Athletic anterior cruciate ligament (ACL) tears have become increasingly common in the United States, and can be severely debilitating to athletes of all ages. This painful injury typically includes surgical repair and a lengthy recovery, causing the athlete to miss his/her season of play.1 Furthermore, younger athletes have an increased risk for graft tear and contralateral ACL tear after the first ACL tear injury, which could severely limit any future athletic endeavors.2 Along with the substantial treatment costs and physical debilitations, ACL injuries can have a significant effect on a young athlete’s mental health.3 In younger athletes, this could manifest itself through diminished grade point averages.3 Several prevention programs have been designed in an effort to reduce the incidence of ACL tears; however, there is no single program indicated for all athletes due to the variability of risk contingent on determinants such as age, sex, and sport. As front line members of the rehabilitative process for athletes with ACL tears, it is important for physical therapists to have a strong foundational understanding of ligament composition and risk factors involved in this injury in order to provide the appropriate preventative program. Instead of simply waiting for ACL tears to occur, physical therapists should be proactive members in the community and use their knowledge as human movement experts to provide individualized programs for local athletes in order to reduce the incidence of this debilitating injury.

In order to understand why athletes are exposed to certain risk factors given his/her sex, age, or sport, it is first necessary to understand the organization and composition of ligaments. The primary function of ligaments is to protect the joint by maintaining joint stability; therefore, when a ligament ruptures, other joint structures become at risk for injury.4 The collagen fibers are oriented such that they can resist several planes of joint motion, including spiral bands that protect horizontal rotation of the joint.4 Ligaments are also involved in neuromuscular protection of the joint, as receptors in the ligament have been found to cause reflexive protective muscle activation when stimulated.4 Due to the difference in mechanical properties of ligaments versus bone, ligaments are more susceptible to midsubstance rupture under higher strain rates.4 Higher strain rates cause bone, the more metabolically active substance, to have a higher ultimate strength than ligament.4 Ligament is also more susceptible to midsubstance rupture when the angle of tensile stress on the ligament is closer to being parallel with the trabecular alignment of the adjoining bone.5 Due to poor blood supply, ligaments are metabolically slow, resulting in a slow healing process.5 In order to avoid this slow healing process, physical therapists must understand how the composition and structure of ligaments can imply a risk for injury under certain modifiable and non-modifiable conditions.

It is generally accepted that ACL injuries occur in a non-contact nature, as a result of changing direction, cutting, deceleration, landing from a jump, or pivoting with the knee in full extension and the foot planted.6 A combination of forces such as knee valgus, knee varus, internal and external rotation moments, and anterior translation force have been identified to place a high magnitude of stress on the ACL.6 During competition, the most common mechanism of an ACL tear is when “the tibia is externally rotated, the knee is close to full extension, and the foot is planted during deceleration combined with genu valgus collapse.”6 There is also mounting evidence that an ACL tear is more likely to occur when the athlete’s center of mass is behind base of support.6 While these mechanisms are common in all athletes who tear their ACL, certain characteristics of the athletes and their sport of choice predispose them to different injury risks. Non-modifiable risk factors for ACL injury include anatomic, neuromuscular, and sex, while some of the modifiable (external) risk factors include type of sport, setting of competition, footwear, and weather conditions.7 While constructing a prevention program, it is important for the physical therapist to take an individual approach with each patient and understand the exposure the athlete will have to certain risk factors. This information will also be helpful educational information for the patients, as the physical therapist instructs them on ways to avoid injury during athletic participation.

Among the modifiable risk factors for ACL injury, type of sport can be considered one of the more influential determinants. While constructing a prevention program, the physical therapist must have a thorough understanding of the biomechanical demands involved with each sport. Prodomos et al suggests that while sports such as soccer and basketball indicate females are at higher risk for injury, sports such as lacrosse and alpine skiing have no sex differences in ACL tears.1 Sport-related factors such as footwear, weather conditions, and protective equipment could have an impact on these injury rates. For example, weather conditions and footwear that increase the coefficient of friction between the athlete’s foot and playing surface to the point that there is too much traction causing the foot to “catch,” could increase the athlete’s risk for ACL injury.8 This indicates that sports played outdoors with cleats, in low rain climates, could place the athlete at a higher risk for having his/her foot stop inadvertently and provide greater torsional resistance, resulting in an ACL tear.8 With the large variety of sport settings and associated factors, physical therapists must examine all aspects of an athlete’s involvement that could place him/her at risk for injury while constructing a prevention program.

Sex is one of the more influential non-modifiable risk factors for ACL injury. Females are reported to have 8-9 times greater risk for ACL tear than their male counterparts.7 Brophy et al suggests there are several biomechanical deviations during pivoting, deceleration, and landing from a jump for this difference in risk.8 According to this article, females land in more knee extension, and have less knee flexion and more genu valgus in the stance phase.8 Furthermore, females have increased quad activation and decreased hamstring activation upon manual muscle testing.8 With reduced hamstring activation, females have reduced dynamic support of the knee, placing them at risk for excessive rotation or translation of the tibia and subsequently increased strain on the ACL. Furthermore, increased quad activation combined with landing in extension after jumping in the sagittal plane increases the strain on the ACL at the initial contact period, with women experiencing higher increases in shear force than men.8 While the lack of hamstring activation could account for this comparatively greater amount of shear force, women also have two anatomical differences from men that place them at higher risk for ACL injuries: the ACL is smaller in females when adjusted for differences in sex size discrepancies, and the anterior-posterior dimension of the distal femoral articulation is larger than in men.5, 8 A larger distal femoral anterior-posterior dimension places the patella more anteriorly, which ultimately results in a higher anteriorly directed patellar tendon pull and place increased strain on the ACL.5 These differences must be considered by the physical therapist while constructing an individualized program for ACL injury prevention in female athletes.

In order to attenuate the female-specific risk factors in a ACL prevention program, the physical therapist should focus on neuromuscular training to establish optimal biomechanical technique.9, 10 These neuromuscular training exercises should improve strength of the stabilizing knee musculature.10 Neuromuscular training will also improve preprogramming and coordination of muscle activation and recruitment, so that functional joint stability will be improved during competition.9 Cone drills that practice cutting, with emphasis on quality safe movements, are examples of exercises that can be used to help improve coordination.9 Improved coordination during cutting and pivoting activities could help female athletes avoid genu valgus, by improving abductor recruitment and activation to resist valgus moments. Hamstring recruitment is another critical component to involve in neuromuscular training of female athletes. Including hamstring strengthening exercises, such as hamstring curls, will improve hamstring muscle recruitment during sport participation and increase dynamic stability at the knee joint.11 Improved hamstring strength may also be able to offset the increased anterior tibial translation caused by the large patellar tendon pull that results from a larger distal femur (anterior-posterior). According to Sugimoto et al, variation of neuromuscular exercises and verbal feedback are important components in a neuromuscular-based injury reduction program for elite female athletes.12 Athletes experience a high variation of complex tasks throughout competition, and need exposure to several types of sport-specific movements during practice in order to train their bodies to produce an optimal response in competitive scenarios. Furthermore, verbal feedback from a physical therapist will allow human movement experts to tell the athlete when she is performing biomechanically correct movements. Modifying athletic techniques can further enable female athletes to avoid ACL injury. For example, teaching female athletes a “soft-landing” technique, by showing them how to land with hip and knee flexion instead of full knee extension could decrease the risk of non-contact ACL injury.13 Neuromuscular training should help engrain these proper movement techniques so that female athletes are able to use these preprogrammed motor strategies automatically during athletic competition. Performing box jumps with emphasis on landing, will allow the athletes to practice this new technique, and improve preprogrammed landing mechanics during competition. By improving biomechanics through neuromuscular training, female athletes can overcome their sex-specific risk factors and reduce the likelihood of ACL injury.

While post-adolescent female athletes have higher ACL injury rates, the same cannot be said for preadolescents. Age can be considered as a risk factor for ACL injury, because injury rates increase as the athlete ages. Preadolescent athletes have similar ACL injury rates when comparing sexes, indicating that female vulnerability to ACL injury could result from changes during puberty.3 LaBella et al suggests that the increase in bodyweight, height, bone length, and hormonal changes during puberty could be involved in the increasing risk for ACL injury.3 Increasing the moment arms (i.e., tibia and fibula) that impose torque on the knee joint, and increasing weight which results in greater joint force will cause an overall increased amount of stress on the ACL.3 While males gain more dynamic protection of the knee joint through increased muscle power and coordination as a result of testosterone increases, females experience similar height and weight gain without the added benefit of testosterone related strength gains.3 Many preadolescent ACL injury prevention programs use neuromuscular training; however, preadolescent athletes need special considerations due to their immature musculoskeletal systems.14 Specifically, younger athletes appear to be at a higher risk for more long-term consequences after an ACL injury, as one study shows that 22% of athletes undergoing surgery for the contralateral knee or revision to the original surgery within 5 years of the initial injury.15 Due to this risk for long-term consequences, it is crucial to the future health of young athletes that incorrect biomechanical motions be detected so that a physical therapist can construct an individualized program that addresses specific movement deficits. Padua et al suggest that the Landing Error Scoring System can be used as a screening tool to identify young athletes at risk for ACL injuries.15 This tool involves biomechanical analysis of jump landing with operational definitions of error.15 With this tool, the evaluator can identify exactly what mechanical errors children make during landing, such as medial knee displacement.15 This information can then be used to formulate neuromuscular training exercises that will focus on correcting these errors.

Poor neurocognitive outcomes have also been associated with increased ACL injury rates.16, 17 Neurocognition, “the cognitive processes and abilities associated with the functioning of cortical and subcortical brain systems,” includes aspects such as visual attention, self-monitoring, agility, processing speed, and dual-tasking that can, if deficient, indicate an increased risk for ACL injury in athletes.16 ACL injuries typically happen too rapidly for protective reflexes to assist in prevention of injury, causing athletes to rely on their neuromuscular control as the front line defense against injury.3 Diminished neurocognition could impair the athlete’s ability to initiate proper neuromuscular responses during the constant, complex demands of competitive sport.16 As an example, an athlete with diminished dual-tasking abilities may not be paying attention to his/her neuromuscular performance while focusing on the athletic task, thus placing him/herself in compromising positions. In a study by Herman and Barth, athletes who were considered “low performers” after neurocognitive testing demonstrated larger knee abduction angle and moment during an unanticipated jump-landing task, which can be predictive of an ACL injury.16 Despite growing evidence that poor neurocognition can be indicative of an ACL injury, most prevention programs focus more on improving neuromuscular function.16, 17 While providing exercises to improve neuromuscular function of an athlete and prevent a future ACL injury, the physical therapist should also consider evaluating the athlete’s neurocognitive status, in order to identify the need for neurocognitive improvements. Implementing exercises that involve reaction time training is one method of improving neurocognition. A common example includes an athlete facing a wall, and the thrower standing in behind the athlete. The thrower tosses a tennis ball off the wall at various speeds and angles, forcing the athlete to process visual information quickly in order to catch the ball. Improved reaction time can increase the athlete’s ability to respond to the constantly changing demands in an appropriate time frame during athletic competition.16 This improved ability will subsequently help reduce the risk for ACL injury, by allowing the athlete to safely and appropriately respond to stimuli.16 Another example of neurocognitive training could be performing single-leg balancing on a variety of surfaces while catching a ball from random directions. This task implements dual-tasking, which trains the athlete to monitor his/her neuromuscular performance while also focusing on the sport-specific task.16 This will allow the athlete to make neuromuscular corrections to his/her biomechanics during competition, and reduce the risk for ACL injury. Training techniques that improve the neurocognitive capabilities of the athlete will allow the athlete to better respond to external factors during competition that are involved in non-contact ACL injuries.

While all prevention programs should take an individualistic approach, there are several general components that should be included in all programs to ensure optimal protection. Improved conditioning through neuromuscular control exercises, strength, plyometric, and balance training are used in prevention programs along with risk factor modification.13 The FIFA 11+ training program for injury prevention in soccer players has gained attention in literature as an effective protocol for ACL prevention through simple means of implementing a dynamic warm-up to the beginning of practice.18, 19 The exercises in this program are only meant to take 10-15 minutes after an athlete is familiarized with the material, and focuses on core stabilization, eccentric thigh muscle training, proprioceptive training, dynamic stabilization, and plyometric drills.18 Athletes progressively increase the level of difficulty of warm-up exercises with a focus on proper technique in order to ensure the body is prepared for the rigors of more competitive play.19 Physical therapists could use the FIFA 11+ protocol as a baseline for formulating prevention programs for all athletes, as the results of implementing this program has shown a 35% reduction in injuries for both male and female athletes.18

Building off of the FIFA 11+ protocol, several of its components such as plyometrics, balance training, and general strength training can be used to help prevent ACL injury in all athletes, regardless of sex, age, and other non-modifiable injury risk factors. As mentioned with female athletes, risk factor modification is an approach physical therapists can take by changing the sport techniques of athletes to reduce the number of risks involved during competition. For example, teaching an athlete about using a three-step deceleration technique as opposed to a one-step technique could reduce his/her risk for injury by improving the athlete’s ability to mitigate and disperse the anterior shear force that occurs during deceleration.13 Sidestep cutting, another movement associated with increased risk for ACL injury, can also be improved to help mitigate risk for injury.13, 20 Specifically, Kristianslund et al suggest teaching toe landings, narrow cuts, and low knee valgus during sidestep cutting in order to reduce knee abduction moment, subsequently minimizing ACL injury risk.20 In order to engrain these improved cutting techniques into the athletes, physical therapists can recommend plyometric and neuromuscular control exercises.13 Using plyometric exercises and other forms of neuromuscular training techniques can help the athlete preprogram safer movement patterns and effectively reduce the risk for ACL injury. It would also be helpful to conduct some of these exercises while incorporating the interpretation of visual cues, to help athletes prepare for unexpected stimuli that are common in athletic competition.13 Visual cues, such as a randomly activated light, can be used to initiate plyometric bouts, causing the athlete to work on improving visual cue processing, which is an important neurocognitive component of athletic competition. Plyometric exercises involve “eccentric loading immediately followed by concentric contraction,” and are meant to simulate quick reactive movements associated with athletic competition.21 Example plyometric exercises include: lateral cone jumps, cone hops with 180 degree turn, and split squat jumps.21 By focusing on proper technique and body mechanics, the athlete is training the neuromuscular system to efficiently initiate and carry out quality preprogrammed movements.13 During these exercises, the physical therapist should provide constant feedback about proper biomechanical form, to ensure the preprogrammed movements being learned by the neuromuscular system are more risk averse than previous motor strategies. Along with plyometric exercises, balance training should be included in prevention programs, in order to improve muscle coordination and joint proprioception in a variety of competitive scenarios. Activities such as single leg balance on different surfaces (i.e., even and uneven), will improve the athlete’s neuromuscular control of his/her knee joint. By performing a variety of balance exercises such as single leg squats, split squats, and lateral single leg hopping, the athlete will learn to consistently control knee valgus/varus during movements.9

An added benefit to balance, plyometric and other neuromuscular training techniques is improved conditioning. Improved functional strength and conditioning in trunk and lower extremity muscles will further reduce the risk of ACL injury. The core is not only represented by the trunk muscles, but also includes the pelvic-hip region.19 Improved strength conditioning of the athlete’s core muscles, such as the gluteal muscles, allows him/her to maintain core stabilization and proper lower extremity alignment during bilateral and unilateral stance.13 Improved conditioning can also reduce muscular fatigue experienced during competition, which in turn can reduce the likelihood of ACL injury secondary to knee-control deficits experienced during muscular fatigue.13 Specifically, improvements in hamstring strength and endurance should be considered during neuromuscular training exercises, as poor hamstring strength can lead to a variety of movement deficits in the transverse plane of the knee joint.13 With improved conditioning, athletes will be able to better tolerate the fatiguing effects of competitive sport, and avoid succumbing to poor biomechanical form.

Risk factors for ACL tears vary between each individual athlete. The aforementioned guidelines should be helpful while implementing a preventative program to mitigate risk for ACL injury, but should not be used as a “blanket treatment.” In order to provide optimal exercises for prevention, physical therapists must use their knowledge as movement experts to thoroughly assess each patient’s movement strategies and other individual risk factors. As the rate of ACL injuries rises, it is becoming increasingly important for physical therapists and other healthcare professions to proactively try to prevent these severely debilitating injuries in all athletes.

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