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## ACL Injuries in Female Athletes: Are Prevention Programs the Answer?

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ACL INJURIES IN FEMALE ATHLETES:  
ARE PREVENTION PROGRAMS THE ANSWER?

by  
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Honors Thesis  
Science, Technology, and Society  
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## **Abstract**

Around 400,000 people tear their anterior cruciate ligaments (ACLs) every year in the United States. The majority of these injuries occur during athletics, and most commonly to females. Their neuromuscular abilities, anatomies, and hormones put female athletes at a much higher risk of ACL injury than male athletes. The current gold standard of treatment, ACL reconstruction, is an imperfect technique at best. It leaves patients with much higher risk of both ACL reinjury and early onset of osteoarthritis. Prevention programs, aimed at reducing the neuromuscular risk factors in female athletes, have proved to effectively reduce the number of noncontact ACL injuries in many studies since the late 1990s. Despite their demonstrated success, ACL prevention programs are not commonplace in high school and collegiate athletics today. It is the responsibility of the athletes, parents, and coaches to educate themselves on the elevated risks of ACL injuries for female athletes. Furthermore, coaches, athletic trainers, and athletic directors must work together to create and implement ACL prevention programs specifically tailored to their sports teams' needs to eliminate this painful and detrimental commonality in today's female athletics. With the dedication to spreading knowledge about ACL injuries and implementing prevention programs, the number of ACL injuries in female athletes will undoubtedly decrease.

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## I. Introduction

Within one hour, you can go grocery shopping, watch a television show, or dry a load of laundry. In that same hour, between 3-40 people will tear their anterior cruciate ligaments (ACLs) in the United States, according to the most recent 2014 evidence. This means that there are as many as 320,000 ACL injuries per year, although some estimate the total to be as high as 400,000.<sup>1</sup> This staggering statistic is more than a cause for concern. ACL injuries can end athletic careers, cost thousands of dollars for the injured athlete and state, and leave the athlete with lasting health problems.

Not every individual in the United States faces the same amount of risk for sustaining an ACL tear. ACL injuries most commonly occur during athletics, with females at a much higher risk than males. Females are 2-8 times more likely to tear their ACLs than males, with the variation often depending on the type of sport.<sup>2</sup> In the late 1990s, two studies in Texas reported that 1 in 60 female athletes might sustain an ACL tear during high school.<sup>3</sup> When other studies reported similar findings, ACL injuries in female athletes began to draw attention from many medical scientists. Since then, researchers have spent tremendous amounts of time, effort, and money to improve their understanding of the disparity between the genders in ACL injuries and their causes. Furthermore, researchers have been introducing

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<sup>1</sup> Martha M. Murray et al., *The ACL Handbook* (New York: Springer, 2014), 5.

<sup>2</sup> Murray et al., *The ACL Handbook*, 6.

<sup>3</sup> Paterno, Mark V. et al., "Incidence of Second ACL Injuries 2 Years After Primary ACL Reconstruction and Return to Sport," *The American Journal Of Sports Medicine* 42 (2014): 1567, accessed November 25, 2014.

prevention programs and monitoring their successes. According to Renstrom et al., "In spite of the fact that some successful prevention programmes have been introduced, ACL injury continues to be the largest single problem in orthopaedic sports medicine, with the incidence... of ACL tears being much higher in female athletes... than in male athletes."<sup>4</sup>

To understand the high number of ACL injuries in female athletes, one must research the many aspects that cause them. One must also understand that because the ACL injury is a relatively new topic, there is still a great deal that researchers do not know or understand. To begin, one must understand ACL anatomy and physiology then, both the biomechanics of the tear and the causes of the injury.

Next, one must understand the surgical process of ACL reconstruction. ACL reconstruction is important for discerning the number of ACL injuries for two reasons. First, 90 percent of individuals who tear their ACLs undergo ACL surgery.<sup>5</sup> Additionally, female patients who undergo ACL reconstruction are about fifteen times more likely than a healthy female to sustain a second ACL injury within the first twelve months after surgery.<sup>6</sup> Thus, a female athlete who has a surgically reconstructed ACL is about thirty times more likely to tear her ACL than a healthy, male athlete. The variability in success of ACL reconstruction is another factor that increases the number of ACL injuries in female athletes.

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<sup>4</sup> Renstrom, P et al., "Non-contact ACL injuries in female athletes: an International Olympic Committee current concepts statement," *British Journal of Sports Medicine* 42 (2008), 395.

<sup>5</sup> Paterno, "Incidence of Second ACL," 1567.

<sup>6</sup> Paterno, "Incidence of Second ACL," 1567.

This discrepancy between male and female ACL injuries is significant: the fact that a female athlete with an ACL reconstructed knee is at a thirty times higher risk than a regular male athlete for experiencing an ACL injury is astonishing. This statistic alone is proof enough that there is an epidemic plaguing female athletes. Some of the proposed causes of the disparity are the development of knee valgus during impact landing, influence of menstrual cycle, intercondylar notch size,<sup>7</sup> and ACL size.<sup>8</sup> Clearly, female athletes require, and deserve, extra attention to eliminate this devastating injury.

The number in ACL injuries and the imperfection of ACL reconstruction has led many researchers to focus on creating prevention programs to decrease the number of ACL injuries in female athletes. Today, there are numerous ACL prevention programs available to anyone with access to the Internet or a library. Yet ACL injuries are still commonplace. One reason may be because it is so hard to experiment with prevention programs when the determining result is an ACL tear. It would be unethical to withhold ACL prevention programs from athletes to prove that the experimenters' program decreases the probability of tearing one's ACL. As a result, researchers have undertaken few controlled experiments with numerous participants that would more directly prove the definitive success of prevention programs.

Moreover, the lack of knowledge and education that high school and college coaches, athletic directors, and athletes have about ACL injuries and their

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<sup>7</sup> Murray et al., *The ACL Handbook*, 6-7.

<sup>8</sup> Noyes, *ACL Injuries in Female Athletes*, 214-15.

prevention hinders the widespread utilization of prevention programs. According to Frank Noyes and Sue Barber-Westin, “Because coaches are frequently responsible for the development and implementation of training and conditioning programs for players, their qualifications and knowledge are important in influencing injury risk.”<sup>9</sup> The lack of knowledge and time are the major factors obstructing the implementation of ACL programs across America. What many athletes and coaches do not understand is that ACL prevention programs not only decrease the likelihood of ACL injuries, but also strengthen athletes’ bodies, which leads to athletic benefits for every sport.

The lack of ACL prevention programs in high schools and colleges across the country is concerning, but not surprising; both ACL injury and prevention programs are still relatively new areas of research. Despite the lack of an abundant number of studies on prevention programs, researchers have concluded that they are effective in reducing ACL tears. For instance, in a large study conducted by Dr. Timothy Hewett in 1999, female athletes who underwent neuromuscular training had an injury rate of 0.12 per 1,000 athletes, whereas untrained female athletes had an injury rate of 0.43.<sup>10</sup> Clearly, the results are statistically significant in showing that Hewett’s neuromuscular training program, Sportsmetrics, decreases probability of an ACL tear in female athletes. While prevention program studies are not complete, the programs themselves are evidently effective. The challenge that faces the

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<sup>9</sup> Noyes, *ACL Injuries in Female Athletes*, 498.

<sup>10</sup> Hewett, TE, et al., “The Effect of Neuromuscular Training on the Incidence of Knee Injury in Female Athletes,” *The American Journal of Sports Medicine* 27 (1999): 699-706, accessed December 5th, 2014.

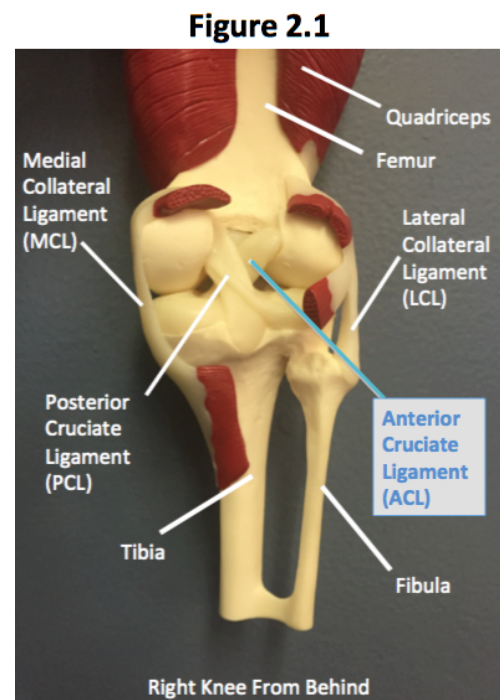


application of prevention programs across the country today is ignorance. Educating coaches, athletic directors, and athletes on the possibility, and probability, of ACL injuries is crucial. Equally, a positive and accurate representation of prevention programs, their successes, and their benefits will help persuade more athletic departments to adopt them. Athletic trainers and coaches must work together to create and introduce effective prevention programs that educate their players and reduce the likelihood of ACL injuries. Finally, future research and studies will help to further highlight and promote the importance of these programs in terminating ACL injuries in female athletes nationwide. Prevention programs are currently the best, most effective solution for ACL injuries in female athletes, and it is the responsibility of coaches, athletic directors, athletic trainers, and athletes to understand and implement these programs within every school across the country. Only when this vision becomes reality, will the number of ACL injuries in female athletes start to decrease.

## II. ACLs for Beginners

To understand the tragedy of an ACL injury, one must understand what an ACL is and what an ACL does. The ACL is one of four ligaments of the knee that attach the femur (the thigh bone) to the tibia and fibula (the lower leg bones). The ACL is intra-articular, meaning it passes through the knee joint. The other three ligaments, Posterior Cruciate (PCL), Medial Collateral (MCL), and Lateral Collateral (LCL) ligaments are all extra-articular, meaning they lay on the outer surface of the joint<sup>11</sup> (Figure 2.1). The typical ACL is 11 mm in width and 38 mm in length,<sup>12</sup> and it attaches the femur to the tibia.

The role of the ACL is to stabilize the knee during movement, especially jumping, pivoting, and landing. It is responsible for limiting dangerous knee motions that could injure the knee during activity. The ACL specifically restrains two movements: internal tibial rotation and anterior tibial translation.<sup>13</sup> Internal tibial rotation is when tibia rotates medially,<sup>14</sup> towards the center of the body (Figure 2.2). Anterior tibial translation, for which the ACL is the



<sup>11</sup> Murray et al., *The ACL Handbook*, 63.

<sup>12</sup> Noyes, *ACL Injuries in Female Athletes*, 4.

<sup>13</sup> Noyes, *ACL Injuries in Female Athletes*, 10.

<sup>14</sup> Wheelless III, Clifford R, "Internal Tibial Torsion," *Wheelless Textbook of Orthopaedics*, April 25, 2012, accessed March 4<sup>th</sup>, 2015, [http://www.wheellessonline.com/ortho/internal\\_tibial\\_torsion](http://www.wheellessonline.com/ortho/internal_tibial_torsion)

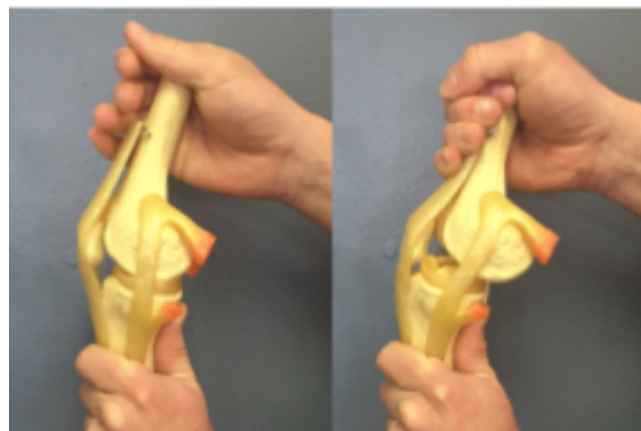
**Figure 2.2:**  
**Internal Tibial Rotation**



ligaments are responsible for so much of the knee stability because of their valuable anatomy. The anatomy of the ACL gives it the ability to stretch when necessary, but also stabilize. The fibers that compose the ligament are wavy, which allows the ACL to stretch when straightening. The design of the ligament allows for only a certain amount of stretching before it restricts the range of motion of the bones. The ACL specifically confines the movement of the tibia

primary restrictor, is when the tibia slides forward or backwards without the femur (Figure 2.3). The ACL provides more than 85 percent of the total restraining force of anterior tibial translation.<sup>15</sup> The ACL and the PCL are also secondary restrictors of both the lateral (side) and medial (middle) joint openings. If the MCL and the LCL are injured, then the ACL and PCL become the primary restraints for these joint openings.<sup>16</sup> The

**Figure 2.3:**  
**Anterior Tibial Translation**



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<sup>15</sup> Noyes, *ACL Injuries in Female Athletes*, 8.

<sup>16</sup> Noyes, *ACL Injuries in Female Athletes*, 12.

and femur and restricts threatening movements such as bending too far backwards (hyperextension), bending too far inwards (valgus), and anterior tibial translation.<sup>17</sup>

The ACL and its structure are essential to the stability of the knee during many athletic movements. Its control of the knee movement keeps athletes' leg bones properly aligned. Without the ACL, movements like cutting, pivoting, jumping, and landing would be extremely difficult, if possible at all. Understanding the biology and recognizing the importance of the healthy ACL is the first step for anyone to realize just how fundamental the ACL is to the human body.

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<sup>17</sup> Murray et al., *The ACL Handbook*, 65.

## II. ACL Injuries in Female Athletes

A “pop,” a “snap,” a “crack” are all common ways that an ACL-torn victim would describe the sound of her injury, and all of these descriptions are actually somewhat accurate. When an athlete’s lower limb does something out of the ordinary, such as too much anterior tibial translation or too much knee valgus, the ACL ruptures. As the ACL stretches to accommodate the unusual movement, it can only support a certain amount of pressure. If the high load of pressure exceeds what the ACL can withstand, the ACL tears.

Despite the common misconception, ACL injuries usually do not occur in high-impact, bodily-threatening situations, such as during a football tackle or hockey check. Instead, according to a recent 2013 report, 80 percent of all ACL injuries are noncontact.<sup>18</sup> This means that during most ACL injuries, the athletes are alone and untouched by other players. These noncontact ruptures often happen when an athlete is pivoting, cutting, accelerating, decelerating, or landing in a way that is harmful to the knee and thus stretching the ACL too far.<sup>19</sup> Because a high percentage of ACL injuries are noncontact, researchers have hypothesized many risk factors that could cause an athlete to tear her ACL.

Although researchers have not yet been able to definitively predict an ACL injury, there are many proposed risk factors. Gender, hamstring and quadricep strength, core strength, ACL size, and sport played are just a few of the many risk

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<sup>18</sup> Murray et al., *The ACL Handbook*, 5.

<sup>19</sup> Noyes, *ACL Injuries in Female Athletes*, 4.

factors that face athletes. As medical scientists continue to discover new information about ACL injuries, the list of risk factors will surely grow.

One of the biggest risk factors of sustaining an ACL injury is simply being female. As previously mentioned, females are at least three times more likely than males to tear their ACLs. Proposed risk factors for females are neuromuscular, biological, and hormonal. A study published by the International Olympic Committee demonstrated that every sport they studied had a higher incidence rate for females than males. Female basketball players between the ages of 14 and 18 demonstrated an ACL injury rate four times greater than their male counterparts; female-competitive alpine skiers are twice as likely, and female team handball players also have a higher incidence rate.<sup>20</sup> As the International Olympic Committee gathered data from many sources around the globe, coincidence is clearly not an adequate explanation for the discrepancy between female and male ACL injuries.

Arguably the most well-known neuromuscular cause of ACL injuries is the hamstring to quadriceps ratio (H:Q). A study by George D. Myer and his associates compared both uninjured female athletes and ACL-torn female athletes with male athletes based on hamstring and quadricep strengths. Myer and his colleagues found that female athletes who tore their ACLs had decreased hamstring strength but normal quadricep strength when compared to male athletes. Conversely, the uninjured female athletes had similar hamstring strengths as males, but weaker

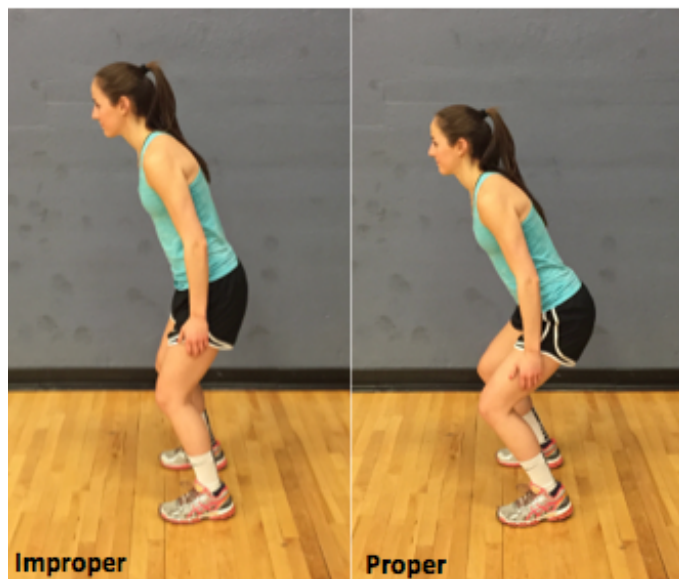
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<sup>20</sup> Renstrom, P et al., "Non-contact ACL injuries in female athletes", 396-397.

quadriceps.<sup>21</sup> This study indicates that first, a low H:Q can result in an ACL tear and that second, on average, females have lower H:Q than males. H:Q ratio is important because, depending on the position of the knee, quadriceps contractions can strain the ACL (Figure 3.1). When the knee is almost fully extended (for example, during the initial ground contact in a jump landing) and the quadriceps contract, it causes pressure on the patella tendon

(the tendon that connects the patella to the tibia). This pressure can result in anterior tibial translation, which strains the ACL. Depending on the amount of knee flexion and force of the patella tendon, the ACL may rupture.<sup>22</sup> On the other hand, if the hamstring co-

**Figure 3.1:**  
**Jump Landing Effect on Quadriceps Contractions**



contracts with the quadriceps, it reduces the strain on the ACL, which is why a high H:Q is crucial for knee stabilization. Since the average female athlete has a lower H:Q ratio than her male counterpart, it increases the risk for ACL injury in females.

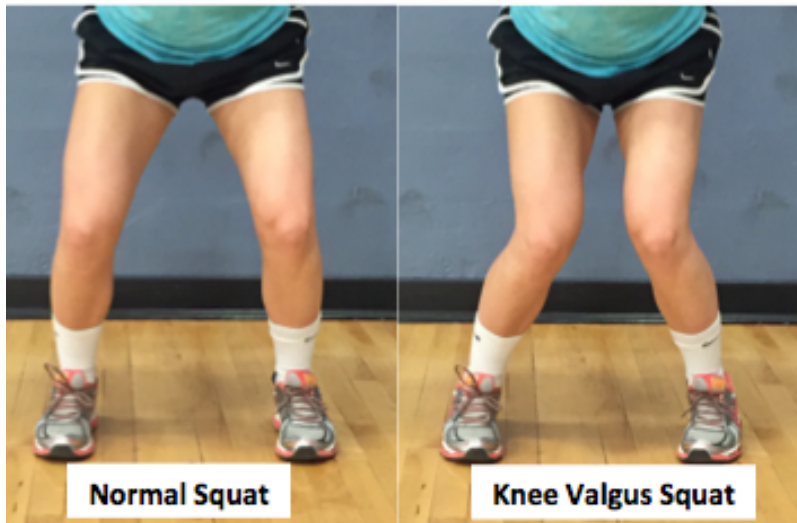
Another recognized explanation of ACL injuries is knee valgus. Knee valgus occurs when an athlete's knees drop in towards each other, resulting in the athlete

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<sup>21</sup> Myer GD, KR Ford, KD, Barber Foss, C Liu, TG Nick, TE Hewett, "The relationship of hamstrings and quadriceps strength to anterior cruciate ligament injury in female athletes," *Clinical Journal of Sports Medicine* 19, no. 1 (2009): 3–8.

<sup>22</sup> Renstrom, P et al., "Non-contact ACL injuries in female athletes", 404-05.

**Figure 3.2:**  
**Normal vs. Knee Valgus Squat**



appearing 'knock-kneed' (Figure 3.2). A correctly aligned knee causes the load-bearing axis to follow a vertical straight line from the hip through the knee to the ankle. In a knee valgus situation, the

knees drop in, which moves the load-bearing axis towards the outside of the knees, straining the knee ligaments.<sup>23</sup> Knee valgus escalates the risk of lateral or medial tibiofemoral joint lift-off, which is when an athlete's femur and tibia pull apart, stressing the ligaments of the knee. The combination of knee valgus and anterior tibial translation significantly increase the ACL force, commonly leading to an ACL tear.<sup>24</sup> In 2007, Tron Krosshaug and his associates conducted a video analysis of 39 ACL tears during basketball games. By monitoring both initial ground contact and 50 milliseconds later, Krosshaug and his colleagues determined that the females had more than five times the relative risk of a knee valgus collapse than the males examined during the study.<sup>25</sup> Therefore, since females are at a higher risk of knee

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<sup>23</sup> Eustice, Carol, "What Is Varus or Valgus Knee Deformity?" AboutHealth, accessed March 7th, 2015, [http://osteoarthritis.about.com/od/kneeosteoarthritis/a/varus\\_valgus.htm](http://osteoarthritis.about.com/od/kneeosteoarthritis/a/varus_valgus.htm)

<sup>24</sup> Noyes, *ACL Injuries in Female Athletes*, 4.

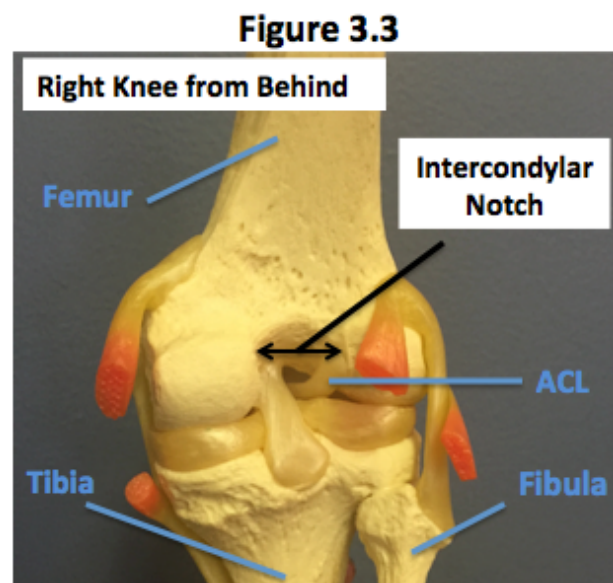
<sup>25</sup> Krausshaug, Tron, Atsuo Nakamae, Barry P. Boden, Lars Engebretsen, Gerald Smith, James R. Slauterbeck, Timothy E. Hewett, and Roald Bahr, "Mechanisms of Anterior Cruciate Ligament Injury



valgus collapse, they are at a higher risk for ACL injury. The combination of the likelihoods of ACL injuries from a low H:Q and knee valgus collapse demonstrates why females are much more prone to an ACL rupture than males..

Females also face increased risk of sustaining an ACL injury due to their anatomy. While more studies and better technology are necessary to determine the exact roles of the following proposed risk factors, evidence shows that they are probable links between these factors

and ACL injuries. First, the size of an athlete's intercondylar notch of the femur (Figure 3.3) may encourage an ACL tear.<sup>26</sup> The intercondylar notch is where the ACL connects to the femur and acts as a compartment in which the ACL moves. A narrower notch means less movement for the ACL.



During exercise, the ACL elongates and moves to accommodate for activity, but with limited space for the ACL to work comes increased risk of a tear. Since females typically have smaller notches than men, this puts them at a heightened risk of ACL injury.<sup>27</sup>

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in Basketball: Video Analysis of 39 Cases," *The American Journal of Sports Medicine* 35, no. 3 (2007): 359-67, accessed November 11, 2014, <http://ajs.sagepub.com/content/35/3/359.short>

<sup>26</sup> Noyes, *ACL Injuries in Female Athletes*, 265.

<sup>27</sup> McAlindon, Robert, "ACL Injuries in Women," Hughston Clinic, accessed March 7th, 2015, [http://www.hughston.com/hha/a\\_11\\_3\\_2.htm](http://www.hughston.com/hha/a_11_3_2.htm).

The size of the ACL also may play a role in its ability to withstand pressure without tearing. In accordance with the intercondylar notch size, women also tend to have thinner ACLs than men. According to Renstrom and his colleagues, the smaller ACLs of females show less stretching and lower energy absorption at the time of rupture.<sup>28</sup> While researchers do not fully understand the properties and mechanisms of smaller ACLs at the moment, less elongation and decreased amount of energy absorption make smaller female ACLs more vulnerable to injury.

The final category of differences between females and males that affects ACL injuries is hormonal. A woman's menstrual cycle influences the likelihood of an ACL injury. A study conducted by Edward M. Wojtys and his associates exposed an increased probability of an ACL tear during the preovulatory phase (days 9-14) of the menstrual cycle.<sup>29</sup> Wojtys and fellow researcher, Benjamin Noonan hypothesize that the hormone fluctuations during the menstrual cycle affect females' knee laxity.<sup>30</sup> Knee laxity, defined as the lack of tension in the knee ligaments, puts athletes at a high risk for injury. Knee laxity allows increased movement of the tibia, which strains the ACL. Sankoon Park and his colleagues recently concluded that females showed more anterior tibial translation during the preovulatory phase.<sup>31</sup>

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<sup>28</sup> Renstrom, P et al., "Non-contact ACL injuries in female athletes", 399-401.

<sup>29</sup> Wojtys, Edward M, Laura J Huston, Melbourne D Boynton, Kurt P Spindler, and Thomas N Lindenfeld, "The Effect of the Menstrual Cycle on Anterior Cruciate Ligaments in Womens as Determined by Hormone Levels," *The American Journal of Sports Medicine* 30, no.2 (2002): 182-188, accessed March 8th, 2015, <http://ajs.sagepub.com.colby.idm.oclc.org/content/30/2/182.long>.

<sup>30</sup> Noyes, *ACL Injuries in Female Athletes*, 126.

<sup>31</sup> Park, Sang-Kyoon, Darren J Stefanyshyn, Barbara Loitz-Ramage, David A. Hart, Janet L. Ronsky, "Changing Changing Hormone Levels During the Menstrual Cycle Affect Knee Laxity and Stiffness in Healthy Female Subjects," *The American Journal of Sports Medicine* 37, no. 3 (2009): 588-598, accessed March 8, 2015, <http://ajs.sagepub.com.colby.idm.oclc.org/content/37/3/588.long>.

Thus, throughout the course of the female menstrual cycle, hormonal variations elevate the risk of an ACL injury. Since male hormones do not fluctuate in the same manner as females, they do not face the same risk.

Finally, the sport that a female athlete chooses to play also contributes to the probability of an ACL injury. Sports with high levels of jumping and pivoting, like gymnastics, basketball, and soccer, have higher ACL injury rates.<sup>32</sup> In a compilation of data from a 16-year span, the National Collegiate Athletic Association (NCAA) reported on the ACL injury rate in female athletes per 1,000 athletes. The study found an ACL injury rate of 0.33 per 1,000 athletes in gymnastics, 0.28 in soccer, and 0.23 in basketball. On the other hand, field hockey had an injury rate of only 0.07 and softball's rate was just 0.08.<sup>33</sup> Whilst some sports' injury rates are relatively low, the sports with very high risk, like basketball and gymnastics, demonstrate the repercussions of this epidemic and prove the need for potential solutions.

While there is a tremendous amount of data on the risk factors for female athletes, the research is not nearly complete. More knowledge of the neuromuscular, biological, and hormonal impacts on the female ACL injury will only increase the ability to prevent and treat them. One must also recognize that there are many other proposed risk factors of ACL injuries not mentioned in this paper due to currently conflicting or scarce statistical evidence. There are so many components that can cause an ACL tear and understanding these factors is extremely important in combating this devastating injury. The elevated risk of ACL tears for females

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<sup>32</sup> Murray et al., *The ACL Handbook*, 8.

<sup>33</sup> Noyes, *ACL Injuries in Female Athletes*, 18.

demonstrates the dire necessity for a change in the ways that female athletes, their coaches, and their trainers approach athletics.

#### IV. ACL Reconstructive Surgery

“Few would dispute the important role of the anterior cruciate ligament for knee stability and function. Significant controversy still exists, however, regarding the optimal management of these injuries,” write Patrick C. McCulloh, MD.<sup>34</sup> Today, the standard of treatment for an ACL tear is reconstructive surgery. While ACL reconstruction may not be the right choice for every patient, it is necessary for almost any athlete who dreams of continuing her career. There are exceptions to the belief that every successful athlete needs functioning ACLs, such as current NBA player DeJaun Blair. Blair has two ACL-deficient knees and still functions at the highest level of basketball in the world. When he entered the NBA draft in 2009, he looked like an early first round draft pick, until the teams heard of his lack of ACLs. He fell to pick number 37 because teams were afraid of drafting a player that was at a such high risk of injury without ACLs. Blair had previously undergone two ACL reconstructions during high school, but the replacement ACLs did not take and his body absorbed them. Despite his lack of ACLs, Blair has successfully played in the NBA and is currently in his 6th year. According to Dr. James Gladstone of Mount Sinai School of medicine, Blair is a “coper.” Defined as people who can perform without ACLs, “copers” only constitute five percent of the ACL-torn population.<sup>35</sup>

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<sup>34</sup> Bach, Bernard R., and Provencher, Matthew T., eds, *ACL Surgery: How to Get it Right the First Time and What to Do if it Fails*, Thorofare, NJ, USA: SLACK Incorporated, 2010, accessed October 21, 2014, ProQuest ebrary.

<sup>35</sup> Beck, Howard, “Spurs’ Blair is Lacking Everything but Success,” *The New York Times*, November 12, 2009, Accessed March 9, 2015, [http://www.nytimes.com/2009/11/13/sports/basketball/13dejuan.html?\\_r=0](http://www.nytimes.com/2009/11/13/sports/basketball/13dejuan.html?_r=0)

With only a five percent chance of returning to full activity without surgery, most athletes choose an ACL reconstruction to continue their careers.

The importance of ACL reconstruction in this paper is twofold: first, to illustrate the shortcomings of current techniques of surgery, and second, to demonstrate the consequences of surgery on the body. There is a common notion that ACL surgery will surely repair an ACL injury, when in fact, the evidence is quite the contrary. Meticulous and difficult, the surgical procedure of ACL reconstruction has many variables and its success can vary depending on the patient. Even after a successful surgery, the odds of a second ACL tear in a female athlete within 24 months of returning to sport rises to five times that of a healthy female athlete.<sup>36</sup> Finally, if a female athletes undergoes a positive surgery and does not sustain a second ACL injury, she still faces a high risk of developing degenerative osteoarthritis in her knee. Osteoarthritis often leads to the requirement of total knee replacements, just for the patients to be able to complete everyday activities.

In 1999, Hewett and his associates estimated the cost of ACL reconstruction and rehabilitation at \$17,000 per athlete.<sup>37</sup> In 2015, Hewett approximated the current cost to be around \$25,000.<sup>38</sup> Yet despite the cost (both financially and medically), about 9 out of 10 victims of an ACL tear choose surgical reconstruction

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<sup>36</sup> Paterno, "Incidence of Second ACL," 1567.

<sup>37</sup> Hewett, "The Effect of Neuromuscular Training," 699..

<sup>38</sup> Hewett Interview

to repair their ACL-deficient knees.<sup>39</sup> Clearly, ACL reconstruction is the standard treatment for ACL ruptures today.

Prior to today's advanced technology, ACL surgeries looked quite different. In 1895, A.W. Mayo Robson performed the first ACL surgery on a patient by suturing the torn ACL. According to the story, the patient neither complained of later reinjury nor missed a day of work.<sup>40</sup> Primary ACL repair, a suture weave from tibia to femur, became the typical method of mending an ACL injury during most of the twentieth century. Yet in 1917, Ernest W. Hey Groves performed the first ACL reconstruction surgery using a graft, which is when the surgeon takes tissue from another part of the patient's body to use as the new ACL. Though it only had moderate success, succeeding doctors picked up Groves' technique using different tendons. By the 1970s, ACL reconstruction (replacing the ACL with different tissue) was more popular and successful than repairing ruptured ACLs.<sup>41</sup> While many surgeons have tested different grafts since the early twentieth century, the standard procedures today manipulate the patellar tendon, the hamstring, or an allograft from a cadaver to use as the new ACL.

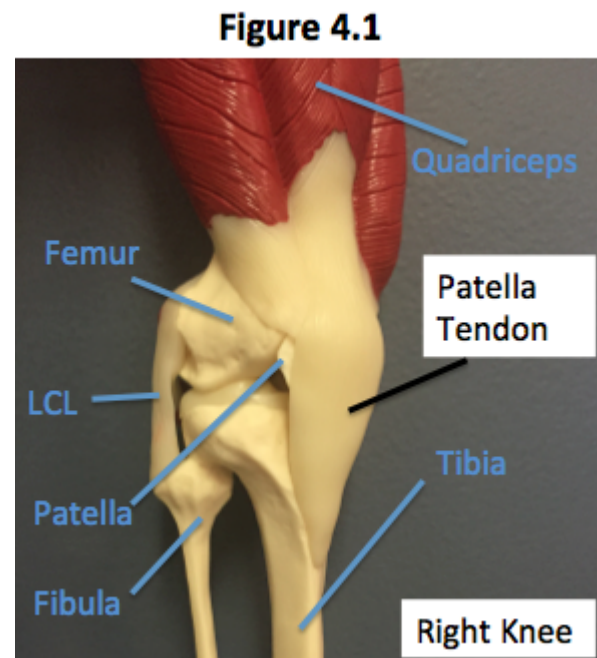
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<sup>39</sup> Paterno, "Incidence of Second ACL," 1567.

<sup>40</sup> Murray et al., *The ACL Handbook*, 21.

<sup>41</sup> Murray et al., *The ACL Handbook*, 23-25.

In ACL reconstruction using the patellar tendon, the surgeon takes a section of the patella tendon (Figure 4.1) and screws it into femur and tibia. Today, surgeons use bioabsorbable screws that disintegrate in the body after several years. The patellar tendon reconstruction is the most popular choice of ACL patients and doctors for the last 30 years.<sup>42</sup> One of the benefits of the patellar tendon procedure results from how surgeon cuts the patellar tendon. When taking the tendon, he or she



removes very small bits of bone on the ends of the tendon, from the tibia and patella. This allows the new graft to heal quicker than a hamstring graft.<sup>43</sup> Furthermore, the patellar tendon has regenerative properties and will regrow fully in 12-18 months. This special property also allows for the use of the newly grown tendon if another ACL injury should occur.

While the patellar tendon is the current “gold standard” of graft reconstruction, there are a few notable drawbacks. First, the patellar tendon procedure requires a longer incision and therefore, a more noticeable scar. Figure

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<sup>42</sup> OA Center for Orthopaedics, “ACL Graft Choices,” accessed March 10, 2015, <http://www.orthoassociates.com/SP11B35/>.

<sup>43</sup> Mannarino, Frank P, “Graft Selection for ACL Reconstruction,” Orthopaedic Institute of Dayton, accessed March 10th, 2015, <http://www.orthodayton.com/patient-education/graft-selection-for-acl-reconstruction.html>.



4.2 shows the patellar tendon scar starting to heal fifteen days after surgery. The bigger incision can also lead to more swelling and pain during the first two weeks after surgery.<sup>44</sup> Figures 4.3 and 4.4 show the swelling of a patient's right leg three days after the patellar tendon reconstruction. Also, patellar tendonitis and anterior knee pain are common side effects reported by

patients who undergo patellar tendon reconstruction.<sup>45</sup> Despite the shortcomings of the patellar tendon surgery, many surgeons and patients still decide it is the best method to return the patient to pre-injury levels.

**Figure 4.2:**  
Fifteen Days after Patellar Tendon ACL  
Reconstruction on Right Knee



**Figure 4.3:**  
Right Leg Swelling Three Days after  
Patellar Tendon Reconstruction



<sup>44</sup> Mannarino, "Graft Selection for ACL Reconstruction."

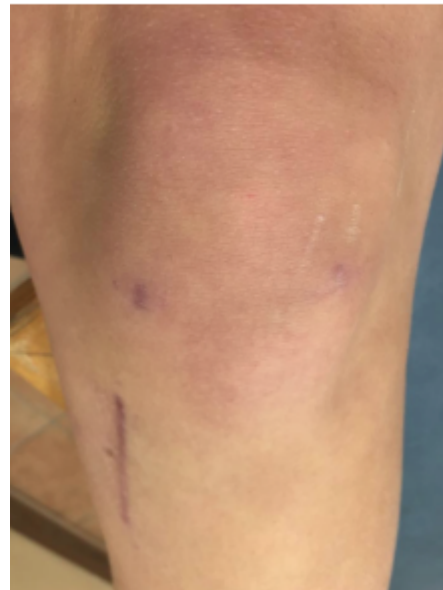
<sup>45</sup> "ACL Graft Choices."

**Figure 4.4:**  
Lateral View of Right Leg Swelling  
Three Days after Patellar Tendon Reconstruction



The other autograft (tissue from the same patient's body) technique popular today is the hamstring graft. While there are a variety of methods using the hamstring tendon, a common method is “doubled,” which is a combination of different parts of the hamstring folded over onto each other to make the strongest possible graft. The hamstring graft procedure allows for a smaller incision (Figure 4.5) and often produces less initial pain than the patellar tendon method. Because the hamstring does not immediately affect the quadriceps, patients do not lose as much of their quadriceps strength as patellar tendon patients do (whilst waiting for their patellar tendon to heal).<sup>46</sup> Often, the quicker a patient regains her quadriceps strength, the faster he or she can return to sports.

**Figure 4.5:**  
Five Months after Hamstring ACL  
Reconstruction on Left Knee



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<sup>46</sup> “ACL Graft Choices.”

On the other hand, there are flaws in the hamstring technique as well. “Tunnel widening” is when the tunnels in the tibia and femur (made by the screws during surgery) enlarge. If the tunnels get too wide and the patient reinjures her ACL, the patient will require two surgeries to have a functional knee again. The reconstructive surgery must occur after another procedure, in which the surgeon fills the widened tunnels with bone graft to allow for a second tunneling.<sup>47</sup> Additionally, unlike the patellar tendon, the hamstring does not regrow, and the patient’s hamstring strength will have permanently decreased. Finally, the hamstring tendon technique is quite difficult and meticulous and requires a surgeon with a good amount of experience. Regardless of the drawbacks, surgeons have continued to improve the hamstring graft procedure, making it a viable option for ACL-deficient patients.

The last of the three graft techniques, allograft, is the least popular among reconstructive patients. In this procedure, a surgeon often harvests a patellar tendon or Achilles tendon from a donor and places it in the patient as the new ACL. The obvious benefit to this method is the lack of patellar or hamstring tendon removal, which produces a shorter surgery and quicker recovery time. Conversely, allografts are more expensive, not always readily available, can lead to a bacterial infection, and above all else, the graft may fail if the body rejects it.<sup>48</sup> It is easy to see why this is the least popular ACL reconstruction method. Patients with a history of

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<sup>47</sup> “ACL Graft Choices.”

<sup>48</sup> McKee, Jennie, “Autograft or Allograft for ACL Reconstruction?” American Academy of Orthopaedic Surgeons, last modified April 2012, <http://www.aaos.org/news/aaosnow/apr12/cover1.asp>.

similar problems in the knee, such as meniscal repair or osteoarthritis, will choose an allograft to minimize collateral damage to the patellar or hamstring tendons.<sup>49</sup>

Working together, the patient, her family, and the surgeon will ultimately choose which procedure is best for them. Patients with lengthy histories of knee problems may only have one of the options realistically available to them, and the others of the ACL-deficient population have to choose between the risks of the three surgeries. While surgeons continue to improve on the methods and technology of all three techniques, the consequences of each surgery is enough to make any patient hesitate before undergoing ACL reconstruction.

According to Mark V. Paterno and his colleagues, “Despite the high percentage of ACLR [ACL reconstruction] after ACL injuries, outcome may be less than optimal.” After surgery, patients face many more severe risks regardless of their graft choice. Graft failure, reinjury, and osteoarthritis are not unlikely results of ACL reconstruction. Researchers, like Paterno and Hewett, have started to generate long-term studies on the effects of ACL reconstruction and the results are often not positive. The variability in success of today’s ACL repairs has made it difficult to depend on reconstruction to fix a torn ACL.

Graft failure can result from autograft reconstructions, not just allografts. Approximately 3-10 of every 1,000 ACL reconstructions fail.<sup>50</sup> One cause is surgical; the erroneous placement of the femoral tunnel during surgery is prevalent in ACL graft failure. According to K. Markatos and his associates,

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<sup>49</sup> Mannarino, “Graft Selection for ACL Reconstruction.”

<sup>50</sup> Bach, *ACL Surgery: How to Get it Right the First Time*, 175.

Frequently, the grafts are placed too far anteriorly on the femur, resulting in a vertically orientated graft. Several in vitro studies suggest a graft placed too far anteriorly on the femur results in excessive tension in the graft in [flexion], which could lead to graft failure. Furthermore, a vertically oriented graft does not reproduce the oblique orientation of the ACL, which could limit the ability of the reconstruction to restore the abnormal kinematics observed after ACL deficiency.<sup>51</sup>

The current technique of creating the femoral tunnel through the tibial tunnel may be the problem. The dimensions of the tibia make it difficult for surgeons to drill the femur tunnel at the center of the femur. Next, because the precise graft placement to fully utilize the new 'ACL' is still unknown, it is even harder for surgeons to place the graft accurately. While improper graft placement is the most prevalent cause of ACL injuries, it is not the only one.

Three other causes commonly lead to graft failure: graft impingement, inappropriate graft tensioning, and deficient graft fixation. In graft impingement, the surgeon positions the tunnels too far medially or laterally, which results in the new graft disrupting the PCL.<sup>52</sup> Discovering the optimal graft tension has proven tremendously difficult, especially when the best level may vary from patient to patient. This makes it challenging for surgeons to complete a perfect surgery. Too much tension restricts the patient's range of motion, and too little tension leads to laxity in the joint. Finally, if a surgeon does not properly fixate the graft into the tunnels and the patient begins rehabilitation before the tunnels have healed, the patient is at risk of bone fractures or a graft laceration, both of which would cause

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<sup>51</sup> Markatos, K, M K Kaseta, S N Lalloos, D S Korres, and N Efstathopoulos, "The anatomy of the ACL and its importance in ACL reconstruction," *European Journal Of Orthopaedic Surgery & Traumatology: Orthopédie Traumatologie* 23, no. 7 (2013): 747-752, MEDLINE, EBSCOhost, accessed November 25, 2014.

<sup>52</sup> Bach, *ACL Surgery: How to Get it Right the First Time*, 179.

the new ACL to fail.<sup>53</sup> Luckily for patients, surgeons continue to improve their techniques to minimize the risk of graft failure, but ACL reconstruction is still far from a flawless procedure.

If a patient comes out of ACL reconstruction and her graft does not fail, he or she probably does not have a new, perfectly functioning 'ACL.' After the reconstruction, the patient's risk of sustaining another ACL tear increases markedly. Lucy Salmon and her colleagues conducted a study over a five year time span to understand the likelihood of a second ACL tear after a primary ACL reconstruction. The results of the study demonstrated that twelve percent of the reconstruction patients tore either their ACL grafts or their contralateral ACLs. The authors conclude that the initial injury increases the likelihood of a ACL graft tear by three, and surgical patients who return to sport multiplied their risk of contralateral ACL rupture by ten.<sup>54</sup> Although the most threatening time for another ACL injury is within the first twelve months after surgery, the probability of a second ACL tear at any time is alarming. Paterno et al. conducted a comparable study on the incidence of ACL injuries two years after reconstruction and reported that almost thirty percent the of ACL reconstruction patients sustained a second ACL injury. This study also indicated that female athletes who underwent reconstruction are five times

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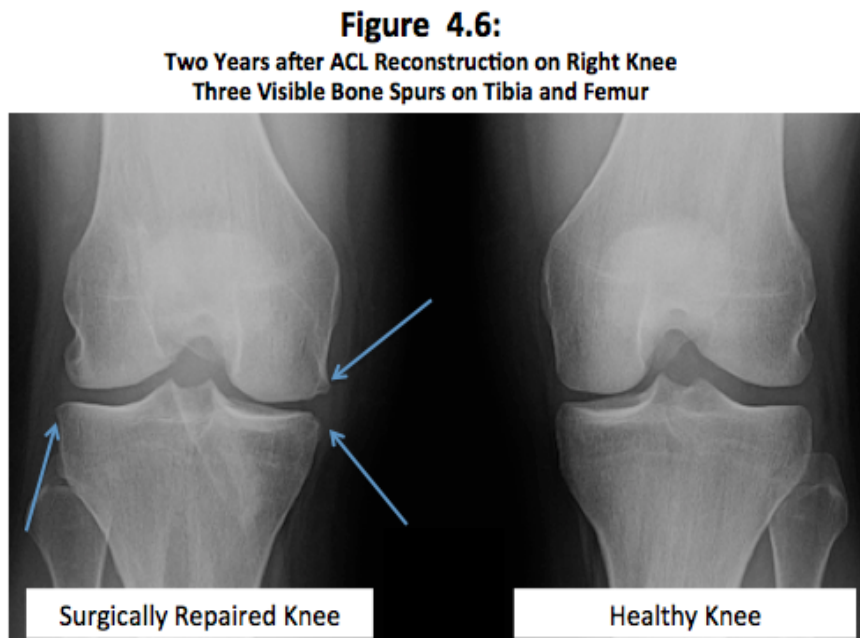
<sup>53</sup> Bach, *ACL Surgery: How to Get it Right the First Time*, 179-80.

<sup>54</sup> Salmon, Lucy, Vivianne Russell, Tim Musgrove, Leo Pinczewski, and Kathryn Refshauge, "Incidence and Risk Factors for Graft Rupture and Contralateral Rupture after Anterior Cruciate Ligament Reconstruction," *Arthroscopy: The Journal of Arthroscopic & Related Surgery* 21 no. 8 (2005): 948-957, accessed March 11th, 2015.

more likely to experience a second ACL injury than their healthy counterparts.<sup>55</sup> One ACL tear can cause an athlete to miss an entire season, but two ACL injuries often force an athlete into early retirement. Despite the obvious drawbacks of this reconstructive method, it is currently the best method for repairing the knee and allowing an athlete to return to sports.

Now, the majority of patients that undergo ACL reconstruction do not face graft failure and do not reinjure their ACLs, but they still face lasting consequences from the surgery. Osteoarthritis has become a frequent repercussion of ACL surgery. Osteoarthritis is the wearing down of the cartilage that protects the ends of the bones.<sup>56</sup> It currently has no cure and exacerbates over time. In the knee, an atypical relationship between the femur and tibia causes osteoarthritis, which subsequently

deforms the tibia and femur, causing painful bone spurs (Figure 4.6). Bone spurs are “bony projections that develop along the edges of the

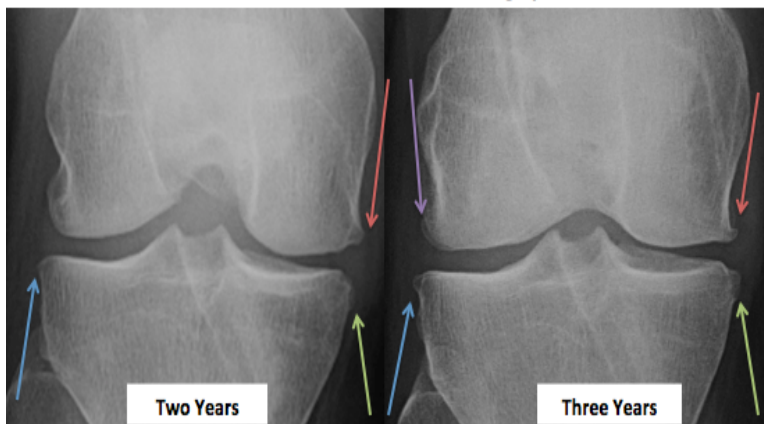


<sup>55</sup> Paterno, “Incidence of Second ACL,” 1570-1572.

<sup>56</sup> Mayo Clinic, “Osteoarthritis,” accessed March 11, 2015, <http://www.mayoclinic.org/diseases-conditions/osteoarthritis/basics/definition/con-20014749>.

bones,”<sup>57</sup> which can cause pain and limit range of motion. A lack of cartilage results in the tibia and femur colliding in high impact situations, causing activities, such as running or jumping, to be painful for the patient. Repeated exercise involving high impact on the atypical knee can result in osteoarthritis and bone spurs in as little as a year after surgery. Figure 4.7 shows a twenty-one year old collegiate female athlete’s ACL-reconstructed knee two years versus three years after surgery. Every contact point between the tibia and femur has worsened, including the development of a fourth bone spur on the lateral femur. This comparison demonstrates the severity of the corrosion of bones from osteoarthritis on the knee joint in a female who returns to athletics after an ACL reconstruction. Eventually the tibia and femur will be so worn down, the patient will require a total knee replacement just to be able to run.

**Figure 4.7:**  
Right Knee Osteoarthritis and Bone Spurs  
Two Years vs. Three Years after Surgery



#### Cartilage

injections or attempts to regrow the cartilage to ease the collision of bones are not perfect procedures and are not permanent solutions.

C.M. Hettrich and K.P.

<sup>57</sup> Mayo Clinic, “Bone Spurs,” accessed April 12, 2015, <http://www.mayoclinic.org/diseases-conditions/bone-spurs/basics/definition/con-20024478>.



Spindler report a forty percent chance that a patient who underwent ACL reconstruction will develop osteoarthritis within ten years of surgery.<sup>58</sup> Those who return to athletics post-surgery have an even higher rate of osteoarthritis. Osteoarthritis can become a debilitating disease for those it affects, and more and more long-term studies are demonstrating its prevalence after surgery. According to Dr. Hewett, the number of middle-aged women requiring total knee replacements (as a result of ACL reconstruction) has increased markedly<sup>59</sup> and demonstrates the shortcomings of current reconstruction techniques. Until there is a favorable treatment available for osteoarthritis, it remains the notorious repercussion of ACL reconstruction.

The technology of today's ACL reconstruction does not allow a complete restoration of the ACL and its kinematics to return an athlete to pre-injury levels.<sup>60</sup> Possible graft failure, potential reinjury, and probable osteoarthritis threaten every ACL reconstruction patient after surgery. It is an imperfect technique, at best. Until the outcomes of ACL surgery are less variable, and its repercussion less devastating, ACL reconstruction should not be the answer to the ACL injury epidemic.

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<sup>58</sup> Murray et al., *The ACL Handbook*, 38.

<sup>59</sup> Hewett, Interview..

<sup>60</sup> Markatos,, "The anatomy of the ACL," 751.

## V. Prevention Programs

The most important aspect surrounding ACL injuries is prevention programs. Prevention programs have the ability to significantly decrease the amount of ACL injuries and consequently, ACL reconstructions. It is necessary to spread information on prevention programs and implement them throughout the country to counteract this epidemic and its currently flawed method of restoration. With today's available information and technology, the best way to decrease the number of ACL injuries in female athletes today is with prevention training programs. While it is impossible to eradicate ACL injuries during sports, many current programs exist that greatly decrease the risk and number of ACL injuries. One such program is Sportsmetrics, which focuses specifically on reducing ACL injuries in female athletes.

At the Cincinnati SportsMedicine Research and Education Foundation, Noyes and Barber-Westin developed Sportsmetrics in 1994. They focused on eliminating two major risk factors for ACL injuries in female athletes: eradicating the development of knee valgus during jump landing, and improving hamstring strength to create a higher H:Q ratio. The designers recommend introducing the six-week Sportsmetrics program during the off-season or just before the season begins.<sup>61</sup> Over the course of the six week program, Sportsmetrics consists of four components: Dynamic Warm-Up, Plyometrics/Jump Training, Strength Training, and Flexibility.

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<sup>61</sup> Noyes, *ACL Injuries in Female Athletes*, 276.

Dynamic Warm-Up equips the body for training exercises by increasing the blood flow, heart rate, and body temperature.<sup>62</sup> Of the ten relatively simple exercises included in Dynamic Warm-Up, four examples are:

- 1) Straight Leg March (Figure 5.1): without leaning backwards, the athlete walks with both legs straight and alternating raising up each leg.
- 2) Leg Cradle (Figure 5.2): the athlete lifts one leg in front of the body, bends at

**Figure 5.1:**  
Straight Leg March



**Figure 5.2:**  
Leg Cradle



the knee and turns it outward, while grabbing the foot.

- 3) High Knee Skip (Figure 5.3): the athlete skips and drives each knee into the air to achieve maximum possible lift off.

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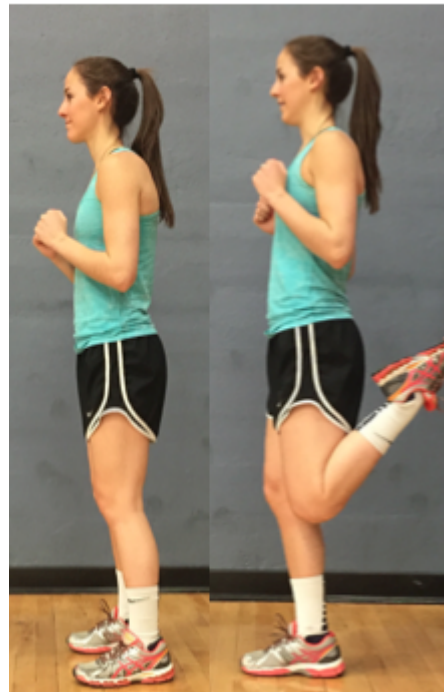
<sup>62</sup> Noyes, *ACL Injuries in Female Athletes*, 276-9.

- 4) Glut Kick (Figure 5.): the athlete jogs quickly and with each repetition she brings her heel as close to her glutes as possible.<sup>63</sup>

**Figure 5.3:**  
High Knee Skip



**Figure 5.4:**  
Glut Kick



The next stage of the program is Plyometric/Jump Training. Plyometrics perfect the muscle control and increase strength important in knee stability. Furthermore, Plyometrics increase speed, vertical jump height, and power.<sup>64</sup>

Plyometrics/Jump Training includes three phases: Technique Development, Fundamentals, and Performance. In Phase I: Technique Development, the athlete's goal is to display perfect form on every exercise. In Phase II: Fundamentals, the athlete performs the same plyometrics as Phase I (combined with a few new routines) with the proper technique for an extended amount of time. Finally, in

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<sup>63</sup> Noyes, *ACL Injuries in Female Athletes*, 278-9.

<sup>64</sup> Noyes, *ACL Injuries in Female Athletes*, 279.

Phase III: Performance, the athlete executes the same plyometrics again, but focuses on speed and increases the repetitions.<sup>65</sup> During the three phases, the athlete will perform nineteen different jumping plyometrics. For example:

- 1) Tuck Jump (Figure 5.5): standing with feet shoulder width apart, the athlete jumps, bringing her knees to her chest, then lands with her knees slightly flexed and feet still shoulder-width apart.
- 2) 180 Degree Jump (Figure 5.6): standing with the feet shoulder-width apart,

**Figure 5.5:**  
Tuck Jump



**Figure 5.6:**  
180 Degree Jump



the athlete jumps and spins 180 degrees in the air, before holding her landing with her knees slightly flexed and feet shoulder-width apart.

- 3) Scissor Jump (Figure 5.7): in a lunge position, the athlete jumps off of the front leg and lands in the same lunge position with the opposite leg in front.

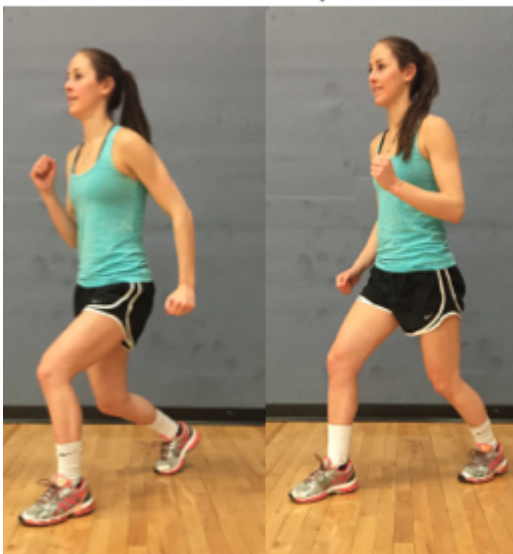
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<sup>65</sup> Noyes, *ACL Injuries in Female Athletes*, 279-80.

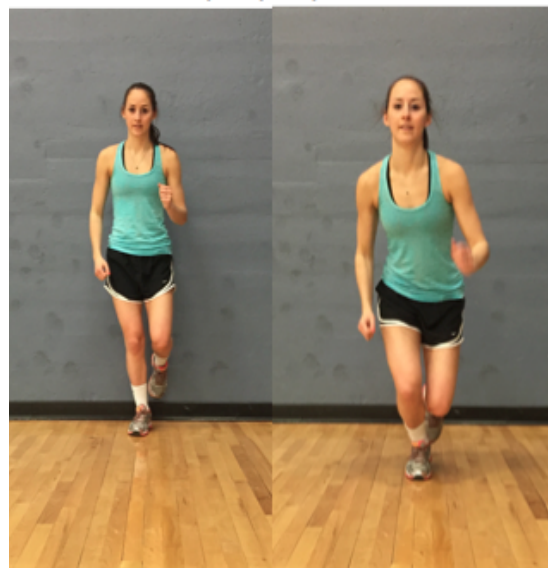
- 4) Hop, Hop, Hop, Stick (Figure 5.8): the athlete executes three single-leg hops then holds her final landing for five seconds.<sup>66</sup>

Phase III of Sportsmetrics is Strength Training, in which fifteen exercises mostly consists of resistance work and core activation to improve muscle tone and strength for joint stability.<sup>67</sup> One example of a resistance exercise is mini-squats

**Figure 5.7:**  
Scissor Jump



**Figure 5.8:**  
Hop, Hop, Hop, Stick



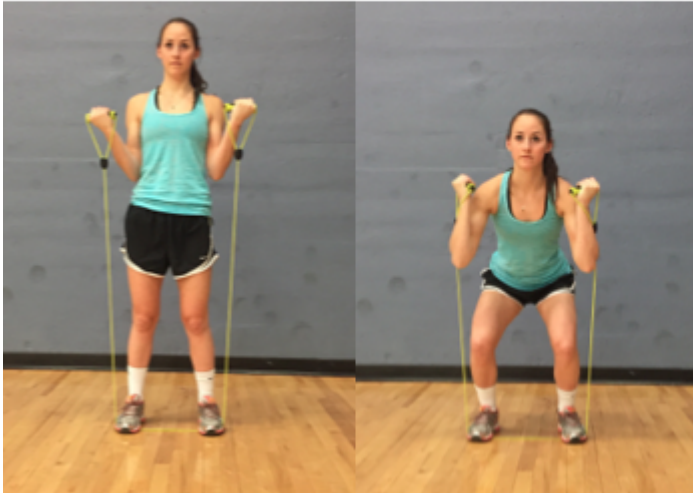
with a resistance band (Figure 5.9). In this exercise, the athlete steps on the resistance band with both feet and holds it firmly in each hand. Then, the athlete performs a mini-squat, keeping her knees over her toes (to avoid valgus collapse). A core activation exercise is the abdominal plank

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<sup>66</sup> "Sportsmetrics Jump Training," accessed Dec. 5th, 2014, <http://chiorthosports.com/physicians/>

<sup>67</sup> Noyes, *ACL Injuries in Female Athletes*, 286-94.

**Figure 5.9:**  
**Mini Squats with a Resistance Band**



(Figure 5.10), in which the athlete lies face down and balances on her elbows (placed directly under the shoulders) and curled toes for 30-90 seconds.<sup>68</sup>

Noyes and Barber-Westin conclude the

Sportsmetrics program with

Flexibility. According to the authors, “Stretching exercises are important to achieve maximum muscle length to allow muscles to work with power through a complete range of motion,”<sup>69</sup> and includes stretches for hamstrings, hip flexors, deltoids and many others. These four components create a training program that teaches athletes to properly train and strengthen their muscles, in order to reduce likelihood of knee valgus and hamstring inefficiencies, which are risk factors of ACL injuries.

**Figure 5.10:**  
**Plank**



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<sup>68</sup> Noyes, *ACL Injuries in Female Athletes*, 286-90.

<sup>69</sup> Noyes, *ACL Injuries in Female Athletes*, 294.



The Sportsmetrics training program was the first published prevention program that focused on knee injuries in high school-aged female athletes. Since its publication, many researchers, clinicians, and training staffs have implemented the program to test its effectiveness. Dr. Hewett and his colleagues conducted a study on the impact of Sportsmetrics plyometrics training in high school volleyball athletes. The researchers found that the subjects had both decreased impact forces when landing and increased hamstring power in both legs after completing the training program. Dr. Hewett and his associates concluded that Sportsmetrics training affects knee stabilization and help lower the risk factors for severe knee injuries, such as ACL tears.<sup>70</sup>

Other studies have given similar positive results since Sportsmetrics' publication. Noyes and his colleagues at the Cincinnati SportsMedicine Research and Education Foundation organized a study of the effectiveness of Sportsmetrics training in female basketball players in 2012. After the six weeks of training, researchers determined that the average distance between knees (in impact landings) in female basketball players had significantly increased.<sup>71</sup> An increased average distance between knees is important because it means knee valgus decreased. This study's findings support Sportsmetrics' goal of reducing ACL injuries through the elimination of knee valgus development during impact landing.

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<sup>70</sup> Hewett, TE et al., "Plyometric training in female athletes. Decreased impact forces and increased hamstring torques," *American Journal of Sports Medicine* 24 (1996): 765-773, accessed December 5th, 2014.

<sup>71</sup> Noyes, Frank et al., "A Training Program to Improve Neuromuscular and Performance Indices in Female High School Basketball Players," *The Journal of Strength and Conditioning Research* 26 (2012): 709-717, accessed December 5th, 2014.



A third study focused on female collegiate basketball players and the effects of Sportsmetrics training on their H:Q ratio. As previously stated, the H:Q is important because it determines the amount of pressure put on an ACL during landing and stabilization. Gary B. Wilkerson and his associates found that the Sportsmetrics program did increase the participating female athletes' H:Qs significantly. The researchers concluded that the Sportsmetrics training program reduced risk factors for ACL injuries in female athletes.<sup>72</sup> From the results of this study, Sportsmetrics succeeds in its goal of strengthening hamstrings in female athletes.

In a comprehensive experiment of 829 female athlete participants, Dr. Hewett and his colleagues looked at the overall incidence of ACL injuries during a complete season with dependence on the implementation of the Sportsmetrics program. The experimental group underwent Sportsmetrics training for the typical six weeks, while the control group did not. At the end of the season, the experimental group reported two ACL injuries while the control group reported ten.<sup>73</sup> This study demonstrates that the Sportsmetrics program actually has the capability to reduce ACL injuries in female athletes.

While the Sportsmetrics training program can take time away from athletic practice, these four studies clearly show its benefits. Decreased impact forces,

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<sup>72</sup> Wilkerson, Gary B, et al., "Neuromuscular Changes in Female Collegiate Athletes Resulting from a Plyometric Jump-Training Program," *Journal of Athletic Training* 39 (2004): 17-23, accessed December 5th, 2014.

<sup>73</sup> Hewett, TE et al., "Plyometric training in female athletes. Decreased impact forces and increased hamstring torques," *American Journal of Sports Medicine* 24 (1996): 765-773, accessed December 5th, 2014.

higher H:Q, and decreased knee valgus all reduce the risk factors of sustaining an ACL injury. Furthermore, Dr. Hewett and his associates demonstrated that Sportsmetrics training decreases ACL injuries in an all-inclusive study. If more athletes had regular access to the Sportsmetrics program, ACL injuries in female athletes will decrease.

The Sportsmetrics program clearly shows the effectiveness of correctly utilized prevention programs. Junior high schools, high schools, and colleges need to be more aware of the available prevention programs to protect their athletes. The implementation of this program, or others like it, is crucial to decreasing the amount of ACL injuries that occur in female athletes every year. The six-week training program has the capability to save high-risk female athletes from months or years of rehabilitating a torn and surgically repaired ACL, as well as cost of surgery and rehabilitation. Schools should require coaches and training staffs to employ prevention programs for their athletes prior to the start of every athletic season and continue throughout the season. If the number of ACL injuries in female athletes is to decrease, the smartest and most efficient method for change is to implement prevention programs like Sportsmetrics across the country as soon as possible.

Today, the problem with prevention programs lies with the people. Anyone can Google a prevention program and educate him or herself, but few chose to do it. With famous athletes, like Tom Brady and Derrick Rose, sustaining ACL tears, the public has become more aware of ACL injuries. Yet, many people are still unaware of the 3-40 ACL injuries that occur every hour in the United States, which is the true

ACL epidemic. According to Noyes and Barber-Westin, “It remains the responsibility of those clinicians and scientists involved to continue their efforts to educate the general public.”<sup>74</sup> While this statement is true, clinicians and scientists are not the only people responsible for passing on education on prevention programs. Trainers, coaches, players, and any other knowledgeable people also share a role in this responsibility.

In female high school and collegiate athletics today, few coaches remain ignorant about the possibility and calamity of their players rupturing their ACLs. Despite their concerns, many coaches do not choose to utilize available programs. In a 2011 study, CR Labella and his colleagues encouraged almost 300 Chicago-area coaches to engage in coach-led ACL prevention programs, yet only 95 complied.<sup>75</sup> Why are coaches resisting the implementation of ACL prevention programs?

According to Jordan Grant, a Junior Varsity Girls’ Basketball Coach at Yarmouth High School in Maine, “I think that some [coaches] think it isn’t worth the time to implement an entire program aimed at preventing ACL injuries.”<sup>76</sup> A common misconception of ACL prevention programs is that they waste precious practice time, of which coaches often get so little. But, as the Sportsmetrics program proved, prevention programs benefit the numerous female athlete’s muscles that improve their athletic ability, such as vertical jump height, acceleration speed,

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<sup>74</sup> Noyes, *ACL Injuries in Female Athletes*, vii.

<sup>75</sup> Labella CR, MR Huxford MR, J Grissom et al., “Effect of neuromuscular warm-up on injuries in female soccer and basketball athletes in urban public high schools: cluster randomized controlled trial,” *Arch Pediatr Adolesc Med* 165 no. 11 (2011):1033–1040.

<sup>76</sup> Grant, Interview, March 3, 2015.

strength, and overall speed. By demonstrating to coaches that ACL prevention programs increase their players' athletic abilities while preventing serious injuries, more coaches would be willing to employ these training programs with their players.

The biggest obstacle to widespread implementation of prevention programs throughout high schools and colleges is a lack of knowledge about available programs. Many coaches do not have much guidance from training staffs or medical professionals on prevention programs, and it is no easy task to execute the implementation of a prevention program alone. According to Dr. Hewett, "Coaches are some of the most overworked and underpaid people in the country, and they just don't have the time."<sup>77</sup> Bryan Gardere, a Girls' Basketball Coach at Piedmont High School in California, says, "The biggest barrier [to the utilization of prevention programs is] getting the information into the coaches' hands to share with their players."<sup>78</sup> Coaches across America need help to implement prevention programs with their teams. Athletic trainers, athletic directors, parents, and athletes all share responsibility with coaches to create awareness of ACL injuries and implement effective prevention programs.

Some schools and coaches have taken strides to employ ACL prevention training within their programs. At Watertown High School in Wisconsin, Girls' Volleyball Coach Travis Hall uses a full body prevention program with emphasis on ACL prevention. "The program we used in the past was created by our trainer, but

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<sup>77</sup> Hewett, Interview.

<sup>78</sup> Gardere, Interview, March 10, 2015.

the one we use now... we developed for our own team.”<sup>79</sup> The collaboration of athletic trainer and coach is absolutely essential for the proper creation of a prevention program right for each team and their players. While the trainer brings the medical and scientific knowledge, the coach also understands the players and is the final implementer of the program. At schools like Watertown, it is up to the individual coaches to enforce properly executed prevention programs. It would be more beneficial and easier for coaches, if schools’ athletic departments required and standardized the use of prevention training across their athletic programs. This is the role of the athletic director in the process. Parents and athletes need to bring the likelihood of ACL injuries to the attention of the athletic directors (if they are unaware) in high schools and colleges across the United States. Once the athletic director has accurate information on the epidemic of ACL injuries, it is their responsibility to instill a requirement or standardization of prevention programs or at least work with training staffs and coaches to create them.

There are schools that have taken an active role in ACL prevention training such as Colby College. Due to a dedicated strength and conditioning coach, Dawn Strout, and an active athletic training staff, Colby athletes benefit from the exercises of prevention programs on a regular basis. The Women’s Basketball team is a notable example. At the start of every practice, the coaches have the players go through dynamic warm-up and activation. During these activities, the athletes do exercises like high skips, straight leg marches, leg cradles, and abdominal planks,

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<sup>79</sup> Hall, Interview, March 2, 2015.

which are all exercises from the Sportsmetrics program. Since the introduction of a new coaching staff and their dedication to injury prevention, there have been no ACL tears or severe lower body injuries in four years for this basketball team. The Colby Women's Basketball program is a great step in the right direction for the diffusion of prevention programs in high schools and colleges.

While the Colby Women's Basketball coaches have introduced ACL prevention exercises into their practice plans, they are also not perfect. The athletes on the team are often unaware of the benefits of these exercises and may not take them seriously. They do not recognize the correlation between their daily dynamic warm up and the lack of injuries during their season. Furthermore, the coaches do not demonstrate correct form of every movement, which is a crucial step in the success of prevention programs. Although the preventative exercises are in place for this team, the athletes may not reap all of their benefits without understanding the importance of doing the exercises properly. The simple communication of the benefits of prevention exercises and demonstration of proper execution is the only missing piece in the Colby Women's Basketball prevention program. Other colleges and high schools should take note of what coaches and trainers are implementing at Colby and mimic their programs for their own athletes' benefits.

Prevention programs are not yet commonplace among athletic programs, especially at the high school level. The nullification of the familiar belief that coaches do not have time for or do not need ACL prevention training is imperative to the widespread implementation of these programs across the country. Then, it is

necessary for athletic trainers and coaches to work together to create prevention training routines that benefit their athletes before and during season. Finally, coaches need to educate their players on the importance of the prevention training and explain proper technique to their players. The only thing these three steps require is time, and any coach with their players' best interest in mind should not refuse to include prevention programs into their teams' practices. Once coaches understand the simplicity and benefits of prevention programs, more and more coaches will start to implement them. Finally, when prevention programs are customary in sports teams across the country, the number of ACL injuries will decrease. The spread of information on prevention programs and their benefits, then their implementation is the most efficient method currently available to reduce the amount of ACL ruptures in female athletes across the country.

## **VI. Conclusion**

ACL injuries can end athletic careers, cost a significant amount of money, and leave athletes with troublesome repercussions for their rest of their lives. Due to a plethora of increased risk factors for females, ACL tears are an epidemic affecting all levels of women's athletics. Although an ACL tear is one of the most gruesome, painful injuries an athlete can sustain, 80 percent of all ACL injuries occur without contact. It is not caused by a full speed collision of two athletes, a blind-sided tackle, or a result of foul play. ACL injuries usually occur because of poor body alignment during noncontact jumping, landing, or pivoting. Regardless of which sport she chooses to play or how strong she is, every female athlete faces a heightened risk of experiencing an ACL injury simply being a female.

While researchers do not know what definitively causes every ACL injury, the proposed risk factors for women are neuromuscular, biological, and hormonal. The muscle ratios in females' legs affect the likelihood of an ACL injury, as well as the size of one's ACL. At certain times during the menstrual cycle, females can be more susceptible to an ACL tear. After an ACL injury, the athlete almost always requires surgery to participate in sports again. Even the "gold standard" of ACL reconstruction today is flawed. ACL reconstruction cannot yet return correct biomechanics to the injured knee, even in the most successful surgical cases. An ACL surgery can fail or often times the athlete sustains a second injury. The surgeries with the most favorable outcomes still often leave their patients with degenerative osteoarthritis that may require further procedures. Thus, the smartest and most



efficient method of dealing with this devastating injury today is through the widespread implementation of prevention programs.

Since the late 1990s, researchers have created many prevention programs that significantly reduce the risk factors of an ACL injury in their experimental populations. In studies of thousands of athletes and athletic programs, prevention training, like Sportmetrics, has proven to decrease the number of ACL injuries in female athletes in every sport. Furthermore, female athletes who underwent prevention training showed an increase in athletic abilities due to new muscle control and definition. Prevention programs are a simple, easy way to ensure the safety and health of female athletes in high school and colleges around the country.

Despite the successes of ACL injury prevention programs over the last twenty years, they are not typical in most high school and some collegiate athletics today. There is a tremendous amount of ignorance hindering the widespread utilization of ACL prevention programs in athletics. Although almost all coaches of female sports in the United States must be familiar with ACL injuries (due to their current prevalence in female athletics), few coaches possess sufficient information or receive the assistance needed to organize and execute prevention programs for their teams. Coaches need to educate themselves and work with athletic training staffs and athletic directors to create and implement ACL prevention programs that benefit their players. Athletes and parents can make a difference too, by understanding the ACL epidemic and by bringing the problem to the attention of athletic directors, coaches, and trainers. Coaches and trainers are also responsible

for educating their players on the risks of ACL injuries and the importance of proper technique. Finally, players are the crucial piece. They must understand the prevalence and consequences of ACL injuries and be willing to complete prevention training to reduce their own risks. Since ACL reconstruction cannot truly repair a torn ACL, prevention programs must become commonplace. Between 3-40 people should not tear their ACLs every hour because of a lack of information. Only the spread of ACL knowledge and the implementation of ACL prevention programs can decrease the number of ACL injuries in female athletes today. Instead of 100,000 ACL reconstructions every year, there could be very few. ACL injury prevention programs do not require additional money, research, or technology to be effective; they only require time, knowledge, and dedicated athletes. Prevention programs are proven to decrease the risks of ACL injuries and benefit the athletes. They truly are the answer to epidemic of ACL injuries in female athletes. The only question is, why are they not in widespread use?

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