The Increased Incidence of ACL Injury in Female Athletes and the Effects of Proprioceptive Training Programs on Tear Rates.

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Honors Thesis Project

Honors Thesis
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PASS WITH DISTINCTION
so my hands-on experience with knees was over for this summer anyway. I thanked Dr. Mandelbaum for the experience. Overall, the whole internship was incredibly beneficial for both my thesis work, as well as my underlying interest in a future career in medicine. Not only had I learned much relevant information from which to begin my thesis, but I had also contributed in a minor way to a great and innovative new ACL prevention program.
TO THE UNIVERSITY HONORS COLLEGE:

As thesis advisor for Jenna Wirtz,

I have read this paper and find it satisfactory.

Jon Mallatt
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Feb 13, 2004
Date
Précis:

While female participation in sports-like activities can be traced back many centuries, only of late have the gender-specific risks involved with such activity been quantified. With its passage in 1972, Title IX granted women equality as far as participation in sports is concerned. Due to the athletic opportunities that title IX brought about, female participation in sports has since proliferated. One unfortunate consequence of this legislation, and the resulting spike in female athletic competition, has been the dramatically increased number of sports-related injuries in female athletes.

One of the most common injuries in females is to the anterior cruciate ligament (ACL) in the knee. The ACL is one of the primary stabilizers of the knee and is vital in preventing the anterior (forward) slippage of the tibia (shin bone) during motion (Ferretti, 1992). Regrettably for females, recent research has revealed a two to eight time increased risk in females for ACL injury compared with male athletes participating in the same sport (Feretti, 1992; Arendt, 1995; Toth, 2001; Trimmer, 2001; Potkey, 2002a; Potkey, 2002b; Wojtys, 2002; Madden, 2003). Many factors have been explored as the possible sources for this inter-sex discrepancy in ACL tear rates, including: intercondylar notch size, lower limb alignment (Q-angle), hormonal influences in ligamentous laxity, momentary lapses in neuromuscular coordination in women, athlete strength and conditioning including learned motor skills such as jump-landing techniques, uneven playing surfaces, and poorly fitted shoes.

This topic is of particular interest to me, having been a competitive athlete for over 12 years, because I have suffered four major knee injuries and had three knee
surgeries since the age of fifteen. I chose to research the susceptibility of women to knee injuries in order to reveal the unforeseen negative impacts of athletics on women’s knees, as well as to attempt to pinpoint the causative factor in the high injury rates of female athletes versus males. To accomplish these goals, I interned with Dr. Bert Mandelbaum, a well-known orthopaedic surgeon from Santa Monica, California and co-creator of the successful Prevent injury, Enhance Performance (PEP) conditioning program. Dr. Mandelbaum and his colleagues have studied first-hand the disproportionate injury rates among the sexes, and believe instantaneous biomechanical mis-fires in females to be the main causative agent of ACL tears in women. The researchers designed the PEP program to teach special avoidance techniques along with stretching, strengthening, plyometrics, and sport-specific drills to address potential weaknesses in the strength and coordination of the stabilizing muscles of the knee. Through three initial trials, the PEP program produced 88%, 74%, and 30% decreases respectively in ACL tear frequencies between the PEP-trained athletes as compared with the untrained, control groups.

While prevention programs may not fully alleviate females’ risks of sports-related injuries (because of the existence of other risk factors), the accomplishments of such regimens have motivated physicians, coaches, and parents across the country to integrate similar programs in their weekly practices. The future success of injury-prevention programs at curbing the growing ACL epidemic among female athletes will depend largely on the dedication of those athletes to their respective programs and to improving their odds against injury.
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**Introduction:**

Stemming from its passage by the NCAA in 1972, Title IX legislation has led to steadily increasing numbers of girls and women competing in various sports at many levels. Today, female sports participation has reached an all time high with more than 2.5 million high school girls and 145,000 college women currently participating in at least one sport (Smith, 2000; Mandelbaum et al., 2002; Griffin et al., 2003). This drastic increase in participation also paved the way for an overall change in the way that female athletes play sports. Once dominated by a defensively slow style, women’s sports are now played with precision, power and speed; however, with these changes have also come increased injuries for female athletes in general (Moeller and Lamb, 1997).

The massive surge of female participation in sports over the last few decades, from about 300,000 in 1971 to nearly three million in 2002 has resulted in an explosion of anterior cruciate ligament (ACL) knee-injuries in women (Potkey, 2002). The commonality of ACL injuries among female athletes has athletic trainers, doctors, and university administrators alike perplexed. One out of every 100 high school female athletes and one out of every ten college female athletes experiences an ACL injury in a single year (Griffin et al., 2000; Adams, 2002). Immediately following Title IX’s passage, researchers frequently attributed the growing number of injuries in female athletes merely to the increased participation of women in sports and the change in their style of play, but most doctors and researchers today now believe females to be
more prone than their male counterparts to injury due to both extrinsic and intrinsic factors (Potkey, 2002a).

The anterior cruciate ligament is one of four main ligaments in the knee (Behnke, 2001). The ACL is composed of densely organized, fibrous collagenous connective tissue, and connects the tibia (shin bone) to the femur (thigh bone) (Behnke, 2001; Mandelbaum et al., 2003). The role of the anterior cruciate ligament is to keep the shin from slipping forward during motion (Ferretti et al., 1992). Research has shown that females who participate in agility-based sports such as basketball and soccer increase their risk of injuring an ACL anywhere from two to eight times per hour of athletic competition, as compared with males participating in the same sport (Ferretti et al., 1992; Arendt and Dick, 1995; Toth and Cordasco, 2001; Trimmer, 2001; Potkey, 2002a; Potkey, 2002b; Wojtys et al., 2002; Madden, 2003).

Presented with increased ACL injuries in females, the National Collegiate Athletic Association (NCAA), using data that it began compiling in 1982, mounted a study of female collegiate soccer and basketball players and recently reported its findings on ACL injuries: in any given year, approximately 2,200 collegiate women will rupture their ACL (Arendt and Dick, 1995). The study performed by Arendt and Dick involved data from 931 Division I, II, and III schools and was collected throughout a five year period. The statistics amassed from 531 men’s and 576 women’s basketball teams showed the ACL injury rate in the women to be 0.29 per one thousand exposures, four times greater than the men’s ratio of 0.07 incidents per one thousand exposures (Potkey, 2002).
Many factors, both anatomical (intrinsic) and extrinsic, have been discussed as the possible sources of females’ increased tendency over men to tear their ACL. Intrinsic factors are those specific to the female gender, which may not be easily altered. These include anatomic and physiologic factors such as intercondylar notch size, lower limb alignment (Q angle), hormonal influences in joint laxity, and instantaneous losses of neuromuscular coordination in women during certain athletic movements. Extrinsic factors are potentially more easily modified and include athlete strength and conditioning, uneven playing surfaces, poorly fitted shoes, and learned motor skills such as landing from a jump (Arendt and Dick, 1995; Griffin et al., 2000; Mandelbaum et al., 2002; Mandelbaum et al., 2003).

Although the outlook in terms of injury appears bleak for women athletes, injury intervention studies have shown that decreasing the statistically elevated risk of ACL injury in women is indeed possible. Doctors and researchers alike concur that early intervention is needed to stem the tide of increasing ACL injuries. Considering the high costs of ACL repair, (nearly twenty-five thousand dollars per surgery) resulting in an annual cost of roughly fifty-five million dollars, it is in no way baffling that the NCAA is willing to invest money in prevention programs to attempt to curb the present female ACL epidemic (Griffin et al., 2000). With the help of the NCAA study and other similar assessments, the inequality between female and male injury rates is now set in stone and researchers have begun within the last few decades to turn their attentions to intrinsic and extrinsic explanations for the disparity. Researchers have developed four main injury theories that deal with intrinsic factors.
Dr. Bert Mandelbaum, an orthopaedic and sports medicine doctor with the Santa Monica Orthopaedic and Sports Medicine Group in California, through his work as the United States Men’s National Soccer Team doctor as well as his experiences as UCLA and Pepperdine University’s team doctor, has observed first-hand the disproportionate number of knee injuries in female athletes compared with their male counterparts. In recent years, his studies and research on this phenomenon and on early intervention programs have made him renowned as one of the foremost experts in the field of female athletic knee injuries in the world.

Through an internship working in his office during the summer of 2002, I visited patients with Dr. Mandelbaum and observed him perform numerous surgeries in order to visually compare the ratio of female versus male injuries, while revealing the unforeseen negative impacts of sports on women’s knees. I also worked with Dr. Mandelbaum and several of his co-workers on the innovative program called Prevent injury and Enhance Performance (PEP) that was implemented in nine NCAA Division I women’s soccer programs during the 2002 fall season. Specific results will be discussed further in this paper.

The ACL

Ligaments are tough bands of fibrous tissue that connect bones. The anterior cruciate ligament is the smallest knee ligament and connects the tibia (shin bone) and femur (thigh bone), providing stability to the knee for activities requiring jumping, landing, twisting, running, decelerating, turning, and changing directions quickly on a straight (extended) knee (see figure 1). The anterior and posterior cruciate ligaments, better known as the primary stabilizers of the
knee, cross each other through the intercondylar notch (Behnke, 2001; Madden, 2003). Together they maintain the rotary stability of the knee and prevent the tibia from moving either too far forward or backward from the femur at the knee. The ACL is a broad, thick cord approximately the size of a person’s index finger that prevents the knee from extending too far beyond its normal range of motion. The ACL originates at the posteromedial aspect of the lateral femoral condyle and inserts into the diamond-shaped portion of the anterior intercondylar eminence of the tibia (Behnke, 2001). The posterior cruciate ligament is the larger of the two ligaments, which may help to explain why the ACL is torn more frequently than the PCL. Despite its small size, the anterior cruciate ligament provides about 90% of the knee’s overall stability (Ireland, 1996; Madden, 2003). The ACL consists of long, interwoven collagen strands and is strong enough to resist 500 pounds of tension before rupturing (Madden, 2003).
ACL injuries occur approximately 250,000 times per year in the United States (Brock, 2001). An ACL becomes torn or ruptured when it is stretched beyond its normal range of elasticity. Injuries to the anterior cruciate ligament most commonly occur in sports such as soccer, basketball, and volleyball, which require the athletes to perform activities such as jumping, landing, decelerating, changing directions, and twisting (Parker, 2002).

**Intrinsic Risk Factors:**

**The Narrow Notch Theory:**

The geometry of the intercondylar notch (see Figure 2) has been implicated as a possible risk factor for ACL injury (La Prade and Burnett, 1994). The intercondylar notch, at the inferior portion of the femur and through which the anterior cruciate ligament passes, has been found in some studies to generally be different in women versus men (Souryal and Freeman, 1993; Shelbourne et al., 1997; Shelbourne et al., 1998; Charlton et al., 2002). In a study published in the American Journal of Sports Medicine, researchers from The Rothman Institute in Philadelphia, Pennsylvania used magnetic resonance imaging (MRI) and found that the volume of the notch tends to be statistically smaller in women compared with men (Charlton et al., 2002). Another study published in the 1998 edition of the American Journal of Sports Medicine measured and recorded the notch widths of 714 consecutive ACL tear patients. They found the mean notch width for females to be 13.9 mm. and for men to be 15.9 mm. The researchers then went on to record the frequency of ACL re-injury and reported that only four out of the 26 patients (15%) with notch widths less than fifteen millimeters tore their reconstructed ACLs
compared with 23 out of the 388 patients (6%) with notch widths greater than sixteen millimeters (Shelbourne et al., 1997). This research supports the correlation between narrow intercondylar notch width and increased frequency of tears as females were found to have statistically narrower notches and were also found to re-injure their ACLs more frequently than males. Here is one possible mechanism of injury: since a narrow notch restricts the ACL’s movement, the femoral condyles can more easily pinch the ACL within the joint, especially during twisting or hyperextending movements, ultimately shearing the ligament and resulting in a tear or rupture.

The present day theory of “notch width” hypothesizes that when an athlete performs certain cuts and jumps, having a narrow notch may cause the ACL to be “shaved” by the femur and thus, predisposes those individuals, particularly females, to ACL tears due to their narrow intercondylar notches (Tillman et al., 2000; Potkey, 2002).

Figure 2: Comparison of Intercondylar Notch Width (Silberg, 2003)
Other studies, such as that presented at the American Society of Biomechanics in October of 1997, detect no differences in notch width between male and female cadavers, but did indeed document a definite difference in shape. According to the study, males’ notches form a more u-shaped angle whereas females’ notches are more v-shaped. The narrower v-shaped femoral notch presents a smaller, more confined space through which the ACL must pass, again promoting the afore mentioned shearing effect (Tillman et al., 2000).

**The Relative Knock-Kneed Theory:**

Another intrinsic factor that is thought to play a major role in the disproportionality of ACL injuries between the sexes is the women’s lower limbs as compared to men’s. A common measurement of this alignment is quadriceps angle (Q-angle). Figure 3 demonstrates that the Q-angle is a measure of the angle formed between a line from the anterior superior iliac spine (at the hip) to the center of the patella (at the knee) and a line from the center of the patella to the tibial tubercle (at the superior shin) (Woodland and Francis, 1992). A woman’s wider pelvis, which exposes the knee and ligaments, creates a greater Q-angle and creates greater stress than in men’s knees (Anderson et al., 2001).}

for the Washington Freedom women’s professional soccer team, notes that one of the most
popular notions in sports medicine today is that females’ generally larger Q-angles leave their knees susceptible to inward torque when jumping, landing, turning, and planting. (French, 2002). Inward torque can be defined as the rolling medially (or inside) of the foot at the ankle, followed by the lower leg, knee and upper leg. Women’s knock-kneed stance places them at a high risk for inward torque-related injuries as their legs naturally arch inward from the hip (see figure 4).

Figure 4: Illustration of Relative Knock-Kneed Stance in Females (www.nismat.org, 2004)

The average Q-angle in women is roughly seventeen degrees compared to only ten degrees in men (Ireland, 2002). This wide angle that is characteristic of the female body results in flat-foot landings adding undue stress to the lower leg and knee during jumping. The large Q-angle concentrates more forces on the anterior cruciate ligament for stability each time that the knee rotates, predisposing the athlete to a tear (Arendt and Dick, 1995).

**The Hormonal Laxity Hypothesis:**
Yet another intrinsic factor thought by many to play a causitive role in the heightened frequency of ACL tears among female athletes is the hormonal fluctuations that women experience throughout their monthly menstrual cycles that may cause ligamentous laxity within the knee joint (Liu et al., 1996; Lebrum, 2000; Slauterbeck et al., 2002). Since the menstrual cycle, with its monthly hormonal fluctuations, is one of the most basic differences between females and males, many researchers consider it to be the root of the imbalance in ACL injuries (Wojtys et al., 2002).

The anterior cruciate ligament contains estrogen receptors in its fibroblasts and is composed of collagen fibers (Liu et al., 1996; Wojtys et al., 1998). ACL fibroblasts respond to the presence of estrogen in the blood by decreasing collagen synthesis, thus increasing the ligamentous laxity (Cooper, 1999). Due to their direct effect on collagen metabolism, undulating estrogen levels throughout the female menstrual cycle result in varying neuromuscular performance (Wojtys et al., 1998).

The menstrual cycle consists of three main phases: the follicular, the ovulatory, and the luteal phases (Lebrum, 2000). The first day of menstrual flow (menses) marks the onset of the follicular phase. This bleeding usually lasts for three to five days and is followed by sustained low hormone levels for eight to ten days (Liu et al., 1996; Wojtys et al., 2002). Around midcycle, (days 13-15) a pulse of lutenizing hormone (LH) is released from the anterior pituitary gland resulting in a spike in blood estrogen levels about 24 hours prior to ovulation (see figure 5). This ovulatory phase lasts an average of 5 days and is characterized by extremely high estrogen levels. The luteal phase usually lasts about fourteen days, beginning at the end of the
ovulatory phase and lasting until the onset of the next menses. Although low levels of both progesterone and estrogen in the blood mark the follicular phase, the luteal phase is typified by high hormonal blood levels (Lebrum, 2000). Due to the extremely high estrogen levels around ovulation, knee laxity has been shown to increase during the ovulatory phase of the menstrual cycle.

**Figure 5: Hormone Levels During the Menstrual Cycle (Huskey, 1998)**

In a 1998 study, Edward J. Wojtys et al. observed and commented on the frequency of ACL injuries throughout the menstrual cycle. The researchers reported a significant statistical correlation between the stage of the menstrual cycle and the likelihood for an anterior cruciate ligament tear and in particular, a 1.6 time greater than expected incidence of ACL injury in the late follicular/ovulatory phase of a woman's menstrual cycle (Wojtys et al., 1998). Upon further examination and following another trial in 2002, the researchers, again headed by Dr. Edward J.
Wojtys, studied the effects of the hormone levels present at various stages throughout the menstrual cycle on ACL tear frequencies. The researchers gathered a group of 69 female athletes, all sufferers of recent non-contact ACL injuries, and tested the females’ individual hormone levels throughout their cycles. They then compared the individual hormone levels with the time of injury for each woman and normalized them. The researchers reported a 2.5 time greater than expected frequency of ACL injury during the ovulatory phase of the menstrual cycle. The data also showed fewer ligamentous injuries than expected during the luteal phase (Wojtys et al., 2002).

The heightened number of ACL injuries during the estrogen-rich ovulatory phase supports the hypothesis that a high estrogen level in the blood adversely affects collagen synthesis in the anterior cruciate ligament and consequently increases the ligamentous laxity in and weakens the ligament (Wojtys et al., 1998; Wojtys et al., 2002).

A possible flaw in this theory is revealed when one considers that some time should elapse between blood-estrogen levels halting collagen synthesis in the ACL and the actual weakening of the ligament. One would expect a subsequent delay in the weakening of the ligament following the spike in hormone levels, due to preexisting collagen fibers giving the ACL strength. Perhaps another plausible hypothesis to explain the increased incidence of ACL tears in females around ovulation should be explored. For example, the increase in estrogen may trigger a rush of fluid to enter the ligament from the blood which in turn, weakens the ACL.
The Momentary Lapse of Neuromuscular Control in Women Hypothesis:

The last intrinsic category hypothesized widely as a causitive agent of the discrepancy between male and female ACL tear rates deals with the actual movement behaviors of the athletes. Non-contact injuries constitute 93% of female ACL injuries (Moeller and Lamb, 1997; Brock, 2001). For reasons unknown, female athletes tend to perform athletic movements such as planting, cutting, and landing from jumps with straight legs. Women also tend to land from jumps flat-footed instead of on the ball of the foot. These straight-legged activities require that the knee absorb forces of about four times the individual’s body weight and ultimately encourage the hyperextension of the knee (Moeller and Lamb, 1997). Since hyperextension is one of the leading causes of non-contact ACL tears, altering female athletes’ jump-landing strategies should help decrease the number of female ACL injuries.

A study presented to the American Academy of Orthopaedic Surgeons in California in February 1999 videotaped athletes to observe their individual running styles (Malinzak et al., 1999). The researchers reported that men generally run in a crouched position whereas women tend to run upright, with their hips pushed forward. Due to their upright posture, female athletes rely on the quadriceps muscles in the front of the thigh more than the hamstrings at the rear, and therefore have decreased flexion in their knees when running (Hewett et al., 1999; Malinzak et al., 1999). Since the hamstring muscles serve to prevent the anterior translation of the tibia onto the femur as does the ACL, females’ inherently weak hamstrings increase their risk of ACL injury (Fagenbaum and Darling, 2003).
Along with the difference in athletic posture, female and male body composition differ on average as well (Hewett et al., 1999; Griffin et al., 2000). When men and women compete in similar sports, they experience nearly identical twisting and stretching stresses on their knees. However, women have less muscle strength in proportion to bone mass than men, particularly surrounding their knee joints, and therefore rely on their anterior cruciate ligaments more for stability (Griffin et al., 2000).

An instantaneous neuromuscular imbalance has also been cited as a prime risk factor in women for ACL tears and is even believed by some researchers to be the underlying cause of intrasex discrepancies in tear frequencies. Neuromuscular control of the knee during athletic activity is maintained by a complex interaction between the quadriceps, hamstring, and various knee muscles (Mandelbaum et al., 2002; Mandelbaum et al., 2003). The integrated regulating system includes both the muscles and the nerves responsible for triggering muscle contraction. Due to the intricate interaction between these separate systems, non-contact ACL injuries may be a result of a breakdown in, or the lack of, certain neuromuscular recruitment patterns necessary to prevent unnecessary stress on the ACL (Mandelbaum et al., 2003; Edell, 2004). Dr. Bert Mandelbaum of the Santa Monica Orthopaedic and Sports Medicine Group who is the team physician for both the U.S. Men’s and Pepperdine University’s soccer teams believes that females possess a sort of momentary lapse in neuromuscular coordination that, at times of imbalance in the knee, results in the muscles not firing fast enough to counteract the forces that cause injury, thus leaving the ACL to absorb all of the shock on its own (Mandelbaum et al.,
2003). This view says that fortunately, with the implementation of a proper training regimen, all athletes can improve their neuromuscular coordination and prevent future injuries.

Combined with the three other main intrinsic factors negatively affecting ACL health in female athletes, movement patterns, muscle imbalances, and jump-landing techniques contribute to the disproportionality of ACL injuries between males and females.

**Extrinsic Factors:**

Researchers attempting to curb the female ACL epidemic have also considered the importance of several extrinsic factors in controlling the rising numbers of ACL injuries. Extrinsic factors include equipment fit, playing surface, and strength and conditioning programs that incorporate jump-landing techniques (Arendt and Dick, 1995; Mandelbaum et al., 2003). While intrinsic factors affecting the prevalence of ACL tears in females such as notch and hip width daunt physicians because of their unalterable nature, extrinsic factors can be changed and provide doctors, trainers, and coaches alike with the ability to improve the odds against ACL injury for female athletes.

**Equipment Fit:**

The fit of an athlete’s shoes is perhaps the simplest factor to regulate. Shoe traction plays a vital role in preventing injuries such as non-contact ACL ruptures in women. Traction is a particular concern with court and cleated sports shoes (see figure 6) in regards to their interaction with the playing surface (Frey, 1997). The effects of shoe traction have long been suspected to
contribute to the high incidence of non-contact ACL injuries. Torg et al. (1974) quantitatively measured “release coefficients” to describe force-to-weight ratios of shoe surface interaction. Heidt et al. (1996) enforced Tourg’s research when they tested 15 different athletic shoes for safety and found that 73% of the shoes demonstrated either “unsafe” or “probably unsafe” behaviors. In 1989, Ekstrand et al. noted the importance of an optimal range in shoe design. He advocated that this range minimize rotational friction to minimize injury but maximize transitional friction (intermediary gripping control) to allow for peak performance in activities such as cutting and decelerating (Ekstrand and Nigg, 1989). Decreasing the degree of traction has proven important in many cases; for example, a woman playing soccer on a field with long, thick grass should avoid wearing shoes with cleats that are longer than one and one half inch each because the longer the cleat, the greater the chance of the spikes getting caught up in the grass, subsequently resulting in an injury to the athlete. Similarly, since female’s heels are on average narrower than males, female basketball and volleyball shoes should be made accordingly. If these athletes do not wear properly fitted shoes, they increase their chances of succumbing to mid-pivot heel slippage that places undue stress on the ACL (Frey, 1997).

Although shoes have the potential to adversely affect athletes participating in all sports, soccer cleats are of special interest to researchers because of the wide variety available. Soccer cleats can either improve an athlete’s performance and help prevent injuries if they are properly fitted and maintained, or they can contribute to injuries if they are worn out or utilized on the wrong playing surface (CDC, 2004). Soccer shoes come in a variety of styles and cleat patterns such as bladed, molded, studded, or flats, each designed for different field conditions (see figure...
6). The higher the friction between the shoe and the surface, the greater the traction and the higher the risk of ligament injury. When considering an athletic shoe, it is important not to forgo safety for the sake of enhanced performance (Frey, 1997). Therefore, to reduce the friction in order to be properly equipped to play soccer on any given day, a female athlete should consider

Figure 6: Comparison of 4 Main Types of Soccer Shoes (Getz and Brannan, 2002)

not only the type of playing surface, but also the condition of the field (i.e. muddy versus hard) before deciding on the ideal cleat to wear.

Playing Surface:

Well conditioned playing surfaces can prevent many injuries. The playing grounds should be kept in good condition for both practice and games (Ekstrand and Nigg, 1989; CDC, 2004). Holes in grass playing fields should be filled and bare spots reseeded. Whether the surface is a hardwood court or a turf or grass field, debris should never be left on it (CDC, 2004).
Hardwood courts should be wiped clean of sweat, blood, or water to decrease the risk of ligament injury due to slipping.

**Strength and Conditioning Programs:**

Injury prevention programs have been instituted in various high risk sports such as soccer, volleyball, basketball, and skiing around the world for decades in an attempt to curb the growing numbers of ACL injuries (Mandelbaum et al., 2002). These programs have seen as high as a 72% to 89% reduction in serious ACL injuries among the athletes trained under these programs as compared with the controls (Griffin et al., 2000; Mandelbaum et al., 2002). One such program was implemented in two Division I basketball programs by Henning beginning in 1983. His study lasted eight years and focused on changing the players’ techniques through continuously addressing the need for correct body positioning and awareness (Henning and Griffis, 1990). Henning’s instructional videos emphasized keeping the knee flexed during jump landings, deceleration with multi-step stops, and acceleration using rounded turns. At the end of eight years, the researchers reported an 89% reduction in ACL injury in the intervention group (Henning and Griffis, 1990).

A second program, which focused on proprioceptive balance training, was implemented by Caraffa et al. (1996) on 600 Italian amateur and semi-professional soccer players. This study spanned a total of three soccer seasons and ultimately resulted in an 87% decrease in ACL injury incidents. Caraffa et al. reported an incidence rate of 0.15 ACL injuries per team per year for the trained athletes compared with a 1.15 rate of injury for the control group (Caraffa et al., 1996).
Hewitt analyzed 1263 male and female athletes participating in various sports using a neuromuscular training program lasting for six weeks (Hewett et al., 1999). The training program consisted of stretching, plyometrics (agility-based jumping exercises), and weight training that all stress proper technique. At the end of the trial, the researchers reported that the incidence of ACL injury among the untrained control group was 2.4 to 3.6 times higher than that of the trained group (Hewett et al., 1999).

Perhaps the most feasible of all injury intervention programs are those directly addressing the injury discrepancies between women and men and aiming specifically to alter the mechanical behaviors in female athletes that contribute to the unequal numbers of ACL injuries. Many such programs have recently been introduced including the Prevent injury, Enhance Performance program (PEP), the innovative training program spearheaded by Dr. Bert Mandelbaum of the Santa Monica Orthopaedic and Sports Medicine Group at Saint John's Health Center. The PEP program is designed to integrate a strategic training program into regular weekly practices in order to decrease the number of ACL injuries among young athletes. This program is a fifteen minute training session that consists of special avoidance techniques, stretching, strengthening, plyometrics, and sport-specific drills designed to address potential weaknesses in the strength and coordination of the stabilizing muscles that surround the knee joint (see Appendix 1)(Griffin et al., 2000; Mandelbaum et al., 2003). The PEP program is a proprioceptive and neuromuscular-rich program that targets biomechanical deficits in females and stresses the importance for female athletes of performing activities such as running, jumping, and pivoting with knees bent (Mandelbaum et al., 2003).
Dr. Mandelbaum, together with Dr. Letha Griffin of the University of Georgia in Augusta, evaluated the effectiveness of the PEP training program in 2000. The researchers compared knee injuries among 1,041 female soccer players from 52 teams in Southern California’s Coast Soccer League trained by the prevention program to 1,902 control players who did not enroll in the course. After the league season ended, the compiled data revealed that the PEP-trained players had only two incidents of ACL tears versus 32 tears in the non-trained control group. The ACL incidence rate in the PEP-trained group was 0.2% while the ACL incidence rate in the control group was 1.7%. The overall decline in ACL ligament injury in athletes who followed the PEP program was 88% (Mandelbaum et al., 2003). According to a study performed by D. Gwinn et al. (2000), male ACL incident rates range from 0.19 to 0.57 depending on the activity; therefore, by reducing the incident rate for the PEP-trained females to 0.2, the PEP program reduced the risk of ACL injury for females to a range comparable to that of males.

Drs. Mandelbaum and Griffin conducted a second trial during the 2001 Coast Soccer League season in which they enrolled 844 female athletes from 45 teams in the PEP program and utilized 1,913 females from 112 teams for the control. Four ACL tears were reported for the intervention group, compared with 35 for the control group. The overall incidence rate for the PEP-trained group was 0.47% versus an incidence rate of 1.8% for the control group. The second trial of the PEP program produced a 74% reduction in ACL injuries in the intervention group compared with the controls (Mandelbaum et al., 2003).
The next step in the researchers’ progression was implementing their successful PEP program into a collegiate setting. In the fall of 2002, Drs. Mandelbaum, Griffin, and Gilchrist, along with their research partners selected nine diverse Division I women’s soccer teams varying in geography, conference, school size, and competitive success to participate in the training program. The PEP-trained group consisted of 206 athletes who combined for a total of 8,888 athlete-exposures (Mandelbaum et al., 2002). From data compiled by the NCAA’s Injury Surveillance System, 1.43 ACL injuries per one thousand athlete exposures are expected, theoretically resulting in 12.7 expected tears among the 206 athletes studied (Arendt and Dick, 1995). Only nine ACL injuries were reported thus accounting for a 30% decrease in the amount of knee injuries suffered by the PEP-trained athletes versus the expected numbers. Although the literature does not say whether or not the collected data was statistically significant, the results from this study supported the feasibility of a randomized and controlled trial to further evaluate the effectiveness of the PEP program; however, the apparent degree of the reduction in ACL injuries was far less in the third trial than in the previous two. One plausible explanation for this discrepancy is that the PEP program must be monitored closely and administered religiously for maximal results and during the third trial, it was not. The first two tests were performed on athletes within close proximity to the research offices and they could therefore be instructed and observed first-hand by the researchers. On the contrary, for the third trial, videotapes and instruction manuals were distributed to the respective coaches, who then were responsible for properly implementing the program into their practices on a weekly basis. The researchers’ detached approach to the third trial resulted in a less successful outcome which emphasized the
importance of teaching the correct technique to the subjects. This suggests that in the future, to maximize the efficiency of the PEP and other such injury prevention programs, trainers, coaches, and medical personnel should all take an instructional course on the program first, to ensure proper administration of the material.

**Conclusion:**

Due to the rise of female participation in sports over the last few decades, the rate of female sports-related injuries has also been on the rise. Of particular interest to researchers studying this phenomenon is the inequality between injury rates in males versus females. It has been documented that female athletes are more prone to knee injuries, particularly ACL ruptures, than are their male counterparts (Arendt and Dick, 1995; Ireland, 1996; Moeller and Lamb, 1997; Cooper, 1999; Smith, 2000; Brock, 2001; Toth and Cordasco, 2001; Trimmer, 2001; Adams, 2002; French, 2002; Ireland, 2002; Parker, 2002; Potkey, 2002; Madden, 2003; Mandelbaum et al., 2003; Silberg, 2003). Several factors have been identified as contributing to the discrepancy in tear rates; however, studies have named the differences in neuromuscular coordination and muscle imbalances between the sexes as the main causitive agents in the frequency of ACL injuries in females (Henning and Griffis, 1990; Caraffa et al., 1996; Hewett et al., 1999; Griffin et al., 2000; Mandelbaum et al., 2002; Mandelbaum et al., 2003). Due to the detrimental effects of momentary lapses in neuromuscular control on the anterior cruciate ligament, many researchers have designed prevention programs aimed at reducing the incidence of ACL injuries by retraining athletes to increase coordination while avoiding high-risk body
positions (Henning and Griffis, 1990; Caraffa et al., 1996; Hewett et al., 1999; Griffin et al.,
2000; Mandelbaum et al., 2002; Mandelbaum et al., 2003). The success of training regimens
such as Dr. Mandelbaum’s PEP program in decreasing the current female ACL epidemic have
motivated team doctors, coaches, parents, and players alike to implement similar programs in
their weekly practices. Title IX may have mandated equality for women in sports, but women
will not truly reap the benefits of equality until their rate of ACL injury is equal to that for men.
Works Cited:


**Works Consulted:**


**Appendix 1:**

*The Santa Monica Orthopaedic and Sports Medicine Research Foundation*

**The PEP Program: Prevent injury and Enhance Performance**

This prevention program consists of a warm-up, stretching, strengthening, plyometrics, and sport specific agilities to address potential deficits in the strength and coordination of the stabilizing muscles around the knee joint. It is important to use proper technique during all of the exercises. The coaches and trainers need to emphasize correct posture, straight up and down jumps without excessive side-to-side movement, and reinforce soft landings. This program should be completed 3 times a week. The field should be set up 10 minutes prior to the warm-up. This will allow for a
smooth transition between the activities. A sample field set-up has been included in your packet. This program should take approximately 15 – 20 minutes to complete. Along side each exercise you will notice a box with the approximate amount of time that should be spent on each activity. This will serve as a guideline to you in order to conduct your warm-up in a time efficient manner.

1. **Warm-up:** Warming up and cooling down are a crucial part of a training program. The purpose of the warm-up section is to allow the athlete to prepare for activity. By warming up your muscles first, you greatly reduce the risk of injury.

   **A. Jog line to line** (cone to cone) Elapsed Time: 0 - .5 minute
   
   *Purpose:* Allows the athletes to slowly prepare themselves for the training session while minimizing the risk for injury. Educate athletes on good running technique; keep the hip/knee/ankle in straight alignment without the knee caving in or the feet whipping out to the side.
   
   *Instruction:* Complete a slow jog from near to far sideline

   **B. Shuttle Run** (side to side) Elapsed Time: .5 to 1 minute
   
   *Purpose:* engage hip muscles (inner and outer thigh). This exercise will promote increased speed. Discourage inward caving of the knee joint.
   
   *Instruction:* Start is an athletic stance with a slight bend at the knee. Leading with the right foot, sidestep pushing off with the left foot (back leg). When you drive off with the back leg, be sure the hip/knee/ankle are in a straight line. Switch sides at half field.

   **C. Backward Running** Elapsed Time: 1 – 1.5 minutes
   
   *Purpose:* continued warm-up; engage hip extensors/hamstrings. Make sure the athlete lands on her toes. Be sure to watch for locking of the knee joint. As the athlete brings her foot back, make sure she maintains a slight bend to the knee.
   
   *Instruction:* Run backwards from sideline to sideline. Land on your toes without snapping the knee back. Stay on your toes and keep the knees slightly bent at all times.

2. **Stretching:** It is important to incorporate a short warm-up prior to stretching. Never stretch a “cold muscle”. By doing the exercises outlined here, you can improve and maintain your range of motion, reduce stiffness in your joints, reduce post-exercise soreness, reduce the risk of injury and improve your overall mobility and performance.

   - Do a large muscle warm-up such as brisk walking for five to 10 minutes before stretching.
   - Don’t bounce or jerk when you stretch. Gently stretch to a point of tension and hold.
   - Hold the stretch for 30 seconds. Concentrate on lengthening the muscles when you're stretching.
   - Breathe normally. Don't hold your breath.

   **A. Calf stretch** (30 seconds x 2 reps) Elapsed Time: 1.5 to 2.5 minutes
   
   *Purpose:* stretch the calf muscle of the lower leg
   
   *Instruction:* Stand leading with your right leg. Bend forward at the waist and place your hands on the ground (V formation). Keep your right knee slightly bent and your left leg
straight. Make sure your left foot is flat on the ground. Do not bounce during the stretch. Hold for 30 seconds. Switch sides and repeat.

**B. Quadriceps stretch** (30 seconds x 2 reps) Elapsed Time: 2.5 to 3.5 minutes

*Purpose:* stretch the quadriceps muscle of the front of the thigh

*Instruction:* Place your left hand on your partner’s left shoulder. Reach back with your right hand and grab the front of your right ankle. Bring your heel to buttock. Make sure your knee is pointed down toward the ground. Keep your right leg close to your left. Don’t allow knee to wing out to the side and do not bend at the waist. Hold for 30 seconds and switch sides.

**C. Figure Four Hamstring stretch** (30 sec x 2 reps) Elapsed Time: 3.5 – 4.5 min

*Purpose:* To stretch the hamstring muscles of the back of the thigh.

*Instruction:* Sit on the ground with your right leg extended out in front of you. Bend your left knee and rest the bottom of your foot on your right inner thigh. With a straight back, try to bring your chest toward your knee. Do not round your back. If you can, reach down toward your toes and pull them up toward your head. Do not bounce. Hold for 30 seconds and repeat with the other leg.

**D. Inner Thigh Stretch** (20 sec x 3 reps) Elapsed Time: 4.5 – 5.5 min

*Purpose:* Elongate the muscles of the inner thigh (adductor group)

*Instruction:* Remain seated on the ground. Spread you legs evenly apart. Slowly lower yourself to the center with a straight back. You want to feel a stretch in the inner thigh. Now reach toward the right with the right arm. Bring your left arm overhead the stretch over to the right. Hold the stretch and repeat on the opposite side.

**E. Hip Flexor Stretch** – (30 sec x 2 reps) Elapsed Time: 5.5– 6.5 min

*Purpose:* Elongate the hip flexors of the front of the thigh.

*Instruction:* Lunge forward leading with your right leg. Drop your left knee down to the ground. Placing your hands on top of your right thigh, lean forward with your hips. The hips should be square with your shoulders. If possible, maintain your balance and lift back for the left ankle and pull your heel to your buttocks. Hold for 30 seconds and repeat on the other side.

3. **Strengthening:** This portion of the program focuses on increasing leg strength. This will lead to increased leg strength and a more stable knee joint. *Technique is everything;* close attention must be paid to the performance of these exercises in order to avoid injury.

**A. Walking Lunges** (3 sets x 10 reps) Elapsed Time: 6.5 – 7.5 min

*Purpose:* Strengthen the thigh (quadriceps) muscle.

*Instruction:* Lunge forward leading with your right leg. Push off with your right leg and lunge forward with your left leg. Drop the back knee straight down. Make sure that your keep your front knee over your ankle. Control the motion and try to avoid you front knee from caving inward. *If you can’t see your toes on your leading leg, you are doing the exercise incorrectly.*

**B. Russian Hamstring** (3 sets x 10 reps) Elapsed Time: 7.5 –8.5 min
Purpose: Strengthen hamstrings muscles

Instruction: Kneel on the ground with hands at your side. Have a partner hold firmly at your ankles. With a straight back, lead forward leading with your hips. Your knee, hip and shoulder should be in a straight line as you lean toward the ground. Do not bend at the waist. You should feel the hamstrings in the back of your thigh working. Repeat the exercise for 3 sets of 10, or a total of 30 reps.

C. Single Toe Raises (30 reps x 2 reps) Elapsed Time: 8.5 – 9.5 min

Purpose: This exercise strengthens the calf muscle and increases balance.

Instruction: Stand up with your arms at your side. Bend the left knee up and maintain your balance. Slowly rise up on your right toes with good balance. You may hold your arms out ahead of you in order to help. Slowly repeat 30 times and switch to the other side. As you get stronger, you may need to add additional repetitions to this exercise to continue the strengthening effect of the exercise.

4. Plyometrics: These exercises are explosive and help to build, power, strength and speed. The most important element when considering performance technique is the landing. It must be soft! When you land from a jump, you want to softly accept your weight on the balls of your feet slowly rolling back to the heel with a bent knee and a straight hip. These exercises are basic however, it is critical to perform them correctly. Please take the time to ensure safe and correct completion of these exercises.

A. Lateral Hops over Cone (20 reps) Elapsed Time: 9.5 – 10 min

Purpose: Increase power/strength emphasizing neuromuscular control

Instruction: Stand with a 6” cone to your left. Hop to the left over the cone softly landing on the balls of your feet and bending at the knee. Repeat this exercise hopping to the right.

B. Forward/Backward Hops over cone (20 reps) Elapsed Time: 10 – 10.5 min

Purpose: Increase power/strength emphasizing neuromuscular control

Instruction: Hop over the cone/ball softly landing on the balls of your feet and bending at the knee. Now, hop backwards over the ball using the same landing technique. Be careful not to snap your knee back to straighten it. You want to maintain a slight bend to the knee. Repeat for 20 reps.

C. Single Leg hops over cone (20 reps) Elapsed Time: 10.5 – 11 min

Purpose: Increase power/strength emphasizing neuromuscular control.

Instruction: Hop over the cone/ball landing on the ball of your foot bending at the knee. Now, hop backwards over the ball using the same landing technique. Be careful not to snap your knee back to straighten it. You want to maintain a slight bend to the knee. Repeat for 20 reps. Now, stand on the left leg and repeat the exercise. Increase the number of repetitions as needed.

D. Vertical Jumps with headers (20 reps) Elapsed Time: 11 – 11.5 min

Purpose: Increase height of vertical jump.
Instruction: Stand forward with hands at your side. Slightly bend the knees and push off jumping straight up. Remember the proper landing technique; accept the weight on the ball of your foot with a slight bend to the knee. Repeat 20 times and switch sides.

E. Scissors Jump (20 reps) Elapsed Time: 11.5 – 12 min
Purpose: Increase power and strength of vertical jump.
Instruction: Lunge forward leading with your right leg. Keep your knee over your ankle. Now, push off with your right foot and propel your left leg forward into a lunge position. Be sure your knee does not cave in or out. It should be stable and directly over the ankle. Remember the proper landing technique; accept the weight on the ball of your foot with a slight bend to the knee. Repeat 20 times.

5. Agilities:
A. Shuttle run with forward/backward running Elapsed Time 12 – 13 min
Purpose: Increase dynamic stability of the ankle/knee/hip complex
Instruction: Starting at the first cone, sprint forward to the second cone, run backward to the third cone, sprint forward to the fourth cone (etc…).

B. Diagonal runs (3 passes) Elapsed Time 13 – 14 min
Purpose: To encourage proper technique/stabilization of the outside planted foot to deter the position from occurring.
Instruction: Face forward and run to the first cone on the left. Pivot off the left foot and run to the second cone. Now pivot off the right leg and continue onto the third cone. Make sure that the outside leg does not cave in. Keep a slight bend to the knee and make sure the knee stays over the ankle joint.

C. Bounding run (44 yards) Elapsed Time 14 – 15 min
Purpose: To increase hip flexion strength/increase power/speed
Instruction: Starting on the near sideline, run to the far side with knees up toward chest. Bring your knees up high. Land on the ball of your foot with a slight bend at the knee and a straight hip. Increase the distance as this exercise gets easier.

6. Alternative Exercises: Warm Down and Cool Down
We all know how imperative a cool down is. Please don’t skip it. It allows the muscles that have been working hard throughout the training session to elongate and deters the onset of muscle soreness. Please emphasize the importance of adequate fluid intake (optimally water). Athletes should have a water bottle by their side during the cool down. The cool down should take approximately 10 minutes. It should begin with a slow jog to allow the heart rate to come down before stretching. This should be followed by some light strength training exercises. We are recommending two strengthening exercises (see below). Finally, stretch the hamstrings, calves, inner thigh, quadriceps, and low back (all of these are explained in the protocol). In addition to those basic stretches, we are offering some additional stretches to target 3 muscle groups that are often forgotten.
A. Bridging with Alternating Hip Flexion (30 reps)
Purpose: Strengthen outer hip muscles (Hip abductors, flexors) and buttocks

Instruction: Lie on the ground with your knees bent with feet on the ground. Raise your buttocks up off the ground and squeeze. Now, lift your right foot off the ground and make sure that your right hip does not dip down. Lower your right foot and now lift your left foot making sure your left hip does not dip down. Repeat 30 times on each side. As you get stronger, you will place your feet on top of a ball and repeat the exercise.

B. Abdominal Crunches (30 reps x 2 reps)

Purpose: Strengthen the abdominals (rectus, abdominus, obliques)

Instruction: Lie on the ground with your knees bent. Place your hands behind your head with your elbows out wide. Support your neck lightly with your fingers. Take a deep breath in and slowly contract your abdominal muscles as you exhale. Repeat 30 times. Drop your legs off to the right side. Slowly crunch up with your elbows out wide. You should feel your oblique muscles working on the side of your waist. Repeat 30 times and switch to the other side.

C. Single and Double Knee to Chest (supine) (30 sec x 2 reps)

Purpose: Elongate the low back muscles

Instruction: Lie on your back. Bring your right knee toward your chest and hug firmly. Keep your left leg out straight in front of you. You should feel a stretch along your low back and into your buttocks. Hold the stretch for 30 seconds and switch sides. Now bring both knees to chest. If you feel any pain in the low back, discontinue the stretch and inform your coach/trainer.

D. Figure Four Piriformis stretch- supine (30 sec x 2 reps)

Purpose: Elongate the rotators of the hip.

Instruction: Lie on your back and bend both of your knees. Fold your left ankle over your right knee. Place your hands behind your right thigh and pull your right knee to chest. You should feel a good stretch in the left gluteals region and the side of the thigh. Hold for 30 seconds and repeat on the other side. If you experience low back pain with this stretch, slowly lower your legs down and let your coach/trainer know.

E. Seated Butterfly stretch - seated (30 sec x 2 reps)

Purpose: Elongate the inner thigh muscles (adductors).

Instruction: Sit up bringing your feet in so that the soles of your feet are touching. Gently place your elbows on your knees and slowly push down. You should feel a good stretch of the inner thigh. Hold this for 30 seconds and repeat 2 to 3 times.

If you have any questions or concerns regarding this program, please contact Holly Silvers, MPT at (310) 315-0292 ext. 1283 or via email: HollySilversPT@aol.com.
Appendix II:

WEEK ONE: (June 3, 2002-June 6, 2002)

This week was anything but introductory. On Monday morning, I unsuspectingly entered the office of the Santa Monica Orthopedic and Sports Medicine Group, inc. at 7:00 am and was immediately shuffled to a patient’s room where Dr. Mandelbaum was already hard at work. This clinic showed no preference toward women over men or toward knee cases over other body parts so its frequency of female versus male patients showed their actual relative injury rates. The first patient (whose name I can not disclose) was my introduction to ACL tears. She was a sixteen year-old competitive soccer player complaining of instability and swelling around her medial knee—consistent with an ACL tear. The girl recalled that during a game the previous Saturday, she had landed awkwardly from a jump and had ‘tweaked’ her knee. Dr. Mandelbaum proceeded to perform several tests diagnostic for ACL tears because they test the subluxation in the joint and then ordered that the girl get x-rays and an MRI (magnetic resonance image).

Out of the seven ACL patients that we saw on Monday, five were females. Several other types of injuries were also observed that day.

Tuesday and Thursday both continued as Monday did with a multitude of varying injuries, mostly sports related, many of which were in females. I found the high number of injured females very intriguing as it supported the notion that female participation in sports is indeed on the rise.

On Wednesday I got the opportunity to observe three different surgeries and although I can not disclose the names of the patients, I will add that one was incredibly fascinating as she
was a professional soccer player on the women’s national team who had suffered an ACL tear while training on her own. The ACL replacement procedure was fascinating. This woman chose to have an autograft (which is taken from her own patellar tendon) to replace her damaged ACL. The autograft procedure is more complex than an allograft procedure (the ligament is taken from a cadaver) as the graft must be surgically “harvested” as well. Once a portion of the woman’s patellar tendon was removed, Dr. Mandelbaum made three small incisions in the woman’s knee. He first went in with the arthroscope to survey the damage. Once he located the torn ACL, he went in through the anterior incision and removed the damaged ACL. He then lined up the knee (this process took at least 45 minutes) to ensure proper post-operative alignment. Once this proper alignment was found, Dr. Mandelbaum in essence became a carpenter with fancy tools as he hammered and screwed the new ligament into place. I found this procedure especially eye-opening as I had naïvely believed that once an ACL was torn, that the ligament would forever be weakened. Dr. Mandelbaum assured me that this weakness was not the case, and instead that the ACL graft (or the replacement ligament) was actually stronger than the original. To demonstrate the new ligament’s strength to the patient (to instill in her confidence that her “new” knee was stable), the surgeon made the patient ride a stationary bike before even leaving the surgery center!

The surgeries were so interesting that I was upset when the day was over. This was a fascinating week as many of the topics that I had already been researching such as the increased number of women participating in athletics, the disproportionate cases of ACL injury in women
versus men, and the frequent cases of ACL injury that occur during competition and in particular, without contact, were all observed.

**WEEK TWO: (June 10, 2002-June 12, 2002)**

This week definitely welcomed me into the meat of the internship. Monday began just like all of the previous clinical days. I saw patients with Dr. Mandelbaum from seven o’clock in the morning until six o’clock at night. Perhaps the most intriguing part of the internship for me thus far was the huge numbers of ACL injuries in general. Today we saw nineteen patients, 9 of which had injured ACLs and 6 of which were females. Again, the disproportionate number of women versus men with injured ACLs left me dumbfounded. Of the six females with torn ACLs, four of the women had injured their ligaments while playing soccer, one while water skiing, and the other while running. Interestingly enough, five of the six injuries resulted from some non-contact movement. This statistic was consistent with the much of the research that I had read previously.

On Tuesday, I had much the same schedule as the day before. I began seeing patients with Dr. Mandelbaum at seven a.m. The first patient was a 14 year-old female volleyball player who presented with the symptoms of a torn ACL. She reported that she had injured her knee while landing from a jump. Since an irregular jump landing is one of the most common causes for ACL tears Dr. Mandelbaum ordered x-rays and MRIs but also assumed that the ligament was torn and scheduled a tentative surgery so this girl could return to competition as soon as possible. The rest of the day was very similar to Monday as we saw eight ACL patients today, four of
which were females. One of these women was in for a post-operative visit. She was four months out of surgery and upon examination, Dr. Mandelbaum released her for immediate return to competitive soccer training. This was very encouraging for me because prior to having seen this girl, I believed that a torn ACL would mean at least six months of rehab.

Wednesday was once again a surgery day and I was extremely excited driving to the office to get the day started. Dr. Mandelbaum had five cases scheduled for that day but I was only scheduled to observe two because I was also scheduled to meet with Diane Watanabe and Holly Silvers who were part of Dr. Mandelbaum’s ACL prevention program.

The first case was a torn rotator cuff in the gentleman’s shoulder, which was fascinating to watch but did not pertain to my thesis. The second of the two surgeries was a medial meniscus and MCL surgery. This woman had injured her knee while playing tennis. Dr. Mandelbaum explained the knee’s ‘dangerous triangle’ to me and explained that this woman was lucky to not have torn her ACL also. Dr. Mandelbaum explained that usually when a person’s knee gets ‘twisted’ the way that this woman’s did, the ACL is the first structure in the knee to be damaged. In this case, the woman had had previous ACL surgery and the graft had been so strong that it remained in her knee unharmed.

After observing these surgeries I hurried back to the office to meet Diane Watanabe and Holly Silvers for the first time. I would be working with these two women throughout the internship on an ACL prevention program that Dr. Mandelbaum had begun. The three of us went to lunch with one of the videographers that was hired to film the ACL prevention video. They immediately included me in the video’s planning and even asked my advice (being a
division one soccer player myself) on certain exercises. I gave input and even designed three soccer-specific drills that were included in the video.

After this meeting I was very encouraged about this project and anticipated its trial.

WEEK THREE: (June 17, 2002-June 19, 2002)

Monday was a shortened clinical day because I had to meet with the video planners again in the afternoon. I followed Dr. Mandelbaum from seven a.m. to one p.m. and then proceeded to Diane’s office where I began filing various sources used in the making of the video and warm-up program. I then attended a committee meeting with Diane, Holly, and Dr. Mandelbaum to finalize filming techniques with the film crew.

While with Dr. Mandelbaum earlier that day, we saw an unusually large number of ACL cases. When I left his office at one o’clock, we had already seen seven new ACL tears, five of which were females. One of the main reasons (interestingly enough) was that there was a huge, and very competitive soccer tournament the weekend before, which resulted in a large increase in ACL injuries. I listened attentively to the causes of injury and found the data striking as three of the five were injured while dribbling the ball, or cutting, and the other two were non-contact injuries as well.

On Tuesday I was in Dr. Mandelbaum’s office from seven a.m. until six p.m. again. Again, we saw an increased number of ACL cases today. Many of these patients had also injured themselves at the soccer tournament the previous weekend. The large numbers of people and especially young, healthy females that suffer ACL injuries was amazing to me. The causes
of injury were all consistent with my reading because most resulted from non-contact movements such as cutting, changing directions, and jumping.

Wednesday was once again a surgery day. I got the privilege to observe four surgeries today, including two knee surgeries, one on a female patient seen last week and the other on a male professional soccer player. The first knee surgery was on the woman who was running at her soccer practice, stepped in a hole, ‘tweaked’ her knee, and tore her ACL. Her surgery was planned very quickly as she was a junior in high school and was anxious to start playing soccer again for all of the college coaches. Her surgery went well and as soon as she recovered from the anesthesia, she rode the stationary bike and then was sent home.

The second knee surgery of the day was not an ACL procedure but a meniscal repair. The professional soccer player had injured his knee in a tackle the past weekend and flew from New York to Santa Monica to get the problem repaired as soon as possible. He hoped to be back to competition the following week (and believe it or not, he was)!!

WEEK FOUR: (June 25, 2002-June 27, 2002)

This week began on a Tuesday. I shadowed Dr. Mandelbaum again today for eleven hours. I learned so much again from just listening to him talk to the patients while explaining their injuries. Today, we saw six ACL patients, three of which were females. Even though the numbers of females and males were equal, listening to Dr. Mandelbaum explain the physiological and anatomical differences in body type to the females was enlightening even though I had already researched the same information.
The anterior cruciate ligament is a small organ that is responsible for controlling the movement of a relatively huge body mass above it so explaining the cause of the tearing is easy but explaining the difference in numbers between genders is the difficult part. Until I began seeing the patients themselves in Dr. Mandelbaum’s office and witnessed the disproportionality in person, I did not grasp the scope of the problem.

On Wednesday I observed three surgeries but only one was an ACL repair. The one knee surgery was performed on a sixteen year-old competitive soccer player from southern California. She not only had torn her ACL, but also tore her MCL and medial meniscus as well (the ‘dangerous triangle’). The procedure took an unusual two hours because of the extent of damage within this youngster’s knee. Dr. Mandelbaum debrided her knee (or remove all of the damaged cartilage), sutured her injured MCL back together and replaced the torn ACL with an auto-graft taken from the girl’s patellar tendon. Due to the large amount of damage other than to the ACL, the patient was not required to immediately ride the stationary bike, but instead she was told to return to Dr. Mandelbaum’s office the following day to do so.

On Thursday, the surgical patient from the previous day returned and I helped her onto the bike and observed her riding. I instantly saw a surge of confidence rush through her as she felt the strength of her new ligament. The newfound confidence that I saw in the girl solidified for me the importance of the bicycle riding. The remainder of the day I spent following Dr. Mandelbaum and visiting patients. We saw four ACL patients all of which were female athletes!! This proportion blew me away.
At four o’clock I went over to Diane’s office quickly per her request. The video was set to be filmed and she wanted me to go over the script one last time. I read over the script, made a few changes and gave it my seal of approval. I thought that the whole Program was very promising as it worked to prevent many of the non-contact situations that now result in ACL tears. The video attempts to retrain athletes proprioceptively to ensure that they avoid potentially dangerous situations.

**WEEK FIVE: (July 1, 2002- July 2, 2002)**

This week was shortened due to the Fourth of July holiday, but it still began Monday morning at seven o’clock. I once again saw patients all day. We saw eleven patients complaining of knee injuries, seven of whom had ACL problems and five of whom were female. Interestingly enough only two of the injured females hurt their ACLs while participating in sports. I found this statistic intriguing as the other three women were merely going about their everyday lives when they injured themselves. This alarming statistic demonstrated the ease at which a woman’s ACL can be torn due to anatomical or physiological restrictions.

Two of the three women that suffered ACL tears were gardening outside. One tripped and felt the ligament give way and the other woman was walking through the grass with a hose, tripped over the coiled mess, landed in a hole and felt her ACL tear. The third woman was vacuuming inside when she tripped over the coiled hose of her vacuum, stepped wrong on her knee and tore her ACL. All three of these women were middle aged and in relatively good health apart from their knees. While the circumstances in which these women tore their ACLs
may not have typified those for most ACL tears, the ways in which the ligaments buckled upon landing or changing directions showed just how accurate many of the statistics on ACL injuries have been.

The two other females that fell victim to the ACL epidemic were teenaged girls who were competitive soccer players in the Coast Soccer League of Southern California. These two girls were of particular interest to me as I was a long-time member of this same league and had many friends with ACL injuries over a period of nine years. One of the girls injured her knee in a tackle that caused her knee to hyperextend, snapping the ACL. The other girl was merely juggling the ball when she stepped back into a hole and felt her leg give out. Both of these scenarios supported the research that I had read previously that said that the majority of ACL injuries occur while landing, changing directions, or by direct contact (such as tackles).

Since Dr. Mandelbaum was going out of town on July 3, he moved his normal surgery day up one day to Tuesday. Today I observed three cases, one of which was an ACL replacement. This case was different from the last because the patient chose to use a cadaver ligament as the new graft. This procedure involved harvesting a ligament from a deceased donor and inserting it into the patient’s knee as was done with the autograft. This procedure was very interesting not only from an orthopedic standpoint, but also considering that I have signed up as an organ donor, knowing that even ligaments could be transplanted was fascinating.

After observing the three surgeries I went to meet with Diane and Holly again. The three of us discussed the filming of the video and went over the written directions for the program as well. We all began to compile a list of the college soccer programs to receive a copy of the ACL
prevention program and to be the pilot programs. This list was to be finalized next week upon finishing the video.

**WEEK SIX: (July 8, 2002-July 10, 2002)**

This was the last week that I would be interning with Dr. Mandelbaum. Since I was going to be leaving the office after this week, I spent a lot of time with Diane and Holly working on the video and program instructions. I began the week following Dr. Mandelbaum around to office visits from seven a.m. until noon. In that short time we saw five ACL cases, three of which were female athletes. At noon, I said goodbye to all of the office aids, including his Physician’s Assistant, Brett because that was to be the final time that I would be in the office. I then met up with Diane and Holly at a local restaurant for lunch. Here we finalized the program’s soccer-specific exercises and I was able to see my contribution on paper, which was very exciting for me.

The following day I went directly to Diane and Holly’s office and began working straight away addressing envelopes to the chosen soccer programs. We also wrote a lengthy cover letter explaining in complete detail what we hoped to get out of the study, and to thank the programs for participating. After today my work on this project was officially finished but needless to say, I had invested too much time and energy to not follow the program through to its end in May (at the end of each program’s respective season).

Wednesday was my last day with Dr. Mandelbaum. I was once again fortunate to observe three surgeries today. Unfortunately, none of the scheduled cases were for ACL repair.
so my hands-on experience with knees was over for this summer anyway. I thanked Dr. Mandelbaum for the experience. Overall, the whole internship was incredibly beneficial for both my thesis work, as well as my underlying interest in a future career in medicine. Not only had I learned much relevant information from which to begin my thesis, but I had also contributed in a minor way to a great and innovative new ACL prevention program.