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Clinical Viewpoint

Why Female Athletes Injure Their ACL's More Frequently? What can we do to mitigate their risk?

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Anterior Cruciate Ligament (ACL) injuries are one of the most deleterious knee injuries reported in sport. They continue to confound the sports medicine community, particularly with respect to the high rates reported in girls and women.[1–4] There are approximately 200,000 to 250,000 ACL injuries that occur in the United States annually, a rate that has doubled over the last 20 years.[5,6] Approximately 25% of these injuries occur in youth athletics; and this rate has been increasing by a rate of 2.5% annually in the United States[7] and has increased by 147.8% over a 10 year period in Victoria, Australia.[8] Although the overall rate of ACL injury is higher in males, primarily due to greater opportunity(s) to participate in contact sports, the relative risk of ACL injury in women is 3 to 8 times greater than males.[9,10] In the National Collegiate Athletic Association (NCAA), the rate of ACL injuries incurred by collegiate females is three times higher compared to men.[1] In high school aged athletes (13-18 years), there is approximately 1.6-fold greater rate of ACL tears in females,[11] and a multisport female athlete is estimated to have a nearly 10% risk of incurring an ACL injury during her high school or secondary school career.[12]

A concerted effort has been made over the last three decades to address the complexities of the "sequence of prevention"; to mitigate ACL injury risk by virtue of the implementation of validated injury prevention program (IPP) interventions.[13,14] A vast majority of these IPP's were designed specifically to address ACL injury in females.[15–19] The targeted risk factors included anatomic, environmental, hormonal, genetic and biomechanical.[20,21] These neuromuscular IPP training programs, that addressed the biomechanical deficiencies, included in-season elements of strength, plyometrics, sport specific agility drills, proper landing technique, proprioception, proximal control and a biomechanical emphasis on addressing the most common pathokinematic movement patterns associated with ACL injury mechanisms.[22–24] Additional components of successful ACL IPPs include socio-economic feasibility, sports-specificity, physiological competency, neurocognitive and psychological (improving confidence and reducing fear) and implementation strategies that may improve overall program adoption.[25–28] The IPP's were typically designed as in-season dynamic warm-up programs, included both intrinsic and extrinsic cues, were strategically offered at no or low-cost, included coaching and athlete web-based educational tools, and were time efficient to promote overall team compliance, program fidelity and adherence.[19,29–31] The IPP's have been largely successful; reporting overall ACL injury reduction rates between 55-88%.[16,17,19,31–33] The programs are designed to be introduced during preseason and continue throughout the season to mitigate biomechanical recidivism.[34,35] Additionally, the day in which the IPP was performed resulted in even lower ACL injury rates, suggesting that a transient, neural preparedness and cortical control element may be favorably impacting overall biomechanics and motor control.[30,36] Including principals of motor learning theories as a component of rehabilitation and in IPPs has led to improvements in efficiency of the motor cortex, ostensibly allowing the athlete to make improvements to their biomechanics while allowing them to interpret and process rapidly changing environmental stimuli due to improved neurocognitive availability.[37,38] Optimization of IPPs must include a synergy of cognitive, perceptual, and motor processes to enhance the athletes' ability to respond to sport-specific demands with comprehensive and low-risk biomechanical movement strategies.[39]

Recent studies have retrospectively analyzed injury mechanisms in male and female athletes to further elucidate the biomechanical pathokinematics specifically involved in the mechanism of injury.[40–50] Video analysis of ACL injuries in male and female athletes have begun to effectively delineate high risk positioning associated with the injury, namely defensive and unanticipated play, with the injured player demonstrating at or near full hip and knee extension, perturbation to the trunk resulting in lateral trunk displacement, hip adduction and internal rotation, knee valgus, and tibial torsion.[40,51,52] Females were more likely to be defending or in an unanticipated/reactive

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position and were more likely to tear their non-dominant limb.[41,53]

Studies analyzing the role of peripheral fatigue and its' role in ACL injury have been in consistent[54]. A study analyzing female ACL injury mechanisms suggested that fatigue was not correlated with injury, as 64% of injuries occurred in the first 30 minutes of a soccer match.[49,55] However, peripheral fatigue has been shown to be a variable for women in Irish Amateur Rugby[56], altering biomechanics during landing performance at initial contact[57,58], increasing trunk flexion[59], and reducing peak knee extensor torque[60,61]. Inclusion of fatigue as one of the metrics for IPP efficacy should be considered.[58] There is inherent complexity to determining the external validity of fatigue on ACL injury incidence. As fatigue increases, psychological stress may increase (stress, emotional lability) and physical response may decrease (performance, velocity, neuromuscular workload and intensity). The decrease in player intensity, performance, and velocity may be more reflective of central fatigue and may ultimately mitigate the overall risk of ACL injury.[58] The continued identification and understanding of the intrinsic and extrinsic sex related ACL injury risk factors will increase the clinician's ability to elucidate and improve IPPs to effectively decrease the ACL injury rate in sport.

One of the major difficulties researchers are enduring, from a public health perspective, is achieving widespread program adoption and implementation of the established and validates IPP's. Despite the earnest efforts of researchers to mitigate ACL injury rate through the development and the evolution of the aforementioned IPPs, the programs' potential to reduce risk has been hindered by the overall low adoption rate of these programs. Interestingly, it has been well documented that high compliance to a scientifically vetted IPP can substantially mitigate ACL injury rates.[62–67] Conversely, when overall compliance was low and the IPPs were performed less than once per week and/or with low program fidelity, the IPPs were found to be largely ineffective.[68,69] Upon analyzing coaching decisions to consistently using an IPP program, researchers determined that it requires a detailed understanding of the unique implementation context, including exercise variety and modification to expand its' reach, sport specific exercises, incorporating sport specific equipment, time and cost efficacy, greater exercise variations and increased difficulty in program progressions.[70,71] These alterations should be heavily considered in IPP design, as the cohesive and consistent implementation of IPPs is a very viable, impactful, and cost-effective option to reducing the overall rate of ACL injury.[72] Several studies have demonstrated a positive effect of IPPs on its effectiveness as a warm-up and overall athlete performance.[73–76] Optimizing implementation and team compliance, particularly at the youth and recreational levels, lies within the coaching decision making paradigm. The notion of improved performance, recognized by and improved win-loss record, and decreasing overall injury rate to improve player availability may optimally incentivize coaches and players in incorporate an IPP with regularity.[77] (Silvers-Granelli, in peer review, Sports Health).

A more nuanced narrative has recently emerged with respect to challenging the prevailing ACL injury prevention debate; are females truly more vulnerable to ACL injury or is this simply a consequence of a series of gendered societal and environmental decisions? Most ACL epidemiological and mechanism studies have been centered around gender-based biology, without considering other social, economic, contextual, and environmental factors. There is a significant disparity in training, coaching and competitive resources in female sports. Despite the advent of the Title IX Educational Amendment in 1972, which prohibited sex discrimination in any education program or activity receiving federal financial assistance in the United States, there is a incongruency in what females are afforded in competitive sporting environments.[78] This includes, but is not limited to, decreased overall salaries for coaching and professional play, diminished access to exercise equipment and high quality and consistent rehabilitation, lower standards for coaching, medical staffing and strength and conditioning professional experience, and decreased access to childcare and maternity benefits during their professional careers.[79] The impact of ACL injury and reconstruction have also differed in males versus females. Upon a two-year longitudinal analysis, females have demonstrated reticence in return to play activity, exhibited through behavioral self-modulation, by virtue of a decrease in vigorous activity, decreased triple hop distance, and a shift away from team sport participation to mitigate secondary injury risk.[80] This concerted decision, to decrease overall secondary risk through behavioral modification, may be partly due to the fact that the risk:reward balance that exists for men is simply not a realistic option for most women. It would behoove the research community to consider additional possibilities to the existing "biological element" influences that currently dominate the prevailing ACL injury prevention algorithm.

As we embark upon our fourth decade on the ACL injury mitigation journey, perhaps we "pivot" and discuss how we effectively disseminate information in a way that encompasses the current social, economic and environmental sex differences across sport. It we recognize the current inequity, and scientifically modify our algorithms, our prevention outreach and interventions may be perceived more favorably and just might increase their overall efficacy. Let us all be prescient as we attempt to minimize the current gender gaps present across sport and respond accordingly.

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