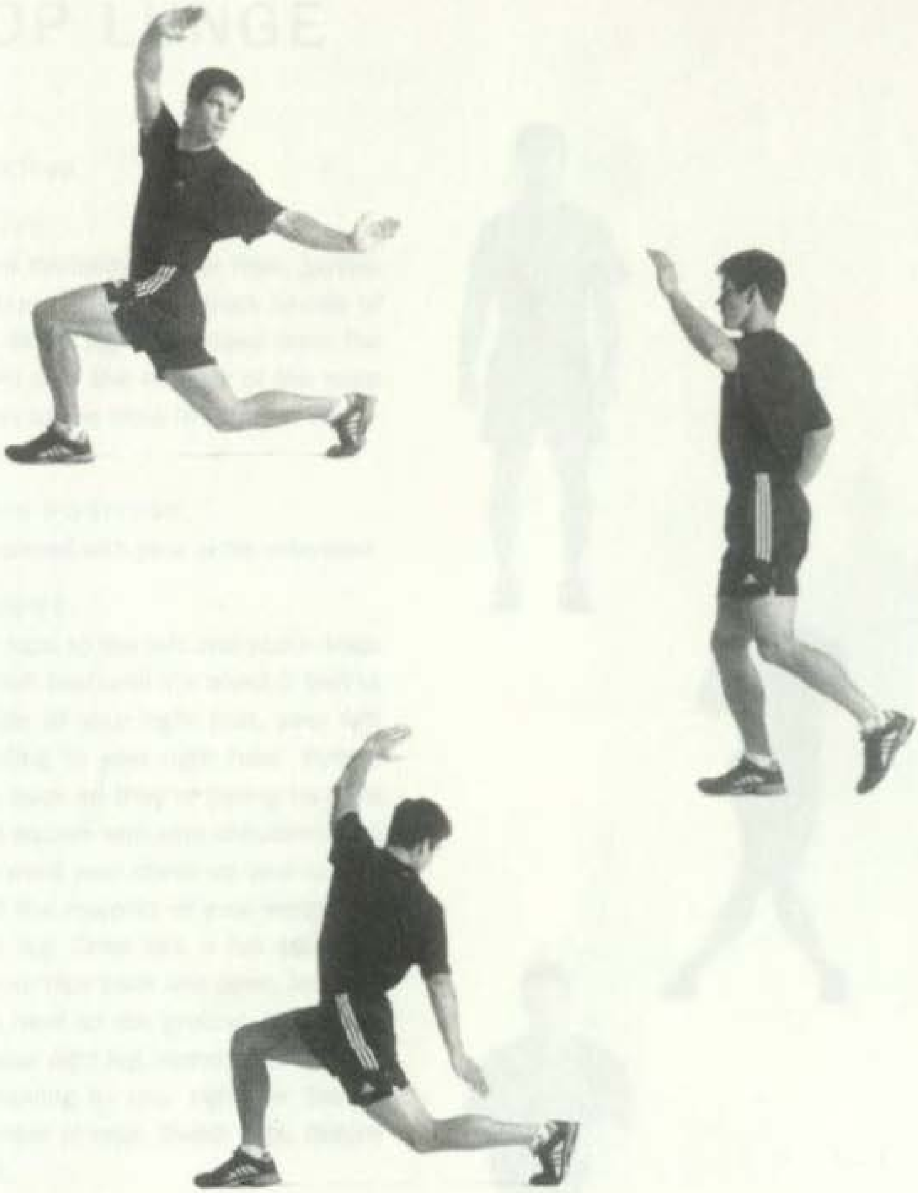
OBJECTIVE:
To lengthen your hip flexors, quads, and core. This stretches everything from your big toes to your hands.

STARTING POSITION:
With your feet together, step back with your right leg into a lunge.

PROCEDURE:
Arch your back slightly while twisting your torso over your left leg and while reaching your right hand to the sky. Push back and out of that position into the next lunge.

COACHING KEY(S):
As you lean back and rotate, fire (squeeze) the glute of your back leg. This creates reciprocal inhibition, lengthening your hip flexors.

YOU SHOULD FEEL:
A stretch from your back leg through your core and lats, and a stretch of your hip flexors.



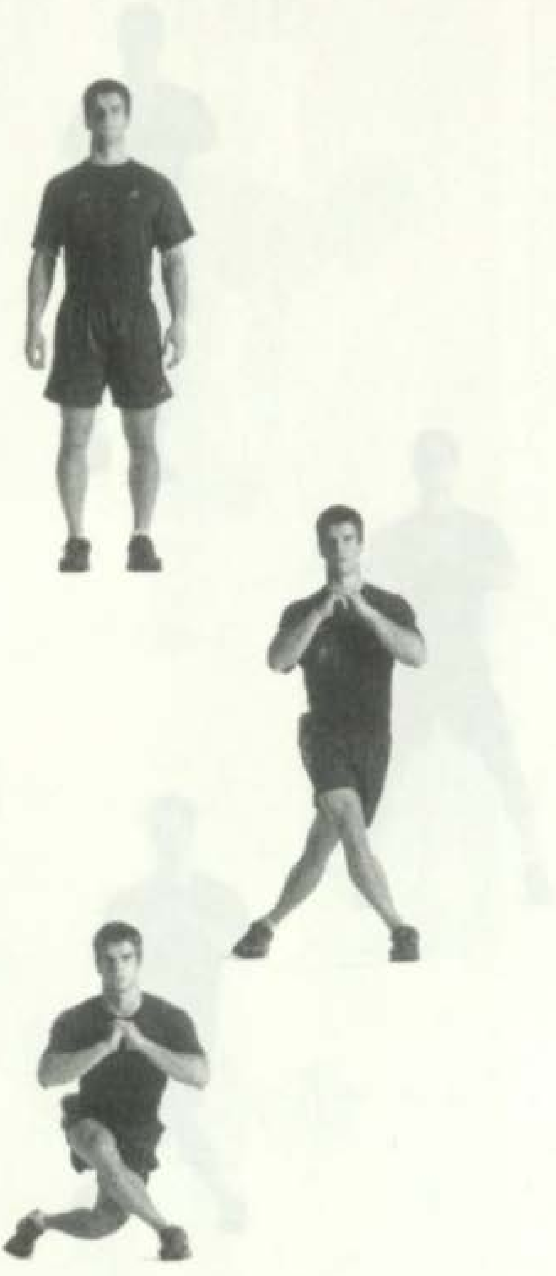
DROP LUNGE

UNIT:
Movement Prep.

OBJECTIVE:
To improve flexibility in your hips, glutes, and iliotibial (IT) bands—thick bands of tissue in either leg that extend from the thigh down over the outside of the knee and attach to the tibia (the larger lower-leg bone).

STARTING POSITION:
Stand balanced with your arms extended.

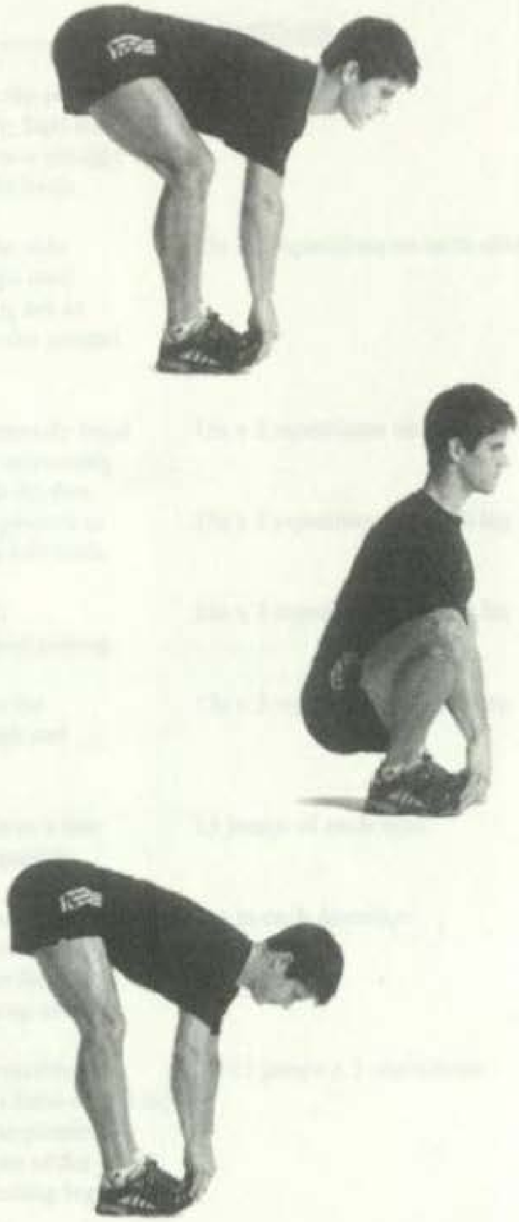
PROCEDURE:
Turn your hips to the left and reach back with your left foot until it's about 2 feet to the outside of your right foot, your left toes pointing to your right heel. Rotate your hips back so they're facing forward again and square with your shoulders and feet. You want your chest up and tummy tight, and the majority of your weight on your right leg. Drop into a full squat by pushing your hips back and down, keeping your right heel on the ground. Now drive hard off your right leg, stand back up, and repeat, moving to your right for the allotted number of reps. Switch legs. Return to the left.



COACHING KEY(S):
Turn your hips to drop your leg behind. Keep your toes pointed straight, with the back toe to the front heel.

YOU SHOULD FEEL:
A stretch in your hips, glutes, and IT bands.

SUMO SQUAT-TO-STAND



UNIT:

Movement Prep.

OBJECTIVE:

To improve flexibility in your hamstrings, groin, ankles, and lower back.

STARTING POSITION:

Stand tall, with your feet outside your hips.

PROCEDURE:

Bend at the waist, grabbing under your big toes. Keeping your arms straight and inside your knees, pull your hips down until they're between your ankles, and lift your chest up. Then tuck your chin and try to straighten your legs, holding on to your toes as you straighten out your hips and knees.

COACHING KEY(S):

Hold on to your toes at the bottom of the movement. Pull your chest up and your shoulders back and down, and try to drive your hips forward to get your torso vertical, not horizontal. As you lift your hips, keep your back flat.

YOU SHOULD FEEL:

A stretch in your groin, glutes, lower back, and, to a lesser degree, ankles.

APPENDIX C
The "11" Injury Prevention Program

Exercises	Description	Repetitions
Core Stability		
The Bench (1)	Leaning on your elbows in the prone position, lift the upper body, hips and knees so that the body forms a straight line from the shoulder to the heels. Hold this position.	15s x 4 repetitions
Sideways Bench(2)	Leaning on one elbow in the side position, lift top leg and hips until the shoulder, hip and top leg are in straight line and parallel to the ground. Hold this position.	15s x 2 repetitions on each side
Balance		
Cross-country Skiing (3)	In single-leg stance, continuously bend and extend the knee of the supporting Leg ands swing the arms in rhythm	15s x 2 repetitions on each leg
Chest pass in Single-leg stance (4)	Partner exercise with both players in single-leg stance. Throw a ball back and forth.	15s x 3 repetitions on each leg
Forward bend in Single-leg stance (5)	As (4). Before throwing back, touch the ball to the ground without putting weight on it.	15s x 3 repetitions on each leg
Figure-of-eights In single-leg stance (6)	As (4). Before throwing back, move the ball in a figure-eight through and around legs.	15s x 3 repetitions on each leg
Plyometrics		
Line jumps (sideways, Forwards-backwards) (7)	Two-leg jumps sideways over a line and forward-backward as quickly as possible	15 jumps of each type
Zigzag shuffle (Forwards & backwards) (8)	Shuffle sideways with a low center of mass to the first cone, turn so that the other shoulder points to the next cone and complete the zigzag course as fast as possible	2 repetitions in each direction (20 m)
Bounding (9)	Spring as high and far as possible off the shooting leg. Bring the knee of the trailing leg up as high as possible and the opposite arm in front of the body. continuous bounding, switching legs on each take off	10-15 jumps x 3 repetitions (20 m)
Strength		
Nordic Hamstrings (10)	Lower legs are held stable by a partner. Slowly lean forward keeping the upper body and hips straight while resisting the forward-falling motion by the hamstring muscles	5 repetitions

*The single-leg balance exercises (4, 5, and 6) were done on a balance mat when the players were able to perform these exercises properly on stable ground.
(Steffen et al, 2008, p. 3)

APPENDIX D

Goniometer Measurement Positioning (Arnheim, 1989)

Knee Flexion and Knee Extension in a seated position

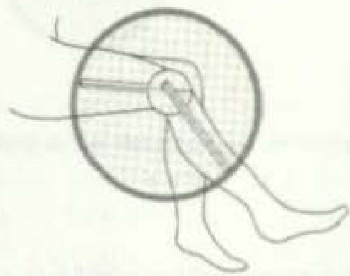


Figure 10-18

Knee extension and flexion while sitting on a table. The stationary arm is parallel to the lateral aspect of the femur. The center of the goniometer is at the lateral condyle of the femur. The moving arm is parallel to the fibula.

Hip Flexion in a supine position

Figure 10-13

Hip flexion. The stationary arm is placed along a line from the crest of the ilium, femur, and greater trochanter. The moving arm is positioned in line with the femur, pointing toward the lateral condyle of the femur.

Hip Hyperextension in a prone position

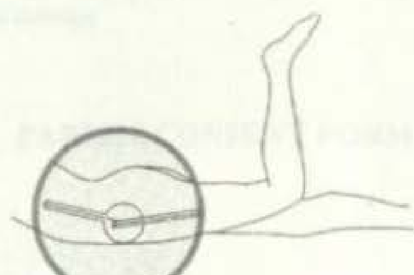


Figure 10-14

Hip extension. The goniometer is placed in the same position as in Figure 10-13, but the athlete takes a prone position.

Hip Abduction and Hyperadduction in a supine position

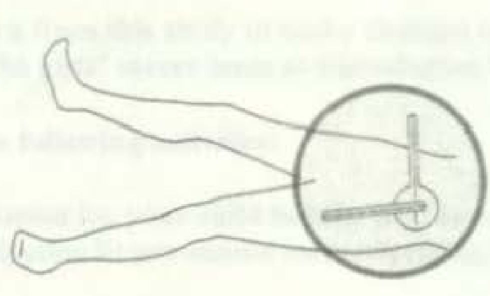


Figure 10-15

Hip abduction and adduction with the athlete in a supine position. The stationary arm is positioned between the anterior superior iliac spine. The moving arm parallels the anterior aspect of the femur, pointing toward the middle of the patella.

APPENDIX E

Parent Consent Form

Adams State College

PARENT CONSENT FORM

May 19, 2010

Dear Parent or Guardian:

I am Shannon Gill, a graduate student in the Human Performance and Physical Education Department at Adams State College. I request permission for your child to participate in a research study to be used for my Master's Thesis. I am conducting a research project on how the Postural Restoration Institute's Soccer Program will help improve the Range of Motion (ROM) in the knees, hip, low back, shoulders, and neck, and reduce the incidence and severity of injury.

I hope to use what I learn from this study to make changes to the current dynamic warm-up program for the girls' soccer team at Farmington High School.

The study consists of the following activities:

1. I will ask your permission for your child to take part in one of two warm-up programs before participation in pre-season soccer training sessions for 6 weeks.

2. These warm-up programs will be conducted before each strength training session, speed and agility training session, and technical or tactical training session. The morning training sessions will be conducted by Head Coach Shannon Gill. Evening training sessions will be conducted by assistant coaches Kent Fink or Nichelle Engels.

3. Participants will perform either the current warm-up program (Core Performance Movement Prep-10 minutes in duration) or the current warm-up program (Core Performance Movement Prep) and the Postural Restoration Institute's Soccer Program, which will be 20 minutes in duration for both.

4. Melynda Brenton, MS (Masters of Science with an emphasis in Sports Medicine), LAT (Licensed Athletic Trainer), will conduct both pre- and post-testing of range of motion in the knees, hip, low back, shoulders, and neck with the use of a goniometer.

5. Melynda Brenton, MS, LAT, will also determine the injury status as well as the severity of injuries.

The project will be explained in terms that your child can understand, and your child will participate only if she is willing to do so.

At the conclusion of the study, results will be reported as group results only. At the end of the study a summary of group results will be made available to all interested parents. Please indicate at the end of this consent form whether you wish to have these results. If so, please provide your e-mail address. Results should be available in approximately four weeks after the conclusion of the study.

Participation in this study is voluntary. Your decision whether or not to allow your child to participate will not affect your child's status with the girls' soccer coaching staff at Farmington High School. Even if you give your permission for your child to participate, your child is free to refuse to participate. If your child agrees to participate, she is free to end participation at any time. You and your child are not waiving any legal claims, rights, or remedies because of your child's participation in this research study.

Should you have any questions or desire further information, please feel free to contact

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Keep this letter after completing and returning the signature page to me.

If you have any questions about your rights as a research subject, you may contact the Adams State College Institutional Review Board (IRB) by mail at C/O Dr. Brent King, Chair of IRB ES 337, by phone at 719-587-7010, or by e-mail at brentking@adams.edu. This study was approved by the IRB on June 8, 2010.

Sincerely,

Shannon Gill
Human Performance and Physical Education Department

Please indicate whether or not you wish to allow your child to participate in this project by checking one of the statements below, signing your name and returning it to me. Sign both copies and keep one for your records.

_____I do grant permission for my child to participate in Ms. Shannon Gill's study of Dynamic Warm-up and Injury Prevention for Adolescent Female Soccer Players.

_____I do not grant permission for my child to participate in Ms. Shannon Gill's study of Dynamic Warm-up and Injury Prevention for Adolescent Female Soccer Players.

______________________________	______________________________
Signature of Parent/Guardian	**Printed Parent/Guardian Name**
______________________________	______________________________
Printed Name of Child	**Date**
______________________________	______________________________
Signature of Researcher	**Date**

__________Yes, I would like a copy of the results of this study. My mailing address is below.

APPENDIX F

Informed Consent

Adams State College

ASSENT TO PARTICIPATE IN RESEARCH

Dynamic Warm-up and Injury Prevention in Adolescent Female Soccer Players

1. **My name is Shannon Gill and I am a student at Adams State College.**

2. **We are asking you to take part in a research study because we are trying to learn more about injury prevention for adolescent female soccer players.**

3. **If you agree to be in this study, I will ask you to participate in either the Core Performance Movement Prep dynamic warm-up that has already been incorporated into the Farmington High School girls' soccer team or the Core Performance Movement Prep dynamic warm-up and the Postural Restoration Institute's Soccer Program dynamic warm-up.**

4. **I do not believe that participation in this study will cause you any harm. If you take part in the study and believe that you have been harmed in any way, you may stop being in the study.**

5. **I believe this study will benefit you by properly warming-up your muscles to prevent injury before participating in strength conditioning sessions, speed and agility sessions, and technical and tactical training sessions. If you choose to participate in this study, it will help me learn what exercises will help prevent injuries in soccer so that you can play to your fullest potential without injury.**

6. **If you choose to participate in this study, your name will not be printed in the results. It will remain confidential. All results from this study will be reported as group findings without individual names.**

7. **Please talk this over with your parents before you decide whether or not to participate. Your parent gave permission for you to take part in this study. Even though your parent said "yes", you can still decide not to do this.**

8. **If you don't want to be in this study, you don't have to participate. Remember, being in this study is up to you and no one will be upset if you don't want to participate or even if you change your mind later and want to stop.**

9. **You can ask any questions that you have about the study. If you have a question later that you didn't think of now, you can call me at 505-860-1561**

or ask me next time. You may call me at any time to ask questions about the study.

10. Signing your name at the bottom means that you agree to be in this study. You will be given a copy of this form after you have signed it.

____

Signature of Subject

____ ____________

Printed Name of Subject **Date**

____ ____________

Signature of Researcher

APPENDIX G

Single Factor ANOVA for ROM Change Scores (pre to post)

Measurement Sites	F	df	p
Right Knee Flexion	1.968	1,20	0.176
Left Knee Flexion	0.254	1,20	0.619
Right Knee Extension	0.034	1,20	0.855
Left Knee Extension	0.461	1,20	0.505
Right Hip Flexion	0.283	1,20	0.601
Left Hip Flexion	0.022	1,20	0.884
Right Hip Hyperextension	0.026	1,20	0.873
Left Hip Hyperextension	2.781	1,20	0.111
Right Hip Abduction	0.143	1,20	0.709
Left Hip Abduction	2.118	1,20	0.161
Right Hip Hyperadduction	0.191	1,20	0.667
Left Hip Hyperadduction	0.014	1,20	0.908
Low Back Hyperextension	0.082	1,20	0.777