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ACL Tears: Their Cause and Prevention

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ACL TEARS: ITS CAUSE AND PREVENTION

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Abstract

There has been an increase in the prevalence of anterior cruciate ligament (ACL) tears among athletes in the recent years. This paper will seek to discover why ACL injury is so common and if there is any way to minimize these injuries. Research has shown a number of things that can lead to prevention of these injuries, including a correlation between the strength of the hip and thigh muscles and the stability of the ACL. Also many recent studies show that individuals most susceptible to ACL injuries often have difficulty performing gross motor skills such that the lower extremities move primarily in the sagittal plane, as the knee is subjected to higher stresses on its internal structures when excessive motions occur in the frontal plane.

Keywords: Anterior Cruciate Ligament, ACL tears, tear causes, ACL injury, prevention

Dedicated to my friends and family

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CHAPTER 1

INTRODUCTION

Sports injuries happen all the time. Anyone who has ever played sports or been around sports can testify to the fact that injuries are a frequent occurrence. Different sports have different injuries that commonly occur. The knee is one of the most frequently injured joints in the human body and it is commonly injured during sporting activities (Meyer, 2005). Among knee injuries, the Anterior Cruciate Ligament (ACL) is one of the most commonly disrupted ligaments in the knee (Boden, 2000). This injury seems to occur in a great majority of sports and can be catastrophic to someone's athletic career, and unfortunately it seems these injuries are occurring much more often, than previously observed. There has been a great deal of information discovered about the ACL in the past twentyfive years, but unfortunately little has been discovered in the area of prevention for these injuries. Nonetheless there has been a great deal discovered about the make up of the ACL and causes of its tear. This information is beginning to be used to discover ways to prevent this terrible injury from happening in the first place. This paper will seek to inform athletes and coaches alike of measures that can be taken to prevent this injury from occurring.

CHAPTER 2

THE ACL

The ACL extends posteriorly and laterally from a point anterior to the intercondlylar area of the tibia to the posterior part of the medial surface of the lateral condyle of the femur (Tortora, 2009). In laymen's terms, it extends diagonally in the middle of the knee joint connecting the shin and thighbones. The ACL is a complex structure that has an irregular nature. It has a multifascicular structure that had been ignored for many years as it was originally thought to function as a simple band of fibers with constant tension as the knee moves.

Multiple collagen bundles lead to the multifascicular nature of the ACL (Arnoczky, 1983). There are three functional bundles that make up the ACL; the anteromedial, intermediate, and posterolateral. These were all identified in cadaver knees in a study by Amis and Dawkins, and this concept leads to the functional anatomy of the ACL (Amis, 1991). This makeup is why the ACL can function during most all movements of the knee because its nature allows a portion of the ligament to be taut at all times, helping to stabilize the knee throughout its normal range of motion (Amis, 1991). The amount of lengthening of the three portions of the ACL during valgus, which will be described momentarily, and anterior loading was observed to increase with knee flexion angle (Hollis, 1991). In this study when the external load was zero, the anteromedial portion of the ACL lengthened with knee flexion and the posterolateral portion shortened, while the intermediate portion wasn't found to change in length (Hollis, 1991).

The ACL provides the majority of the resistance to anterior tibial translation. In doing so, it limits hyperextension of the knee and prevents the anterior sliding of the tibia on the femur (Sakane, 1999 & Marieb, 2008). This resistance towards anterior tibial translation is more significant when the knee is near extension. A study by Guoan Li and colleagues on the *in vivo kinematics of the ACL during weight-bearing knee flexion* showed that the ACL primarily functions at low flexion angles and its role decreases with increasing flexion (Li, 2005). A test on the functional anatomy of the ACL by Amis showed that the different functional bundles of the ACL contribute to resisting anterior subluxation of the knee during flexion and extension.

The ACL also plays a role in stabilization against rotatory loads (Petersen, 2006). Rotary loads occur in the knee when a force causes the turning of the tibia and/or femur inward or outward. Due to the connection of the ACL to both of these bones, it aids in stabilizing them and preventing their sliding (Tortora, 2009).

CHAPTER 3

INCREASE IN TEARS

Anterior cruciate ligament injuries are receiving a great deal of notice because of the incidence of injury that occurs not only in the athletic population but also in those individuals who are recreationally active (Russell, 2006). Each year in the United States there are approximately 250,000 ACL injuries. This is approximately 1 in 3,000 in the general population (Boden, 2000). Of these injuries, about 175,000 require reconstructive surgery. These surgeries had an estimated cost of over two billion dollars annually in the United States (Yu, 2007). These statistics alone make it obvious that this injury occurs very often. The ACL is one of the most commonly disrupted ligaments in the knee.

While the prevalence of the injury has increased, so has the number of athletes in the world since ACL injury research first began. Women are now allowed to participate in sports and new sports are being participated in on the competitive level, which didn't occur in the past. Also, there has been an increase in recreational sports. Although there has been an increase in the number of athletes, it is evident that there has been an increase in the prevalence of the injury. Even though the ACL has received much attention in the last 25 years and much understanding has been discovered, little focus has been on the causes of the injury and even less on its prevention. Prevention research is growing however, given the growing concern about the larger number of incidents, the greater treatment costs, and the serious consequences which result from this injury (Yu, 2007).

It is unfortunate that not much has been researched as far as prevention of this injury considering the extensive implications that result from this injury. First of all, this is an injury that requires reconstruction, which occurs through an invasive surgery. Not only is this a surgery, it is also expensive. Each reconstruction costs approximately seventeen thousand dollars (Boden, 2000). This cost doesn't include the costs of the initial evaluation or the cost of future medical treatment for those who face other problems related to this injury (Boden, 2000). Therefore, the actual cost of treating ACL injuries is much greater than the surgical fees. Due to the significant financial impact of this injury, it can also take an emotional toll on the athlete, especially those who are young (Boden, 2000). This emotional toll can result in disability, inability to participate in sports, long recovery, painful surgery and rehabilitation, along with the added stress of the financial burden on the athlete or athlete's family.

Following the surgery, a great deal of physical therapy must occur to restore function in the lower extremity as many of the muscles in the leg are weakened due to the effects of this injury. It can take a long time to return to the person's original functional or athletic state prior to the injury, possibly even years.

This injury alone is bad enough but also can cause other injuries at the same time. Research has shown that associated lesions can occur to other structures in the knee at the time of injury (Indelicato, 1985). The medial collateral ligament, called the MCL, along with osteochondral surfaces of the knee joint may also be at significant risk of associated injury. The MCL is a broad, flat ligament on the medial surface of the joint that extends from the medial condyle of the femur to the medial condyle of the tibia. This ligament resists force that would push the knee medially causing a valgus moment (Tortora, 2009). Osteochondral surfaces of the knee joint, specifically the femoral surface can be damaged when a rupture of the ACL occurs leading to an osteochondral fracture (Tortora, 2009). This injury increases the chances of osteoarthritis occurring in the knee.

Combined ACL and MCL disruption has been found to seriously diminish the patient's joint stability, and also can lead to gross deterioration of both the menisci and articular cartilage (Sakane, 1999). Considering the influence all of these structures have on one another, the status of other structures in the knee joint can have a large influence on the outcome of ACL reconstruction.

There are still more injuries that can occur during the ACL tear in addition to those already mentioned. If the injury occurs when the knee is flexed beyond 60°, then the menisci and joint capsule are at increased risk of injury (Sakane, 1999). The menisci are two fibrocartilage discs between the tibial and femoral condyles that help compensate for the irregular shapes of the bones. The joint capsule is an envelope that encompasses the knee joint and helps produce and maintain synovial fluid within the joint, allowing the joint to move with limited amounts of friction (Tortora, 2009). Further instability and associated injuries in ACL deficient knees can increase the incidence of meniscal tears and articular changes (Indelicato, 1985). Due to all these circumstances, when the ACL tears it is a potentially disabling injury (McLean, 2004).

CHAPTER 4

CAUSES OF TEARS

Mechanically, ACL injury occurs when an excessive tensile force is applied to the ACL. This happens through two different types of injuries, contact and non-contact (Yu, 2007). Contact injuries, just as they sound, are a result of contact between the lower extremity and someone or something. They occur in sports such as football, rugby, and skiing where athletes are more likely to collide with great force into one another or the ground. These contact injuries place the knee in abnormal positions, resulting in increased tensile forces to the ACL. Unfortunately the contact that causes these injuries isn't something that can be easily prevented, especially if someone chooses to play a contact sport. The only prevention that can be done for those who choose to play these types of sports is to avoid this contact if at all possible and perform movements that would protect the knee and shield it from receiving the brunt of the force. Some sports also have certain rules that prevent movements that would cause the type of contact that could result in injury. Football for example doesn't allow "chop blocks" or those that include blunt force to the lower extremities. Although the contact itself cannot be avoided or prevented, the injury itself can be prevented through the same prescription as non-contact.

Non-contact injuries, also as they sound, occur without contact from other competitors or the environment. These situations may place the knee in vulnerable positions resulting in the increased tensile forces ultimately disrupting the fibers of the ACL. Due to this fact they are something enigmatic and have led to a great deal of research to figure out why they occur in the past ten years (Uhorchak, 2003). Approximately seventy percent of ACL injuries occur as a result of a non-contact episode (McLean, 2004). In soccer one of the most common knee injuries is an ACL tear, which occurs through non-contact mechanisms almost always (Yu, 2007). This injury occurs when an excessive tension force is applied on the ACL and usually happens when a person themselves generates great forces or moments at the knee which apply this excessive loading on the ACL (Yu, 2007). There are specific movements that have been found to primarily cause these noncontact mechanism resulting in ACL tears.

Movements which have been found to place stress on the ACL and result in its rupture include the following: rapid deceleration and change of direction while the foot is fixed; cutting or pivoting; plant maneuvers; and one foot stopping or landing from a jump (Shultz, 2009 & Cross, 1989 & Russell, 2006 & Boden, 2000). One reason these movements seem to harm the ACL is because of the body position associated with them. During these movements generally, the tibia is outwardly rotated, the knee is close to full extension, the femur is inwardly rotated, and the foot is planted. These circumstances are potentially damaging for the ACL because as the limb is decelerated it collapses into a valgus position. Valgus is a deformity of movement where the limb is in oblique placement and has been moved away from the midline. Valgus movements have been proven to place high stress on the ACL and almost always result in its rupture (Myer, 2004).

Another reason these movements may cause injury is they produce a large anterior tibial translational movement. The resulting pull of the quadriceps muscle through the patella tendon produces this translational force. This force places a major stress on the ACL and without something to take on this force the ACL will give way and rupture (DeMorat, 2004).

A third reason the movements can be detrimental to the ACL is that when these movements occur the anterior shear force on the proximal end of the tibia is greatly increased and this causes a dominant strain on the anterior medial bundle of the ACL. When this shear force increases and the knee is forced into a valgus position, which has been shown to place a high tensile force on the ACL, which in turn significantly increases its risk of rupture (Yu, 2007).

There are also factors that affect the stability of the ACL such as the dynamic limb misalignment and generalized ligamentous laxity. Luckily, many things can be done to help correct these issues and help prevent these non-contact injuries, which will be discussed momentarily. The main factor affecting the ACL is the stability of the knee joint.

CHAPTER 5

STABILITY OF THE KNEE JOINT

The knee is the largest and most complex joint in the body, which is one of the reasons there are so many knee injuries, including ACL tears. The knee is three joints in one, and because of this it allows extension, flexion, and a little rotation. There are two tibiofemoral joints, one laterally and one medially. The lateral tibiofemoral joint is between the lateral condyle of the femur, lateral meniscus, and lateral condyle of the tibial, which is weight-bearing. The medial tibiofemoral joint is between the medial condyle of the femur, medial meniscus, and medial condyle of the tibia, which is also weight-bearing. Together these joints are called the tibiofemoral joint, which as previously noted is a multifunctional joint. It is functionally a hinge joint, but its stability is greatly dependent upon the menisci and the ligaments. Some rotation occurs when the knee is partially flexed, but during extension, rotation is limited by the menisci and ligaments. The knee also has a patellofemoral joint, is located between interior surface of the patella and the femoral condyles (Marieb, 2008 & Tortora, 2009). As previously stated, the knee's complexity calls for a high degree of stability for regular function. The stability of the knee joint depends on the stiffness of the muscles around and ligaments within the knee (Sinkjaer, 1991).

The main dynamic stability of the knee comes directly from the thigh muscles, which cross the knee to produce flexion and extension. These muscles include the hamstrings and quadriceps. There are also other muscles which indirectly stabilize the knee including the adductors and abductors which have and indirect effect as they act on the thigh. Another muscle that can have a degree of effect on the knee’s stability is the gastrocnemius, or calf muscle. The calf muscle doesn’t appear to have much impact on the knee at glance thought but upon further consideration, it is clear that the calf muscle co-activates with the quadriceps and hamstrings, and this concept seems to be important for knee stability during weight-bearing activities such as walking, running, and jumping (Kvist, 2001).

Another factor affecting the stability of the knee joint is its alignment in relationship to the hips and upper body. If proper alignment does not occur a resulting high amount of stress can be placed on the associated muscles and ligaments. These structures weren’t designed to bear the stresses related to abnormal static and dynamic alignment. In order for the knee joints to be in proper alignment, the hip joints must also be in proper alignment with the upper body, therefore it is critical that muscles which have an impact on the hips be properly strengthened. These muscles include the gluteals, adductors, abductors, and abdominal muscles. There is no need to focus heavily on these proximal muscles are critical to the stability of the knee and they should be strengthened on a regular basis. If one muscle group is neglected it can produce asymmetry particularly during dynamic activity, or that of movement, resulting in the hip joint to be unstable, which in turn causes the knee joint to be unstable, and in turn increasing the risk of subjecting the ACL to high tensile forces while participating in sport, fitness, or work activities.

Primary muscles of the knee, the hamstrings and quadriceps, are important for proper alignment and function of the knee, and subsequently are critical to the stability of the ACL. Recent biomechanical studies have indicated that hip muscle activation significantly affects the ability of the quadriceps and hamstrings to generate resist forces that occur on the leg during jump landing. Considering the fact that landing from a jump has been noted in numerous articles as a cause of non-contact ACL tears, this concept is critical to both prevention and rehabilitation of ACL injuries. Such findings, in addition to other evidence have led some authors to state that the knee has been a “victim of core instability” with respect to lower extremity stability and alignment during athletic movements such as those previously discussed (Leetun, 2004 & Hewitt, 2010).

A case study addressing the role of core stability measures as risk factors for lower extremity injury in athletes documented a female athlete who experienced a season-ending ACL injury. Although the purpose of this study wasn’t to focus on ACL injuries, it was noted this girl had demonstrated preseason deficiencies in both of the core stability tests they had administered during the preseason. Although one case doesn’t prove this to be completely true, they found many other cases in which lower extremity injuries resulted from discrepancies in core stability (Leetun, 2004).

Hewett showed that females show neuromuscular imbalances that men do not. Some of these will be discussed later, but one that is relevant in this discussion is the trunk dominance that exists in woman. During this trunk dominance momentum of the trunk is not controlled sufficiently which leads to uncontrolled motion of the center of mass during deceleration and movement of the ground reaction force to the lateral side of the joint. This imbalance was found to be adjusted with core stability training (Hewett, 2010).

The study by Leetun and colleagues also looked at what effect core stability can have on valgus moments to a flexed knee. As previously described, the valgus moment places extreme amounts of tensile stress on the ACL and almost always results in its rupture. This study found that by increasing the strength of muscles that resist this moment, like the core muscles, athletes may decrease the incidence of injury to this important ligament (Leetun, 2004). Not only are all of these factors discussed critical to the stability of the knee, the plane in which the movement of the knee occurs is also important.

CHAPTER 6

PLANES OF MOVEMENT

The body moves and functions in a three-dimensional environment. In order fully describe the complexities of movements, it is helpful to develop cardinal planes of the body. There are three primary or cardinal planes: the frontal plane, sagittal plane, and the transverse plane. These planes can be used for many purposes, including our purpose of describing and identifying abnormal movements in certain planes of movement which result in predisposition to injury.

The frontal plane divides the body into anterior and posterior parts, or front and back parts. Movements in the frontal plane include anything that involves sideways movements (Marieb, 2008). Common examples of movement in this plane are “jumping jacks” and “snow angles.” Examples of movements that are linked in the scientific to abnormal stresses on the knee are cutting, side stepping, and defensive slides. Valgus moment is an abnormal movement in this plane.

The sagittal plane is a plane that divides the body into right and left parts. Any movement that involves movement forward or back without crossing the mid-line of the body is movement in the sagittal plane (Marieb, 2008). This is the most common plane of movement. One example of movement in this plane is squatting. Walking gait also primarily occurs in this cardinal plane.

The transverse plane runs horizontally and divides the body into superior and inferior parts. Movements in this plane are rotational in nature. A common example of transverse plane motion is "looking both ways before crossing the street," as the cervical spine rotates to allow an individual to look to the left and to the right. An example of transverse plane motion in the lower extremity is the rotation that occurs when one twists the foot to extinguish a cigarette butt.

Human movement is not constrained to these three cardinal planes. This is clear when considering the many different ways the body may move. The body moves in ways other than side to side, front and back, and rotationally. The body can also move in each of these planes at the same time. Multi-plane or coupled motions are an everyday occurrence, necessary for tasks such as opening a door, pouring lemonade into a glass, or shooting a layup in basketball. However, such multi-plane motions can place abnormal stresses upon tissues within the body, such as the ACL, if these motions are performed with poor technique or body mechanics.

Movements in any of the three cardinal planes can occur when doing any of the movements previously described, as well as during strengthening exercises for the leg muscles. It is important to understand which plane of movement can place harm or stress on the ACL in order to try to prevent abnormal ACL loading resulting in its rupture. Sagittal plane knee motions are frequently associated with and place loads on the ACL (Tung, 1993). Although this is true, this is not the only plane of knee movement the ACL is associated with. The ACL can also resist movements in the frontal plane, for example during a valgus position of the knee. Extreme amounts of valgus loads on the ACL can result in too much tensile force resulting in damage.

It has been shown that well-executed sagittal plane movements typically do not produce abnormal ACL loads during landing or side-step cutting (Kernozek, 2005). It is also evident that movements in the frontal plane can contribute more to ACL injury than sagittal plane movements. Epidemiological and clinical studies that cite knee kinematic movements show that abnormal movements in the frontal plane are a key element in noncontact ACL injuries (Kernozek, 2005). When an athlete loses the ability to control external tibial rotation of the knee, which often occurs during sidestep cutting, this is typically abnormal movement in the transverse plane and this causes the ACL to tear (Cross, 1989). As the tibial rotates externally the femur rotates internally, throwing the knee into a valgus moment, which is abnormal movement which occurs primarily in the frontal plane, resulting in an ACL rupture (Kernozek, 2005).

It has also been found that movements which occur in both the sagittal plane and the frontal plane at the same time contribute more to ACL injury than frontal plane movements alone (Kernozek, 2005). This means that it is important to train muscles in one plane at a time before moving to multi-plane training, based on the notion that these multi-plane movements are generally more taxing from a motor coordination standpoint. Doing exercises that contain movements in both planes of movements may set up the ACL for failure; therefore any exercises which fit this description should be carefully evaluated and taught with a high attention to detail when integrating into any training or exercise regimen. Although this is easy to do when participating in weight bearing exercises, for many sports it is nearly impossible to limit all movement to one plane at a time.

Sports such as soccer and basketball are nearly impossible to limit all movement to one plane at a time. Therefore, in these circumstances it is important to teach athletes how to do the necessary movements, including those previously discussed, while not allowing the knee to perform any abnormal movements in each plane of movement (Boden, 2000).

Injury prevention programs focusing on dynamic control of knee motion in all planes of movement will help to prevent ACL injury (Russell, 2006). Movements which occur in the sagittal plane require approximately five times as great a force as movements in the frontal plane, therefore when trying to build muscle, the majority of high level strength training should focus on the muscles which cause sagittal plane movement of the knee, such as the hamstrings and the quadriceps (Dananburg, 2000). However, when trying to limit movement in the transverse and frontal plane an emphasis should be placed on strengthening the hip abductors and external rotators, which have a large impact on knee motion(Hewett, 2010).

CHAPTER 7

MUSCULAR STRENGTH

The primary movements of the hamstrings and quadriceps both occur in the sagittal plane. In the past, focus for strengthening these muscles has primarily been placed on squats, which are thought to equally strengthen the quadriceps and hamstrings. Squats have been found to have the highest muscle activation levels observed in lower limb exercises, but hamstring activity was found to be relatively low during this exercise in one study (Kvist, 2001). The level of hamstring activity varies depending on the phase of the squat. In this regard, the quadriceps is the muscle group receiving the majority of benefit from this exercise leaving the hamstrings significantly weaker than their antagonists, the quadriceps.

The quadriceps are antagonists of the hamstrings and therefore when contracted, they place a strain on the ACL if this force is unopposed by the hamstrings (Russell, 2006 & Withrow, 2006). Aggressive quadriceps loading with the knee in slight flexion has been shown to produce significant anterior tibial translation, which can contribute to ACL injury. A recent study showed that a 4500 Newton quadriceps muscle force could cause ACL injuries at twenty degrees of knee flexion, suggesting that the quadriceps activation is a possible intrinsic force in non-contact ACL injuries (DeMorat, 2004).

The anterior tibial translational force places a very high tensile load on the ACL, thus it is the force causing the injury, which is often compounded by the position of the knee. Strong quadriceps without the co-activation of the hamstrings to counteract anterior tibial translation may be a contributing factor to noncontact injuries. The quadriceps muscles are the major contributor to the anterior shear force at the proximal end of the tibia through the patella tendon in the absence of hamstring contraction (Yu, 2007). This anterior shear force then falls directly on the ACL unless there is an antagonist to counteract this force.

The hamstrings are antagonists and therefore must counteract the work of the quadriceps (Russell, 2006). The hamstring muscles exert a posterior force on the proximal tibia that protects the ACL. The addition of load to the hamstrings significantly reduces anterior tibial translation, which often occurs in jump landing and is one of the main causes of noncontact tears; thus making the hamstrings instrumental to the prevention of abnormal forces upon the ACL during dynamic activities (Li, 1999). Due to the role the hamstrings have in ACL stability, any weakness in this muscle group increases the susceptibility to ACL injury. The balance of power and recruitment pattern between the quadriceps and the hamstring muscles is critical to the knee joint being functionally stable (Boden, 2000). Acting alone, the isometric hamstring activity decreased ACL strain relative to the passive normal strain at all positions of the knee, while quadriceps activity alone increases ACL strain (Renstrom, 1986). Therefore it is important that the hamstrings not be neglected and a focus be placed on their strengthening in order to be able to remove the strain placed on the ACL by the quadriceps. It has been found that the hamstring-to-quadriceps strength ratio should be 66%, which is a more favorable condition for the ACL (Boden, 2000).

This does not mean the quadriceps shouldn't be strengthened; it simply means that a greater emphasis should be placed on hamstring strengthening than upon quadriceps strengthening. This can be done by doing squats that strengthens both sets of muscles but also doing leg curls or other exercises aimed at further strengthening the hamstrings. Although hamstring exercises alone are beneficial, quadriceps extension exercises should be avoided. These exercises should be avoided because terminal knee extension tends to place high tensile forces on the ACL. One thing that is important to be noted when discussing strength training is that inflexibility and muscular strength combined increase stress on the ACL in females (Anderson, 2001). Differences in males and females will be discussed momentarily, however it is important to realize that females require flexibility training if strength training is increased.

The reduced coactivation of the quadriceps and hamstrings increase the risk of ligamentous damage in the knee including, but not limited to, the ACL (Baratta, 1988). Woman are often found to be quadriceps dominant, which occurs because they tend to activate their knee extensors over their knee flexors and gluteal muscle groups in an attempt to stabilize the knee during movement. This is a factor that predisposes them to ACL injury (Hewett, 2010). This shows it is important to do exercises, which require co-activation of the hamstrings and the quadriceps, as this coactivation is what lessens the risk of ACL damage. If the hamstrings are strengthened to 66% of the quadriceps but don't coactivate with them, then the load will have already been placed on the ACL and it will be too late for the hamstrings to counteract that force. This being said, as discussed previously, additional hamstring exercises must be done in order to strengthen them to a further degree than the quadriceps, however the majority of thigh muscle strengthening should be exercises which require the hamstrings and quadriceps to coactivate. There is no significant tension on the ACL during the leg press and squat exercises, qualifying them as coactivation exercises (Zheng, 1998).

Generally, closed chain exercises tend to have higher levels of coactivation and therefore should be focused on as opposed to open chain exercises. Closed chain exercises are those that occur when the foot is fixed and the lower extremity remains in contact with an immobile surface (Dillman, 1994). Because of the nature of these exercises they lead to greater levels of coactivation. Open chain exercises on the other hand, are those that occur when the foot is free to move and because of this they tend to target specific muscles rather than multiple muscles at once.

As previously discussed, the stability of the core is also important and therefore, must be strengthened on a regular basis. In addition to the abdominals, the adductors and abductors should be strengthened on a regular basis. It has been found that increasing hip muscle contraction, done by the abductors and adductors, prior to landing can reduce the possibility of ACL rupture (Chaudhari, 2006). The hip is also found to be the key energy dissipater during double-leg landing, which takes a load off of the ACL during landing (Yeow, 2011). There is a significant role of hip muscle strength in the control of frontal plane knee motion (Claiborne, 2006). Frontal plane knee motion has already been determined to be harsh on the ACL.

Although this is true and these movements should be avoided if at all possible, unfortunately these movements will have to occur sometimes. That being said, the strength of the hip muscles can help control the knee movement in this plane when it is forced to occur. This proves the importance of strengthening these muscles regularly. With this thought, it is important to remember that the most important muscles to strength train are the hamstrings and quadriceps, but it is important to regularly do exercises that will strengthen the hip muscles as well.

CHAPTER 8

IMPACT OF FLEXIBILITY

Considering the importance of the muscles around the knee have on its stability and the integrity of the ACL, it is important to consider the effects poor flexibility or excessive flexibility could have on the ACL. This is not an area that has been studied extensively, however there have been a few studies on this topic.

First and foremost it has been shown that muscular inflexibility in the hamstrings and quadriceps increases stress on the ACL in female athletes (Anderson, 2001). This implies that flexibility is somewhat important for the female athlete. This study doesn't discuss the degree of flexibility that is needed nor what effect really good flexibility has on the ACL, it only shares that poor flexibility places additional stress on the ACL in the female knee. Although this information is vague, it is important to consider and should be known by coaches of female athletes.

Another study on the prevention of noncontact ACL injury found that in female athletes who have above average hamstring flexibility, the protective ability of this muscle group may be diminished and the forces required to stabilize the knee are consequently transferred to ligaments within the knee, including the ACL (Boden, 2000). Although this isn't something that is the primary cause of ACL injury, it does predispose female athletes to a greater risk of ACL injuries. It was also shown that in general for both male and female athletes any weakness or increased flexibility to the hamstrings can be a cause of increased susceptibility to ACL injury (Boden, 2000).

Although there isn't a great deal of information on the effect of flexibility on the ACL, there is enough research to show that increased flexibility leaves the ACL susceptible to greater forces and thus more likely to rupture. Also, while considering this fact it also must be noted that at least for females poor flexibility can also be harmful to the ACL. Therefore, for females at least, it is important to make sure the athletes are relatively flexible, but do not have above average flexibility. This however, is a concept that could use a great deal more research.

CHAPTER 9

DIFFERENCES IN MALE AND FEMALE SUSEPTIBILITY

It has been noted that several risk factors may predispose young athletes to noncontact ACL injury. Although this applies to both male and female athletes, it has been shown that females who possess a combination of risk factors sustain a noncontact ACL injury, indicating that some combinations of risk factors are remarkably detrimental to the female knee joint (Uhorchak, 2003).

Hewett discovered that females show neuromuscular imbalances that men do not. He describes four different imbalances that leave women more susceptible to ACL injury. These imbalances are that women show ligament dependence, quadriceps dependence, leg dominance, and trunk dominance (Hewett, 2010). Powers showed that females exhibit decreased knee and hip flexion and increased activation, knee valgus angles, and valgus moments when compared with males (Powers, 2010).

Women tend to be ligament-dominant because there is an absence of muscle control of medial-lateral knee motion, resulting in higher valgus knee torques and higher ground reaction forces. The quadriceps dominance seen among women seems to occur because they activate their knee extensors to a much greater level than their knee flexors and gluteal muscle groups in order to stabilize the knee during movement, which is less optimal recruitment strategy. The leg dominance occurs because one leg tends to have weaker and less coordinated hamstring musculature than the other. This in turn typically predisposes the weaker, less coordinated leg to greater risk of injury. Trunk dominance occurs because the momentum of their trunk is not controlled sufficiently, which leads to uncontrolled motion of the center of mass during deceleration and movement of ground reaction force to the lateral side of the joint. These issues can be address with awareness training emphasizing proper biomechanical technique, plyometric power training in flexion positions, single leg balance and symmetry training, and core stability training (Hewett, 2010).

Some of these risk factors that have been shown to predispose an athlete to noncontact ACL injury are preventable, while others are not. It has been shown that females typically utilize less effective neuromuscular activation strategies which contribute to dynamic valgus moments and the ACL rupture when performing high-risk maneuvers such as those previously discussed (Myer, 2005). The motor control problem may be preventable, by training athletes how to perform movements properly while doing plyometric exercises, which will assist them in training their muscles to work differently when performing these movements.

It has also been shown that valgus loading is a more likely injury mechanism in females. Although valgus moments can be harmful to the ACL in both the male and female knee, it has been shown that this is more so the case with females (McLean, 2004). While not much can be done to prevent the ACL's injury when in a valgus position , the valgus moment can be minimized or prevented by increasing hip and core muscle strength as well as retraining the muscles to activate in a more efficient and effective manner. Strength training of the associated muscles is very important, but it has been discovered that skill training may increase brain activity of muscles more so than an increase in the strength of the muscle, therefor this skill training is vital in all athletes, especially females (Powers, 2010).

Females tend to perform movements such as landing from a jump and side-stepping with lesser knee flexion than males. This is most likely due to inadequate amounts of functional hip strength (McLean, 2004). It is important for coaches to train their female athletes to perform these movements with a greater degree of flexion at the knee. It is also important that these coaches monitor the level of flexibility of their female athletes and ensure they do not perform exercises which would increase their flexibility if they already have above average flexibility.

Another study discovered intrinsic factors that increase the susceptibility of the female ACL including, joint laxity, hormonal influences, limb alignment, notch dimensions, and ligament size (Harmon, 2000 & Shultz, 2009). Some of these factors cannot be changed in order to prevent this injury, but some of them can. Hormonal influences cannot be changed. Recent studies have looked at the effect that estrogen levels have on ligamentous laxity and how this predisposed female athletes to ACL injuries (Boden, 2000). Joint laxity can be prevented as well as can limb alignment. These can be prevented using the methods previously discussed, including strengthening the hip and abdominal muscles in addition to the hamstrings and quadriceps.

Another issue pertaining to muscular strength is that female athletes seem to rely more on their quadriceps muscles during movements and they take significantly longer to generate maximum hamstring muscle force (Boden, 2000). This is an important issue considering that the quadriceps force is applied directly on the ACL without the hamstrings there to counteract that force. In order to help alter this, it is important for coaches of females to focus on exercises that encourage coactivation of both the hamstrings and quadriceps.

As females become more experienced in a movement they increase the movement at the knee and use less muscle contraction, increasing their susceptibility to injury (Powers, 2006). In one study, Powers found that novice female athletes had smaller knee moments and greater muscle co-contraction than those athletes who had more experience and were more skilled. This sets female athletes who are more skilled at a great risk of having an ACL injury. This study proves the importance of skill training even for those who are experienced. It is important to continue to train athletes to perform necessary actions with normal movements in all planes of motion.

Overall, noncontact ACL injuries occur five to seven times more frequently in females than males (McLean, 2004). This is very unfortunate for female athletes and due to this fact it is vital that coaches of female athletes to do all they can to help decrease the prevalence of some of these factors that have been found to be preventable, or capable of manipulation.

CHAPTER 10

IMPLICATIONS OF DISCOVERY

As a result of the research that has been gathered and now discussed, coaches should make changes to the exercise regimens they are currently prescribing and utilizing. They should first and foremost include skill training that will teach their athletes to perform needed movements in ways that will not allow any abnormal movements in any of the three cardinal planes of movement.

Secondly, coaches should have their athletes place more of an emphasis on strengthening the hamstrings more than the quadriceps. As previously stated this does not mean that the quadriceps shouldn't be strengthened, it simply means the hamstrings must be strengthened proportionally more. It is also vital that these coaches implement closed chain exercises such as squats, lunges, and plyometric workouts that will cause the hamstrings and quadriceps to coactivate.

Thirdly, coaches should make sure they implement workouts that contain strengthening of hip muscles and abdominal muscles. These groups of muscles have a large effect on the stability of the hips and that stability affects the stability of the knee joint. Therefore, strengthening of these muscles must occur. While all hip muscles are important, specifically the abductors must be strengthened as they help stabilize the pelvis and indirectly the knee and keep it from falling into a moment of valgus. It is important to note that these muscle don't need to be incredibly strong, they just need to be stable. This means that while there should be exercises that are done regularly that strengthen these muscles, these are not muscles that you want to try to max out on and develop to the highest degree possible.

Next, coaches need to be aware of their athletes' level of flexibility. While it has been discovered that flexibility shouldn't be neglected, it also should not be emphasized in some cases. Coaches want to make sure their athletes don't have hyperlaxity but they also want to make sure their program doesn't cause them to have above hyperflexibility, as this may possibly make the ACL more susceptible to harm. Although this has some information to back this up, trainers should look for new information on this topic as time goes on since this is a topic that needs further studying and developing to discover if there is a direct correlation.

Lastly, athletic coaches who coach women should make sure to know the factors, which make them more susceptible to ACL injury and place a significant amount of focus on those factors that can be changed. Primary focus should be placed on the four neuromuscular imbalances that were discovered by Hewett and then discussed in this paper. These factors can fairly easily be altered by implementing awareness training and biomechanical technique, plyometric power training in flexion positions, single leg balance and symmetry training, and core stability training.

If this information gets out to sports medicine professionals across the world and they can help coaches make changes to their exercise regimens it could have a significant impact in decreasing the amount of non-contact ACL tears and lead to a significant decrease in these incredibly brutal injuries.

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