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Factors Increasing Risk of ACL Injury in Females

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FACTORS INCREASING RISK OF ACL INJURY IN FEMALES

by

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Abstract

Females are more than 3.5 times more likely to suffer an ACL (Anterior Cruciate Ligament) injury than males are. Largely in part to neuromuscular differences, the risk of injury is ever present. Quadriceps dominance, joint laxity, and pelvic width are some of the leading risk factors affecting females. Most are anatomical differences that are ingrained from an early age. This paper introduces ACL injuries and highlights the reasons why females tend to tear their ACL in a non-contact way. Anatomical differences such as comparing quadriceps dominance versus hamstring dominance followed by pelvic width, and trunk dominance will all be reviewed. Hormonal differences will then be explained. Different muscle activations mentioned are involved in risk of injuring the ACL. Along with anatomical and hormonal differences, movements such as jumping and landing allow for different muscles to activate differently. Because of this, looking at muscle activation aids in potentially fixing the problem. Prevention is the second to last section which looks at the differences mentioned as well as muscle activation and how they could be corrected. ACL non-contact injuries occur far more in females than in males, with the help of this paper, various reasons as to why that is will be talked about. Additionally, solutions to factors causing a higher risk of injury will be provided.

Acknowledgments

Thank you to Dr. Smith for his constant support and valuable feedback. I would also like to thank my family, my roommates, and my girlfriend for giving me the motivation I needed.

Dedication

Queiro dedicarle esto a mis padres, Duvan y Stella, gracias por el constante apoyo y amor inconditional. Sophia, thank you for being my biggest fan.

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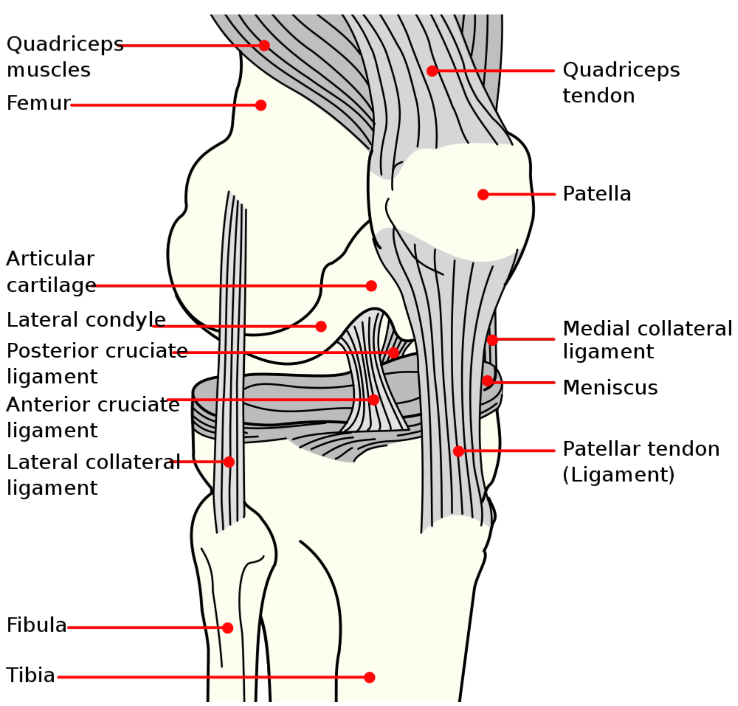
Factors Increasing Risk of ACL Injury in Females

Introduction

The anterior cruciate ligament, most known by its acronym 'ACL' is one of two cruciate ligaments, the other being the posterior cruciate ligament, that help stabilize the knee joint (Yoo, 2023). Cruciate refers to cross. This cross can be seen in the way the two ligaments appear in the body. It prevents the tibia from sliding anteriorly to the femur by having both cruciate ligaments form an x shape in the knee (Larwa et al., 2021). This movement is known as anterior tibial translation (Yoo, 2023). Made up of around 90% type I collagen and 10% type III collagen (Yoo, 2023), it also restricts internal rotation. Connected to the femur and tibia, the ACL is made up of two bundles (Yoo, 2023), the anteromedial and posterolateral band.

Figure 1

Illustration of the knee joint



Note. From Mysid. (2011, April 17). *English: Right knee, seen from an angle between anteriorly and laterally.* Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Knee_diagram.svg

It originates from the notch of the distal femur and ending at the intercondylar eminence of the tibia. The anteromedial band (AMB) and posterolateral (PLB) band attach to the anteromedial and posterolateral part of the tibial attachment respectively (Yoo, 2023). The anteromedial and posterolateral bands come from the posterior and distal parts of the femoral attachment.

Non-contact injury is sustained when a quick change of direction occurs while the foot is stationary. Research has shown the common period of injury is within 100ms of contacting the floor after landing (Wong et al., 2020). Additionally, landing incorrectly from a jump and sudden stops are typical movements experienced. Once an injury occurs, the severity of the injury is graded from one to three. One is where slight damage has occurred, possible stretching but stability is not compromised (Evans, 2022). Two is a partial tear and the ACL is stretched as well. Grade three is the final grade given to an ACL injury, here, the ACL is completely torn and there is no stability in the knee joint.

Surgical and nonsurgical options are presented to the patient. Typically, grade one requires physical rehabilitation while grade three typically requires surgery (Johns Hopkins Medicine, ACL injury or tear). Nonsurgical treatment includes physical therapy where physical therapists provide exercises to strengthen the muscles around the ACL. Surgical treatment is the route most patients tend to go if they lead an active lifestyle. ACL reconstruction surgery utilizes arthroscopic techniques to insert the autograft, an implant provided by the own patient's body, or allograft, an implant provided by another species, prepared by the surgeon depending on the type of graft the patient decides to use. The new graft will act as the patient's new ACL. Depending on the level of previous activity, recovery usually takes anywhere from six to nine months after surgery.

ACL injuries are common injuries. Typically seen as sports related injuries, the National Collegiate Athletics Association estimates over 2,000 student athletes will experience an ACL related injury (NCAA, 2012). When looking at this number it is important to note women are two to six times more likely to injure their ACL in a non-contact way than males are (Larwa et al., 2021). There are several reasons for an increase in risk. Anatomical and hormonal differences as well as muscle activation all have an impact on the increase in risk of an ACL injury in females. Research has shown that there are steps which can be taken to decrease the risk of injury. This is a problem which can be managed if more research is done on this topic.

Neuromuscular training as well as visual stimuli and corrective training has been found to have success when aiming to lessen the risk of injury. Although not found to be one hundred percent preventable, studies have shown that with certain treatment, the risk of injury decreases. These methods will be reviewed in this paper.

The aim of this paper is to explain the function of the ACL, provide evidence and examples of why females are at a higher risk to tear their ACLs than males, and supply prevention/treatment to decrease risk of injury. Limitations in research and studies reviewed in this paper will be discussed as well as discuss any further research needed.

Common Terminology Explained

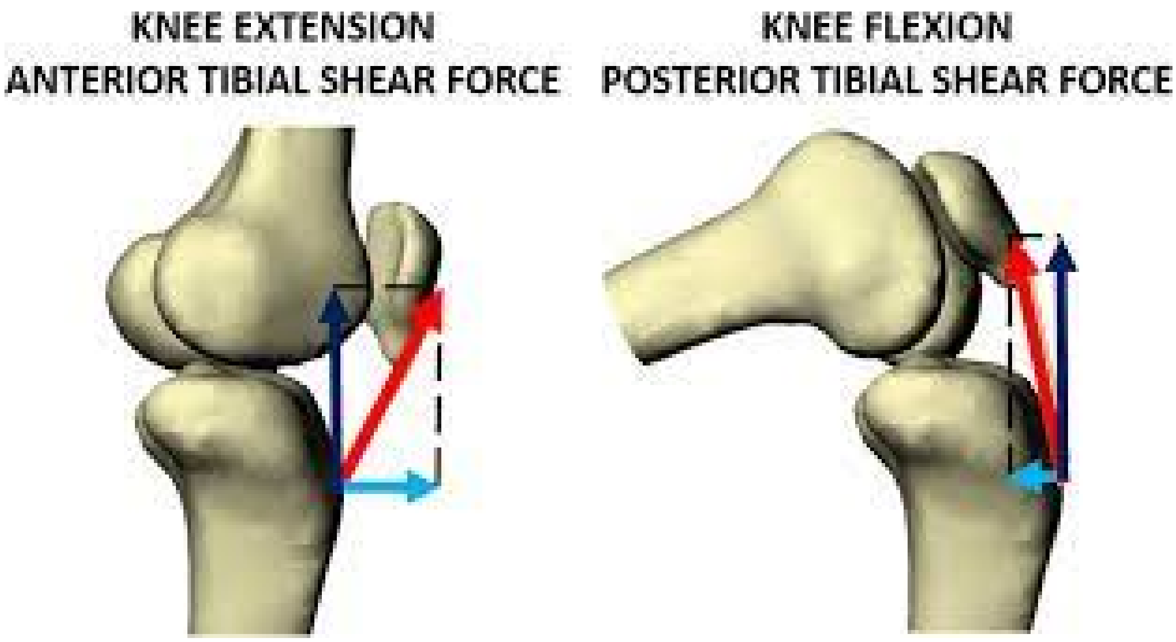
When referring to the knee, there is a lot of terminology used to properly explain joint function`. This section will define the most common terminology used in reference to the knee and surrounding areas.

External knee abduction refers to when the knee moves away from the midline of the body. In the same way knee adduction is moving the knee towards the midline of the body.

According to Bennett et al., (2008), anterior tibial shear force comes from co-contraction the quadriceps and hamstrings produce.

Figure 2.

Illustration of anterior and posterior tibial shear force



Note. From Patellar Tendon Orientation and Strain Are Predictors of ACL Strain In Vivo During a Single-Leg Jump. Z. A. Englander, B. C. Lau, J. R. Wittstein, A. P. Goode & L. E. DeFrate, 2021. *Orthopaedic Journal of Sports Medicine*, *9*(3), 232596712199105. https://doi.org/10.1177/2325967121991054

When referring to prevention, plyometric training programs are the typical programs trainers go to. Plyometrics aims to exert the most amount of force in the shortest amount of time. The goal of plyometrics is to use the muscles in a rapid manner with the goal of boosting speed, power, and endurance (Robinson, 2022) Some examples of plyometric exercises include split squat jump, alternating lunge jump, tuck jump, burpees, and box jumps to name a few. A trunk flexion angle, as the name suggests, looks at the motions of the cervical, thoracic, and lumbar portions of the spine.

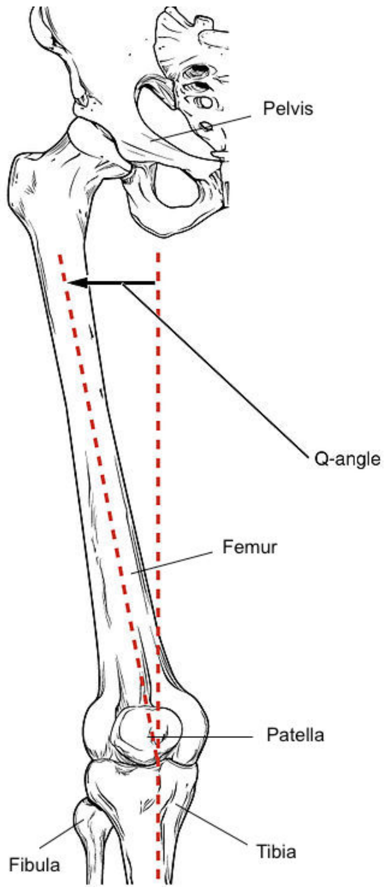
Anatomical Differences

To understand why females tear their ACL more than males, one must first look at the anatomical differences, starting off with a commonly known one, the pelvic width. As the name suggests, the pelvic diameter is measured. A wider pelvis is found in females because they have evolved to accommodate childbirth. With a wider pelvis the quadriceps angle, which is the measurement of pelvic width formed by quadriceps muscle, and patella tendon increases.

Ensuring the knee is positioned properly is essential. The lower limbs bear a lot of weight, thus having the load correctly positioned to go through the center of the leg, hips, knee and then eventually ankle prevents pain and any future complications. A result of a misalignment is known as knocked knees, medically referred to as knee valgus (KV). This is a pattern observed in the lower limb (Wilczyński et al., 2020). An abnormal q angle (how much the quadricep pulls on the patella) is measured in a standing position using an angle finder. The patient is typically in a standing position to include weight bearing (Q Angle - Physiopedia). The patient's patella is put in the intercondylar notch and measured from the center to the Anterior Superior Iliac Spine (ASIS), another line is then formed looking at the tibial tubercle and the center of the patella (Q Angle - Physiopedia). That angle the two lines create is the q angle measured. A typical q angle for females is <22° and for males it is <19° when extended, and <9° and <8° when at a 90° respectively (Q Angle - Physiopedia).

Figure 3

Lower limb anatomy highlighting quadriceps angle

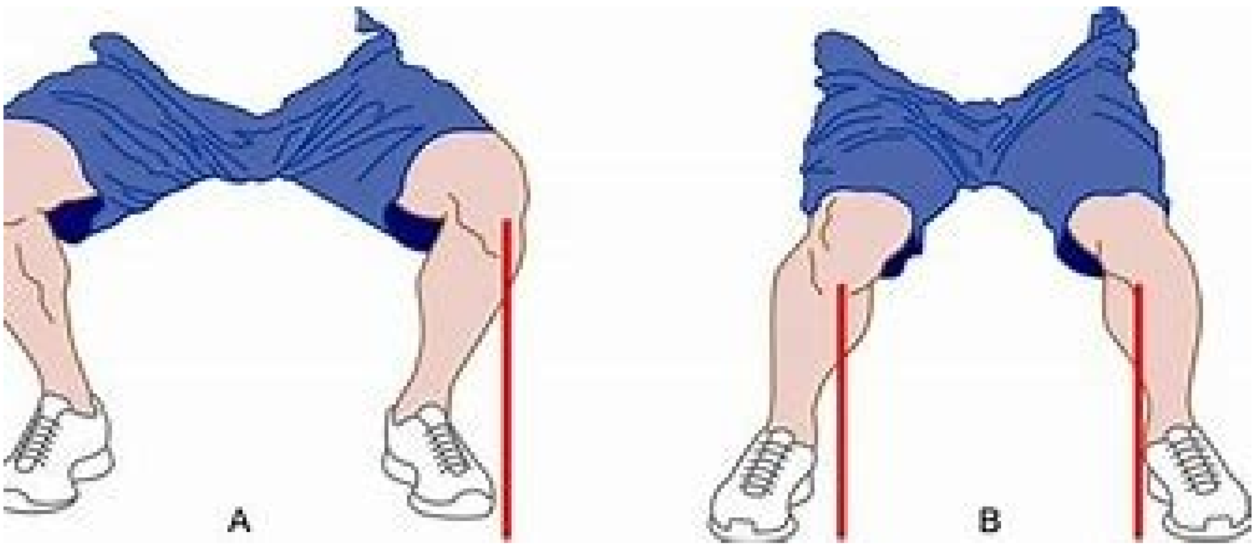


Note. From College, O. (2018, March 24). *English: Labelled image of leg with Q angle*. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Labelled_Femur_Q_Angle.jpg

An imbalance in the hip abductors and adductors, weak gluteal muscles, popliteal and tibialis posterior weakness are all caused as a result of DKV (dynamic knee valves). A large emphasis is placed on knee valgus when mentioning ACL injuries. Another way to look at knee valgus is when the knee caves inward. This movement can occur during squatting and jumping (Wilczyński et al., 2020). Prevention of knee valgus includes strengthening of muscles causing the issue. A more detailed explanation can be seen in the prevention section. Dynamic knee valgus is when there is a combination of incorrect rotation at the ankle, knee, and hip joint.

Figure 4

Proper Form vs Knee Valgus



Note. From "Barbell back squat: how do resistance bands affect muscle activation and knee kinematics," by M.B. Reece, G.P Arnold, S Nasir, W. W. Wang and R Abboud, 2020, BMJ Open Sport & Exercise Medicine, (http://orcid.org/0000-0002-1753-9606)

Often, females are referred to as being quadriceps dominant while males are considered hamstring dominant. This is an issue brought up when referring to ACL injuries. The quadriceps femoris is a group of muscles responsible for extending the knee. It aids in movements such as running, jumping, and walking (Hewett et al., 2010). When jumping occurs, females land with less flexion in the knee compared to males. Much like ligament dominance, which is when less muscles absorption of ground reaction forces, this is a neuromuscular imbalance occurring. Using the quadriceps muscle to stabilize the knee when landing causes, the knee to extend. This can also lead to knee valgus. This extension is seen when an ACL injury takes place.

Looking at the anatomy of the quadriceps femoris, the common tendon attaches at the superior portion of the patella (Hewett et al., 2010) as well as the infra-patellar tendon attaches to the tibial tubercle on the anterior tibia (Hewett et al., 2010). Contraction of the quadriceps results in pulling the anterior tibia to the femur. Instead of having the ACL hold the tibia posteriorly, anterior shear stress to the tibia occurs thus also affecting the ACL. If comparing quadricep dominance to hamstring dominance, the reason that hamstring dominant is more advantageous is because unlike the quadriceps muscles, the hamstrings have tendons on each side of the knee which aid in stabilizing the knee (Hewett et al., 2010). The hamstrings are also ACL synergists because they provide posterior tibial stress forces which work against anterior stress forces. This helps take the load off the ACL (Bencke et al., 2016).

When referring to ligament dominance, the muscles do not absorb the ground reaction forces properly, thus ligaments and joints retain copious amounts of force (Hewett et al., 2010). Bony configuration and articular cartilage are used as anatomic stabilizers while ligaments are used as static stabilizers. Using those stabilizers instead of primarily using muscles to absorb ground force during an activity is a problem females have more frequently than males.

According to Hewett et al., (2010), if a female soccer player cuts on one foot or a female basketball player lands after rebounding, they both are met by the surface after landing with an ‘equal and opposite reaction force.’ Due to the athlete’s ligament dominance, all that force is being absorbed through the ligaments and joints instead of dispersing through the muscles (Hewett et al., 2010). Common movements known to cause injury such as landing, cutting, and jumping have two to three times greater body mass thus adding the amount of weight the body absorbs when landing (Hewett et al., 2010). Part of a neuromuscular imbalance, ligament dominance can also affect the trunk. The ground reaction force is geared towards the center of mass which is in the trunk (Hewett et al., 2010). Because of the importance of trunk control, a female's ability to control their body is important. When the trunk moves laterally, the ground reaction force tracks and the center of mass follows (Figure 3). This means the knee joint will eventually fall into a valgus position (Hewett et al., 2010).

Females are trunk dominant if they lack awareness of their body in three-dimensional space. As previously mentioned, lack of awareness can put the female in various movements which can lead to injury. Trunk dominance can be seen when females hit puberty. As explained by Hewett et al., (2010) when females have a growth spurt, they have more to control with the already existing motor programs and neuromuscular strategies. Hewett et al., (2010) compared the growth spurt to putting on stilts. While the female gets used to the growth spurt it is as though she is walking around in stilts. Body mass is increased, making the female's center of mass higher off the ground (Hewett et al., 2010).

A male also experiences a growth spurt. The difference, however, is that the male also experiences a neuromuscular spurt. This is where more power is created and muscles are developed. Even though both males and females go through growth spurt, males adapt to their growth spurt through the neuromuscular spurt while females have no neuromuscular adaptation (Hewett et al., 2010). Since females do not have as big of a neuromuscular spurt as males, must create their own neuromuscular spurt to not be at an anatomical disadvantage.

Hormonal Differences

Although not commonly talked about, research has shown that the menstrual cycle effects the ACL which can result in a non-contact injury. The menstrual cycle is made up of four phases: menstruation, follicular, ovulation, and luteal phases. Studies showed a significant joint laxity during the follicular phase, compared to the luteal phase (Balachandar et al., 2017). The follicular phase causes more estrogen to be released from the female's body while luteal phase causes progesterone to be released. The follicular phase leaves the female more exposed to joint laxity (Balachandar et al., 2017).

The follicular phase consists of the first day of the period and ends with the ovulation phase, typically a fourteen-day phase. Noteworthy evidence showed joint laxity during the follicular phase when the participant engaged in cutting and drop jumping (Balachandar et al., 2017). Not only was greater joint laxity found in females during the follicular phase, greater DKV (Dynamic Knee Valgus) was found as well as more tibial external rotation. As explained in the anatomical portion of this paper, these alone can cause an increase in ACL injuries. Coupling them with more exaggerated movements due to a female's menstrual cycle, it is clear as to why there is a greater risk of ACL injuries during the menstrual cycle (Balachandar et al., 2017). Females experience different effects from their period which can increase risk of injury. It is after puberty that significant joint laxity is present in females compared to males because the female has started the menstrual cycle (Hewett et al., 2016).

Early on, females and males show the same ACL morphology. In one study in 2020, Hosseinzadeh and Kiapur conducted 269 magnetic resonance imaging of three-to-eighteen-year-olds with 81% being females. The length, cross-sectional area, elevation angle, and length to cross section area was recorded. Hosseinzadeh and Kiapur (2020) found during the early years' male and female ACL morphology stayed relatively the same. ACLs thickened and elongated depending on the age. Participants in their adolescent years were found to have a difference. Male adolescents had increased cross sectional area-to-length. Researchers found that they males had longer and thicker ACLs when compared to their female counterpart at the same age (Hosseinzadeh and

Kiapur, 2020). Additionally, the fiber orientation of the ACLs appeared to be different through adolescent years. Due to more growth rates in males, their ACLs become elongated and thicker than their respective counterpart. As a result, their ACLs can withstand greater impact than females. This important finding highlights a key in hormonal differences that leaves female ACLs more vulnerable than male ACLs.

Movements Involved in Injury

Fatigue is felt when the muscles feel weak, and the body is tired. It is normal to feel muscle fatigue when partaking in strenuous workouts. The power the knee produces, height of a jump, muscle contraction force, and physical coordination are all lost during fatigue according to Wong et al., (2020) Shock absorption is decreased because of diminished biomechanical movements during the fatigue phase. Wong et al., (2020) believe that it is during muscle fatigue where movements occur which can increase injury. If the knee joint is unable to lengthen the quadriceps muscle as resistance increases thus increasing the amount of force it produces, injury can occur. When feeling fatigue, the athlete's range of motion in the knee as well as trunk flexion angle decrease (Wong et al., 2020). Due to the body's fatigue, improper mechanics begin to be used, thus leading to a stiff landing position (Wong et al., 2020). A stiff landing refers to when there is less knee flexion yet more knee movement (Larwa et al., 2021). When landing in a stiff position, there is a decrease in the peak knee and trunk flexion time. Due to trunk flexion time, the quadriceps were activated less causing the ACL to bear the weight of the landing.

To compensate for incorrect movements acquired during tired periods, less knee joint extension was used in order to make up for incorrect technique (Wong et al., 2020). This was done to prevent the center of mass from collapsing thus causing injury. Wong et al., (2020) looked at twelve female college athletes with an average age of 23.33 ± 1.49, average height 1.64 ± 0.05 m, and body mass of 59.88 ± 6.18 kg. Using a motion capture camera and two force plates, kinematic and kinetic data was collected. Retro-reflective markers were placed in forty-five distinct locations. Markers were placed in various places. Some of the main markers were placed in the front and back of head, the torso, both upper and lower arms, the pelvis, upper and lower legs, as well as the feet (Wong et al., 2020).

The participants started with a three-minute run of three meters per second- and two-minute stretching. They then performed three maximal effort vertical double legged jumps (Wong et al., 2020). They were given five minutes to rest and then were asked to stand on a thirty-centimeter box. The participants jumped from the box onto the two force plates which was fifty percent of that participant's height away from the box they were standing on and then go into a vertical jump as well. A fatigue protocol was followed to cause fatigue. The protocol called for fifty step ups onto the box and fifteen full effort vertical jumps using a single leg (Wong et al., 2020). The Borg CR-10 scale was used to determine the exertion of the participants. Once the participants reached a ten percent decrement in their vertical jump height the post fatigue data was collected by having the participants complete another set of forward drop jump to vertical jump (Wong et al., 2020). Wong et al., (2020) results showed there was an increase of knee flexion at the initial ground contact. As shown in Table 1, there is a change in the pre-fatigue stage compared to the post-fatigue stage. The table shows kinematic or the participants body motions and how it changes depending on fatigue levels. In addition, when the participants were in their post-fatigue condition, the trunk forward lean angle decreased. Range of motion decreased by 9.8% at the knee joint in the post-fatigue phase during landing.

Table 1.

Variable	Pre-fatigue	Post-fatigue	t	p	Cohen's d
At initial ground contact					
Knee flexion angles	22 ± 6.65	26.07 ± 3.41	-2.884	.018	.69
Hip flexion angles	22.80 ± 5.65	4.79 ± 7.21	1.258	.240	.31
Trunk forward lean angle	90.62 ± 3.63	86.04 ± 4.42	-5.91	.001	1.13
During landing					
Knee ROM	83.28 ± 13.63	75.12 ± 11.2	-3.278	.010	.65
Hip ROM	69.54 ± 16.9	63.93 ± 12.1	-1.580	.148	.38

Note. The table above shows the kinematic variable in both the pre and post fatigue conditions. ROM = range of motion. Adapted from: Wong, T. L., Huang, C. F., & Chen, P. C. (2020). Effects of Lower Extremity Muscle Fatigue on Knee Loading During a Forward Drop Jump to a Vertical Jump in Female Athletes. *Journal of human kinetics*, *72*, 5–13. https://doi.org/10.2478/hukin-2019-0122

Muscle Activation

During cutting movements as well as landing movement, it is widely known that females tend to use their quadriceps significantly more than males do (Benke et al., 2018). When a side cutting motion is done, unlike males, females tend to use their lateral quadriceps rather than their vastus medialis. The problem with this is that when the lateral quadricep is used more than it needs to be, knee abduction occurs (Benke et al., 2018). Less hamstring to quadricep ratio has been observed in females when looking at the moments prior to making ground contact during movements such as side cutting and vertical drop landing.

The quadriceps contraction force to anterior shear force is seen most when the knee is extended at 0° to 35° of flexion (Benke et al., 2018). Due to the large amount of force used when the knee is extended, a lot of strain is put on the ACL especially during a forceful landing or side cutting (Benke et al., 2018). With there being a lot of force associated with more dominant quadricep muscle activation, females are at higher risk to injure their ACL, especially from a non-contact injury.

Looking at the sagittal, frontal, and transverse planes can help create a better image of the hamstring to quadricep ratio and how this affects the ACL. As mentioned above, in the sagittal plane, because of the forward translation of the tibia, the quadriceps contraction force causes anterior shear force. In the frontal plane, the ACL is meant to restrain the knee from abduction or adduction movements. In the transverse plane, additional loading of the ACL occurs with internal rotation of the tibia (Bencke et al., 2016).

Prevention

Ideally, the goal of prevention is to eliminate or limit the risk of injury. Another goal is to understand the shortcomings and risk factors present. Prevention is typically seen as exercises done to correct bad habits and poor technique. In this prevention section various training and rehabilitation methods are mentioned. These have been shown to work regarding muscles and movements being used that can be attributed to an ACL injury. Neuromuscular training are exercises designed to help nerves and muscles react to each other. In theory, this type of training is meant to not only increase strength but most importantly increase awareness of body movement, balance, and technique (Petushek et al., 2019). Exercises such as Nordic hamstrings, lunges, calf raises, jump and hold, drop and land (Petushek et al., 2019) all help create proper muscle activation.

Exercises strengthening the muscles contributing to DKV is a common treatment plan prior to any type of injury occurring. DKV is diagnosed through physical testing performed by a doctor. These tests include landing from a jump, squatting, and range of motion. Other diagnostic tools include an x-ray and MRI scans. Once DKV is assessed in the patient and corrective measures are taken to reduce the likelihood of injury. A common denominator found in most prevention exercises is proper form. Emphasizing proper form allows for less injury, and proper technique to be used thus eliminating unnecessary movements and elements from the exercise. According to Attwood et al. 2018, introducing an Injury Prevention Exercise Program and a strength program showed improvements in balance, landing, cutting, and body awareness. This program consisted of 41 male rugby players whose warmup lasted five to ten minutes and then the main section was for about fifteen minutes (Attwood et al., 2018). This study does have limitations. The sample size is small and contains only males. The benefit of including this study shows the impact strength exercises as well as a proper warmup, can have on the lower limbs.

The difference between the control group and the treatment group was that although the control group still had a dynamic warm up and exercises to do, those exercises were non-targeted resistance exercises. In the treatment group, the lower limbs, head, shoulders, and neck were targeted.

The 42-week program showed a 40% decrease in injuries seen in the lower limbs. The control group saw an incidence rate of 1.24 while the treatment group had an incidence rate of 0.61 (Attwood et al., 2018). The researchers found exercises focusing on strengthening the muscles and balance and plyometric training was beneficial in decreasing risk of injury. This was due to the strengthening program as well as a proper warmup.

The largest issue with females being quad dominant is their lack of use of other muscles. The goal when dealing with prevention of quad dominance is not to turn off the quad activation but instead turn on activation of the hamstrings and gluteal muscles. Russian hamstring curls are of great benefit to the patients because they can use both eccentric and concentric movements. Utilizing an exercise band around the patient's chest to facilitate the movement, the patient is knelt onto a pad, so it is less harsh on the knees. The patient then begins eccentric and concentric reaction by engaging their hamstrings. Essentially, they are lowering down from their knees with the help of another person holding the exercise band. When the quadricep is primarily used, the gluteal muscles and hamstrings are used less, thus resulting in knee valgus. By engaging in exercises which require hamstring and gluteal use, the patient will learn to "turn on" the other two required muscles so all the work is not put on the quadriceps (Hewett et al., 2010).

Bencke et al., (2010) also looked at muscle activation training in six studies. The first study, Lephart et al., conducted an eight-week plyometric and basic resistance training program to assess the biomechanical and neuromuscular changes once the program was complete. Their findings showed that the training they created improved knee extensor isokinetic strength (Bencke et al., 2018). Peak gluteus medius electromyograph increased for both the pre-active and reactive periods thus providing further support in correcting knee valgus. Letafakar et al., (2019) examined effects of perturbation training in females. Perturbation training is balance training. When training balance, patients are put in destabilizing positions to learn to correct them. Using EMG, data was recorded during a single leg drop of the quadriceps and hamstrings and the knee flexion angle during a tuck jump for a baseline and once the six weeks were done. During the six weeks, perturbation training was done with the experimental group. The authors concluded females with quadriceps dominance neuromuscular deficit would benefit from such training as it improved the co-contraction between the vastus lateralis and lateral hamstring as well as the vastus medialis and medial hamstring in the feed forward/back phases (Bencke et al., 2018).

Nagano et al., introduced a jump and balance training program which increased knee flexion and hamstring activity in landing. The study consisted of eight female participants. They did a single limb landing during initial testing, five weeks later, and after one week of going through the jump and balance training. After five weeks on the program the Nagano et al., (2011), found an increased knee flexion as well as more hamstring activity when landing. Through this program, typical knee movements seen in ACL injuries were decreased, decreasing risk of injury (Bencke et al., 2018).

The fourth study was Wilderman et al, which had an agility training group and a control group. Using a six-week agility training program, the experimental group participants found an increase in medial hamstring activation when contacting the ground (Bencke et al., 2018). Zebis et al, incorporated balancing, jumping, and landing in a training program. The outcome showed an increase in medial hamstring activity with the experimental group (Bencke et al., 2018). The last study, conducted by Zebis et al., included a six-week program meant to impose neuromuscular activation of both the quadriceps and the hamstrings. The study showed an increase in activation of the lateral hamstring (Bencke et al., 2018). Because of the activation, anterior translation is reduced.

All six studies implemented plyometric, neuromuscular and perturbation training in the hopes of creating better co-contraction between the hamstrings and quadriceps. All experimental groups improved some kind of activity that was either weak or nonexistent before the training program took place.

Unlike some of the other preventable/fixable movements in this section, joint laxity is particularly hard to correct. Because of how it presents, typically during the follicular/ovulatory stage in the menstrual cycle, direct correction is not possible currently. The way this would be tackled is indirectly (Hewett et al., 2016). Having more muscular strength in addition to having more neuromuscular control, are two ways that can make up for joint laxity (Hewett et al., 2016).

Training the muscles in the core that provide stability is the way to address females being trunk dominant. Both the transverse abdominis and lumbar multifidus should be trained to provide more trunk stability (Hewett et al., 2010). Hamstring curls on a Swiss ball is one of the many exercises' females can perform. The key to this is to engage their core to provide stability when flexing and extending their legs. Controlling the pelvis/hips is another important aspect to core stabilizing. An exercise to address this is to have the patient stand on one leg, with an elastic tubing around their pelvis. With the other leg flexed at the knee and hip, the patient moves concentrically and eccentrically through the transverse plane (Hewett et al., 2010).

Further Research

Regarding further research, amplifying the sample pool used in the studies conducted would be beneficial. A larger sample size would provide more accurate mean values and smaller errors. It is important to note that some studies looked at previously collected data of injured players therefore they had no control over the sample size they were working with.

Although there are incredible articles published about proper prevention and decrease in risk of injury regarding females and ACL injuries, there is still much work needing to be done to educate coaches, trainers, etc. Understanding that females are at a disadvantage regarding increase in risk of injury should promote proper prevention methods put in place to protect females. Continuous effort should be made to reduce as many anatomical disadvantages as possible. Knowing preventative injury programs have been seen to work, those involved in sports with female participation should be involved more as well and taken seriously. Studies are being conducted but far too little involve only females. Using females helps narrow down the differences and allows for adaptations to be made.

Conclusion

The female athlete is two to eight times more likely to injure their ACL in a non-contact manner compared to males. This is due to female quadriceps dominance and greater pelvic width. Additionally, females are more prone to injuries during the follicular stage of their menstrual cycle due to release of estrogen. Although some contributing factors to increase risk of injury cannot be changed, some can. Implementing proper neuromuscular training can greatly improve female muscle activation (Petushek et al., 2019).

Females tear their ACL at an alarmingly higher rate than males. As stated throughout this paper, there are multiple anatomical and muscle activation differences which can be attributed to the difference in risk between females and males. Most of these differences, mostly muscle activation, can be corrected and worked on to implement proper techniques. Overall, the most important take away is that there is something that can be done to reduce the likelihood of injury for females. Educating those in female sports will cause a difference in prevention of injury. The disadvantages females have compared to males in an anatomical aspect can often be corrected with proper training and exercises.

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