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Anterior cruciate ligament injury: Toward a gendered environmental approach

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ABSTRACT

Background The anterior cruciate ligament (ACL) injury rate for girls/women has not changed in over 20 years, and they remain 3-6 times more likely to experience injury compared to boys/men. To date, ACL injury prevention and management has been approached from a sex-based biological point of view which has furthered our understanding of injury risk factors, mechanisms, and prevention and rehabilitation programs. However, the traditional sex-based approach does not take into account the growing recognition of how sex and gender (a social construct) are ‘entangled’ and influence each other.

Objective This paper discusses the curious absence of gender as an influencer in the dialogue surrounding ACL injuries. We propose adding gender as a pervasive developmental environment as a new theoretical overlay to an established injury model to illustrate how gender can operate as an extrinsic determinant from the pre-sport, training, and competition environments through to ACL injury and the treatment environment.

Approach We draw on social epidemiological theories of the embodiment of gender and health to provide plausible examples of how gender may influence ACL injury, and demonstrate the opportunity for new, interdisciplinary research in the field.

Conclusion Over 20 years of research has failed to decrease the ACL injury rate disparity between girls/women and boys/men. Embedding gender in the study of ACL injury will heighten awareness of possible influences outside the traditional biological elements, challenge

us to think about the inextricable ‘entanglement’ of sex and gender, and inform more effective approaches to ACL injury prevention and treatment.

What is already known?

- The ACL injury rate disparity between girls/women and boys/men has not changed in over 20 years.
- The approach to addressing the injury rate disparity and establishing effective prevention and treatment programs is multifactorial and complex.

What are the new findings?

- Gendered factors present in the pre-sport, training, competition, and rehabilitation environments have not been explicitly included in ACL injury models to date.
- Gender, as an extrinsic social construct, likely influences many of the risk factors previously considered intrinsic to the athlete.

INTRODUCTION

The sporting world was first alerted to the extent of the anterior cruciate ligament (ACL) injury problem in the 1990s. The fact that girls and women were experiencing these life-altering injuries at 3-6 times the rate of boys and men^{1,2} caught the attention of parents and coaches, who demanded action. Researchers responded with enthusiasm; as of July 15, 2020, a PubMed search for “anterior cruciate ligament” or “ACL” returned over 27,000 results. However, from the beginning, investigation into the injury rate disparity between women and men has focused heavily on ‘sex’-based biological traits such as anatomy, physiology and hormones,³ and has not considered wider gendered social influences, aside from brief mentions in review papers.⁴⁻⁶ Annual ACL injury rates in the general population have remained unchanged in girls and women, while they have decreased among boys and men,⁷ suggesting that strictly biological explanations may be insufficient to improve outcomes for girls and women. In collegiate athletes, injury incidence has actually increased, with women experiencing higher rates than men in the same sports.⁸ However, ACL injuries are not limited to high level athletes; in one study, the largest difference in incidence rates between women and men was seen in recreational athletes.⁹ Clearly, the extensive work done to date has not been fully effective in teasing out the complex, interacting factors which contribute to these injuries in girls and women.

Improving our understanding of the ACL injury disparity between girls/women and boys/men is essential, as the acute and longer-term consequences of injury can significantly affect health. In addition to the immediate impact on physical and emotional health, experiencing an ACL injury at a young age is associated with a higher likelihood of developing

early onset osteoarthritis, and requiring a total joint arthroplasty.¹⁰ ACL injury results in only 65% of individuals returning to their pre-injury level of sport, with men 1.7 times more likely than women to do so.⁴ As childhood and youth physical activity levels influence those in adulthood,¹¹ the sequelae of ACL injury are lifelong and particularly concerning for women who already participate in physical activity at lower rates than men.¹²

Approaching ACL injury prevention and management with a strictly biological view can propagate sexism in sport with detrimental consequences for girls and women as seen in two recent cases. Based on a cross-sectional study, it was suggested that oral contraceptive pills prevent ACL injury, and should be prescribed to all young athletes.¹³ Methodological and ethical problems associated with those conclusions were identified;^{14,15} nevertheless, the original work continues to be cited. In the second case, media reported that the women's Australian Rules football league was experiencing high ACL injury rates, and the league's default response was to investigate the association with the menstrual cycle.¹⁶ Framing women's sport participation, as in these two examples, as "dangerous predominantly due to female biology"¹⁷ demonstrates how the wider gendered social context of labelling women's bodies as not being 'naturally' fit for sport strongly influences how ACL injuries have been studied. This also relies on normative assumptions of what a woman's body is or should be and does not hold space for those individuals beyond the sex binary. Fox et al. (2020) put forward a compelling case that reducing women's injury risk to biological causes (e.g., hormones, anatomy, physiology) fundamentally misrepresents the root cause of ACL injury,¹⁷ which is likely to be strongly influenced by gendered environmental disparities including access to and experiences with sport and training.

As such, injury risk factors previously considered to only be intrinsic to the athlete (e.g. muscle strength, body composition, skill level) conceivably contain some degree of extrinsic influence.

In this paper, we propose that gender operates as an extrinsic ‘pervasive developmental environment’,¹⁸ present in the ACL injury cycle from pre-sport, to training and competition, through to treatment and rehabilitation. Rather than a linear pathway, ACL injury risk can be considered cyclical, as “adaptations occur within the context of sport (both in the presence and absence of injury) that alter risk and affect etiology in a dynamic, recursive fashion.”¹⁹ We first describe and critique the current sex-based ACL injury paradigm including the traditional view of risk factors as binary (i.e., intrinsic or extrinsic), the mechanism of injury, prevention programs, and injury models. We next introduce our gendered environmental approach to ACL injury as a new theoretical overlay to Meeuwisse et al.’s (2007) widely-accepted dynamic, recursive model of etiology in sport injury.¹⁹ We illustrate how considering gendered environmental factors can enhance our understanding of the disparate rates of ACL injury among girls/women and boys/men. By ‘placing bodies in context,’ our alternative lens identifies opportunities to disrupt the ACL injury cycle and achieve more equitable outcomes for girls and women. We argue that by shifting the focus of risk from individual bodies to also include the gendered environments characterizing the state of play, we are better positioned to understand the interaction of risk factors and develop interventions that can systemically change the injury landscape for all girls and women in sport.

THE CURRENT ACL INJURY PARADIGM

First, it is important to acknowledge that it is common practice in sport medicine literature related to ACL injury to use the terms sex and gender (similarly: female and women) interchangeably, without consideration or explanation as to how research participants were delineated and why this was appropriate in the given context. Because of the manner in which sport has been institutionalized, with the convention of dividing competition into binary categories of girls/women and boys/men, athlete study participants are presumably most often classified according to their sex assigned at birth, regardless of which term is used in the manuscript. Sex refers to a complex blend of physical and physiological characteristics (e.g., hormones, genes, anatomy), while gender refers to identities, roles, and structures that are formed by society, which may or may not align with sex – neither of which is binary.²⁰ Therefore, how sex and gender are constructed—or, more often, how this is not adequately accounted for or explained—in many papers related to ACL injury is largely misguided. There is an overall need for greater specificity in ACL injury research to report the sexed and/or gendered characteristics considered. While beyond the scope of the present paper, we refer the reader to other authors for guidance.²¹

Risk factors

Much effort has been devoted to determining factors that may identify individuals at greater risk of ACL injury, with the ultimate goal of implementing appropriate prevention programs. Risk factors have traditionally been categorized as either intrinsic or extrinsic, meaning internal or external to the individual athlete, respectively.^{19,22} Typical intrinsic factors include anatomy, hormones, genetics, and qualities of the neuromuscular system (e.g., quadriceps/hamstrings

ratio). Commonly listed extrinsic factors include weather conditions and the playing surface,²² essentially the material conditions of play. Table 1 provides a snapshot of the current understanding of intrinsic and extrinsic risk factors identified in the ACL literature. What is apparent from this summary is an overwhelming focus of risk at an intrinsic (individual) level, with minor environmental nods to coaching and opponent behaviour.

We suggest that the traditional binary labelling of factors as either intrinsic or extrinsic is problematic, as many seemingly intrinsic factors can be heavily influenced by environment and society. For example, muscular strength is traditionally considered an intrinsic factor, suggesting that it is the individual's responsibility to address. However, we know that the programs and environments (e.g., gyms) required to build muscular strength are heavily gendered in ways that disadvantage women's participation.²³⁻²⁶ During the teenage years, boys experience a muscular strength and motor performance growth spurt, while girls plateau.^{27,28} Yet, in the literature, these differences are discussed mainly in relation to sex. The underlying assumption is that boys/men and girls/women are situated in equivalent training contexts, which, as mentioned above, they are likely not. It leaves open the question as to how the immediate social context of training and playing, as well as wider gender norms about girls' participation in sports and physical activity, shape girls' learned behaviours and body movements, and whether this factors into injury risk.

Table 1. A snapshot of the current binary categorization of intrinsic and extrinsic risk factors for noncontact anterior cruciate ligament injury^a

Modifiable Risk Factors	Nonmodifiable Risk Factors
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Environmental	Environmental
Meteorological conditions (E)	Playing situation (E)
Playing surface (E)	Opponent behaviour (E)
Rules (E)	Unanticipated events during play (E)
Referees (E)	Anatomical
Coaching (E)	Q angle (I)
Equipment	Navicular drop (I)
Footwear (E)	Structural knee valgus (I)
Knee braces (E)	Postural alignment (I)
Anatomical	Notch size, ACL geometry and properties (I)
Foot pronation (I)	Tibial slope angle (I)
Body composition and body mass index (I)	Generalized joint hypermobility or laxity (I)
Neuromuscular	Hormonal
Dynamic knee valgus (I)	Menstrual phase (I)
Muscle strength (I)	Hormone concentrations (I)
Muscle strength ratios (I)	Demographic
Muscle activation patterns (I)	Age (I)
Muscle stiffness (I)	Maturation (I)
Physical fitness and muscle fatigue (I)	Previous contralateral knee ACL injury (I)
Skill level (I)	Familial history and genetics (I)
Neuromuscular control (I)	Sex (I)
Proprioception (I)	Height (I)
Psychological (I)	Race (I)
Personality (I)	Sports played (I)
Stress response (I)	

^aAbbreviations: E, extrinsic; I, intrinsic. Table collated and modified from XX; and based on XX.

Mechanism of injury

ACL injuries can occur due to direct contact, or indirectly via a non-contact mechanism during sudden deceleration or planting a foot and changing direction.²⁹ Contact injury rates are higher in boys and men, while non-contact mechanisms are more frequently reported in girls and women,⁸ perhaps partly reflecting participation in different types of sports. Multiplanar

movement patterns observed at the time of non-contact injury that are thought to place high strain on the ACL³⁰ involve multiple joints and include decreased knee flexion, excessive knee valgus,²⁹ lateral trunk displacement, and increased hip extension.³¹ Some research suggests differences in movement patterns which disadvantage girls and women (e.g., dynamic knee valgus³² and peak landing forces³³), but no strong evidence exists that the biomechanics *at the moment of ACL injury* is different between sexes.^{34,35} If the athlete's position at the instant of injury is the same, but the rate of ACL injury in girls/women is 3-6 times higher than in boys/men, this suggests that biomechanical differences are insufficiently explanatory on their own.

ACL injury prevention programs

To improve movement control in high risk positions, many exercise-based ACL injury prevention programs have been developed. When girls and women participate in this dedicated training, they experience a significant 67% decrease in non-contact ACL injuries.³⁶ While found to be highly efficacious when delivered in a structured, supervised manner as part of a research study, ACL injury prevention programs have suffered from low levels of adherence once that structure disappears.³⁷ Perhaps this is not surprising, given that one type of activity important for effective ACL injury prevention is strength training.³⁸ Improving neuromuscular strength is essential, as lower levels of hip abduction and external rotation strength are predictors of increased ACL injury risk in both women and men.³⁹ However, girls and women participate in resistance training at a much lower rate than boys and men,^{40,41} and this gap is associated with

strong gendered expectations of how a woman's body is 'supposed' to look and the gender-typing of weightlifting as masculine.^{23,42-45}

Some authors suggest sex-specific training programs are required to improve the effectiveness and uptake of prevention programs.⁴⁶ However, because of the traditional sex-based approach to studying ACL injury, the need for these programs is largely based on perceived biological, unchangeable differences. In the wider gender and health literature, there is increasing recognition that sex and gender are 'entangled' - that is, the biological and the social influence each other in ways that are not always empirically discernible but are theoretically plausible.⁴⁷ To date, gender has not been considered in concert with sex when studying ACL injury prevention, despite the plausibility that they are both contributing to injury risk.

Injury models

Mention of general societal expectations that contribute to the ACL injury cycle is included in van Mechelen et al.'s (1992) sports injury model;⁴⁸ however, studies that use that model and others^{49,50} as a basis for their work tend to largely focus on individualized approaches as the primary method to address injury. In a review which used the Haddon matrix⁴⁹ to describe the target of prevention initiatives for acute sport injuries, the vast majority required changes in behaviour on the part of the individual. Very few injury prevention strategies targeted policies and rules, or the context in which the injury was occurring.⁵¹ In a recent scoping review of primarily ACL injury studies, Truong et al. (2020) reported a dearth of studies that considered social and contextual factors at time of injury and in recovery.⁶ Further, consideration of gendered factors was superficial, with only a small sub-set of studies reporting aspects of

‘masculine sport culture’ and a ‘no pain no gain’ approach to risk-taking. Updates to the original injury models⁴⁸⁻⁵⁰ have been proposed which emphasize a more biosocial approach^{52,53} but they have not included gendered factors specifically.

Recognizing that sports injuries do not fit a traditional cause-and-effect model, Meeuwisse et al. (2007) presented a multifactorial, cyclical model outlining how risk factors need to be considered in the manner in which they interact in different ways for different athletes in different settings to bring about an injury.¹⁹ The authors described how an athlete possesses predisposing traits, which when influenced by external factors and exposed to an inciting event during training or competition, can lead to injury. They state that clinicians and researchers tend to focus on the events at the moment of injury (in the case of non-contact ACL injury, an upright body position with knee valgus), since it is very visible and real to both the practitioner and the athlete. The more remote contributors (e.g., why girls and women may lack the strength to avoid the risky position) are rarely considered.

Bekker and Clark (2016) agree, and argue that because “injuries are influenced by interactions between people, the physical environment and the social environment”, sport injury prevention research needs to adopt a more complex approach.⁵⁴ However, while there is consensus that ACL injury risk is multifactorial, and emerges from a complex “web of determinants”, the discussion continues to remain largely within the confines of an individual’s sex-linked biology.⁵⁵ There has been little consideration of the larger sociocultural influences acting on coaches, parents, and athletes which may contribute to increased injury risk.⁵⁶ The role of gender, a social construct which is present from the moment we are born, is conspicuously missing from the ACL injury discussion. Therefore, we propose the addition of

gender as a “pervasive developmental environment”¹⁸ as a new theoretical overlay to

Meeuwisse et al.’s ACL injury model, which can influence and interact with previously identified

risk factors throughout the ACL injury cycle (Figure 1).

UPDATING THE ACL INJURY PARADIGM

“bodies tell stories about—and cannot be studied divorced from—the conditions of our existence”⁵⁷

The current paradigm for ACL injury displaces bodies from the conditions of our existence, instead focusing heavily on biomechanical explanations, as if our muscles and joints are not impacted by the weight of our life experiences.⁵⁸ To reimagine the approach to ACL injury, we draw upon social epidemiological theories of embodiment to conceptualize how social conditions can be materially borne out in the body.^{47,57-59} The addition of gender as an environmental factor in the ACL injury model (Figure 1) moves us toward a more dynamic consideration of sex/gender in ACL injury research. To do this, we draw specifically on Cheslack-Postava and Jordan-Young’s formulation of gender as a “pervasive developmental environment,” which conceives of human development as “a ‘looping process’ in which gender is a critical, ongoing factor.”¹⁸ This allows us to question the higher-order processes and structures in sporting environments that plausibly differ, purposefully or not, on the basis of sex/gender. Our proposal disrupts the primacy of sex-based explanations of ACL injury and instead suggests that we start from a point of assuming that both biological and social factors are at play. We take up Springer et al.’s (2012) call that “this entanglement should be theorized, modeled, and assumed until proven otherwise.”⁴⁷

As Nancy Kreiger says, “we live embodied”; that is, “we, like any living organism, literally incorporate, biologically, the world in which we live, including our societal and ecological circumstances.”⁵⁷ From this perspective, ACL injury can be conceived, at least in part, as a biological manifestation of cumulative exposure to exogenous social (read: gendered, racialized, etc.) conditions that render the body susceptible. This re-positions biology from being the sole, central cause of ACL injury (i.e., female biomechanics are more prone to injury) to overlaying and making explicit the influence of exposure to gendered processes over the lifecourse and playcourse. Our addition of gender to the ACL injury model illustrates some potential pathways through which the gendered conditions of society and sport function to make girls’ and women’s bodies ‘risky’. Furthermore, embracing the possibility for dynamic processes interconnecting sex and gender embeds potential for the ACL injury model to be inclusive beyond the sex binary.

Our gendered environmental approach offers additional explanations for the sex/gender disparity in ACL injury rates, and opens up new avenues of research. Our goal is to raise a series of possibilities for plausible explanations for the ACL injury rate disparity that focus on gendered influences, which can push us to expand our approach to ACL injury research, prevention, and treatment. We present examples of where gendered influences may occur related to four developmental environments surrounding an athlete: 1) the pre-sport environment, 2) the training environment, 3) the competition environment, and 4) the treatment environment (Figure 1).

The pre-sport environment

The material effects of gendered socialization on the body can potentially shape susceptibilities in the bodies of girls and women before even entering sporting environments. Particularly prescient is Iris Marion Young's (1980) iconic essay that explored the concept 'throwing like a girl' to make the case as to how gender socialization manifests in bodily comportment and spatial mobility.⁶⁰ From birth, gendered parenting occurs implicitly by, for example, purchasing different toys or allowing greater independent mobility for boys versus girls.^{61,62} Exposure to different experiences during infancy and childhood requires and develops differential physical skill sets which could manifest as altered movement patterns in sport later in life.⁶³ Gendered expectations that could affect physical development are further illustrated in a study which found that mothers underestimated the crawling abilities of their daughters, but overestimated the abilities of their sons.⁶⁴ These types of implicit experiences and expectations are pervasive, extend to other environments such as schools, and result in "environmentally induced" physical abilities⁶⁵ and a motor control gender gap.⁶⁶ The impact of possibly rendering the female-presenting body more susceptible to injury prior to even entering the realm of sport is unknown.

The training environment

Resistance training is an important component for effective ACL injury prevention,³⁸ but there is significant evidence that participating in resistance training and increasing muscle mass is not seen as socially acceptable or desirable for girls and women,^{23,42-45,67} even as new body ideals such as a 'thin muscular' physique emerge.⁶⁸ Women competing in collegiate sports report constantly having to negotiate issues of muscularity and femininity in resistance training

environments.^{69,70} Although these athletes recognize the benefits to their sport performance, they tend to hold back during training sessions because of concerns of becoming too 'bulky' and muscular. The weight room environment itself is a highly gendered space where many women feel uncomfortable,^{23-26,42-45} and even materially shrink their consumption of time, space, and equipment in response.²³ Strength and conditioning (S & C) coaches play a significant role in creating the training environment for athletes, and strongly influence athletes' opinions of resistance training.^{26,69} Because S & C coaches are overwhelmingly men,⁷¹ women are likely to continue to feel that weight rooms are not a place for them. These gendered training dynamics may be a significant contributor to the ACL injury rate disparity between women and men, given the well-documented lower resistance training participation rates among girls and women compared to boys and men,^{40,41} and the importance of that activity for effective ACL injury prevention programs.³⁸

Some authors have suggested that sex-specific training programs may be required because injury risk factors⁴⁶ or athlete motivations and abilities⁷² may differ between girls/women and boys/men. However, many of the assumptions behind these perceived differences are based on a belief that they are biological and unchangeable, when in fact they are heavily shaped by modifiable gendered factors.¹⁷ Sex-specific programming may also knowingly or unknowingly embed and perpetuate sexed/gendered stereotypes and differences that disadvantage girls and women. Before we assume that training for ACL injury prevention needs to be different for girls/women and boys/men, we need information as to the gendered environments that already exist. It is likely that training is *already* different, but in a way that disadvantages girls/women. As far as we are aware, no literature exists regarding how ACL

injury prevention programs, or resistance training in general, are communicated or presented to girls/women and boys/men. Men and women coaches have been found to differ in the types of stretching activities they program for their athletes during warm-up.⁷³ It is plausible that these gendered coaching actions could extend to ACL injury prevention efforts, with unknown effects on the athlete. Are there differences in how the coaches explain, support, and interact with their athletes during the training program, depending on the sex/gender of the coach or athletes? Are the expectations and exercise standards different? Perhaps sex-specific injury prevention training programs are not required - perhaps we just need to better understand the societal influences already at play, and ensure equitable delivery of interventions so that all athletes benefit.

Some authors⁷⁴ mention training background as an influencer on ligament strength, and other soft tissue and bony structural characteristics, such as the size of the ACL and femoral notch shape, are supported as risk factors for injury.^{75,76} These are typically categorized as intrinsic, non-modifiable, anatomical risk factors;⁷⁷ however, bone, joint and muscle loading that may appear to manifest sex differences could also be a result of gendered processes,⁵⁸ and gender is an extrinsic factor created by society. Loading anatomical structures causes changes to their material properties. The principles of tissue adaptability state that soft tissue and bone will adapt and model according to the forces with which they are subjected, and is the cornerstone of preventative and rehabilitative exercise programming.⁷⁸ There is some evidence to suggest that the structure of the ACL can change with loading;^{79,80} however, the consequences are unknown. Anatomical risk factors for ACL injury may very well include both a biological and a societal influence (i.e., the 'entanglement' of sex/gender).

The competition environment

By its very binary nature, sport places girls/women and boys/men in different playing situations. It may appear superficially that they are divided in most sports strictly based on sex; however, gendered expectations of acceptable activities strongly influence sport opportunities and experiences. For example, American football is ubiquitous across North America up to the professional level for men, but hardly exists for women.⁸¹ Bodychecking is not allowed in women's ice hockey, while it is a large part of the men's game. As of 2021, women in Australian Rules football play quarters that are five minutes shorter compared to the men's league, and tennis matches for women are capped at three sets, and for men at five sets. Men comprise a tiny fraction of netball players in the United Kingdom, which is classified as a non-contact sport. These are clear examples of how sex/gender are 'entangled' to produce diverse sport experiences for women and men, which we argue must factor into ACL injury risk.

Another example of how gender can affect the competition environment is through athlete behaviour and sport culture. Player and opponent behaviour can influence whether an injury occurs or not.⁴⁸ Risk-taking behaviour and winning are traditionally viewed as masculine traits, are highly valued in sport environments, but can lead to injury.⁸² Girls and women may adopt hyper-masculine traits as a way to 'fit in' to sport, further compounding an already complicated set of risk factors for ACL injury. This may have material consequences. For example, women athletes who conformed more strongly to these masculine traits were more likely to continue to play with concussion symptoms.⁸² Since cognitive function has been associated with ACL injury risk,⁸³ this demonstrates how gender could be contributing to the injury rate disparity between women and men. However, despite the link between injury and

the typically hyper-masculine expectations and behaviour valued in sport, only 2 of 77 studies found in a scoping review of non-biological factors that could affect recovery from knee injury included contextual elements such as sport culture.⁶

The treatment environment

We need to consider gender as a potential influencer right through to the post-injury, rehabilitation, and return to sport portions of the ACL injury cycle. Examples in the literature show the pervasiveness of gendered assumptions in medical interventions and treatment, and the negative effects they can have on women's health.^{84,85} Compared to men, after ACL reconstruction, women have greater knee laxity, lower patient reported knee function, less chance of returning to sport, and a more frequent need for revision surgery.⁸⁶ Comparing post-surgical outcomes between men and women again assumes that their pre-injury status, rehabilitation, and subsequent training environments are equal. Could it be that men and women experience rehabilitation differently due to biases in healthcare settings? The sex and/or gender of the athlete, as well as the sex and/or gender of all the healthcare professionals the athlete comes into contact with (i.e., emergency room physician, referring physician, surgeon, physical therapists) from the onset of injury to return to sport, may be important. Since systemic change is not solved at the clinical level by individual practitioners, this affords us an opportunity to look more broadly and use interdisciplinary, multi-level approaches to the ACL injury problem.

Like previous work which found surgical treatment options were more frequently offered to men,⁸⁴ there is evidence of a similar institutional gender bias in recommending ACL reconstruction surgery more often to boys/men.⁸⁷ However, if they do have ACL reconstruction,

women are more likely to require revision surgery.⁸⁶ Women subsequently experience a higher incidence of total knee arthroplasty within 20 years after rupturing their ACL.⁸⁸ Rehabilitation from an ACL injury, whether surgically repaired or not, requires dedication to a training program for an extended period of time. Current evidence suggests the chance of re-injury is significant if athletes do not wait at least 9 months to return to sport.⁸⁹ Given that men and women experience training and competition environments differently, what implications does that have for rehabilitating from an ACL injury? Boys and men return to sport more quickly than girls and women after ACL injury,⁴ which could be a result of gendered expectations related to a masculine sport culture where playing through pain and winning at all costs is valued.⁸² But it could also relate to the types of training environments that women and men experience and have access to during rehabilitation. Likewise, the wider gendered context of women's and men's lives (e.g., inequities in familial and domestic labour⁹⁰) may create different opportunities and constraints for women and men to complete effective rehabilitation. Until the approach to studying ACL injury transforms and includes consideration of gendered factors, we will continue to have an incomplete picture of ACL injury and the disadvantages to girls and women will endure.

Going forward: Applying a gendered environmental lens

If we revisit Table 1 through our gendered environmental lens, we can see how most of the injury risk factors identified as intrinsic could be strongly influenced by social and cultural expectations of what girls/women and boys/men should be and do. We suggest, in agreement with Cameron (2010),⁹¹ that viewing risk factors as modifiable or nonmodifiable is more useful

to front-line practitioners who are working to decrease injury risk. This perspective also suggests that we can address a factor by modifying the environment, not just the individual. Through Marmot's work on the Social Determinants of Health,⁹² we now know that understanding and acting upon upstream social and contextual factors are vital in improving individual and population health. In the same way that these contemporary understandings have shown that it is racism, not race that influences health and injury outcomes,^{93,94} we argue here that it is sexism (positioned as a "structural phenomenon, perpetuated by *social* institutions, policies, and broader cultural mores"),⁹⁵ not simply sex that plays a role in ACL injury outcomes. In this way, gendered experiences (together with class, disability, sexuality, racism and other social structures) matter for shaping girls' and women's sport participation and injury outcomes. Rather than positioning sex or gender as intrinsic risk factors (as is the norm in a field where cisgender male whiteness is the default^{96,97}), it is worth considering them as also extrinsic. Effects observed at the individual level can be understood as outcomes of ways that the social and material contexts of sport condition sporting bodies. Moving beyond a biological starting point to incorporate both biology and society as possible influences on ACL injury risk can lead to new advances in the field.

CONCLUSION

By overlaying gender as a pervasive developmental environment onto an existing ACL injury model, we are urging researchers and clinicians to consider and include gendered factors when attempting to address the higher injury rate in girls and women. The ACL injury cycle requires a holistic and intersectional approach; for example, we cannot simply tell girls/women to 'get

stronger' to reduce injury risk if society and the environment do not support those types of activities for everyone. Work in public health tells us that prevention efforts are most effective when broader society and cultural norms are targeted, rather than placing the burden on individual people to change their behaviour.^{98,99} Previous authors have suggested a real need to understand the broader factors at play,^{52,53} yet there has been a curious and alarming absence of gender in the conversation, given that the higher rate of ACL injury in girls and women reported in the 1990s caused an explosion of research in the area. Our hope is that positioning gender as a pervasive developmental environment in the ACL injury cycle will spur new, interdisciplinary research that will further our understanding of the complexities of ACL injury. Over 20 years of research has failed to decrease the ACL injury rate in girls and women; it is time to take a different approach.

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Box: Key definitions

Sex and Gender:

Sex refers to a complex blend of physical and physiological characteristics (e.g., hormones, genes, anatomy), while gender refers to identities, roles, and structures that are formed by society, which may or may not align with sex – neither of which is binary.²⁰

Sex/gender:

Sex/gender is increasingly being used as a term to recognise the empirical and conceptual ‘entanglement’ of biological and social factors in expressions of sex and gender.⁴⁷ It acknowledges the dynamic processes and interactions through which “body-based characteristics...are shaped by gendered social interactions”.^{100,101}

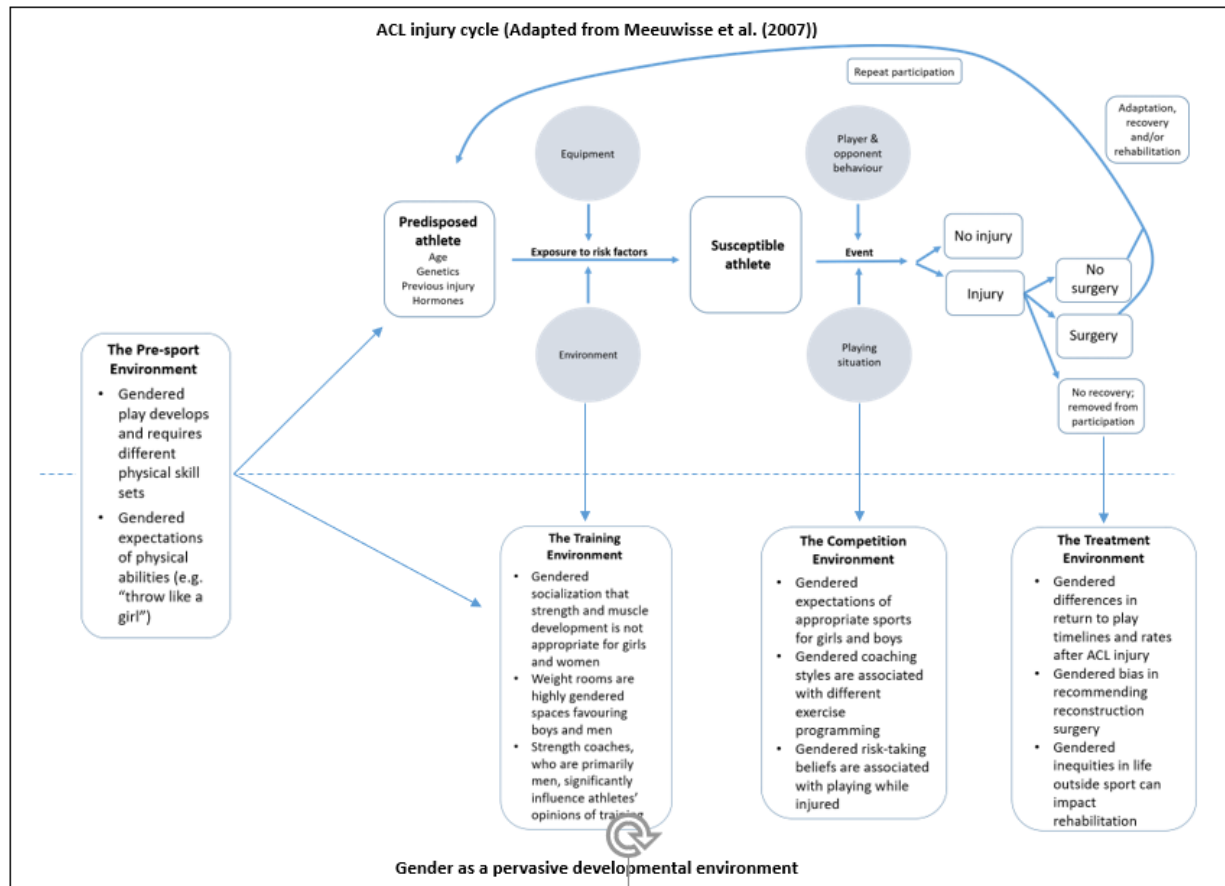
Table Legends and Footnote

Table 1. A snapshot of the current binary categorization of intrinsic and extrinsic risk factors for noncontact anterior cruciate ligament injury^a

^aAbbreviations: E, extrinsic; I, intrinsic. Table collated and modified from^{91,102}; and based on^{31,103-106}.

Figure Legends

Figure 1 Gender as a pervasive developmental environment in the ACL injury cycle. This figure illustrates how integrating gender as a pervasive developmental environment shaping the context of ACL injury risk expands the traditional ACL injury cycle (based on Meeuwisse et al. (2007)). Key examples from the pre-sport, training, competition, and treatment environments illustrate how gendered processes can lead to susceptibilities in girls and women.



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